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THE UNIVERSITY OF TEXAS AT AUSTIN JACKSON SCHOOL OF GEOSCIENCES

STRUCTURE / TECTONICS THE GEOLOGICAL SOCIETY OF AMERICA

GSA FOUNDATION

Modification

Session number 43 appearing on pages 22 and 77 have been modified. Below is the correct listing for this session. Please note the day and date have changed to what you see below. Terry Engelder and Mark Rowan's abstracts do not appear on page 77, therefore, they are listed below.

Thursday, 7 October 2010: 09:30–16:30, METU Convention and Cultural Centre, Salon D

SESSION NO. 43

Sedimentary basin evolution and oil fields in the Middle & Near East (Special Petroleum Geology Session sponsored by the Turkish Association of Petroleum Geologists) (Orta ve Yakin Dogu'da sedimanter havza gelismeleri ve petrol olanaklari)

09:30, METU Convention and Cultural Centre, Salon D

Dogan Perinçek and Dan Carpenter, Presiding

43-1	09:30	Rock, Greg*; Niewland, Dirk; Pim, Jonathon; Ferreira, Luke: **EXPLORING UNDER THE OPHIOLITE**
43-9	10:00	Engelder, Terry*: **TO WHAT EXTENT SHOULD THE DEVONIAN-MISSISSIPPIAN BLACK SHALES OF THE APPALACHIAN BASIN SERVE AS A MODEL FOR GLOBAL EXPLORATION OF SHALE GAS?** *Abstract below*
	10:30	**Break**
43-5	10:50	As-Saruri, Mustafa*; Sorkhabi, Rasoul: **PETROLEUM BASINS OF YEMEN: THEIR TECTONIC DEVELOPMENT AND LITHOSTRATIGRAPHY**
43-7	11:10	Zaigham, Nayyer Alam*; Hissam, Noushaba; Nayyar, Zeeshan Alam: **DELINEATION OF NEW HORIZON FOR DISCOVERY OF HYDROCARBON POTENTIAL IN PAKISTAN**
43-8	11:30	Tong, Hengmao*: **A NEW MODEL FOR THE ORIGIN AND EVOLUTION OF THE RIFT BASIN FAULT-SYSTEMS IN THE EAST AND SOUTH CHINA –A CASE STUDY FROM BEIBUWAN BASIN**
43-6	11:50	Miroshnichenko, Inna*: **UNCONVENTIONAL OIL AND GAS TRAPS OF FERGANA VALLEY (UZBEKISTAN)**
	12:10	**Discussion**
	12:30	**Lunch Break**
43-2	14:30	Perinçek, Dogan*: **SEDIMENTATION on THE ARABIAN SHELF HAS BEEN UNDER THE CONTROL OF TECTONIC ACTIVITIES ALONG THE ZAGROS–TAURIDE THRUST BELT FROM THE CRETACEOUS TO THE PRESENT**
43-10	15:00	Rowan, Mark G.*:**FOLD-AND-THRUST BELTS DETACHED ON SALT.** *Abstract below*
	15:30	**Break**
43-3	15:50	Bozdogan, Nihat*; Erten, Tayfun: **PALEOZOIC SEDIMENTARY BASIN EVOLUTION AND OIL FIELDS, SE ANATOLIA, TURKEY**
43-4	16:10	Erten, Tayfun*: **EVOLUTION OF MESOZOIC AND CENOZOIC SEDIMENTARY BASINS IN SE TURKEY**
	16:30	**Discussion**

43-9 10:00 Engelder, Terry Geological Society of London 2010 Unconventional Shale Gas Keynote Lecturer

TO WHAT EXTENT SHOULD THE DEVONIAN-MISSISSIPPIAN BLACK SHALES OF THE APPALACHIAN BASIN SERVE AS A MODEL FOR GLOBAL EXPLORATION OF SHALE GAS?

ENGELDER, Terry, Department of Geosciences, The Pennsylvania State University, 336 Deike Building, University Park, PA 16802, jte2@psu.edu

Shale gas occurs in mudstones with common characteristics including a minimum TOC buried to depths sufficient to achieve a certain thermal maturity. Various mudstones around the globe differ in thickness and regional extent but these characteristic are often not the most important in controlling economic viability, particularly when the shales are developed with horizontal drilling. Rock properties and tectonic histories are quite distinct from shale play to shale play and it is these parameters that can make all the difference in the evolution of an economic play. Rock properties are a function of conditions at the time of deposition and have a strong influence on such engineering considerations as drilling and completion. Tectonic history is the final step in the evolution of gas shales toward or away from economic viability, depending on structural complexity. Devonian black shale of the northern Appalachian Basin developed through two periods of tectonic loading. The earlier (Acadian loading) affected depositional style whereas the later (Alleghanian loading) affected tectonic fabric. As a consequence of the Alleghanian orogeny black shales of the northern Appalachian Basin (mainly the Marcellus) carry tectonic structures ranging from microscopic to seismic in scale. These Appalachian structures present some challenges to horizontal drilling and completion that may or may not appear in other basins of the world. Nevertheless, lessons learned in dealing with structures of the Appalachian Basin will undoubtedly provide valuable models as the global gas shale play continues to expand to new basins of the world.

43-10 15:00 Rowan, Mark G. American Association of Petroleum Geologists 2010 Distinguished Instructor

FOLD-AND-THRUST BELTS DETACHED ON SALT

ROWAN, Mark G., Rowan Consulting Inc, 850 8th St, Boulder, CO 80302, mgrowan@frii.com

Fold-and-thrust belts detached on salt, whether in passive-margin deepwater provinces or along convergent-margin orogens, have fundamentally different structural styles than those detached on normal to moderately overpressured shale. They can be broadly divided into two subsets: those where no salt mobility preceded shortening, and those where diapirs and minibasins were established prior to the onset of shortening. In both cases, the critical taper angle is small and deformation occurs practically simultaneously over broad areas or propagates landward or toward the hinterland from the salt pinchout due to the viscous nature of the décollement.

When there is no early salt movement, shortening results in a regular wavetrain of elongate, generally symmetrical salt-cored detachment folds. The spatial and thickness distribution of the salt influences fold orientation, thrust-fault development, and strike-parallel geometries. Stacked salt layers lead to disharmonic and polyharmonic folding.

In fold-and-thrust belts where salt withdrawal and diapirism predated shortening, the variable strength of the overburden controls the deformation and yields much more complex geometries. Folds nucleate at the weak diapirs, which get squeezed and sometimes thrusted, with high lateral strain gradients common directly adjacent to the diapirs. In the case of circular diapirs connected by a polygonal array of deep salt ridges, variably oriented folds, thrusted folds, strike-slip faults, and even normal faults form as strong minibasins translate somewhat independently above the décollement and rotate about vertical axes. Elongate salt walls tend to be squeezed more at their centers than at their ends, resulting in steep salt welds linking diapirs at fold terminations. In all instances, the preexisting structural architecture strongly controls the deformation, with significant strike-parallel variations in structural style.

Tectonic Crossroads: Evolving Orogens of Eurasia-Africa-Arabia

PREFACE

Tectonic Crossroads: Evolving Orogens of Eurasia-Africa-Arabia is taking place in Ankara, the capital city of Turkey, located in the central Anatolian plateau, from 4 to 8 October 2010. This global meeting, which is the first one sponsored by the International Section of the Geological Society of America (GSA), has been convened in collaboration with the Department of Geological Engineering at Middle East Technical University (METU), the Chamber of the Geological Engineers of Turkey, and the Turkish Association of Petroleum Geologists, and has been endorsed and sponsored by the Middle East Technical University (METU), the Directorate of the Mineral Research and Exploration Institute (MTA), European Geosciences Union (EGU), The Geological Society of London, the International Union of Geological Sciences (IUGS), and the Turkish Petroleum Corporation (TP). The purpose is provide a forum for international earth scientists to exchange and discuss their recent observations and interpretations on the crustal structure, mantle dynamics, and landscape development of evolving orogens around the world, with an emphasis on the eastern Mediterranean region. Using the recent plate interactions among Africa, Arabia, and Eurasia, and their geological, geophysical, and geomorphological artifacts as the best natural cases, the conference is designed to explore crustal motions, mantle dynamics and GPS velocities in continental collision; tectonic, magmatic and geomorphic evolution of high plateaus; Aegean geodynamics and extensional tectonics; seismicity, palaeoseismicity, and landscape, climate and archaeological evolution of the Mediterranean region; and the mode and nature of structural, geochemical, magmatic, metamorphic, and sedimentological processes involved in strike-slip and transform fault tectonics; subduction and collision geodynamics; development of modern and ancient accretionary wedges; and, formation of ophiolites, blueschists, and mélanges. The participants and contributors (both student and professional researchers) come from around the world in order to compare and contrast regional geology and processes with the local experts working in this extraordinary region at the tectonic crossroads of Eurasia-Africa-Arabia. One of the most important expectations of this meeting is to improve our understanding of the region's natural hazards and mineral-energy resource potential, which brings more societal relevance to this international scientific gathering.

Situated at the intersection of the Eurasian, African, and Arabian plates, Anatolia and the eastern Mediterranean region form one of the most seismically and volcanically active tectonic zones in the Alpine-Himalayan orogenic system. This broad zone of convergence is dominated by crustal extension and shortening, as well as strike-slip faulting, as part of collision-induced escape tectonics. The patterns and diversity of sedimentation, magmatism, metamorphism, crustal uplift, deformation, and global changes spectacularly record the region's complex geodynamic history. Subduction rollback processes along the Hellenic trench throughout the Cenozoic have resulted in upper plate extension, core complex formation, and attendant magmatism, and have led to the opening of backarc basins. Collisional processes since the late Mesozoic caused mélange development, ophiolite emplacement, inversion of backarc basins, and formation of orogenic high plateaus. Transform faulting makes this region a type-example of strike-slip tectonics, in which sedimentation, block uplifting, basaltic volcanism, and intra-plate deformation have varied histories through their complex interplay. Collision-induced mantle dynamics caused slab breakoff, delamination, and lithospheric tearing, which have collectively affected the mode of crustal tectonics, magmatism, and mineralization at all scales since the early Cenozoic.

The field trips are organized to complement the thematic sessions of the conference and should present ideal settings to further explore the geological phenomena and related processes. An array of mid-conference field trips takes all participants to some of the most fascinating geological, archaeological, and cultural sites in and around Ankara. Two field trips before the meeting explore the active faulting and archaeoseismology of western Anatolia, and the Tethyan blueschists, ophiolites and suture zones in northwest Anatolia. Post-meeting field trips provide the participants with an excellent opportunity to observe first-hand the tectonic, magmatic, and geomorphic processes that have affected the crustal and landscape evolution of the central Anatolian accretionary complex (Ankara Mélange), Cappadocian volcanic province, and the northwestern edge of the Arabian platform and the East Anatolian and Dead Sea transform fault systems.

The conference themes are examined in a combination of keynote and invited talks, oral sessions, and poster presentations. The topics of the keynote presentations emphasize some of the fundamental geological phenomena and provide an excellent starting point for other contributions in the scientific sessions that follow. A special session sponsored by the Turkish Association of Petroleum Geologists brings together scientists from academia and various industry sectors to discuss sedimentary basin evolution and the present and future exploration of oil fields in the Middle and Near East and Asia.

As co-conveners, we would like to express our sincere appreciation to the members of the scientific organization committee, the field-trip leaders, the session conveners, the invited and keynote speakers, the contributors to the poster and oral sessions, and all scientists and guests who have contributed to the success of this meeting. We gratefully acknowledge all those organizations and individuals who have provided financial contributions, and thank Middle East Technical University for hosting this global meeting in its Cultural and Convention Centre. We warmly welcome all participants and guests to Ankara, Turkey, and invite them to enjoy the meeting and the great culture and warm hospitality of Turkey and its people.

Yildirim Dilek, USA
Erdin Bozkurt, Turkey

Welcome from Chamber of Geological Engineers—Turkey

Chamber of Geological Engineers (CGE)-Turkey, is very pleased to co-host to one of the conspicuous regional meetings throughout the world, together with the Turkish Association of Petroleum Geologists and Middle East Technical University on the Anatolian territory and at its heart, in Ankara.

Locating on Eurasian border zone of on-going collision between Eurasian and Arabian plates and within the one of the most prominent orogenic belts of neo-tectonic era, Anatolian terrane also includes the other deforming structures associated with the same period, such as (possibly being reactivation of a zone dating pre-neotectonic time span) North Anatolian Transform Fault Zone, East Anatolian Fault Zone, each of those are still active, massifs and older suture zones.

Being a center situated on trade roads in the past, Ankara, a capital simply urbanized recently on the steppe, surely, not respectable for natural scenes for most of you, the participants from abroad; but, obviously, it is possible to trace the past via monuments, Roman baths and other historical remains in and around. But, no reason to be worry! We think that, the (technical) trips to Aegean, Black Sea and Southeast regions as well as to Cappadocia, that pre- and/or post-dating the event, will gratify you for both, the professional interest and the wine and dine, the landscape and historical-cultural mosaic of centuries, probably thousands of years.

Dündar ÇAGLAN
President of *Chamber of Geological Engineers of Turkey*

*The leading professional organization in geology, **Chamber of Geological Engineers of Turkey**, founded in 1974, is one of the (professional) chambers constituting UCTEA (Union of Turkish Architects and Engineers) grounded by Act No: 6235. The Chamber, having actually more than twelve-thousand members and trying to fulfill its responsibilities by head office in Ankara and eleven regional branches and otherwise representatives, throughout the country. Recognizing its dual function, i. e. seeking to improve professional benefits and participating in activities in earth-sciences and closely-related fields, the Chamber, particularly since 1990's, has hosted (and/or co-hosted) many international meetings, such as HABITAT-2, Geology of the Black Sea, Geology of Menderes Masif and internationally participated other scientific and technical congresses and symposia.*

Welcome from The Geological Society of America

On behalf of The Geological Society of America, I welcome you to the Tectonic Crossroads: Evolving Orogens of Eurasia-Africa-Arabia meeting, which is jointly organized and co-convened with the Chamber of the Geological Engineers of Turkey and the Turkish Association of Petroleum Geologists and hosted by Middle East Technical University (METU). The program integrates a wide range of geoscience themes, which reflect the fact that Turkey and the surrounding region make up one of the great crossroads of tectonic activity and world culture.

The Tectonic Crossroads meeting is being held on the campus of Middle East Technical University in Ankara in their spectacular convention center facility. We are very excited about this opportunity for learning and intercultural exchange at this extraordinary event. Ankara is a very special meeting location, because Turkey is situated at the junction of the Eurasian, African, and Arabian plates. The dynamic interplay of tectonics, sedimentation, metamorphism, and magmatism has created a geologic tapestry blessed with significant natural resources and a populace facing notable seismic and volcanic hazards. These characteristics have been developed into meeting session themes chaired by world experts and field trips led by local experts.

The lead organizers of the Tectonic Crossroads meeting are Yildirim Dilek of Miami University and Erdin Bozkurt of METU. They are heartily thanked for their work to make this meeting, the first sponsored by the new International Section of GSA, a great success.

We anticipate a scientifically dynamic meeting and look forward to your participation.

Mark Cloos
International Secretary
Geological Society of America

GSA is known throughout the world as a leading professional scientific organization dedicated to advancing the science of geology and to supporting the efforts of earth scientists. Since its founding in 1888, this non-profit society of over 22,000 members worldwide has served the scientific community with honor and distinction. The purpose of the Society is to provide the opportunity for the exchange of ideas and discoveries in the various fields of geology. GSA publishes scientific papers, journals, and books encompassing the broad spectrum of the geological sciences. It also organizes and promotes regional and national meetings.

The GSA International Section was formed in 2009. GSA, along with the International Section, provides a global forum for knowledge-sharing and networking among geoscientists. Serving members in over 95 countries, GSA programs unite the global science community in shaping the future of the Earth sciences.

Welcome from Turkish Association of Petroleum Geologists

On the behalf of Turkish Association of Petroleum Geologists, I welcome you to Turkey and Ankara.

It is a great honor for the Turkish Association of Petroleum Geologists to co-organize *Tectonic Crossroads: Evolving Orogens of Eurasia-Africa-Arabia* with The Geological Society of America and the Chamber of the Geological Engineers of Turkey.

The Turkish Association of Petroleum Geologists was founded by Enver Necdet Egeran and his friends on 2 August 1958 in Ankara, about the tenth year after the discovery of oil in the Raman Mountain in Southeast Turkey. This period corresponds to the first peak of exploration activities in Turkey. Later, the Association was entitled to the right of using the prefix "Turkish" with a Council of Ministers decision, and it became Turkish Association of Petroleum Geologists (TAPG).

The main drive behind the activities of the Association for that time and now, according to the founding members, was the idea that a professional society should have responsibilities for establishing an environment in which the petroleum geologists of the country would enjoy the awareness of and be exposed to current developments in scientific concepts and industry technologies, generally accepted business practices, and a global business perspective. Today, TAPG continues this mission by publishing the semiannual *TAPG Bulletin* and various symposium proceedings, holding distinguished lecture series, and organizing oil and gas events of a broad spectrum from local symposiums of geological focus to business-oriented international meetings. As a principle, TAPG always maintains close ties with other international geoscience organizations and is an affiliated society of the American Association of Petroleum Geologists (AAPG).

The Turkish Association of Petroleum Geologists will continue its activities oriented toward hydrocarbon exploration both on a national and international scale with many members from petroleum companies, universities, and research institutes with the hope that success will give new perspectives to energy policies and investments and will lead to establishment of solid business practices in every aspect of exploration and development of oil and gas resources of Turkey. The Turkish Association of Petroleum Geologists, in its 53rd year, is proud to have already secured an important place among worldwide professional societies with its respected members active in various aspects of oil and gas exploration from practicing petroleum geology in solution of real world problems to developing and applying state of the art concepts and technologies through international research.

Being at the "center of Anatolia," you will enjoy your time in Ankara because of the top quality of participant presentations together with pre- and post-conference field trips and midweek trips. I profoundly hope that the meeting will lead to enhancement of the productivity of international collaborations between geologists across the world.

Respectfully,

Ismail Bahtiyar
Chairman of Turkish Associaiton of Petroleum Geologists
Board of Directors

Conference Schedule and Calendar of Events

WEDNESDAY, 29 SEPTEMBER		
Field Trip:		
Active Faulting and Archaeoseismology of Western Anatolia	29 Sept.–3 Oct.	

FRIDAY, 1 OCTOBER		
Field Trip:		
Blueschists, Ophiolites and Suture Zones in Northwest Anatolia	1–3 Oct.	

SUNDAY, 3 OCTOBER		
Registration	16:00–20:30	Foyer, CCC, METU
Opening Reception	18:00–20:30	CCC, METU

MONDAY, 4 OCTOBER		
Registration	07:30–18:30	Foyer, CCC, METU
Opening Ceremony	09:00–09:50	Kemal Kurdas Salon, CCC, METU
• Yildirim Dilek, Lead Organizer, Geological Society of America and Miami University, USA		
• Erdin Bozkurt, Lead Organizer, Middle East Technical University, Turkey		
• Mark Cloos, International Secretary, Geological Society of America, USA		
• Jack Hess, Executive Director, Geological Society of America, USA		
• Edmund Nickless, Executive Secretary, The Geological Society of London, U.K.		
• Alberto C. Riccardi, President, The International Union of Geological Sciences (IUGS), Argentina		
• Ahmet Acar, President, Middle East Technical University, Turkey		
Keynote Talk	10:00–10:45	Salon, CCC, METU
Joann M. Stock, Caltech, USA "*The Southern San Andreas Fault System and Northern Gulf of California: Formation of New Crust Along a Transtensional Plate Boundary*"		

MORNING ORAL TECHNICAL SESSIONS		
Landscape, climate and archaeological evolution of the Mediterranean region. Part 1	10:50–12:30	Salon B, CCC, METU
Ophiolites, blueschists, and suture zones. Part 1	10:50–12:30	Salon A, CCC, METU
Strike-slip and transform fault tectonics. Part 1	10:50–12:30	Kemal Kurdas Salon, CCC, METU

POSTER SESSIONS (POSTERS SHOULD BE UP BETWEEN 8:30–18:30; AUTHORS WILL BE PRESENT FROM 17:00–18:30)		
Landscape, climate and archaeological evolution of the Mediterranean region.		Exhibition Hall, CCC, METU
Magmatism in evolving orogens: Collision to extension.		Exhibition Hall, CCC, METU
Ophiolites, blueschists, and suture zones. Part 1		Exhibition Hall, CCC, METU
Strike-slip and transform fault tectonics.		Exhibition Hall, CCC, METU
Subduction, collision and orogeny. Part 1		Exhibition Hall, CCC, METU
Tectonic, magmatic & geomorphic evolution of high plateaus.		Exhibition Hall, CCC, METU

Lunch	12:30–13:30	CCC, METU
Keynote Talk	13:30–14:15	Kemal Kurdas Salon, CCC, METU
Andreas Mulch, Universität Hannover, Germany *“Miocene to Pliocene Plateau Development and Precipitation Patterns in Central Anatolia”*		

AFTERNOON ORAL TECHNICAL SESSIONS		
Landscape, climate and archaeological evolution of the Mediterranean region. Part 2	14:30–16:50	Salon B, CCC, METU
Ophiolites, blueschists, and suture zones. Part 2	14:30–16:50	Salon A, CCC, METU
Strike-slip and transform fault tectonics. Part 2	14:30–16:50	Kemal Kurdas Salon, CCC, METU
Tectonic, magmatic & geomorphic evolution of high plateaus. Part 1	14:30–16:50	Salon C, CCC, METU

Afternoon Break	15:30–15:50	Foyer, CCC, METU

TUESDAY, 5 OCTOBER		
Registration	07:30–18:30	Foyer, CCC, METU
Keynote Talk	08:30–09:15	Kemal Kurdas Salon, CCC, METU
Robert Reilinger, MIT, USA *“Subduction Drives Arabia/Africa Plate Convergence with Eurasia and Provides a Unifying, Dynamic Mechanism for Mediterranean/Middle East Tectonics”*		

MORNING ORAL TECHNICAL SESSIONS		
Crustal motions, mantle dynamics & GPS velocities in continental collision. Part 1	09:30–12:30	Kemal Kurdas Salon, CCC, METU
Magmatism in evolving orogens: Collision to extension. Part 1	09:30–12:30	Salon B, CCC, METU
Mélanges and mélange–forming processes. Part 1	09:30–12:30	Salon A, CCC, METU

POSTER SESSIONS (POSTERS SHOULD BE UP BETWEEN 8:30–18:30; AUTHORS WILL BE PRESENT FROM 17:00–18:30)		
Crustal motions, mantle dynamics & GPS velocities in continental collision.		Exhibition Hall, CCC, METU
Magmatism in evolving orogens: Collision to extension. Part 2		Exhibition Hall, CCC, METU
Mélanges and mélange–forming processes.		Exhibition Hall, CCC, METU

Morning Break	10:30–10:50	Foyer, CCC, METU
Lunch	12:30–13:30	CCC, METU
Keynote Talk	13:30–14:15	Kemal Kurdas Salon, CCC, METU
Sun-Lin Chung, National Taiwan University, Taiwan *“A Comparative Study of the Tibet/Himalaya and Caucasus/Iran Orogenic Belts: Magmatic Perspectives”*		

AFTERNOON ORAL TECHNICAL SESSIONS		
Crustal motions, mantle dynamics & GPS velocities in continental collision. Part 2	14:30–16:50	Kemal Kurdas Salon, CCC, METU
Magmatism in evolving orogens: Collision to extension. Part 2	14:30–16:50	Salon B, CCC, METU
Mélanges and mélange–forming processes. Part 2	14:30–16:50	Salon A, CCC, METU
Tectonic, magmatic & geomorphic evolution of high plateaus. Part 2	14:30–16:50	Salon C, CCC, METU

Afternoon Break	15:30–15:50	Foyer, CCC, METU

WEDNESDAY, 6 OCTOBER		
Mid-Week Field Trips	08:00–17:00	

THURSDAY, 7 OCTOBER		
Registration	07:30–18:30	Foyer, CCC, METU
Keynote Talk	08:30–09:15	Kemal Kurdas Salon, CCC, METU
Robert Hall, Royal Holloway University of London, U.K. "*Subduction, Collision and Development of Orogenic Belts: A Southeast Asian Perspective on the Tectonic Crossroads of Eurasia–Africa–Arabia*"		

MORNING ORAL TECHNICAL SESSIONS		
Aegean geodynamics and extensional tectonics. Part 1	09:30–12:30	Salon B, CCC, METU
Palaeomagnetic perspectives on the Africa-Arabia-Eurasia plate interactions	09:30–12:30	Salon C, CCC, METU
Sedimentary basin evolution and oil fields in the Middle & Near East (*Sponsored by the Turkish Association of Petroleum Geologists*)	09:30–12:30	Salon D, CCC, METU
Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region. Part 1	09:30–12:30	Salon A, CCC, METU
Subduction, collision and orogeny. Part 1	09:30–12:30	Kemal Kurdas Salon, CCC, METU

POSTER SESSIONS (POSTERS SHOULD BE UP BETWEEN 8:30–18:30; AUTHORS WILL BE PRESENT FROM 17:00–18:30)		
Aegean geodynamics and extensional tectonics.		Exhibition Hall, CCC, METU
Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region.		Exhibition Hall, CCC, METU
Subduction, collision and orogeny. Part 2		Exhibition Hall, CCC, METU

Morning Break	10:30–10:50	Foyer, CCC, METU
Lunch	12:30–13:30	CCC, METU
Keynote Talk	13:30–14:15	Kemal Kurdas Salon, CCC, METU
Philippe Agard, Université P.M. Curie, Paris, France *"Zagros Convergence: A Subduction-Dominated Process?"*		

AFTERNOON ORAL TECHNICAL SESSIONS		
Aegean geodynamics and extensional tectonics. Part 2	14:30–16:50	Salon B, CCC, METU
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Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region. Part 2	14:30–16:30	Salon A, CCC, METU
Subduction, collision and orogeny. Part 2	14:30–16:50	Kemal Kurdas Salon, CCC, METU

Afternoon Break	15:30–15:50	Foyer, CCC, METU
Conference Dinner	20:00–23:00	CCC, METU

FRIDAY, 8 OCTOBER		
Registration	07:30–16:00	Foyer, CCC, METU
Field Trip:		
Late Mesozoic-Cenozoic Stratigraphy of Southeast Anatolia and the East Anatolian Fault System	8–15 Oct.	
Keynote Talk	08:30–09:15	Kemal Kurdas Salon, CCC, METU
Harry W. Green, II, University of California at Riverside, USA "*Subduction Zone Earthquake Mechanisms and Exhumation of Rocks From Depths Exceeding 300 Km in Collision Zones*"		

MORNING ORAL TECHNICAL SESSIONS		
Modern accretionary wedges and ancient analogues	09:30–12:30	Kemal Kurdas Salon, CCC, METU
Ophiolites, blueschists, and suture zones. Part 3	09:30–12:30	Salon B, CCC, METU
Subduction, collision and orogeny. Part 3	09:30–12:30	Salon A, CCC, METU

POSTER SESSIONS (POSTERS SHOULD BE UP BETWEEN 8:30–18:30; AUTHORS WILL BE PRESENT FROM 17:00–18:30)		
Modern accretionary wedges and ancient analogues.		Exhibition Hall, CCC, METU
Ophiolites, blueschists, and suture zones. Part 2		Exhibition Hall, CCC, METU
Sedimentary basin evolution and oil fields in the Middle & Near East. *(Sponsored by the Turkish Association of Petroleum Geologists)*		Exhibition Hall, CCC, METU

Morning Break	10:30–10:50	Foyer, CCC, METU
Lunch	12:30–13:30	CCC, METU
Keynote Talk	13:30–14:15	Kemal Kurdas Salon, CCC, METU
Henry J.B. Dick, Woods Hole Oceanographic Institution, USA "*Modes of Accretion at Slower Spreading Ocean Ridges*"		

AFTERNOON ORAL TECHNICAL SESSIONS		
Mélanges and mélange–forming processes. Part 3	14:30–16:50	Salon A, CCC, METU
Ophiolites, blueschists, and suture zones. Part 4	14:30–16:50	Salon B, CCC, METU

Afternoon Break	15:30–15:50	Foyer, CCC, METU

SATURDAY, 9 OCTOBER		
Field Trips:		
Central Anatolian Accretionary Complex: Ankara Mélange	9–10 Oct.	
Cappadocian Volcanic Province	9–11 Oct.	
North Anatolian Fault Zone – *cancelled*	9–12 Oct.	
Menderes Core Complex and Extensional Tectonics in Western Anatolia – *cancelled*	9–15 Oct.	

Technical Sessions

Meeting policy prohibits the use of cameras or sound-recording equipment at technical sessions and poster sessions.

A no-smoking policy has been established by the Programme Committee and will be followed in all meeting rooms for technical sessions.

NOTICE

In the interest of public information, the Geological Society of America provides a forum for the presentation of diverse opinions and positions. The opinions (views) expressed by speakers and exhibitors at these sessions are their own and do not necessarily represent the views or policies of the Geological Society of America.

NOTE INDEX SYSTEM

Numbers (3-4, 15-4) indicate session and order of presentation within that session.

*denotes speaker

MONDAY, 4 OCTOBER 2010

MORNING ORAL TECHNICAL SESSIONS

SESSION NO. 1

Keynote Talk 1

10:00, METU Convention and Cultural Centre, Kemal Kurdas Salon

1-1 10:00 Stock, Joann M.*: **THE SOUTHERN SAN ANDREAS FAULT SYSTEM AND NORTHERN GULF OF CALIFORNIA: FORMATION OF NEW CRUST ALONG A TRANSTENSIONAL PLATE BOUNDARY**

SESSION NO. 2

Landscape, climate and archaeological evolution of the Mediterranean region. Part 1 (Akdeniz bölgesinin topografik, iklimsel ve arkeolojik tarihçesi)

10:50, METU Convention and Cultural Centre, Salon B

Kathleen Nicoll and Yildirim Dilek, Presiding

2-1 10:50 Pazzaglia, Frank J.*; Wegmann, Karl W.; Brandon, Mark: **CLIMATIC, LITHOLOGIC, AND TECTONIC CONTROLS on TERRACE GENESIS IN ACTIVE OROGENS**

2-2 11:10 Yin, A.*: **CLIMATE CHANGE, TECTONICS AND THE EVOLUTION OF THE HIMALAYAN RIVERS AND TOPOGRAPHY**

2-3 11:30 Nicoll, Kathleen*: **GEOARCHAEOLOGY, ENVIRONMENTAL HISTORY, AND TECTONIC UPLIFT IN EASTERN ANATOLIA (SE TURKEY)**

2-4 11:50 Kazanci, Nizamettin*; Gulbabazadeh, Tirzad; Suludere, Yasar: **GEOLOGICAL EVOLUTION OF THE SEFIDRUD DELTA, SOUTHERN CASPIAN SEA, IRAN**

2-5 12:10 Pope, Richard J.J.*; Skourtsos, Emmanuel: **RESOLVING PATTERNS OF CRETAN FAN SEDIMENTATION: PRELIMINARY INSIGHTS FROM MINERAL MAGNETIC AND CHRONOMETRIC DATA**

SESSION NO. 3

Ophiolites, blueschists, and suture zones. Part 1 (Ofiyolitler, mavisistler ve kenet kusaklari)

10:50, METU Convention and Cultural Centre, Salon A

Karlis Muehlenbachs and Ali Polat, Presiding

3-1 10:50 Kusky, Timothy M.*: **ORIGIN AND EMPLACEMENT OF ARCHEAN OPHIOLITES OF THE CENTRAL OROGENIC BELT, NORTH CHINA CRATON**

3-2 11:10 Furnes, Harald*; De Wit, Maarten; Robins, Brian: **EVOLUTION OF THE ONVERWACHT SUITE OF THE PALEOARCHEAN BARBERTON GREENSTONE BELT (SOUTH AFRICA) AS OCEANIC CRUST AND ISLAND ARCS**

3-3 11:30 Muehlenbachs, Karlis*; Furnes, Harald; De Wit, Maarten: **RELATIONSHIP BETWEEN BASALT ALTERATION, CHERT FORMATION AND TECTONOSTRATIGRAPHY AT BARBERTON MT. LAND, SOUTH AFRICA**

3-4 11:50 Polat, Ali*: **TRACE ELEMENT AND RADIOGENIC (ND AND PB) ISOTOPE SYSTEMATICS OF THE MESOARCHEAN FISKENAESSET ANORTHOSITE COMPLEX, SW GREENLAND: IMPLICATIONS FOR ARCHEAN CONTINENTAL GROWTH**

3-5 12:10 Abd El-Rahman, Yasser*: **THE TECTONIC EVOLUTION OF THE CENTRAL EASTERN DESERT OF EGYPT DURING THE NEOPROTEROZOIC ERA: AN OPHIOLITIC PERSPECTIVE AND IMPLICATION ON GOLD METALLOGENY**

SESSION NO. 4

Strike-slip and transform fault tectonics. Part 1 (Dogrultu atim ve transform fay tektonigi)

10:50, METU Convention and Cultural Centre, Kemal Kurdas Salon

Zvi Garfunkel and Paul Mann, Presiding

4-1 10:50 Anderson, Thomas H.*: **COEVAL GLOBAL EXTENSIONAL EVENTS – AN INDICATION OF TRANSMISSION OF CHANGES IN PLATE MOTIONS IN RESPONSE TO COLLISION, COUPLING, AND CAPTURE**

4-2 11:10 Busby, Cathy J.*; Putirka, Keith: **BIRTH OF A PLATE BOUNDARY: TRANSTENSIONAL TECTONICS AND MAGMATISM, SIERRA NEVADA MICROPLATE AND GULF OF CALIFORNIA RIFT**

4-3 11:30 Dalziel, Ian W.D.*; Lawver, Lawrence: **TRANSFORM MOTION ACROSS THE SCOTIA ARC: INFLUENCE ON OCEANIC CIRCULATION**

4-4 11:50 Mann, Paul*: **THE CARIBBEAN PLATE: A NATURAL LABORATORY FOR THE STUDY OF THE STRUCTURE AND SEISMIC POTENTIAL OF ACTIVE STRIKE-SLIP FAULTS**

4-5 12:10 Wyld, Sandra J.*; Wright, James E.: **STRIKE-SLIP TRANSLATIONS IN EVOLVING OROGENS: THE NORTH AMERICAN CORDILLERA EXAMPLE AND IMPLICATIONS FOR PALEOTECTONIC AND PALEOGEOGRAPHIC ANALYSES**

POSTER TECHNICAL SESSIONS

SESSION NO. 5

Landscape, climate and archaeological evolution of the Mediterranean region. Posters (Akdeniz bölgesinin topografik, iklimsel ve arkeolojik tarihçesi)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

5-1 1 Kucukuysal, Ceren*; Turkmenoglu, Asuman; Kapur, Selim; Yilmaz, Ismail Omer: **SWELLING CLAY PALEOSOLS AS INDICATORS OF SEASONAL DRYNESSS DURING PLIO-QUATERNARY IN ANKARA, TURKEY**

SESSION NO. 6

Magmatism in evolving orogens: Collision to extension. Posters Part 1 (Aktif orojenik kusaklarda magmatizmanin evrimi: Çarpisma tektoniginden gerilmeli tektonige gidis)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

6-1 2 Barich, Amel*; Bouybaouène, Mohamed Larbi: **MG-AL RICH ZONE IN THE CONTACT BETWEEN MANTLE ROCKS (PERIDOTITES) AND GRANULITES FACIES ROCKS IN THE BENI BOUSERA MASSIF (INTERNAL RIF, MOROCCO)**

6-2 3 Palinkas, Ladislav*; Sopstaric Borojevic, Sibila; Strmic Palinkas, Sabina; Neubauer, Franz: **DATING OF NEOTETHYAN INCIPIENT RIFTING MAGMATISM on THE MID-ADRIATIC ISLANDS JABUKA, BRUSNIK AND VIS, CROATIA**

6-3 4 Nouraliee, Javad*; Farahkhah, Nasrin: **CONCEPTUAL MODEL OF KHORHE GEOTHERMAL RESERVOIR**

6-4 5 Eskandary, Amir*; Amini, Sadraddin V.: **MAGMA DYNAMICS INFERRED FROM GEOCHEMICAL MODELING AND QUANTITATIVE TEXTURAL MEASUREMENTS OF IGNEOUS ROCKS FROM SE-BIRJAND (EAST OF IRAN)**

6-5 6 Farahkhan, Nasrin*; Eskandary, Amir; Zaeim Nia, Fateme: **MAGMATIC FRACTIONATION MODELLING IN KARAJ DAM SILL IGNEOUS ROCKS**

6-6 7 Remichi, L.*; Yesba, S.; Sadaoui, M.; Badari, K.: **CHARACTERISATION OF THE VOLCANIC SERIEES IN THE DAMRANE (WESTERN OUGARTA, ALGERIA) AND IMPLICATION FOR THE GLOBAL MODEL OF THE WEST AFRICAN SHIELD NORTEASTERN MARGIN**

6-7 8 Rajabinasab, Babak*; Maghsoudi, Meysam: **PROMISING AREA DETECTION USING MULTIVARIATE STATISTICS**

6-8 9 Zaeimnia, Fatemeh*; Kananian, Ali; Qin, Kezhang; Su, Benxun: **SURVEY OF MINERAL CHEMISTRY OF SOUTH AMLASH CLINOPYROXENE, NORTH OF IRAN: AN EVIDENCE OF BI MODAL GABBRO**

6-9 10 Khatib, Mohammad Mahdi*; Zarrinkoub, Mohammad Hossein: **STRUCTURAL CONTROL FOR EMPLACEMENT OF THE ANDESITIC DIKES IN ROMENJAN AREA, SOUTH OF BIRJAND, EAST OF IRAN**

6-10 11 Moghaddas, Yousef*; Hajialioghli, Robab: **METALUMINOUS SUB-ALKALINE GRANITOIDS FROM THE TAKAB AREA, NW IRAN**

6-11 12 Saki, Adel*: **MINERALOGY, GEOCHEMISTRY AND GEODYNAMIC SETTING OF THE GRANITOIDS FROM NW IRAN**

6-12 13 Chiu, Han-Yi*; Zarrinkoub, Mohammad Hossein; Chung, Sun-Lin; Lin, I-Jhen; Yang, Hsiao-Ming; Lo, Ching-Hua; Mohammadi, Seyyed Saeid; Khatib, Mohammad Mahdi: **ZIRCON U-PB AGE AND GEOCHEMICAL CONSTRAINTS on THE MAGMATIC AND TECTONIC EVOLUTION IN IRAN**

6-13 14 Lin, Yu-Chin*; Chung, Sun-Lin; Karakhanyan, Arkadi; Jrbashyan, Ruben; Navasardyan, Gevorg; Galoyan, Ghazar; Chiu, Han-Yi; Lin, I-Jhen; Chu, Chiu-Hong; Lee, Hao-Yang: **GEOCHEMICAL CONSTRAINTS on THE PETROGENESIS OF EOCENE TO QUATERNARY VOLCANIC ROCKS IN ARMENIA**

SESSION NO. 7

Ophiolites, blueschists, and suture zones. Posters Part 1 (Ofiyolitler, mavisistler ve kenet kusaklari)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

7-1 15 Rebay, Gisella*; Spalla, Maria Iole; Bernardoni, Jacopo: **DEFORMATION-METAMORPHISM RELATIONSHIPS IN THE ECLOGITISED RODINGITES OF THE UPPER VALTOURNENCHE (ZERMATT-SAAS ZONE, ITALY)**

7-2 16 Malatesta, Cristina*; Gerya, Taras; Federico, Laura; Scambelluri, Marco; Crispini, Laura; Capponi, Giovanni: **THE HIGH PRESSURE VOLTRI MASSIF (LIGURIAN ALPS, ITALY) AND 2D NUMERICAL MODELS: AN INSIGHT INTO EXHUMATION MECHANISM**

7-3 17 Farahat, Esam S.*: **NEOPROTEROZOIC EGYPTIAN CENTRAL EASTERN DESERT ARC-BACK-ARC SYSTEM AS EVIDENCED BY SUPRA-SUBDUCTION OPHIOLITES**

SESSION NO. 8

Strike-slip and transform fault tectonics. Posters (Dogrultu atim ve transform fay tektonigi)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

8-1 18 Seyitoglu, Gurol; Esat, Korhan*; Temel, Abidin; Telsiz, Sevgi: **DETERMINATION OF MAIN STRAND OF A STRIKE-SLIP FAULT BY USING SUBSIDIARY STRUCTURES: ESKISEHIR FAULT ZONE AS A CASE STUDY**

8-2 19 Isik, Veysel*; Caglayan, Ayse; Seyitoglu, Gurol; Uysal, Tonguc; Zhao, Jian-xin; Sozeri, Koray; Esat, Korhan: **GEOLOGY OF THE SAVCILI FAULT ZONE, CENTRAL TURKEY**

8-3 20 Çinar, Seray*; Tutkun, Salih Zeki; Özden, Süha; Ateş, Özkan: **KINEMATICS OF THE GANOS FAULT, NW TURKEY: IMPLICATIONS LATERAL EXTRUSION OF THE ANATOLIAN BLOCK SINCE LATE MIOCENE**

8-4 21 Cicek, Ceren*; Doyuran, Vedat: **IMPLEMENTATION OF A ROCKFALL HAZARD RATING SYSTEM TO THE CUT SLOPES ALONG KIZILCAHAMAM-GEREDE SEGMENT OF D750 HIGHWAY**

8-5 22 Parlak, Oktay*; Seyitoglu, Gurol: **THE RELATIONSHIP BETWEEN ELDIVAN-ELMADAG PINCHED CRUSTAL WEDGE AND NORTH ANATOLIAN FAULT ZONE: AN APPROACH TO THE AGE OF CENTRAL NORTH ANATOLIAN FAULT ZONE**

8-6 23 Rashidi, Mohadese*; Almasian, Mahmuod; Soltani, Mahyar: **STRUCTURAL INVESTIGATION OF NAYBAND FAULT (MIDDLE PART) BY USING SATELLITE IMAGE PROCESSING**

8-7 24 Toori, Moosarreza*; Seyitoglu, Gurol: **NEOTECTONICS OF ZANJAN (CENTRAL IRAN): A LEFT LATERAL STRIKE-SLIP SYSTEM AND RELATED STEPOVER STRUCTURES**

8-8 25 Gürbüz, Alper*: **PULL-APART BASIN FEATURES IN 2D AND 3D**

SESSION NO. 9

Subduction, collision and orogeny. Posters Part 1 (Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

9-1 26 Dokukina, Ksenia*; Konilov, Alexander; Kaulina, Tatiana: **ARCHAEAN AGE AND PETROLOGY OF GRANITOIDS FROM GRIDINO AREA (BELOMORIAN ECLOGITE PROVINCE) AS LIMIT IN THE TIME OF HIGH-PRESSURE PROCESSES**

SESSION NO. 10

Tectonic, magmatic & geomorphic evolution of high plateaus. Posters (Yüksek platolarin tektonik, magmatik ve jeomorfik evrimleri)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

10-1 27 Sanaei, Saman; Abbasi, Madjid*; Sobouti, Farhad: **THE STUDY OF CRUSTAL STRUCTURES FOR THE IRANIAN PLATEAU BY TERRESTRIAL GRAVITY DATA**

AFTERNOON ORAL TECHNICAL SESSIONS

SESSION NO. 11

Keynote Talk 2

13:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

11-1 13:30 Mulch, Andreas*; Mikes, Tamas; Rojay, Bora; Schemmel, Fabian: **MIOCENE TO PLIOCENE PLATEAU DEVELOPMENT AND PRECIPITATION PATTERNS IN CENTRAL ANATOLIA**

SESSION NO. 12

Landscape, climate and archaeological evolution of the Mediterranean region. Part 2 (Akdeniz bölgesinin topografik, iklimsel ve arkeolojik tarihçesi)

14:30, METU Convention and Cultural Centre, Salon B

Kathleen Nicoll and Stefano Catalano, Presiding

12-1 14:30 Felis, Thomas*; Rimbu, Norel; Al-Rousan, Saber: **MEDITERRANEAN CLIMATE VARIABILITY DOCUMENTED IN OXYGEN ISOTOPE RECORDS FROM NORTHERN RED SEA CORALS**

12-2 14:50 Cosentino, Domenico*; Radeff, Giuditta; Darbas, Güldemin; Dudas, Frank; Gürbüz, Kemal; Schildgen, Taylor F.: **LATE MIOCENE GEOHISTORY OF THE MUT AND ADANA BASINS (SOUTHERN TURKEY): INSIGHT FOR UPLIFT OF THE SOUTHERN MARGIN OF THE CENTRAL ANATOLIA PLATEAU**

12-3 15:10 Currano, Ellen D.*; Jacobs, Bonnie F.; Tabor, Neil J.; Pan, Aaron D.: **RECONSTRUCTING PALEOLANDSCAPE, PALEOCLIMATE, AND PALEOECOLOGY OF THE LATE OLIGOCENE CHILGA BASIN, NORTHWESTERN ETHIOPIA**

15:30 **Break**

12-4 15:50 Gjani, Eleni*; Dilek, Yildirim: **PALYNOSTRATIGRAPHY, PALEOECOLOGY AND PALEOCLIMATOLOGY OF TERTIARY MOLASSE BASINS AND THE PERI-ADRIATIC DEPRESSION IN ALBANIA AND PALEOGEOGRAPHIC IMPLICATIONS**

12-5 16:10 Yilmaz, Ismail Omer*; Ozcan, Ercan; Less, George; Okay, Aral; Fodor, Laszlo; Pálfalvi, Sarolta: **EVOLUTION AND STEPWISE DROWNING OF A RAMP-TYPE CARBONATE PLATFORM IN THRACE BASIN, NW TURKEY (LATE MIDDLE EOCENE –OLIGOCENE)**

12-6 16:30 Catalano, Stefano*; Tortorici, Giuseppe; Romagnoli, Gino; Sturiale, Giovanni: **THE EFFECTS OF LATE QUATERNARY CLIMATE CHANGES ON THE STRATIGRAPHY OF THE M. ETNA VOLCANO (SOUTHERN ITALY)**

SESSION NO. 13

Ophiolites, blueschists, and suture zones. Part 2 (Ofiyolitler, mavisistler ve kenet kusaklari)

14:30, METU Convention and Cultural Centre, Salon A

Aral Okay and Michael Bröcker, Presiding

13-1 14:30 Okay, Aral*: **DEEP SUBDUCTION OF A PASSIVE CONTINENTAL MARGIN: COMPARISON OF THE TAVSANLI ZONE AND OMAN**

13-2 14:50 Pourteau, Amaury*; Oberhänsli, Roland; Candan, Osman; Bousquet, Romain; Sudo, Masafumi: **ALPINE SUBDUCTION-RELATED GEODYNAMICS OF WESTERN TO CENTRAL TURKEY: INSIGHTS FROM PETROLOGY OF HP METASEDIMENTS AND 40Ar/39Ar GEOCHRONOLOGY**

13-3 15:10 Whitney, Donna L.*; Teyssier, Christian; Toraman, Erkan; Seaton, Nicholas C.: **LAWSONITE VORTICITY AND SUBDUCTION KINEMATICS (SIVRIHISAR, TURKEY)**

15:30 **Break**

13-4 15:50 Rebay, Gisella*; Spalla, Maria Iole: **TI-CLINOHUMITE IN THE ECLOGITISED SERPENTINITES OF THE UPPER VALTOURNENCHE (ZERMATT-SAAS ZONE, ITALY): THE TECTONIC RECORD OF UHP IMPRINT?**

13-5 16:10 Bröcker, Michael*; Fotoohi Rad, Gholamreza; Theunissen, Stephanie: **NEW TIME CONSTRAINTS FOR HP METAMORPHISM AND EXHUMATION OF MELANGE ROCKS FROM THE SISTAN SUTURE ZONE, EASTERN IRAN**

13-6 16:30 Omrani, Hadi*; Moazzen, Mohssen; Oberhansli, Roland; Moayyed, Mohsen; Tsujimori, Tatsuki; Bousquet, Romain: **GEOCHEMISTRY OF SHANDERMAN ECLOGITES; CONSTRAINS ON NATURE OF PALEOTETHYS OCEANIC CRUST**

SESSION NO. 14

Strike-slip and transform fault tectonics. Part 2 (Dogrultu atim ve transform fay tektonigi)

14:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

T.A.C. Zitter and Alvis L. Lisenbee, Presiding

14-1 14:30 Niemi, Tina M.*; Ben-Avraham, Zvi; Al-Zoubi, Abdallah; Tibor, Gideon; Hartman, Gal; Abueladas, Abdel-rahmen; Al-Ruzouq, Rami; Akawi, Emad: **ACTIVE TECTONIC DEFORMATION ACROSS THE NORTHERN SHELF OF THE GULF OF AQABA/EILAT, DEAD SEA RIFT SYSTEM**

14-2 14:50 Hubert-Ferrari, Aurelia*; Van Der Woerd, Jerome; King, Geoffrey; Villa, Igor Maria; Altunel, Erhan; Armijo, Rolando: **LONG-TERM EVOLUTION OF THE NORTH ANATOLIAN FAULT**

14-3 15:10 Zitter, T.A.C.*; Grall, C.; Henry, P.; Géli, L.; Cagatay, M.N.; Ozeren, S.; Dupré, S.; Tryon, M.; Bourlange, S.: **FLUID SEEPAGE ALONG THE NORTH ANATOLIAN FAULT, IN THE SEA OF MARMARA, IN RELATION WITH TECTONICS AND SEDIMENTARY ENVIRONMENTS**

15:30 **Break**

14-4 15:50 Lisenbee, Alvis L.*; Uzunlar, Nuri; Terry, Michael: **THE DAVUTOGLAN WRENCH FAULT: INTRA-ANATOLIAN PLATE, NEOGENE DEFORMATION, ANKARA PROVINCE, TURKIYE**

14-5 16:10 Koral, Hayrettin*; Emre, Hasan: **THE NORTH ANATOLIAN FAULT ZONE IN NW TURKEY: INFERENCES FROM NEOGENE STRATIGRAPHY TO EARTHQUAKE RUPTURES**

14-6 16:30 Esat, Korhan*; Seyitoglu, Gurol: **NEOTECTONICS OF NORTH CENTRAL ANATOLIA: A STRIKE-SLIP INDUCED COMPRESSIONAL REGIME**

SESSION NO. 15

Tectonic, magmatic & geomorphic evolution of high plateaus. Part 1 (Yüksek platolarin tektonik, magmatik ve jeomorfik evrimleri)

14:30, METU Convention and Cultural Centre, Salon C

Paul T. Robinson and Zhidan Zhao, Presiding

15-1 14:30 Mo, Xuanxue*; Zhao, Zhidan; Niu, Yaoling; Zhu, Di-Cheng; Dilek, Yildirim: **CENOZOIC MAGMATISM IN GANGDESE, SOUTHERN TIBET: RECORDS OF COLLISION AND SUBDUCTION BETWEEN INDIA AND ASIA**

15-2 14:50 Zhao, Zhidan*; Mo, Xuanxue; Zhu, Di-Cheng; Niu, Yaoling; Dilek, Yildirim: **HIDDEN CRUST-DERIVED MAGMATISM REVEALED BY THE ~23 MA POTASSIC MAGMATISM IN THE WESTERN LHASA TERRANE, TIBET: INSIGHT FROM ZIRCON U-PB DATING AND HF ISOTOPES**

15-3 15:10 Zhu, Di-Cheng*; Zhao, Zhidan; Pan, Gui-Tang; Lee, Hao-Yang: **EARLY CRETACEOUS SUBDUCTION-RELATED ADAKITE-LIKE ROCKS FROM THE SOUTHERN MARGIN OF THE LHASA TERRANE, TIBET: PRODUCTS OF SLAB MELTING AND SUBSEQUENT MELT–PERIDOTITE INTERACTION?**

15:30 **Break**

15-4 15:50 Bartol, Jeroen*; Govers, Rob; Wortel, M.J. Rinus: **THE CENTRAL ANATOLIAN PLATEAU: NEW INSIGHTS FROM THERMAL-FLEXURAL MODELLING**

15-5 16:10 Yildirim, Cengiz*; Schildgen, Taylor F.; Echtler, Helmut; Melnick, Daniel; Strecker, Manfred R.: **LATE NEOGENE UPLIFT ASSOCIATED WITH THE NORTH ANATOLIAN FAULT IN THE CENTRAL PONTIDES; THE NORTHERN MARGIN OF THE CENTRAL ANATOLIAN PLATEAU, TURKEY**

15-6 16:30 Schildgen, Taylor F.*; Cosentino, Domenico; Dudas, Frank; Niedermann, Samuel; Strecker, Manfred R.; Yildirim, Cengiz: **UPLIFT OF THE SOUTHERN CENTRAL ANATOLIAN PLATEAU FROM 87Sr/86Sr STRATIGRAPHY AND CRN DATING OF RIVER TERRACES**

TUESDAY, 5 OCTOBER 2010

MORNING ORAL TECHNICAL SESSIONS

SESSION NO. 16

Crustal motions, mantle dynamics & GPS velocities in continental collision. Part 1 (Kitasal çarpismalarda kabuk hareketleri, manto dinamigi ve GPS hiz dalgalanmalari)

09:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

Eric Sandvol and Yildirim Dilek, Presiding

16-1 09:30 Spakman, Wim*: **MANTLE DYNAMICS OF THE MIDDLE EAST INFERRED FROM TOMOGRAPHY**

16-2 09:50 Govers, Rob*; De Franco, Roberta; Wortel, M.J. Rinus: **HOW THE SUBDUCTION CONTACT CONTROLS THE RESPONSE TO CONTINENTAL COLLISION**

16-3 10:10 Sandvol, Eric*: **THE SEISMIC STRUCTURE OF THE ARABIAN PLATE AND THE SURROUNDING PLATE BOUNDARIES**

10:30 **Break**

16-4 10:50 Wortel, M.J. Rinus*; Meijer, Paul Th.; van Yperen, Guido C.N.: **THE ROLE OF CONTINENTAL COLLISION IN THE SEPARATION OF ARABIA FROM AFRICA AND THE FORMATION OF THE DEAD SEA FAULT**

16-5 11:10 Bridges, David; Bender, Carrie; Abdelsalam, Mohamed*; Gao, Stephen; Mickus, Kevin; Thurmond, Allison: **THE MAKING OF A DIVERGENT PLATE BOUNDARY: THE ARABIA-AFRICA PLATE BOUNDARY WITHIN AFAR, ETHIOPIA**

16-6 11:30 Jackson, James*: **ACTIVE TECTONICS OF THE SOUTH CASPIAN REGION**

16-7 11:50 Klein, Elliot*; Özeren, M. Sinan: **THE QUESTION OF LONG-TERM FAULT STRENGTH ACROSS DEFORMING ZONES IN TURKEY**

16-8 12:10 Özbakir, Ali Deger*; Wortel, M.J. Rinus; Govers, Rob: **THE NATURE AND LOCATION OF THE PLATE BOUNDARY BETWEEN THE ANATOLIAN AND AFRICAN PLATES**

SESSION NO. 17

Keynote Talk 3

08:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

17-1 08:30 Reilinger, Robert*; McClusky, Simon: **SUBDUCTION DRIVES ARABIA/AFRICA PLATE CONVERGENCE WITH EURASIA AND PROVIDES A UNIFYING, DYNAMIC MECHANISM FOR MEDITERRANEAN/MIDDLE EAST TECTONICS**

SESSION NO. 18

Magmatism in evolving orogens: Collision to extension. Part 1 (Aktif orojenik kusaklarda magmatizmanin evrimi: Çarpisma tektoniginden gerilmeli tektonige gidis)

09:30, METU Convention and Cultural Centre, Salon B

Sun-Lin Chung and Harald Furnes, Presiding

18-1 09:30 Seghedi, Ioan*: **GEOCHEMISTRY AND TECTONICS OF CENOZOIC MAGMATISM IN THE CARPATHIAN-PANNONIAN REGION**

18-2 09:50 Prelevic, Dejan*; Akal, C.; Foley, S.F.; Romer, R.L.; Stracke, A.; van den Bogaard, P.: **POSTCOLLISIONAL MANTLE DYNAMICS OF AN OROGENIC LITHOSPHERE: LAMPROITIC MAFIC ROCKS FROM SW. ANATOLIA, TURKEY**

18-3 10:10 Catlos, Elizabeth*; Baker, Courteney; Sorensen, S.S.; Jacob, Lauren; Çemen, Ibrahim: **LINKING MICROCRACKS WITH MINERAL ZONING OF DETACHMENT-EXHUMED GRANITES TO THEIR TECTONOMAGMATIC HISTORY: EVIDENCE FROM THE SALIHLI AND TURGUTLU PLUTONS IN WESTERN TURKEY (MENDERES MASSIF)**

10:30 **Break**

18-4 10:50 Tokcaer, Murat*; Agostini, Samuele; Savaþçýn, Mehmet Y.ýlmaz: **VOLCANIC ROCKS FROM FOCA-KARABURUN AND AYVALIK-LESVOS GRABENS (WESTERN ANATOLIA) AND THEIR PETROGENIC-GEODYNAMIC SIGNIFICANCE (FOCA-KARABURUN VE AYVALIK-MIDILLI GRABENLERINDEKI (BATI ANADOLU) VOLKANIK KAYALAR VE ONLARIN PETROJENETIK-JEODINAMIK ÖNEMLERI)**

18-5 11:10 Gullu, Bahattin; Kadioglu, Yusuf Kagan*: **TEMPORAL RELATION OF KARAKAYA (ESKISEHIR) GRANITE WITHIN THE FELSIC INTRUSIVE ROCKS OF NW ANATOLIA: GEOLOGY AND PETROLOGY**

18-6 11:30 Agostini, Samuele*; Savaşçın, Mehmet Y.ılmaz; Manetti, Piero: **SUBDUCTION-RELATED AND INTRAPLATE-TYPE VOLCANISM IN CENTRAL ANATOLIA: AN OVERVIEW**

18-7 11:50 Boztuğ, Durmuş*; Satir, Muharrem: **TRACE ELEMENT AND SR-ND-PB- ISOTOPIC CONSTRAINTS on THE GENESIS OF CRETACEOUS GRANITOIDS IN CENTRAL ANATOLIA, TURKEY**

18-8 12:10 Imer, Ali*; Richards, Jeremy P.; Creaser, Robert A.: **GEOLOGY, GEOCHEMISTRY, AND GEOCHRONOLOGY OF THE ÇöPLER PORPHYRY-EPITHERMAL GOLD DEPOSIT, CENTRAL EASTERN TURKEY**

SESSION NO. 19

Mélanges and mélange–forming processes. Part 1 (Melanjlar ve melanj olusturan mekanizmalar)

09:30, METU Convention and Cultural Centre, Salon A

Andrea Festa and Yujiro Ogawa, Presiding

19-1 09:30 Cloos, Mark*: **MELANGES AT CONVERGENT PLATE MARGINS: THE FRANCISCAN COMPLEX OF CALIFORNIA**

19-2 09:50 Festa, Andrea*; Pini, Gian Andrea; Dilek, Yildirim; Ogata, Kei; Codegone, Giulia; Camerlenghi, Angelo: **MELANGE AND MELANGE-FORMING PROCESSES: CASE STUDIES FROM THE APENNINES, APPALACHIANS AND NEW ZEALAND**

19-3 10:10 Pini, Gian Andrea*; Ogata, Kei; Camerlenghi, Angelo; Codegone, Giulia; Festa, Andrea; Lucente, Claudio Corrado: **OLISTOSTROMES, MASS-TRANSPORT DEPOSITS AND THE ORIGIN OF MéLANGES**

10:30 **Break**

19-4 10:50 Federico, Laura*; Crispini, Laura; Capponi, Giovanni; Scambelluri, Marco: **DEVELOPMENT OF TECTONIC MéLANGES DURING SUBDUCTION AND EXHUMATION PROCESSES: CASE-STUDY FROM THE LIGURIAN ALPS (ITALY)**

19-5 11:10 Pandolfi, Luca*; Marroni, Michele; Meneghini, Francesca: **A RECORD OF FRONTAL TECTONIC EROSION IN A FOSSIL ACCRETIONARY WEDGE: THE EXAMPLE OF THE BOCCO SHALE MÉlange, INTERNAL LIGURIDE OPHIOLITIC SEQUENCE (NORTHERN APENNINE, ITALY)**

19-6 11:30 Perotti, Elena*; Bertok, Carlo; d'Atri, Anna; Martire, Luca; Musso, Alessia; Piana, Fabrizio; Varrone, Dario: **SEDIMENTOLOGICAL AND GEOCHEMICAL FEATURES OF CHAOTIC DEPOSITS IN THE VENTIMIGLIA FLYSCH (ROYA-ARGENTINA VALLEY- NW ITALY)**

19-7 11:50 Alonso, Juan Luis*; Marcos, Alberto; Súarez, Angela: **PROCESSES OF STRATAL DISRUPTION IN THE PORMA MELANGE: SOURCE AND SIGNIFICANCE OF THE "NATIVE" AND "EXOTIC" BLOCKS**

19-8 12:10 De Souza, Stéphane*; Tremblay, Alain; Ruffet, Gilles; Meshi, Avni: **THE MéLANGE – OPHIOLITE CONUNDRUM: INSIGHTS FROM IAPETAN AND TETHYAN OPHIOLITES, CANADA AND ALBANIA**

POSTER TECHNICAL SESSIONS

SESSION NO. 20

Crustal motions, mantle dynamics & GPS velocities in continental collision. Posters (Kitasal çarpismalarda kabuk hareketleri, manto dinamigi ve GPS hiz dalgalanmalari)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

20-1 1 Sobouti, Farhad*; Mortezanejad, Gholamreza; Ghods, Abdolreza; Priestley, Keith: **CRUSTAL STRUCTURE IN NORTHWEST IRAN FROM RECEIVER FUNCTION STUDIES**

20-2 2 Vanacore, Elizabeth; Saygin, Erdinc; Taymaz, Tuncay*; Cubuk, Yesim: **CRUSTAL STRUCTURE OF TURKEY FROM RECEIVER FUNCTIONS AND AMBIENT NOISE TOMOGRAPHY**

20-3 3 Ozacar, A. Arda*; Biryol, C. Berk; Beck, Susan; Zandt, George; Kaymakci, Nuretdin: **CRUST AND UPPER MANTLE DYNAMICS OF TURKEY INFERRED FROM PASSIVE SEISMOLOGY: IMPLICATIONS OF SEGMENTED SLAB GEOMETRY**

SESSION NO. 21

Magmatism in evolving orogens: Collision to extension. Posters Part 2 (Aktif orojenik kusaklarda magmatizmanin evrimi: Çarpisma tektoniginden gerilmeli tektonige gidis)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

21-1 4 Azimzadeh, Zohreh*; Dilek, Yildirim; Jahangiri, Ahmad; Ameri, Ali: **MAGMATIC ORIGIN AND TECTONIC SETTING OF THE TERTIARY MAGMATIC ROCKS FROM NORTHWEST OF AHAR-NW IRAN (ORUMIEH-DOKHTAR BELT)**

21-2 5 Ünal, Ezgi*; Güleç, Nilgün; Kuscu, İlkay: **HIGH SULFIDATION EPITHERMAL DEPOSITS: A CASE STUDY FROM NW TURKEY, BIGA PENINSULA**

21-3 6 Simmonds, Vartan*; Calagari, Ali Asghar; Moayyed, Mohsen; Jahangiri, Ahmad: **PETROLOGIC AND PETROGENETIC STUDY OF KIGHAL PORPHYRY STOCK (NORTH OF VARZEGHAN, EAST AZARBAIDJAN PROVINCE, NW IRAN)**

21-4 7 Maghsoudi, Meysam*; Ghorashi, Manouchehr; Nezampour, Mohammad Hadi: **STRUCTURAL INVESTIGATION IN SOUTHEAST OF THE BATLAQ-E-GAVKHUNI (CENTRAL IRAN), WITH SPECIAL TO MINERALIZATION OF THE REGION**

21-5 8 Hadj Mohamed, Nacera*: **MINERALISATIONS DU HORST DE GHAR ROUBAN (ALGERIE OCCIDENTALE)**

21-6 9 Abdelhak Boutaleb, A.B. Sr.*; Khadidja Moussaoui, Kh.M. Jr.: **PRELIMANARY PETROGRAPHIC AND MICROTHERMOMETRIC STUDIES OF THE DOLOMITES AND SPHALERITE MINERALIZATION OF EL ABED ZN – PB DEPOSIT – TLEMCEN – NORTH WESTERN ALGERIA**

21-7 10 Salehian, Mosayeb*; Ghaderi, Majid: **FLUID INCLUSION EVOLUTION AT DARALU PORPHYRY COPPER DEPOSIT, SOUTHEAST IRAN**

21-8 11 Shahbazi, Somayeh*; Ghaderi, Majid; Rashidnejad-Omran, Nematollah: **COPPER, OXYGEN AND SULFUR STABLE ISOTOPE EVIDENCE FROM BASHKAND IRON DEPOSIT, NORTHWEST IRAN**

21-9 12 Pickard, Megan*; Furman, Tanya; Kürkcüoglu, Biltan; Hanan, Barry B.; Furlong, Kevin P.: **GEOCHEMICAL INSIGHTS INTO MANTLE FLOW BENEATH THE ANATOLIAN PLATE**

21-10 13 Dönmez, Mustafa*: **STRATIGRAPHY AND NEW AGE FINDINGS IN THE VOLCANIC ROCKS AROUND, ÇUBUK (ANKARA)-TURKEY**

21-11 14 Genç, Can; Gülmez, Fatma*; Keskin, Mehmet; Tüysüz, Okan: **THE MISSING PART OF NW ANATOLIA OLIGO-MIOCENE VOLCANIC BELT: ALMACIK MOUNTAIN, NEW K-AR AGE AND ISOTOPIC AND GEOCHEMICAL DATA**

21-12 15 Siebel, Wolfgang*; Schmitt, Axel K.; Danisik, Martin; Aydin, Faruk; Kiemele, Elena; Jahn, Simone: **SR-ND-PB ISOTOPIC AND AGE CONSTRAINTS ON THE ORIGIN OF LAVAS FROM THE ACIGOEL COMPLEX, NEVSEHIR, CENTRAL TURKEY**

21-13 16 Jacob, Lauren*; Catlos, Elizabeth; Sorensen, Sorena S.: **CATHODOLUMINESENCE (CL) EVIDENCE FOR THE TECTONIC HISTORY OF THE EGRIGOZ PLUTON, NORTHERN MENDERES MASSIF, WESTERN TURKEY**

21-14 17 Akçay, Ali Ekber*: **THE STRATIGRAPHY OF YAMADAG VOLCANIC COMPLEX BETWEEN YESILKALE AND BEKTAS NEW K/AR AGE FINDINGS**

21-15 18 Agrò, Alessandro*; Le Pennec, Jean-Luc; Temel, Abidin; Zanella, Elena: **ROCK-MAGNETIC INVESTIGATION OF THE KIZILKAYA IGNIMBRITE (CENTRAL ANATOLIAN VOLCANIC PROVINCE)**

21-16 19 Deniz, Kiymet*; Kadioglu, Yusuf Kagan: **INVESTIGATION OF BUZLUKDAGI (KIRSEHIR-TURKEY) SYENITOIDS BY CONFOCAL RAMAN SPECTROSCOPY**

21-17 20 Fritschle, Tobias*; Prelevic, Dejan; Foley, S.F.: **MINERAL VARIATIONS FROM MEDITERRANEAN LAMPROITES: MAJOR ELEMENT COMPOSITIONS AND FIRST INDICATIONS FROM TRACE ELEMENTS IN PHLOGOPITES, OLIVINES AND CLINOPYROXENES**

21-18 21 Prelevic, Dejan*; Akal, C.; Romer, R.L.; Foley, S.F.: **MACROCRYSTAL POPULATIONS RETRIVED FROM LAMPROITES INDICATE ACCRETION OF YOUNG SSZ OCEANIC LITHOSPHERE IN THE ASSEMBLY OF SW. ANATOLIA, TURKEY**

21-19 22 Fischer, Sebastian*; Prelevic, Dejan; Akal, C.: **ALKALINE INTRUSIVES AND WHAT THEY TELL US ABOUT THE UPLIFT OF THE MENDERES MASSIF, W. ANATOLIA, TURKEY**

SESSION NO. 22

Mélanges and mélange–forming processes. Posters (Melanjlar ve melanj olusturan mekanizmalar)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

22-1 23 Moix, Patrice; Beccaletto, Laurent*; Masset, Olivier; Kozur, Heinz W.; Dumitrica, Paulian; Vachard, Daniel; Martini, Rossana; Stampfli, Gerard: **GEOLOGY, CORRELATION AND GEODYNAMIC EVOLUTION OF THE MERSIN MéLANGES, SOUTHERN TURKEY**

22-2 24 Beccaletto, Laurent*; Stampfli, Gerard: **PALEOTECTONIC AND PALEOGEOGRAPHIC SIGNIFICATION OF MELANGES: EXAMPLES FROM THE TETHYAN REALM**

22-3 25 Ogata, Kei*; Mutti, Emiliano; Tinterri, Roberto; Pini, Gian Andrea: **MASS TRANSPORT-RELATED STRATAL DISRUPTION WITHIN SEDIMENTARY MELANGES**

22-4 26 Codegone, Giulia*; Festa, Andrea; Dilek, Yildirim; Pini, Gian Andrea: **FORMATION OF MELANGES, BROKEN FORMATIONS, AND MASS-TRANSPORT CHAOTIC DEPOSITS DURING THE ORDOVICIAN TACONIC OROGENY: EXAMPLES FROM CENTRAL AND NORTHERN APPALACHIAN OROGENIC BELT, EASTERN USA**

22-5 27 Festa, Andrea*; Ghisetti, Francesca C.; Vezzani, Livio: **MELANGES AND BROKEN FORMATIONS IN THE EXHUMED MIOCENE-PLIOCENE OUTER ACCRETIONARY WEDGE OF THE CENTRAL-SOUTHERN APENNINES (ITALY)**

22-6 28 Ozturk, Alican*: **GEOCHEMICAL, GEOISTATISTICAL INVESTIGATION OF HEAVY AND PRECIOUS METALS IN THE BOZKIR OPHIOLITIC MELANGE (BOZKIR, KONYA, TÜRKİYE)**

22-7 29 Ülgen, Semih Can*; Okay, Aral: **TECTONIC SETTING OF THE OPHIOLITIC MELANGES SOUTH OF THE MARMARA SEA BETWEEN THE IZMIR-ANKARA AND INTRA-PONTIDE SUTURES**

AFTERNOON ORAL TECHNICAL SESSIONS

SESSION NO. 23

Crustal motions, mantle dynamics & GPS velocities in continental collision. Part 2 (Kitasal çarpismalarda kabuk hareketleri, manto dinamigi ve GPS hiz dalgalanmalari)

14:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

Victor Mocanu and David Scholl, Presiding

23-1 14:30 Scholl, David*; Redfield, Tim F.; Fitzgerald, Paul G.: **ANALOGOUS TO ANATOLIA, COLLISIONAL AND NON-COLLISIONAL PLATE BOUNDARY FORCES EXTRUDE WESTERN ALASKA TOWARD OFFSHORE SUBDUCTION ZONES**

23-2 14:50 Mann, Paul*; Wallace, Laura; Ellis, Susan: **TECTONIC BLOCK ROTATION, ARC CURVATURE, AND BACK-ARC RIFTING: COMPARISON BETWEEN MEDITERRANEAN AND WESTERN PACIFIC EXAMPLES**

23-3 15:10 Mocanu, Victor*: **MANTLE FLOW IN THE CARPATHIAN BEND ZONE? INTEGRATION OF GPS AND GEOPHYSICAL INVESTIGATIONS**

15:30 **Break**

23-4 15:50 Amer, Aimen*: **OFFSHORE CYRENAICA SUBDUCTION; NEW BATHYMETRY DATA, NORTHEAST LIBYA**

23-5 16:10 Sidorova, Irina Sr.*: **INTEGRATED GEOPHYSICAL MODEL OF LITHOSPHERE IN WESTERN UZBEKISTAN**

23-6 16:30 Hosseini, Sayyed Keivan*; Rahimi, Behnam; Shokraei, Seyedeh Fargol: **LITHOSPHERIC DEFORMATION OF NE IRAN INFERRED FROM SHEAR WAVE SPLITTING**

SESSION NO. 24

Keynote Talk 4

13:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

24-1 13:30 Chung, Sun-Lin*; Zarrinkoub, M.H.; Karakhanyan, A.S.; Javakhishvili, Z.; Lo, Ching-Hua: **A COMPARATIVE STUDY OF THE TIBET/HIMALAYA AND CAUCASUS/IRAN OROGENIC BELTS: MAGMATIC PERSPECTIVES**

SESSION NO. 25

Magmatism in evolving orogens: Collision to extension. Part 2 (Aktif orojenik kusaklarda magmatizmanin evrimi: Çarpisma tektoniginden gerilmeli tektonige gidis)

14:30, METU Convention and Cultural Centre, Salon B

Dejan Prelevic and Ioan Seghedi, Presiding

25-1 14:30 Jahn, Bor-ming*: **ACCRETIONARY OROGEN AND EVOLUTION OF THE JAPANESE ISLANDS - IMPLICATIONS FROM A SR-ND ISOTOPIC STUDY OF THE PHANEROZOIC GRANITOIDS FROM JAPAN**

25-2 14:50 Lee, Hao-Yang*; Chung, Sun-Lin; Yang, Hsiao-Ming; Chu, Chiu-Hung; Lo, Ching-Hua; Mitchell, A.H.G.: **AGE AND GEOCHEMICAL CONSTRAINTS on THE PETROGENESIS OF LATE CENOZOIC VOLCANISM IN MYANMAR**

25-3 15:10 Zhu, Di-Cheng*; Zhao, Zhidan; Niu, Yaoling; Mo, Xuanxue; Chung, Sun-Lin: **THE LHASA TERRANE: RECORD OF A MICROCONTINENT AND ITS HISTORIES OF DRIFT AND GROWTH**

15:30 **Break**

25-4 15:50 Karsli, Orhan*: **LATE MESOZOIC TO LATE CENOZOIC MAGMATIC EVOLUTION OF THE EASTERN PONTIDES, NE TURKEY**

25-5 16:10 Zarrinkoub, M.H.*; Chung, Sun-Lin; Chiu, H.-Y.; Mohammadi, S.S.; Khatib, M.M.; Lin, I-Jhen: **ZIRCON U-PB AGE AND GEOCHEMICAL CONSTRAINTS FROM THE NORTHERN SISTAN SUTURE ZONE on THE NEOTETHYAN MAGMATIC AND TECTONIC EVOLUTION IN EASTERN IRAN**

25-6 16:30 Irannezhadi, Mohammad Reza*; Ghorbani, Mohammad Reza: **TERTIARY MAGMATISM IN ALBORZ MOUNTAINS AND ITS RELATIONSHIP TO THE CONVERGENCE OF EURASIA WITH SOUTHERN PLATES**

SESSION NO. 26

Mélanges and mélange–forming processes. Part 2 (Melanjlar ve melanj olusturan mekanizmalar)

14:30, METU Convention and Cultural Centre, Salon A

Andrea Festa and Gian Andrea Pini, Presiding

26-1 14:30 Kitamura, Yujin*; Kimura, Gaku: **DYNAMIC ROLE OF TECTONIC MéLANGE IN RELATION TO MEGA SEISMOGENESIS – SPACE AND TIME PARTITION OF DEFORMATION IN SUBDUCTION PLATE BOUNDARY**

26-2 14:50 Yamamoto, Yuzuru*; Kameda, Jun; Yamaguchi, Haruka: **THICKENING OF TECTONIC MéLANGES DUE TO CLAY-MINERAL TRANSITION IN 2-4 KM DEPTH IN SUBDUCTION ZONE: HOTA ACCRETIONARY COMPLEX, CENTRAL JAPAN**

26-3 15:10 Kimura, Gaku*: **MéLANGE AS A PLATE BOUNDARY FAULT ROCK- EARTHQUAKE AND SLOW SLIP**

15:30 **Break**

26-4 15:50 Wakita, Koji*: **MELANGES ON GEOLOGICAL MAPS AT A SCALE OF 1:50,000**

26-5 16:10 Ogawa, Yujiro*; Mori, Ryota; Tsunogae, Toshiaki: **RETROGRADE DEFORMATION WITH RETROGRADE METAMORPHISM IN VARIOUS BLOCKS IN MINEOKA OPHIOLITIC MELANGE: COMPARATIVE STUDY TO THE ANKARA AND FRANCISCAN MELANGES**

26-6 16:30 Ukar, Estibalitz*; Cloos, Mark: **TECTONIC EVOLUTION OF BLUESCHIST-FACIES BLOCKS IN THE FRANCISCAN MéLANGE AT SAN SIMEON, CALIFORNIA: INSIGHTS INTO SUBDUCTION ZONE EVOLUTION**

SESSION NO. 27

Tectonic, magmatic & geomorphic evolution of high plateaus. Part 2 (Yüksek platolarin tektonik, magmatik ve jeomorfik evrimleri)

14:30, METU Convention and Cultural Centre, Salon C

Cengiz Yildirim and Ahmad Jahangiri, Presiding

27-1 14:30 Gogus, Oguz H.*; Pysklywec, Russell N.: **LITHOSPHERIC DELAMINATION IN AN OROGENIC SETTING: AN**

EXAMPLE FROM THE EASTERN ANATOLIA COLLISION ZONE

27-2 14:50 Toker, Mustafa*; Krastel, Sebastian; Demirel-Schlueter, Filiz; Demirbag, Emin: **SEISMIC AND CRUSTAL IMPLICATIONS FOR EVOLVING ACCRETIONARY WEDGE-BASIN: LAKE VAN, EASTERN ANATOLIA ACCRETIONARY COMPLEX (E-TURKEY)**

27-3 15:10 Jahangiri, Ahmad*: **GEOCHEMISTRY OF PLIOCENE/ QUATERNARY BASALTS ALONG NORTH TABRIZ FAULT, NW IRAN**

15:30 **Break**

27-4 15:50 Rezaeian, Mahnaz*; Hovius, Niels; Carter, Andrew; Allen, Mark: **EXHUMATION EPISODES IN THE ALBORZ MOUNTAINS WITHIN IRANIAN-TURKISH PLATEAU**

27-5 16:10 Abdollahi, Somayeh; Abbasi, Madjid*; Sobouti, Farhad: **THE STUDY OF CRUSTAL STRUCTURE IN THE IRANIAN PLATEAU BY GRAVIMETRIC DATA BASED on GEOPOTENTIAL MODEL EIGEN-5S**

27-6 16:30 Sheth, Hetu C.*; Kshirsagar, Pooja V.; Shaikh, Badrealam: **MAFIC ALKALIC MAGMATISM IN CENTRAL KACHCHH, INDIA: A MONOGENETIC VOLCANO FIELD IN THE NORTHWESTERN DECCAN TRAPS**

THURSDAY, 7 OCTOBER 2010

MORNING ORAL TECHNICAL SESSIONS

SESSION NO. 28

Aegean geodynamics and extensional tectonics. Part 1 (Ege bolgesinin jeodinamik evrimi ve gerilmeli tektonikte güncel problemler)

09:30, METU Convention and Cultural Centre, Salon B

Laurent Jolivet, Uwe Ring, and Erdin Bozkurt, Presiding

28-1 09:30 Ring, Uwe*; Glodny, Johannes; Will, Thomas M.; Thomson, Stuart N.: **THE RETREATING HELLENIC SUBDUCTION SYSTEM: HIGH-PRESSURE METAMORPHISM, EXHUMATION, NORMAL FAULTING AND LARGE-SCALE EXTENSION**

28-2 09:50 van Hinsbergen, Douwe*: **A KEY EXTENSIONAL METAMORPHIC COMPLEX REVIEWED AND RESTORED: THE MENDERES MASSIF OF WESTERN TURKEY**

28-3 10:10 Gessner, Klaus*; Ring, Uwe; Duclaux, Guillaume; Porwal, Alok: **MIOCENE DEFORMATION OF THE MENDERES MASSIF: CONCURRENT FOLDING, FAULTING AND CORE COMPLEX FORMATION CAUSED BY A LITHOSPHERE SCALE WRENCH ZONE**

10:30 **Break**

28-4 10:50 Bozkurt, Erdin*; Satır, Muharrem; Buğdaycýoğlu, Çağrı: **TIMING OF POST-OROGENIC EXTENSION IN THE GöRDES MIGMATITE DOME, WESTERN TURKEY: INSIGHTS FROM U-PB AND RB-SR GEOCHRONOLOGY**

28-5 11:10 Faulds, James E.*; Bouchot, Vincent; Moeck, Inga; Oguz, Kerem: **FAVORABLE STRUCTURAL SETTINGS OF GEOTHERMAL SYSTEMS IN THE AEGEAN EXTENSIONAL PROVINCE OF WESTERN TURKEY**

28-6 11:30 Rey, Patrice; Teyssier, Christian*; Kruckenberg, Seth C.; Whitney, Donna L.: **COEVAL SHALLOW EXTENSION AND DEEP CONTRACTION DURING OROGENIC COLLAPSE: COLLIDING CHANNELS AND DOUBLE DOMES**

28-7 11:50 Caputo, Riccardo; Catalano, Stefano; Tortorici, Luigi*: **NEOGENE-QUATERNARY EVOLUTION OF CRETE: FROM LITHOSPHERIC COMPRESSION TO CRUSTAL EXTENSION**

28-8 12:10 Altinoglu, Fatma Figen*; Aydin, Ali: **DETERMINATION OF CRUST STRUCTURE OF WESTERN ANATOLIA BY USING THE GRAVITY INVERSION TECHNIQUES**

SESSION NO. 29

Keynote Talk 5

08:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

29-1 08:30 Hall, Robert*: **SUBDUCTION, COLLISION AND DEVELOPMENT OF OROGENIC BELTS: A SE ASIAN PERSPECTIVE ON THE TECTONIC CROSSROADS OF EURASIA–AFRICA–ARABIA**

SESSION NO. 30

Palaeomagnetic perspectives on the Africa-Arabia-Eurasia plate interactions (Afrika-Arap-Avrasya levha iliskilerinde paleomanyetik gözlemler)

09:30, METU Convention and Cultural Centre, Salon C

John Piper and Orhan Tatar, Presiding

30-1 09:30 Van der Voo, Rob*; Torsvik, Trond H.; Domeier, Matthew M.: **PERMO-TRIASSIC PANGEA FITS: WHEN DID A PROPOSED 3500 KM MEGASHEAR BETWEEN GONDWANA AND LAURUSSIA HAPPEN, IF It HAPPENED AT ALL**

30-2 09:50 Tatar, Orhan*; Piper, J.D.A.; Gürsoy, H.; Koçbulut, F.; Mesci, B.L.: **PALAEOMAGNETIC ANALYSIS OF DISTRIBUTED NEOTECTONIC DEFORMATION AND BLOCK DEFINITION IN THE ANATOLIDES OF TURKEY**

30-3 10:10 Peynircioglu, Ali Ahmet*; Langereis, Cor G.; Kaymakci, Nuretdin; van Hinsbergen, Douwe: **APPLYING PALEOMAGNETIC CONSTRAINTS ON ROTATION AND DEFORMATION OF THE ARABIAN PLATE SINCE THE EOCENE IN SOUTHEAST TURKEY**

10:30 **Break**

30-4 10:50 Akpınar, Z.; Tatar, Orhan*; Piper, J.D.A.; Gürsoy, H.; Koçbulut, F.; Mesci, B.L.: **PALAEOMAGNETIC ANALYSIS OF NEOTECTONIC ROTATION IN THE ERZINCAN BASIN, EAST TURKEY**

30-5 11:10 Meijers, Maud J.M.; Kaymakcý, Nuretdin; van Hinsbergen, Douwe; Langereis, Cor G.*; Stephenson, Randell A.; Hippolyte, Jean-Claude: **LATE CRETACEOUS TO PALEOCENE OROCLINAL BENDING IN THE CENTRAL PONTIDES (TURKEY)**

30-6 11:30 Meijers, Maud J.M.*; Langereis, Cor G.; van Hinsbergen, Douwe; Dekkers, Mark J.; Kaymakcı, Nuretdin; Altıner, Demir: **PERVASIVE PALAEOGENE REMAGNETIZATION OF THE CENTRAL TAURIDES FOLD-AND-THRUST BELT (SOUTHERN TURKEY) AND IMPLICATIONS FOR ROTATIONS IN THE ISPARTA ANGLE**

30-7 11:50 Uzel, Bora*; Sözbilir, Hasan; Kaymakcı, Nuretdin; Langereis, Cor G.; Özkaymak, Çağlar; Gülyüz, Erhan; Sarıoğlu, Onur: **BLOCK ROTATIONS AND STRIKE-SLIP TECTONICS IN WEST ANATOLIAN EXTENSIONAL PROVINCE: PRELIMINARY PALEOMAGNETIC, GEOCHRONOLOGICAL AND STRUCTURAL RESULTS FROM ÝZMIR BAY AREA**

30-8 12:10 Çinku, Mualla Cengiz*; Hisarlý, Z. Mümtaz; Orbay, Naci: **NEW CONSTRAINTS on THE TECTONIC HISTORY OF THE NW ANATOLIAN REGION: PALEOMAGNETIC RESULTS FROM MIDDLE EOCENE VOLCANIC UNITS AROUND THE ALMACýK BLOCK, TURKEY**

SESSION NO. 31

Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region. Part 1 (Akdeniz bölgesinin sismik, paleosismik ve arkeosismik evrimi)

09:30, METU Convention and Cultural Centre, Salon A

Erhan Altunel and Mustapha Meghraoui, Presiding

31-1 09:30 Altunel, Erhan*; Meghraoui, Mustapha: **SEISMICITY, PALAEOSEISMICITY & ARCHAEOSEISMOLOGY OF THE MEDITERRANEAN REGION**

31-2 09:50 Wegmann, Karl; Brandon, Mark T.*; Pazzaglia, Frank J.; Fassoulas, C.: **Reassessment of the ORIGIN of the AD 365 Earthquake FROM Geologic and Geochronologic Relationships, Crete, Greece**

31-3 10:10 Niemi, Tina M.*; Allison, Alivia J.; Rucker, John D.: **THE 11th CENTURY COLLAPSE OF AQABA on THE NORTH COAST OF THE GULF OF AQABA, DEAD SEA FAULT SYSTEM, JORDAN**

10:30 **Break**

31-4 10:50 Hubert-Ferrari, Aurelia*; Fraser, Jeff; Vanneste, Kriss; Avsar, Ulas: **AN INTEGRATED HISTORY OF PALEOEARTHQUAKES ALONG THE NORTH ANATOLIAN FAULT (TURKEY)**

31-5 11:10 Avsar, Ulas*; Hubert-Ferrari, Aurélia; Fagel, Nathalie; De Batist, Marc; Schmidt, Sabine; Piotrowska, Natalia; De Vleeschouwer, François: **SEDIMENTOLOGICAL FINGERPRINTS OF PALEOSEISMIC ACTIVITY REVEALED FROM LAKE SEDIMENTS: A CASE STUDY FROM THE NORTH ANATOLIAN FAULT (NAF), TURKEY**

31-6 11:30 Kozaci, Özgür*; Altunel, Erhan; Clahan, Kevin B.; Yönlü, Önder; Sundermann, Sean; Lettis, William R.: **A LATE HOLOCENE SLIP RATE FROM NORTH ANATOLIAN FAULT on HERSEK PENINSULA IN IZMIT BAY, TURKEY**

31-7 11:50 Deveci Gürboga, Sule*; Kocyigit, Ali: **PALAEOSEISMOLOGICAL RESULTS on THE SOURCE OF 1970.03.28 GEDIZ EARTHQUAKE**

31-8 12:10 Kazmer, Miklos*; Major, Balazs: **DISTINGUISHING DAMAGES OF TWO EARTHQUAKES – ARCHAEOSEISMOLOGY OF A CRUSADER CASTLE (AL-MARQAB CITADEL, SYRIA)**

SESSION NO. 32

Subduction, collision and orogeny. Part 1 (Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez)

09:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

Robert Hall and Manuel Pubellier, Presiding

32-1 09:30 Pubellier, Manuel*; Dilek, Yildirim; Rabaute, Alain: **COLLISION FACTORY IN THE OROGENIC BELTS OF SOUTHERN EURASIA; LARGE SCALE COMPARISON**

32-2 09:50 Cloos, Mark*; Sapiie, Benyamin: **COLLISIONAL DELAMINATION IN NEW GUINEA: THE GEOTECTONICS OF SUBDUCTING SLAB BREAKOFF**

32-3 10:10 Baldwin, Suzanne L.*; Webb, Laura E.; Fitzgerald, Paul G.; Zirakparvar, Nasser A.; Catalano, Joseph P.: **FROM SUBDUCTION TO RIFTING: THE LATE CRETACEOUS–CENOZOIC TECTONIC EVOLUTION OF EASTERN PAPUA NEW GUINEA**

10:30 **Break**

32-4 10:50 Ringenbach, Jean-Claude*; Pubellier, Manuel; Sapin, Francois; Bailly, Vivien: **EVIDENCE FOR VARIOUS STAGES OF COLLAPSE IN THE SOUTHEAST ASIAN FOLD-THRUST BELT: BORNEO, PAPUA AND SOUTH CHINA SEA**

32-5 11:10 Bohannon, Robert G.*: **ENERGY CONSIDERATIONS FOR THE ARABIAN, INDO-AUSTRALIAN, AND ASIAN COLLISIONAL SYSTEMS OF NEOTETHYS**

32-6 11:30 Ernst, W.G.*: **MESOZOIC PLATE UNDERFLOW, COLLISION, CONTINENT FORMATION AND HYDROTHERMAL GOLD DEPOSITS ALONG THE NORTH PACIFIC RIM**

32-7 11:50 Hildebrand, Robert S.*: **ARC, COLLISIONAL AND SLAB-FAILURE MAGMATISM WITHIN THE CORDILLERAN OROGEN OF NORTH AMERICA**

32-8 12:10 Wright, James E.*; Wyld, Sandra J.: **LATE CRETACEOUS SUBDUCTION INITIATION on THE EASTERN MARGIN OF THE CARIBBEAN-COLOMBIAN OCEANIC PLATEAU (CCOP): ONE GREAT ARC OF THE CARIBBEAN (?)**

POSTER TECHNICAL SESSIONS

SESSION NO. 33

Aegean geodynamics and extensional tectonics. Posters (Ege bolgesinin jeodinamik evrimi ve gerilmeli tektonikte güncel problemler)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

33-1 1 Skourtsos, Emmanuel*; Fountoulis, Ioannis: **BASIN SEDIMENTATION, NORMAL FAULTING AND LATE-STAGE EXHUMATION IN EXTERNAL HELLENIDES, SOUTH PELOPONNESUS, GREECE**

33-2 2 Bröcker, Michael*; Huyskens, Magdalena; Knoblauch, Susanne: **DATING OF SHEAR ZONE ACTIVITY IN THE CYCLADES, GREECE: EXAMPLES FROM THE ISLANDS OF SYROS AND ANDROS**

SESSION NO. 34

Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region. Posters (Akdeniz bölgesinin sismik, paleosismik ve arkeosismik evrimi)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

34-1 3 Ozkaptan, Murat*; Gokalp, Huseyin: **DETERMINATION OF THE DELAY TIMES BETWEEN TWO OR MORE INTERFERED BODY WAVE TRAINS USING BY SPECTRAL TECHNIQUES**

34-2 4 Tüfekçi, Nesrin*; Schoups, Gerrit; Giesen, Nick van de; Leijen, Freek J. van; Hanssen, Ramon F.: **ESTIMATING SEASONAL GROUNDWATER PUMPING RATE USING InSAR DERIVED LAND DEFORMATION**

34-3 5 Amirpour-asl, Amir; Ghods, Abdolreza*; Rezaeian, Mahnaz; Bahroudi, Abbas: **DEPTH OF CURIE TEMPERATURE ISOTHERM FROM AEROMAGNETIC SPECTRA IN IRAN: TECTONICS IMPLICATIONS**

34-4 6 Raghaghi, Javad*: **THE ROLE OF SEISMICITY AND ACTIVE FAULT ZONES ON OPTIMUM SITE SELECTION FOR DESTRUCTED KHANOUK AND REYHANSHAHR TOWNS-EAST CENTRAL IRAN)**

34-5 7 Rezaeian, Mahnaz*; Abbasi, Madjid; Ghods, Abdolreza; Sobouti, Farhad: **IS THE TEMPORAL PATTERN OF SEISMICITY IN THE ALBORZ MOUNTAINS, INFLUENCED BY SEASONAL PATTERN OF PRECIPITATION?**

34-6 8 Choi, Sung-Ja*; Choi, Jeong-Heon; Chwae, Ueechan; Shim, T.M.: **PALEOSEISMOLOGICAL STUDY IN GEYONGJU CITY, KOREA**

34-7 9 Ryoo, Chung-Ryul*; Choi, Sung-Ja; Chwae, Ueechan: **ACTIVE FAULTS IN GAEGOK-RI, GYEONGJU, KOREA**

34-8 10 Covellone, Brian M.*; Savage, Brian: **A COMPREHENSIVE EVALUATION OF EARTHQUAKE SOURCE MECHANISMS WITHIN THE MIDDLE EAST**

34-9 11 Karasözen, Ezgi*; Ozacar, A. Arda; Biryol, C. Berk; Beck, Susan; Zandt, George: **EARTHQUAKE FOCAL MECHANISM AND STRESS TENSOR INVERSION ALONG THE CENTRAL SEGMENT OF THE NORTH ANATOLIAN FAULT**

34-10 12 Cubuk, Yesim*; Taymaz, Tuncay: **TIME DOMAIN MOMENT TENSOR INVERSION OF BALA-SIRAPINAR (CENTRAL TURKEY) EARTHQUAKES OF 2005-2008**

34-11 13 Galbán Rodríguez, Liber Sr.*: **MODEL FOR GEOLOGIC RISK MANAGEMENT IN THE BUILDING AND INFRASTRUCTURE PROCESSES**

34-12 14 Rouai, M.*; Telesca, Luciano; Cherkaoui, Taj-Eddine: **SCALING BEHAVIOR OF AFTERSHOCKS SEQUENCE OF AL HOCEIMA FEBRUARY 24, 2004 EARTHQUAKE (MOROCCO)**

SESSION NO. 35

Subduction, collision and orogeny. Posters Part 2 (Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

35-1 15 Zack, Thomas*; Okay, Nilgun; Okay, Aral: **DETRITAL RUTILE AGES FROM THE CARBONIFEROUS FLYSCH OF THE ISTANBUL ZONE, TURKEY: NEW INSIGHTS FOR PROVENANCE STUDIES**

35-2 16 Okay, Nilgun*; Zack, Thomas; Okay, Aral: **A MISSING PROVENANCE: SANDSTONE PETROGRAPHY AND DETRITAL ZIRCON-RUTILE GEOCHRONOLOGY OF THE CARBONIFEROUS FLYSCH OF THE ISTANBUL ZONE**

35-3 17 Sapiie, Benyamin*; Pamumpuni, Astyka; Adyagharini, A.C.; Riadini, Putri: **SOME CONSTRAINT IN TECTONIC RECONSTRUCTIONS OF BIRD'S HEAD REGION, PAPUA, INDONESIA**

35-4 18 Akbayram, Kenan*; Okay, Aral; Satir, Muharrem: **NEW U-PB, PB-PB AND RB-SR AGES FROM NORTHWEST TURKEY; RELICTS OF STRANDJA MASSIF BETWEEN ISTANBUL AND SAKARYA ZONE ALONG INTRA-PONTIDE SUTURE**

35-5 19 Sayab, Mohammad*; Shah, Syed Zahid: **EVENT-WISE COLLISIONAL OROGENIC SEQUENCE OF THE INDIAN PLATE WITH EURASIA DEDUCED FROM PORPHYROBLAST INCLUSION TRAIL MICROSTRUCTURES IN THE NW HIMALAYA**

35-6 20 Gogus, Oguz H.*; Corbi, Fabio; Faccenna, Claudio; Pysklywec, Russell N.: **THE SURFACE TECTONICS OF LITHOSPHERIC DELAMINATION FOLLOWING OCEAN PLATE SUBDUCTION: INSIGHTS FROM LABORATORY AND NUMERICAL EXPERIMENTS**

35-7 21 Gedik, Ismet*: **BERDIGA TERRANE AND ITS ROLE IN THE DEVELOPMENT OF EAST PONTIDE (TURKEY)**

35-8 22 Topuz, Gültekin*; Okay, Aral; Altherr, Rainer; Schwarz, Winfried; Altınkaynak, Lütfi: **EARLY EOCENE OVERPRINT OF A PERMO-TRIASSIC ACCRETIONARY COMPLEX IN THE EASTERN PONTIDES (Ağvanis MASSIF)**

35-9 23 Amini, Sadraddin V.*; Faramarzi, Narges; Sheikhi, Farhad: **TECTONIC ACTIVITIES EFFECTS on MINERALIZATION IN HORMUZ ISLAND, PERSIAN GULF, SOUTHERN IRAN**

35-10 24 Dadaev, Dmitriy M. Jr.*: **GEOLOGY AND TECTONIC CHARACTERISTICS OF THE NORTH-NURATA FAULT**

35-11 25 Madanipour, Saeed*; Rezaeian, Mahnaz; Yassaghi, Ali; Bahroudi, Abbas: **EXHUMATION PATTERN IN THE TALESH MOUNTAINS, NW IRAN "CLIMATE FORCING"**

35-12 26 Alania, Victor Michael*: **LATE CENOZOIC TECTONIC EVOLUTION OF THE GEORGIA (SW CAUCASUS)**

35-13 27 Winn, Robert D. Jr.*: **NEW GUINEA OROGEN: MODEL FOR THE 200 MILLION YEAR OLDER ZAGROS OROGEN OF IRAN**

35-14 28 Konilov, Alexander*; Dokukina, Ksenia; Shchipansky, Andrey: **ECLOGITES OF BELOMORIAN ECLOGITE PROVINCES: HIGH-PRESSURE OR ULTRA-HIGH-PRESSURE?**

AFTERNOON ORAL TECHNICAL SESSIONS

SESSION NO. 36

Aegean geodynamics and extensional tectonics. Part 2 (Ege bolgesinin jeodinamik evrimi ve gerilmeli tektonikte güncel problemler)

14:30, METU Convention and Cultural Centre, Salon B

Nikolay Bonev and Veysel Isik, Presiding

36-1 14:30 Isik, Veysel*; Seyitoglu, Gurol: **CENOZOIC EXHUMATION AND SEDIMENTARY BASIN FORMATION IN THE MENDERES MASSIF, WESTERN TURKEY**

36-2 14:50 Oner, Zeynep*; Dilek, Yildirim: **SYN-EXTENSIONAL FAULT GENERATIONS AND THEIR ROLE ON THE LATE CENOZOIC ALASEHIR SUPRADETACHMENT BASIN EVOLUTION IN THE MENDERES METAMORPHIC CORE COMPLEX, WESTERN TURKEY**

36-3 15:10 Kurt, F. Serap*; Isik, Veysel; Seyitoglu, Gurol: **ALTERNATIVE CENOZOIC EXHUMATION HISTORY OF THE KAZDAG CORE COMPLEX, WESTERN TURKEY**

15:30 **Break**

36-4 15:50 Bonev, Nikolay*; Spikings, Richard; Moritz, Robert; Stampfli, Gerard; Dilek, Yildirim; Marchev, Peter: **REGIONAL TECTONICS AND 40Ar/39Ar TIMING OF CRUSTAL EXTENSION IN THE EASTERN RHODOPE MASSIF, BULGARIA-GREECE, AND MESOZOIC-CENOZOIC GEODYNAMIC EVOLUTION OF THE NORTH AEGEAN REGION**

36-5 16:10 Hajialioghli, Robab*; Moazzen, Mohssen; Droop, Giles; Oberhänsli, Roland; Bousquet, Romain; Jahangiri, Ahmad: **TECTONIC IMPLICATIONS OF THE OLIGOCENE MAFIC MIGMATITES IN THE TAKAB CORE COMPLEX, NW IRAN**

36-6 16:30 Aissa, Djamel-Eddine*; Marignac, Christian: **CONTINENTAL COLLISION AND METALLOGENIC RESULTS IN NORTHEST OF ALGERIA**

SESSION NO. 37

Keynote Talk 6

13:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

37-1 13:30 Agard, Philippe*: **ZAGROS CONVERGENCE: A SUBDUCTION-DOMINATED PROCESS?**

SESSION NO. 38

Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region. Part 2 (Akdeniz bölgesinin sismik, paleosismik ve arkeosismik evrimi)

14:30, METU Convention and Cultural Centre, Salon A

Erhan Altunel and Mustapha Meghraoui, Presiding

38-1 14:30 Ghods, Abdolreza*; Rezapour, Mehdi; Bergman, Eric; Mortezanejad, Gholamreza; Talebian, Morteza: **FAULT SEGMENTATION AND STRESS TRIGGERING IN THE 2006/03/31 SILAKHOUR EARTHQUAKE**

38-2 14:50 Haque, AKM Eahsaul*: **SEISMICITY IN THE BENGAL BASIN: POTENTIAL FOR FUTURE MASSIVE EARTHQUAKES**

38-3 15:10 Ruleman, Cal*: **NEOTECTONIC INVERSION OF THE HINDU KUSH-PAMIR MOUNTAIN REGION**

15:30 **Break**

38-4 15:50 Talebian, Morteza*; Tabatabaei, Saeed; Fattahi, Morteza: **ACTIVE TECTONIC AND SLIP RATE OF BAM EARTHQUAKE FAULT, CENTRAL IRAN**

16:10 **Discussion**

SESSION NO. 39

Subduction, collision and orogeny. Part 2 (Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez)

14:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

Gary Axen and Yildirim Dilek, Presiding

39-1 14:30 Garfunkel, Zvi*: **THE RELATIONS BETWEEN PERI-GONDWANA BLOCKS AND THE INTERIOR OF GONDWANA IN THE LATE NEOPROTEROZOIC AND EARLY PALEOZOIC TIMES**

39-2 14:50 Dilek, Yildirim*: **CRUSTAL ARCHITECTURE AND TECTONIC EVOLUTION OF THE ANATOLIAN-AFRICAN PLATE BOUNDARY AND THE CENOZOIC OROGENIC BELTS IN THE EASTERN MEDITERRANEAN REGION**

39-3 15:10 Hall, Jeremy*; Hübscher, Christian; Ehrhardt, Axel; Dehghani, Ali; Hölz, Sebastian; Louden, Keith; Aksu, Ali; Schattner, Uri: **FROM SUBDUCTION TO COLLISION: THE ROLE OF THE ERATOSTHENES SEAMOUNT IN THE EASTERN MEDITERRANEAN**

15:30 **Break**

39-4 15:50 Kaymakci, Nuretdin*; Spakman, Wim; Ozacar, A. Arda; Biryol, C. Berk; van Hinsbergen, Douwe: **HOW MANY SUBDUCTION ZONES AND OCEANS, POST-**

CRETACEOUS EVOLUTION OF TURKEY: INFERENCES FROM MANTLE TOMOGRAPHY

39-5 16:10 Axen, Gary*; Fakhari, Mohammad; Guest, Bernard; Gavillot, Yann; Stockli, Daniel F.; Horton, Brian: **DISTRIBUTED OBLIQUE-DEXTRAL TRANSPRESSION IN THE HIGH ZAGROS MOUNTAINS, IRAN**

39-6 16:30 Sorkhabi, Rasoul*; Stump, Edmund: **LATE PLIOCENE DENUDATION OF THE HIGHER HIMALAYA: FISSION-TRACK EVIDENCE FROM NEPAL AND IMPLICATIONS FOR TECTONIC EVOLUTION OF THE HIMALAYA**

FRIDAY, 8 OCTOBER 2010

MORNING ORAL TECHNICAL SESSIONS

SESSION NO. 40

Keynote Talk 7

08:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

40-1 08:30 Green, Harry W. II.*: **SUBDUCTION ZONE EARTHQUAKE MECHANISMS AND EXHUMATION OF ROCKS FROM DEPTHS EXCEEDING 300 KM IN COLLISION ZONES**

SESSION NO. 41

Modern accretionary wedges and ancient analogues (Güncel ve fosil yigisma-prizmasi kamalarinin iç yapilari ve tektonik evrimleri)

09:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

Mark Brandon and Mark Cloos, Presiding

41-1 09:30 Brandon, Mark T.*; Willett, Sean D.; Rahl, Jeffrey M.; Cowan, Darrel S.: **DOUBLE-SIDED WEDGE MODEL FOR RETREATING SUBDUCTION ZONES: APPLICATIONS TO THE APENNINIC AND HELLENIC SUBDUCTION ZONES**

41-2 09:50 Rahl, Jeffrey M.*; Brandon, Mark T.: **THE TECTONIC EVOLUTION OF THE HELLENIC SUBDUCTION WEDGE IN CRETE, GREECE**

41-3 10:10 Cloos, Mark*: **SUBDUCTION CHANNEL MODEL FOR ACCRETION, SEDIMENT SUBDUCTION, AND TECTONIC EROSION AT CONVERGENT PLATE MARGINS**

10:30 **Break**

41-4 10:50 Roda, Manuel; Marotta, Anna Maria*; Spalla, M. Iole: **DEEP CRUSTAL RECYCLING IN OROGENIC WEDGES FACILITATED BY MANTLE HYDRATION: NUMERICAL MODELING VS. NATURAL DATA**

41-5 11:10 Anma, Ryo*; Ogawa, Yujiro; Kawamura, Kiichiro: **DEVELOPMENT OF TRENCH-SLOPE BREAK NEAR SPLAY FAULT ZONE IN THE NANKAI TROUGH: RESULTS OF SUBMERSIBLE STUDIES**

41-6 11:30 Yamamoto, Yuzuru*; Saito, Saneatsu; Kanamatsu, Toshiya; Kitamura, Yujin; Chiyonobu, Shun; Kameda, Jun: **ONLAND ACCRETIONARY WEDGE IN THE MIURA AND BOSO PENINSULAS, CENTRAL JAPAN: ONE OF THE BEST ANALOGS OF MODERN SUBDUCTION-ACCRETION SYSTEM**

41-7 11:50 Meneghini, Francesca*; Di Toro, Giulio; Rowe, Christie D.; Moore, Casey: **THE SEISMIC CHARACTER OF MELANGE ZONES: RECORD OF MEGA-EARTHQUAKES IN THE KODIAK ACCRETIONARY COMPLEX, PASAGSHAK POINT, KODIAK IS., ALASKA**

41-8 12:10 Tortorici, Luigi*; Catalano, Stefano; Cirrincione, Rosolino; Tortorici, Giuseppe: **THE OPHIOLITIC MELANGE OF CENTRAL CRETE (GREECE): REMNANTS OF ALPINE ACCRETIONARY WEDGE**

SESSION NO. 42

Ophiolites, blueschists, and suture zones. Part 3 (Ofiyolitler, mavisistler ve kenet kusaklari)

09:30, METU Convention and Cultural Centre, Salon B

Akira Ishiwatari and Yildirim Dilek, Presiding

42-1 09:30 Dilek, Yildirim*; Furnes, Harald: **GEOCHEMICAL AND TECTONIC FINGERPRINTING OF OPHIOLITES**

42-2 09:50 Smith, Alan G.*: **TETHYAN OPHIOLITES, EMPLACEMENT MODELS AND ATLANTIC SPREADING**

42-3 10:10 Gregory, Robert T.*; Gray, David R.: **OMAN BEFORE THE POST-MIOCENE OMAN MOUNTAINS: OPHIOLITE OBDUCTION RESULTING FROM PLATE BOUNDARY REORGANIZATION**

10:30 **Break**

42-4 10:50 Ishiwatari, Akira*; Machi, Sumiaki; Hayasaka, Yasutaka; Ledneva, Galina V.; Bazylev, Boris A.; Sokolov, Sergey D.; Palandzhyan, Suren A.: **GEOTECTONIC IMPORTANCE OF VERY FERTILE LHERZOLITE AMONG THE CIRCUM-PACIFIC OPHIOLITES WITH SPECIAL REFERENCE TO THE L-TYPE UST'-BELAYA OPHIOLITE IN NE RUSSIA**

42-5 11:10 Anma, Ryo*: **RECOGNITION CRITERIA OF OPHIOLITES FORMED DUE TO RIDGE COLLISION/SUBDUCTION**

42-6 11:30 Robinson, Paul T.*; Yang, Jingsui: **UHP MINERALS AND CRUST-MANTLE RECYCLING: EVIDENCE FROM OPHIOLITES**

42-7 11:50 Green, Harry W. II.*: **RECORD OF DEEP UPWELLING IN OPHIOLITES: HIGHLY REDUCED ENVIRONMENT CONTAINING VERY HIGH PRESSURE PHASES AND NITRIDES FROM AT LEAST 300 KM DEPTH**

42-8 12:10 Spalla, Maria Iole*; Zucali, Michele; Roda, Manuel; Marotta, Anna Maria; Gosso, Guido: **LAWSONITE-BEARING ASSEMBLAGES IN CONTINENTAL CRUST: WHICH TECTONIC MECHANISM MAY PRODUCE SUCH A COLD CONTINENTAL SUBDUCTION?**

Please see modified version of Session 43 on page 4.

SESSION NO. 43

Sedimentary basin evolution and oil fields in the Middle & Near East (Sponsored by the Turkish Association of Petroleum Geologists) (Orta ve Yakin Dogu'da sedimanter havza gelismeleri ve petrol olanaklari)

09:30, METU Convention and Cultural Centre, Salon C

Dogan Perinçek and Dan Carpenter, Presiding

43-1 09:30 Rock, Greg*; Niewland, Dirk; Pim, Jonathon; Ferreira, Luke: **EXPLORING UNDER THE OPHIOLITE**

43-2 09:50 Perinçek, Dogan*: **SEDIMENTATION on THE ARABIAN SHELF HAS BEEN UNDER THE CONTROL OF TECTONIC ACTIVITIES ALONG THE ZAGROS–TAURIDE THRUST BELT FROM THE CRETACEOUS TO THE PRESENT**

43-3 10:10 Bozdogan, Nihat*; Erten, Tayfun: **PALEOZOIC SEDIMENTARY BASIN EVOLUTION AND OIL FIELDS, SE ANATOLIA, TURKEY**

10:30 **Break**

43-4 10:50 Erten, Tayfun*: **EVOLUTION OF MESOZOIC AND CENOZOIC SEDIMENTARY BASINS IN SE TURKEY**

43-5 11:10 As-Saruri, Mustafa*; Sorkhabi, Rasoul: **PETROLEUM BASINS OF YEMEN: THEIR TECTONIC DEVELOPMENT AND LITHOSTRATIGRAPHY**

43-6 11:30 Miroshnichenko, Inna*: **UNCONVENTIONAL OIL AND GAS TRAPS OF FERGANA VALLEY (UZBEKISTAN)**

43-7 11:50 Zaigham, Nayyer Alam*; Hissam, Noushaba; Nayyar, Zeeshan Alam: **DELINEATION OF NEW HORIZON FOR DISCOVERY OF HYDROCARBON POTENTIAL IN PAKISTAN**

43-8 12:10 Tong, Hengmao*: **A NEW MODEL FOR THE ORIGIN AND EVOLUTION OF THE RIFT BASIN FAULT-SYSTEMS IN THE EAST AND SOUTH CHINA –A CASE STUDY FROM BEIBUWAN BASIN**

SESSION NO. 44

Subduction, collision and orogeny. Part 3 (Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez)

09:30, METU Convention and Cultural Centre, Salon A

Chan-Sung Oh and Marco Beltrando, Presiding

44-1 09:30 Doglioni, Carlo*: **ASYMMETRIC SUBDUCTIONS IN AN ASYMMETRIC EARTH**

44-2 09:50 Wang, Chi-yuen*; Wang, Chung-Ho: **EARTHQUAKES AND HEAT FLOW**

44-3 10:10 Beltrando, Marco*; Manatschal, G.: **THE BACKBONE OF OROGENS: WHY A REALISTIC PALAEOGEOGRAPHY MATTERS**

10:30 **Break**

44-4 10:50 Oh, Chang Whan*: **SYSTEMATIC CHANGES IN METAMORPHIC STYLES ALONG THE DABIE–HONGSEONG AND HIMALAYAN COLLISION BELTS, AND THEIR TECTONIC IMPLICATIONS**

44-5 11:10 Wang, Lu*; Kusky, Timothy M.: **STRUCTURAL GEOMETRY OF AN EXHUMED UHP TERRANE IN YANGKOU BAY, THE EASTERN SULU OROGEN, CHINA: IMPLICATIONS FOR CONTINENTAL COLLISIONAL PROCESSES**

44-6 11:30 Moazzen, Mohssen*; Omrani, Hadi; Oberhansli, Roland; Moayyed, Mohsen; Tsujimori, Tatsuki; Bousquet, Romain: **SHANDERMAN ECLOGITES FROM NORTHERN IRAN, P-T PATH AND PALEOTETHYS GEODYNAMICS FROM SUBDUCTION TO EXHUMATION**

44-7 11:50 Toraman, Erkan*; Seaton, Nicholas C.; Whitney, Donna L.; Teyssier, Christian: **CHARACTERIZATION OF DEFORMATION MICROSTRUCTURES IN SUBDUCTION ZONE COMPLEXES AND IMPLICATIONS FOR EXHUMATION MECHANISMS**

44-8 12:10 Casale, Gabriele*; Cowan, Darrel S.; Bennett, Richard A.: **EXHUMATION OF THE BOSNIAN SCHIST: IMPLICATIONS FOR DINARIC AND PANNONIAN TECTONICS**

POSTER TECHNICAL SESSIONS

SESSION NO. 45

Modern accretionary wedges and ancient analogues. Posters (Güncel ve fosil yigisma-prizmasi kamalarinin iç yapilari ve tektonik evrimleri)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

45-1 1 Yamamoto, Yuzuru*: **FORMATION OF CHAOTIC ROCK-UNITS DURING PRIMARY ACCRETION PROCESSES: LIQUEFACTION AND MASS TRANSPORT DEPOSITS IN THE MIURA BOSO ACCRETIONARY PRISM, CENTRAL JAPAN**

45-2 2 Meneghini, Francesca*; Marroni, Michele; Moore, Casey; Pandolfi, Luca Sr.; Rowe, Christie D.: **THE PROCESSES OF UNDERTHRUSTING AND UNDERPLATING IN THE GEOLOGIC RECORD: STRUCTURAL DIVERSITY BETWEEN THE FRANCISCAN COMPLEX (CALIFORNIA), THE KODIAK COMPLEX (ALASKA) AND THE INTERNAL LIGURIAN UNITS (ITALY)**

SESSION NO. 46

Ophiolites, blueschists, and suture zones. Posters Part 2 (Ofiyolitler, mavisistler ve kenet kusaklari)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

46-1 3 Kilic, Ayse Didem*: **DUNITE BLOCKS IN MAFIC-ULTRAMAFIC SEQUENCE: EVIDENCE FOR MAGMA CHAMBER**

46-2 4 Azimzadeh, Zohreh*; Dilek, Yildirim; Jahangiri, Ahmad; Ameri, Ali: **REMNANTS OF THE PALEOTETHYAN SUTURE ZONE IN NW IRAN (MISHO MOUNTAINS) AND REGIONAL CORRELATIONS**

46-3 5 Elitok, Ömer*: **GEOLOGICAL AND GEOCHEMICAL CONSTRAINTS ON THE NORTHWARD PROPAGATED OCEAN BASIN EVOLUTION AND SUPRA-SUBDUCTION ZONE TYPE OPHIOLITE IN THE ISPARTA ANGLE AREA, SW TURKEY**

46-4 6 Kolndreu, Dede*: **OUTLINE ABOUT GEOSTRUCTURES IN OPHIOLITES OF THE NORTH CENTRAL MIRDITA IN ALBANIA, BASED ON THE INTEPRETATION BY METHODS OF GEOMECHANICS**

46-5 7 Banerjee, Neil R.*; Muehlenbachs, Karlis; Dilek, Yildirim: **PETROGRAPHY AND GEOCHEMISTRY OF EPIDOSITES FROM THE MIRDITA OPHIOLITE, ALBANIA**

46-6 8 Meshi, Avni*; Milushi, Ibrahim; Dilek, Yildirim: **MIRDITA OPHIOLITE (ALBANIA) AS A REMANT OF AN EARLY JURASSIC BACKARC SPREADING CENTER–EXTENSIONAL TRANSFORM ZONE INTERSECTION**

46-7 9 Plissart, Gaëlle*; Diot, Hervé; Monnier, Christophe; Maruntiu, Marcel; Neubauer, Franz; Genser, Johann; Demaiffe, Daniel: **OCCURRENCE OF A MYLONITIC ZONE DEVELOPED on OCEANIC AND SEDIMENTARY ROCKS (ALMAJ MOUNTAINS, ROMANIA): RECORD OF THE OBDUCTION OF THE DANUBIAN OPHIOLITE?**

46-8 10 Huber, Kathryn G.*; Catlos, Elizabeth: **PETROLOGICAL EVOLUTION OF OPHIOLITE ASSEMBLAGES EXPOSED NEAR THE NORTH ANATOLIAN FAULT IN THE TOKAT MASSIF, NORTHEASTERN TURKEY**

46-9 11 Köksal, Serhat*; Göncüoğlu, M. Cemal; Toksoy-Köksal, Fatma: **RE-EVALUATION OF THE PETROLOGICAL FEATURES OF THE EKECIKDAG OCEANIC PLAGIOGRANITES IN CENTRAL ANATOLIA / TURKEY**

46-10 12 Foudazi, Mohammad*; Alai Mahabadi, Soleiman: **PETROGRAPHY AND MINERALOGY STUDY OF PYROXENITE AND WHERLITIC DIKES IN NAIN OPHIOLITE,CENTRAL IRAN**

46-11 13 Toksoy-Köksal, Fatma*; Köksal, Serhat; Göncüoğlu, M. Cemal: **IS A SINGLE MODEL ADEQUATE TO EXPLAIN ORIGIN OF THE GABBROS FROM CENTRAL ANATOLIA, TURKEY?**

46-12 14 Faridazad, Morovvat*; Moayyed, Mohsen; Modjtahedi, Mansour; Moazzen, Mohssen: **PETROLOGY AND PETROGENESIS OF ULTRAMAFIC ROCKS OF THE KHOY OPHIOLITIC COMPLEX-NW IRAN**

SESSION NO. 47

Sedimentary basin evolution and oil fields in the Middle & Near East. Posters (Sponsored by the Turkish Association of Petroleum Geologists) (Orta ve Yakin Dogu'da sedimanter havza gelismeleri ve petrol olanaklari)

08:30, METU Convention and Cultural Centre, Exhibition Hall

Authors will be present from 17:00 to 18:30

Booth #

47-1 15 Omrani, Mehdi*; Khosrotehrani, Khosro; Baghbani, Darioush: **BIOSTRATIGRAPHY OF THE ILAM FORMATION IN HALEGAN WELL, SOUTHERN IRAN**

47-2 16 Bülent, Coskun*: **STRUCTURAL EVOLUTION-OIL POTENTIAL RELATIONSHIPS IN THE MARMARA SEA,NW TURKEY**

47-3 17 Sadaoui, M.*; Remichi, L.; Chaouchi, R.: **STRUCTURAL EVOLUTION OF THE ILLIZI BASIN AND ITS IMPACT ON THE GENERATION OF HYDROCARBONS. THE SAHARAN PLATFORM**

47-4 018 Yousefzadeh, Elham*: **MICROBIOSTRATIGRAPHY, MICROFACIES AND SEDIMENTARY ENVIRONMENT STUDIES OF TARBOUR FORMATION (SOUTHWEST OF IRAN)**

AFTERNOON ORAL TECHNICAL SESSIONS

SESSION NO. 48

Keynote Talk 8

13:30, METU Convention and Cultural Centre, Kemal Kurdas Salon

48-1 13:30 Dick, Henry J.B.*: **MODES OF ACCRETION AT SLOWER SPREADING OCEAN RIDGES**

SESSION NO. 49

Mélanges and mélange–forming processes. Part 3 (Melanjlar ve melanj olusturan mekanizmalar)

14:30, METU Convention and Cultural Centre, Salon A

Andrea Festa and Gian Andrea Pini, Presiding

49-1 14:30 Harris, Ron*; Huang, Chi-Yue: **LINKING MéLANGE TYPES AND OCCURRENCES WITH ACTIVE MéLANGE-FORMING PROCESS IN TIMOR AND TAIWAN**

49-2 14:50 Huang, Chi-Yue*: **MECHANISM AND CONSEQUENCE OF FOREARC BACK-THRUSTING IN FORMATION OF LICHI MéLANGE IN COASTAL RANGE, EASTERN TAIWAN**

49-3 15:10 Zhai, Qingguo*; Jahn, Bor-ming: **PALEOZOIC OPHIOLITIC MELANGE IN CENTRAL QIANGTANG, NORTHERN TIBET: GEOCHEMISTRY AND SHRIMP U-PB DATING**

15:30 **Break**

49-4 15:50 Sarifakioglu, Ender*; Dilek, Yildirim; Sevin, Mustafa; Uysal, Ibrahim: **THE IZMIR-ANKARA-ERZINCAN SUTURE ZONE AS A PACIFIC-TYPE SUBDUCTION-ACCRETION COMPLEX IN THE TETHYAN REALM**

49-5 16:10 Rojay, Bora*: **TECTONIC EVOLUTION OF THE CRETACEOUS OPHIOLITIC MéLANGE (THE “ANKARA MéLANGE BELT”) DURING LATE CRETACEOUS-PRE-MIOCENE PERIOD**

49-6 16:30 El Bahariya, Gaafar A.*: **ON THE CLASSIFICATION AND ORIGIN OF THE NEOPROTEROZOIC OPHIOLITIC MELANGE OF THE CENTRAL EASTERN DESERT, EGYPT: GEOLOGICAL AND GEOCHEMICAL STUDIES**

SESSION NO. 50

Ophiolites, blueschists, and suture zones. Part 4 (Ofiyolitler, mavisistler ve kenet kusaklari)

14:30, METU Convention and Cultural Centre, Salon B

Tomoaki Morishita and Ercan Aldanmaz, Presiding

50-1 14:30 Furnes, Harald*; Dilek, Yildirim: **GEOCHEMICAL AND TECTONIC EVOLUTION OF A TRENCH-DISTAL BACKARC OPHIOLITE, SOLUND-STAVFJORD COMPLEX (443 MA), IN THE WESTERN NORWEGIAN CALEDONIDES**

50-2 14:50 Machi, Sumiaki*; Ishiwatari, Akira; Morishita, Tomoaki; Hayasaka, Yasutaka; Ledneva, Galina V.; Sokolov, Sergey D.; Palandzhyan, Suren A.; Bazylev, Boris A.: **SERPENTINIZATION AND METASOMATISM IN THE MANTLE WEDGE; A CASE STUDY IN THE UST’-BELAYA OPHIOLITE**

50-3 15:10 Morishita, Tomoaki*; Dilek, Yildirim: **PETROLOGICAL AND GEOCHEMICAL EVOLUTION OF THE MOHO IN A JURASSIC SUPRASUBDUCTION ZONE OCEANIC LITHOSPHERE: EASTERN MIRDITA OPHIOLITE, ALBANIA**

15:30 **Break**

50-4 15:50 Tremblay, Alain*; Deschamps, Thomas; Meshi, Avni; Ruffet, Gilles: **THE VARDAR ZONE AS A SUTURE FOR THE MIRDITA OPHIOLITE : CONSTRAINTS FROM THE STRUCTURAL ANALYSIS OF THE KORABI ZONE, NE ALBANIA**

50-5 16:10 Aldanmaz, Ercan*; Meisel, Thomas; Çelik, Ömer Faruk: **MULTI-STAGE EVOLUTION OF THE NEO-TETHYAN OCEANIC UPPER MANTLE: EVIDENCE FROM OS ISOTOPE AND HSE SYSTEMATICS OF SPINEL-PERIDOTITES FROM SW TURKEY**

50-6 16:30 Shafaii Moghadam, Hadi*; Stern, Robert J.; Rahgoshay, Mohamad: **A TRIP TO THE ZOO: ZAGROS OPHIOLITE OVERVIEW**

Abstracts

Abstracts to be presented at the meeting of the
Tectonic Crossroads: Evolving Orogens of Eurasia-Africa-Arabia
Ankara, Turkey
4–8 October 2010

NOTE INDEXING SYSTEM
Numbers (2-4, 15-4) indicate session and order of presentation within that session.
Further information concerning the presented papers on which these abstracts are based should be obtained by contacting the authors of the abstracts.

SESSION NO. 1, 10: 00
Monday, 4 October 2010
Keynote Talk 1
METU Convention and Cultural Centre, Kemal Kurdas Salon

1-1 10:00 Stock, Joann M.

THE SOUTHERN SAN ANDREAS FAULT SYSTEM AND NORTHERN GULF OF CALIFORNIA: FORMATION OF NEW CRUST ALONG A TRANSTENSIONAL PLATE BOUNDARY

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The Pacific-North America plate boundary , between 23° N and 40° N latitude, provides useful examples of a variety of processes that produce new crustal area in regions of transtension. This plate margin changes geometry along strike, going, at a large scale, from the right-lateral strike-slip fault tectonics of the NW-trending San Andreas fault system in the north to the oblique rifting of the Gulf of California in the south. Approximately 300 km of right-lateral strike-slip motion took place between these two plates since 6 Ma. At a smaller scale, regions of localized production or destruction of crustal area are found in each segment of the boundary. In the Gulf of California/Salton Trough region, where considerable new crustal area has been formed, this new area was produced by different mechanisms in different places. The mechanisms include: seafloor spreading in the southernmost basins; continental crustal normal faulting and possible lower crustal flow in the northern basins; extremely heavy sedimentation filling extensional basins in the northern Gulf of California and southernmost San Andreas fault system; and formation of new crustal area by magmatic input into a thick pile of sediments (Imperial Valley) . The geometrical adjustment of the deforming region has additionally been controlled by high-angle or listric normal faults, low-angle detachment faults, active NE-striking left-lateral strike-slip faults, and significant tilting and vertical-axis rotations (up to 30 degrees) of smaller fault blocks. In the northern Gulf of California basins, true seafloor spreading is not yet occurring. Localized magmatism contributes to formation of new crust, but geophysical constraints (gravity, moho depth, and seismic velocities) do not permit the crust to contain a high percentage of mafic rock. Thus, as a rifted margin, this is considered a magma-poor end member. Changes in the age of the continent/ocean transition, thickness of new crust, and width of transitional crust along the strike of the oblique rift do not show a simple spatial pattern. In some cases, these have been attributed to differences in depletion of the underlying asthenosphere, arising from variations in geological history, particularly differences in pre-rift subduction-related magmatism. This presentation will summarize the work of many authors who have constrained the tectonic development and the crustal architecture of this transtensional plate boundary, in order to then compare it to other transtensional plate boundary settings such as the Marmara Sea.

SESSION NO. 2, 10:50
Monday, 4 October 2010
Landscape, climate and archaeological evolution of the Mediterranean region. Part 1 (*Akdeniz bölgesinin topografik, iklimsel ve arkeolojik tarihçesi*)
METU Convention and Cultural Centre, Salon B

2-1 10:50 Pazzaglia, Frank J.

CLIMATIC, LITHOLOGIC, AND TECTONIC CONTROLS ON TERRACE GENESIS IN ACTIVE OROGENS

PAZZAGLIA, Frank J., Earth and Environmental Sciences, Lehigh University, 31 Williams Dr, Bethlehem, PA 18015, fjp3@Lehigh.edu, WEGMANN, Karl W., North Carolina State University, 2800 Faucette Drive, Jordan Hall 1125, Campus Box 8208, Raleigh, NC 27695-8208, and BRANDON, Mark, Dept of Geology and Geophysics, Yale Univ, PO Box 208109, New Haven, CT 06520-8109

In the Mediterranean region and elsewhere, the geodynamic processes building active orogens are constrained by the deformation of geomorphic and stratigraphic markers. Fluvial terraces are a common geomorphic and paleo-geodetic marker composed of both landforms and deposits that integrate tectonic, climatic, and geomorphic processes at the watershed scale. Terrace formation and preservation attests to a fundamental unsteadiness in the rate of vertical incision of a river as it carves its valley. The most common sources of that unsteadiness are vegetative, geomorphic, and hydrologic responses to climate, which for the Quaternary, are dominated by 100-k.y. glacial-interglacial cycles; however, the precise response depends much on watershed substrate and the climatic, tectonic, and base level setting. When coupled with numeric ages, the key terrace observable, the rate of incision, can be used to infer active tectonics. The Italian Apennines offer an excellent natural laboratory where terrace formation has been influenced by climatic, lithologic, and tectonic gradients. Northern Apennine rivers are dominated by bedrock channels and strath terraces, the formation of which is controlled by rapid rock uplift (~1 mm/yr) and watersheds underlain by siliciclastic rock-types. Here alluvium deposited during the last glacial maximum (LGM) climate is distinctly exposed as a terrace and provides a widespread, correlative geomorphic marker. Rivers in the central Apennines are dominated by thick fill terraces, the formation of which are controlled by modest rates of rock uplift (~0.25 – 0.5 mm/yr) and watersheds underlain by carbonates. Similarly, the LGM terrace is well exposed and regionally correlative. Terrace formation in both cases is in phase and paced by glacial-interglacial climate changes characteristic of the broader continental Europe. In contrast, the rivers of the southern Apennines are dominated by alluvial channels despite locally rapid rates of rock uplift (~1mm/yr), fill terraces with complex, composite stratigraphy, and diverse watershed geology. The drier, Mediterranean climate of southern Italy drives terrace genesis out of phase with respect to the northern and central Apennines. Most southern Italian streams have yet to incise and expose alluvium deposited during the LGM as a terrace, resulting in late-Pleistocene rates of incision that are slower than their more northern counterparts. These differences in terrace type and genesis color the tectonic interpretation of river incision, the correct understanding of which is rooted in a genetic rationalization of the local surficial processes driving terrace genesis.

2-2 11:10 Yin, A.

CLIMATE CHANGE, TECTONICS AND THE EVOLUTION OF THE HIMALAYAN RIVERS AND TOPOGRAPHY

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How major rivers evolve during orogeny is a fundamental question in Earth Sciences. For example, mountain building can cause focused erosion that in turn may trigger thermal weakening and localized contraction, leading to positive feedback between erosion and uplift. One of the best places to address the coupled interactions among tectonics, climate change and surface processes is the active Himalayan orogen. There all these factors can be well quantified due to significantly larger and thus more readily detectable signals than most places on Earth. To address the how tectonics, surface processes, and climate may have interacted with one another, we investigated how the Himalayan drainage system has evolved in the Late

Cenozoic as a result of interactions between north-trending Tibetan rifts and east-trending Himalayan uplift. We examined this complex yet scientifically stimulating problem via determining when and how the east-flowing Yalu River (Yarlung Tsangpo) was captured by the Subansiri River, the largest transverse drainage system in the eastern Himalaya. Understanding capture mechanisms of the Yalu River by major Himalayan transverse rivers has first-order implications for the Himalayan exhumation history, sediment-transport processes, and petrologic evolution of the Himalayan foreland basin. The main hypothesis we are testing is that a climate event marked by protracted glacier advances triggered the formation of a rift dam in SE Tibet via strongly coupled tectonic-climate processes. This rift-induced dam blocked and subsequently diverted the east-flowing Yalu River into the south-flowing Subansiri River. Accelerated Himalayan uplift, possibly energized by the capture event, eventually forced the Yalu to return to its original course. The possibility of Yalu-Subansir connection was first raised by our initial detrital-zircon study of Late Miocene-Pliocene foreland-basin sediments from the eastern Himalaya using coupled U-Pb zircon dating and Hf isotope analysis. Subsequent fieldwork in SE Tibet further bolsters this possibility by revealing a sequence of valley-fill sediments distributed across the Yalu-Subansir drainage divide. The valley fill, likely representing the paleo-Yalu-Subansiri river sediments, is located in the north-trending Cona-Zedong rift zone of SE Tibet and contains thick (>150 m locally) moraine deposits. These associations suggest that the capture event of the Yalu by the Subansir was controlled by rifting and occurred during major glacier advances. A key prediction of our climate-induced rift-dam hypothesis is a sequence of events starting with initial glacier advances followed by synchronous fast rift-induced uplift (relative to river incision), deposition of the paleo-Yalu-Subansi river sediments (represented by the valley fill in SE Tibet), and deposition of foreland sediments carrying Gangdese-batholith detritus from southern Tibet. The restoring mechanism of the Yalu River by Himalayan uplift predicts that the uplift rate of the eastern Himalaya was accelerated in the latest Pliocene.

2-3 11:30 Nicoll, Kathleen

GEOARCHAEOLOGY, ENVIRONMENTAL HISTORY, AND TECTONIC UPLIFT IN EASTERN ANATOLIA (SE TURKEY)

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The Eastern Anatolian (or Turkish-Iranian) Plateau of southeastern Turkey contains some of the most impressive and high elevation landforms associated with the active Alpine-Himalayan orogen, and is the headwater region for the Tigris and Euphrates River Systems. The geomorphic evolution of these important drainages reflects the interplay of surface processes and tectonics -- the development of topographic relief and lithospheric deformation since the closing of the Southern Neo-Tethyan (or Bitlis) Ocean. Hence, the study of these "Big Rivers" is an important proxy for deep crustal processes associated with mountain building and volcanism along the continent-continent plate collision zone. This paper synthesizes new observations about the geomorphic development, environmental history, and archaeology of this region, which preserves artefacts in stratigraphic contexts dating from the prehistoric Middle Stone Age to the Iron Age (Assyrian and Urartu Kingdoms), through the Achaemenid (Persian) Empire and later periods (Medieval-Islamic). Field survey, mapping, and geochronology across the Upper Tigris Basin enable (1) description of the modern and ancient landscape elements, including fault scarps, valley fills, scroll bars, floodplains, etc; (2) assessment of hydrologic, paleoclimatic, and cultural archives for reconstructing patterns of environmental and tectonic change. Delineation of Quaternary deposits and dated contexts will be presented reach-by-reach along a regional transect commencing at the Tigris Source near Lake Hazar, and moving downstream through the Bitlis suture zone, and through the terrain that is part of the Arabian Plate near Batman. The evolution of the Upper Tigris drainage over the past ~13 Myr can be reconstructed as a function of vertical movement (e.g. base-level changes, tectonic uplift, doming, downwarp, and sagging), horizontal deformation (e.g. folding, faulting, compression, and extension), volcanism, weathering, and erosion (e.g. dissolution processes, karstic erosion, and sapping). It is important to assess the first-order tectonic controls on the evolving fluvial systematics of the Tigris so that its sedimentary and geomorphic records can be used to accurately reconstruct hydroclimatic changes affecting this part of the Near East during antiquity.

2-4 11:50 Kazanci, Nizamettin

GEOLOGICAL EVOLUTION OF THE SEFIDRUD DELTA, SOUTHERN CASPIAN SEA, IRAN

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The Sefidrud delta is a large, wave-dominated clastic sediment prism associated with wide beach ridges, coastal dunes, lagoonal and related sediments in the southern Caspian Sea, Iran. It has been formed by the River Sefidrud which has a drainage area of 61300 km^2 covering nearly whole tectonically active Albroz mountain ranges and partly central Iran. This river is the largest sediment source of the Caspian Sea compared to drainage area, water and sediment discharge with 5.2 million ton a year. At present, surface of subaerial delta plain and coastal length of the delta are 1405 km^5 and 91 km respectively. Progradation is about 65 km, despite active delta lobe has prograded 5 km in the last 500 years. The receiving basin, southern Caspian Sea is highly energetic because of regional geography, therefore coastal deposits included the Sefidrud delta are composed of wave-dominated clastic facies. In addition, Caspian Sea has a regular, long-time water fluctuation with 400-450 years of period. The marine terraces of Gilan-Anzali coastal plain at 50 m, 20 m and 0 m (present water surface elevation of Caspian Sea is -26 m bsl) and fluvial terraces at 150 m prove the long-term sea-level oscillation in late Plesitocene. Therefore, the Sefidrud delta has been developed during repetitive transgressive and regressive coastal conditions. Indeed, the Sefidrud delta is a unique example of sediment accumulation under joint and complex effects of active tectonism, high volume of sediment input, long-term water-level oscillation and high wave energy. This study aims to explain evolution of the Sefidrud delta based on geology, facies analysis and core logs.

2-5 12:10 Pope, Richard J.J.

RESOLVING PATTERNS OF CRETAN FAN SEDIMENTATION: PRELIMINARY INSIGHTS FROM MINERAL MAGNETIC AND CHRONOMETRIC DATA

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Analysis of fan sediments and post-incisive soils was combined with optically stimulated luminescence (OSL) and U-series dating to reassess Nemec and Postma's (1993) model of fan evolution on the Sfakian piedmont, southern Crete. Field mapping supports the assertion that sedimentation occurred in three developmental stages. Stage 1 sediments consist of angular debris flows that form small cone-like deposits. Stage 2 fluvial gravels form large, relatively steep stream flow-dominated telescopic fans, while stage 3 sediments consist of coarse sieve-type alluvium and localised mudflows. Irrespective of gradient, fan surfaces are capped by post-incisive soils that form a chronosequence comprising remnant chromic luvisols. Soils formed on stage 1 surfaces are characterised by highly eroded Bt horizons, but contain high concentrations of magnetic minerals. The stage 2 and 3 soils display less well developed profiles and record significantly lower magnetic values, indicating that the stage 1 soils and fan surfaces formed first, followed by stage 2 and 3 soils and fan surfaces.

Nannofossil data strongly suggest that stage 1 sedimentation commenced towards the end of the early Pleistocene. For stage 2 sedimentation OSL and U-series techniques produce remarkably similar age estimates (with differences being statistically insignificant [p>0.1]). Multiple phases of sedimentation between 79 ka and 68 ka culminated in the emplacement of lower fan units. Following a period of minor depositional and concomitant erosion, the formation of the middle fan units resulted from further sedimentation between 54ka and 33 ka. By comparison, the chronology for the formation of the upper fan units is currently less well constrained, although later sedimentation phases are dated to between 15.5 ka and 11.4 ka. The new chronometric data have two significant implications for the evolution of Sfakian fan systems. First, the timing of sedimentation phases and the formation of stage 2 fans apparently occurred over a much shorter timescale compared to a previous chronology proposed by Nemec and Postma (1983, 1985). Second, the estimated ages strongly suggest a close link between sedimentation and climate whereby major depositional phases were coincident with infrequent intense rainfall events during phases of rapid regional cooling and increased aridity during marine isotope stage (MIS) 4, 3 and 2.

SESSION NO. 3, 10:50

Monday, 4 October 2010

Ophiolites, blueschists, and suture zones. Part 1 (*Ofiyolitler, mavisistler ve kenet kusaklari*)

METU Convention and Cultural Centre, Salon A

3-1 10:50 Kusky, Timothy M.

ORIGIN AND EMPLACEMENT OF ARCHEAN OPHIOLITES OF THE CENTRAL OROGENIC BELT, NORTH CHINA CRATON

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Understanding Archean crustal and mantle evolution hinges upon identification and characterization of oceanic lithosphere. We describe a complete, yet dismembered and metamorphosed Archean ophiolite sequence in the North China Craton, in the Dongwanzi-Zunhua structural belt and correlatives in the Wutaishan area. Banded iron formation structurally overlies several tens of meters of variably deformed pillow lavas, mafic flows, and picritic amphibolites. These are in structural contact with a 2 kilometer thick mixed gabbro and dike complex with gabbro screens, exposed discontinuously along strike for more than 20 km. The dikes consist of metamorphosed diabase, basalt, hb-cpx-gabbro, and pyroxenite. Many have chilled margins developed on their NE sides, indicating one-way chilling. The dike/gabbro complex is underlain by several kilometers of mixed isotropic and foliated gabbro, which preserve compositional layering approximately 2 kilometers below the dike complex, and then over several hundred meters merge into strongly compositionally layered gabbro and olivine-gabbro. The layered gabbro becomes mixed with layered pyroxenite/gabbro marking a transition zone into cumulate ultramafic rocks including serpentinized dunite, pyroxenite and wehrlite, and finally into strongly deformed and serpentinized olivine and orthopyroxene-bearing ultramafic rocks interpreted as depleted mantle harzburgite tectonites. A U/Pb zircon age of 2.505 Ga from gabbro of the Dongwanzi ophiolite makes it the world's oldest recognized, laterally-extensive complete ophiolite sequence. This age is confirmed by a circa 2.6 Ga Re-Os isochron from chromites from the belt, and a number of dated 2.5-2.4 Ga cross-cutting younger igneous units. Characteristics of this remarkable ophiolite may provide the best constraints yet on the nature of the Archean oceanic crust and mantle, and offer insights to the style of Archean plate tectonics and global heat loss mechanisms.

The Dongwanzi ophiolite is one of the largest well-preserved greenstone belts in the Central Orogenic belt that divides the North China craton into eastern and western blocks. More than 1,000 other fragments of gabbro, pillow lava, sheeted dikes, harzburgite, and podiform-chromite bearing dunite occur as tectonic blocks (tens to hundreds of meters long) in a biotite-gneiss and BIF matrix, intruded by tonalite and granodiorite, in the Zunhua structural belt. Blocks in this metamorphosed Archean ophiolitic mélange preserve deeper levels of oceanic mantle than the Dongwanzi ophiolite. The ophiolite-related melange marks a suture zone across the North China Craton, traced for more than 1600 km along the Central orogenic belt. Many of the chromitite bodies are localized in dunite envelopes within harzburgite tectonite, and have characteristic nodular and orbicular chromite textures, known elsewhere only from ophiolites. The ultramafic and ophiolitic blocks in the Zunhua melange are interpreted as dismembered and strongly deformed parts of the Dongwanzi ophiolite. We suggest the name "Dongwanzi-Zunhua ophiolite belt" for these rocks.

3-2 11:10 Furnes, Harald

EVOLUTION OF THE ONVERWACHT SUITE OF THE PALEOARCHEAN BARBERTON GREENSTONE BELT (SOUTH AFRICA) AS OCEANIC CRUST AND ISLAND ARCS

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The Paleoarchean Onverwacht Suite of the Barberton Greenstone Belt (BGB) comprises seven separate complexes of volcanic and intrusive rocks ranging from komatiite to dacite, with subalkaline basalt as the predominant type. The complexes have tectonic contacts, are tectonically stacked with a total tectonostratigraphic thickness of ~15 km and have an age range of ~120 million years [1]. From tectonically lowest to highest they are: Sandspruit- (lowest), Theespruit-, Komati-, Hooggenoeg-, Noisy-, Kromberg- and Mendon (highest) Complexes. Some of the complexes have ophiolite-like lithological associations, whereas others are more akin to island-arc assemblages [1]. Detailed logging of the volcanic stratigraphy of two of the complexes (Hooggenoeg and Kromberg) shows a dominance of non- to slightly-vesicular pillows, indicating eruption in deep (2000-4000m) water [2]. A major unconformity separates two of the complexes, demonstrating rapid uplift (~ 2-4 mm/year) of the deep-water lavas (of the Hooggenoeg Complex) to above sea level, and erosion and deposition of shallow water/fluvial/glacial (?) deposits (of the Noisy Complex).

Compilation of available data for the mafic extrusive and extrusive rocks from the tectonostratigraphically lowest to highest complexes of the BGB shows a large compositional spread from komatiites to dacites. The various complexes, however, show their own special geochemical characteristics, but their trace element patterns invariably indicate a subduction fingerprint. The combined geological and geochemical relationships indicate that the magmatic rocks of the BGB formed as oceanic crustal units, associated with subduction and islands arc formation.

3-3 11:30 Muehlenbachs, Karlis

RELATIONSHIP BETWEEN BASALT ALTERATION, CHERT FORMATION AND TECTONOSTRATIGRAPHY AT BARBERTON MT. LAND, SOUTH AFRICA

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The basalts and cherts of the Mesoarchean Barberton Greenstone Belt in South Africa have been the focus of continuous study. Here we report the $\delta^{18}O$ of basalts sampled along 18 measured sections from the Mendon, Kromberg and Hooggenog Complexes. The pillow basalts are enriched in ^{18}O suggesting alteration by ambient seawater but the details of the alteration pattern may be obscured due to extensive metamorphism and tectonism but regional metamorphism has not erased the isotopic record. The lavas are commonly silicified and are intralayered between prominent chert horizons that systematically decrease in $\delta^{18}O$ from 20‰ from the Mendon Complex to 13.3‰ at the Middle Marker, the base of the Hooggenog complex. All the cherts in the Hooggenog Complex are silicified volcanoclastic rocks. The $\delta^{18}O$ of the basalt in some exposures is proportional to the degree of silicification extrapolating to the overlying chert value implying in those cases that the silicification of basalt was by the same fluid that formed the chert. Correlation of $\delta^{18}O$ and SiO_2 is not observed in sections containing dykes, or enveloped by shear zones. In the lower parts of the Hooggenog such an extrapolation of $\delta^{18}O$ vs. SiO_2 leads to higher $\delta^{18}O$ end member than the actual chert. The $\delta^{18}O$ of major cherts within the Hooggenog Complex translate to temperatures of about 110° at top to about 180° C at the Middle Marker, if the cherts formed in the presence of seawater derived fluids. The combined thickness of the volcanic pile and associated intrusive rocks of the Hooggenog is 4 to 4.5 km, and thus the implied thermal gradient seems too low to be the ambient geothermal gradient. The basalts under the higher $\delta^{18}O$ cherts, which are also higher in the sections, may be silicified by the same fluid at the same time whereas the basalts associated with lower $\delta^{18}O$ cherts, lower in the section, where silicified by a higher $\delta^{18}O$ fluids or at lower temperature. These observations indicate a complex and dynamic relationship between the alteration of basalt and formation of these cherts.

3-4 11:50 Polat, Ali

TRACE ELEMENT AND RADIOGENIC (ND AND PB) ISOTOPE SYSTEMATICS OF THE MESOARCHEAN FISKENAESSET ANORTHOSITE COMPLEX, SW GREENLAND: IMPLICATIONS FOR ARCHEAN CONTINENTAL GROWTH

POLAT, Ali, Earth and Environmental Sciences, University of Windsor, Windsor, ON Ontario N9B Canada, polat@uwindsor.ca

The Archean Fiskenaesset Complex, southern West Greenland, composed of ca. 550-meter-thick layered anorthosite, leucogabbro, gabbro, dunite, peridotite, pyroxenite, and hornblendites. The Fiskenaesset Complex appears to have been intruded as multiple sills of magma and crystal mush into Mesoarchean oceanic crust. The complex was intruded by tonalite, trondhjemite, and granodiorite (TTG) sheets (now orthogneisses) during thrusting that was followed by several phases of isoclinal folding. Despite polyphase deformation and amphibolite to granulite facies metamorphism, primary cumulate textures and igneous layering are well preserved throughout the complex.

Trace element (e.g., REE, HFSE) systematic of the Fiskenaesset Complex and associated volcanic rocks are consistent with a supra-subduction zone geodynamic setting. On recently developed new petrogenetic discrimination diagrams, based on the log-transformed ratios of immobile elements, such as La/Th, Sm/Th, Yb/Th , Nb/Th, Fiskenaesset volcanic rocks display a trend projecting from mid-ocean ridge basalt (MORB) to island arc basalt (IAB) field. This trend is interpreted as reflecting the entrainment by induced convection of Archean depleted upper mantle (i.e., the source of Archean MORB) into a subarc mantle wedge following the initiation of intra-oceanic subduction and arc migration.

On several variation diagrams, samples from three differentiated (dunite to anorthosite) sequences plot along a well-defined liquid line of descent, consistent with in situ fractional crystallization. Bulk chemical compositions of these sequences are used to constrain the approximate compositions of parental magmas. Normative *olivine* (85 to 4 wt.%) and *magnetite* (2.5 to 0.1 wt.%) decrease, whereas *anorthite* (5 to 80 wt.%) increases upward in all sequences. Petrographic observations and geochemical data suggest that Sequences 2 and 3 were solidified from evolved magmas that underwent olivine fractionation prior to their intrusion. In contrast, Sequence 1 appears to have derived from a near-primary picritic parental magma (MgO=20 wt.%, Ni=780 ppm, Mg-number=81).

If the relative thickness of ultramafic layers, the sum of dunite, peridotite and pyroxenite layers, in differentiated sequences is taken as an analog for the original complex emplaced into Archean oceanic crust, the Fiskenaesset Complex might have had a minimum thickness of 1000 m, with a 500 m thick ultramafic unit at the bottom. The thickness of ultramafic unit in the preserved complex is less than 50 m, suggesting that more than 90% of the original ultramafic unit was detached and recycled back into the mantle through either delamination or subduction zone processes.

The Fiskenaesset anorthosites, leucogabbros, gabbros and ultramafic rocks yield a Sm-Nd isochron age of 2973±28 Ma (MSWD=33), with an initial epsilon-Nd = +3.3, consistent with a long-term depleted mantle source. Regression of Pb isotope data defines an age of 2945±36 Ma (MSWD=44); and the regression line intersects the average growth curve at 3036 Ma. Despite multiple phases of deformation and amphibolite to granulite facies metamorphism, the Sm-Nd and U-Pb isotope systems in the Fiskenaesset Complex appear to have not been significantly disturbed.

Complex internal structures in zircon from TTGs reveal several episodes of zircon growth and recrystallization between ca. 3200 and 2650 Ma. Zircon ages peak at about 3200, 3100, 3000, 2950, 2820, and 2750 Ma. The 3200-3000 Ma zircon cores are interpreted as inherited xenocrysts from older reworked crustal rocks. The 2950 Ma is considered as an approximate intrusion age of TTGs. The 2940-2650 Ma ages are attributed to metamorphic overgrowth and recrystallization in response to multiple tectonothermal events that affected the Fiskenaesset region.

On the basis of trace element, Nd and Pb isotope, and U-Pb zircon age data, a three-stage geodynamic model is proposed to explain the evolution of the Fiskenaesset Complex. Stage 1 represents the formation of depleted shallow mantle source > 3000 Ma (epsilon-Nd = +3.3) for the complex. Stage 2 corresponds to the development of an intra-oceanic island arc between 3000-2950 Ma. Stage 3 is characterized by the collision of the island arc with either a passive continental margin or with an older arc between 2950-2940 Ma. Archean continental crust in southern West Greenland was grown by accretion of Eoarchean to Mesoarchean oceanic island arcs and intrusion of granitoid magmas into these island arcs.

3-5 12:10 Abd El-Rahman, Yasser

THE TECTONIC EVOLUTION OF THE CENTRAL EASTERN DESERT OF EGYPT DURING THE NEOPROTEROZOIC ERA: AN OPHIOLITIC PERSPECTIVE AND IMPLICATION ON GOLD METALLOGENY

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The tectonic evolution of the central Eastern Desert (CED) of Egypt includes an early intra-oceanic island arc stage and a later cordilleran margin stage. The ophiolitic rocks in the CED have both back-arc and forearc geochemical signatures. The forearc ophiolitic rocks are located towards the west of the back-arc ophiolitic rocks, which may indicate the formation of an intra-oceanic island arc system above an easterly dipping subducted slab. The western arc/forearc belt is delineated by major serpentinite masses running almost NNW-SSE. The eastern back-arc ophiolitic assemblages show an increase in the subduction signature from the north to the south till the occurrence of bimodal volcanism further towards the south. The variation in subduction signature can be attributed to the progressive opening of a back-arc basin from the north going to the south till a rifted volcanic arc further towards the south with characteristic bimodal volcanism. The intra-oceanic island arc system approached the continental margin to the west represented by Saharan Metacraton. With either accretion or collision between the island arc and the Saharan Metacraton, reversal of subduction polarity happened and the cordilleran margin magmatism started above the new westerly dipping subduction zone.

During the tectonic evolution of the CED, both the intra-oceanic island arc stage and the cordilleran margin stage show unique modes of occurrence of gold mineralization. The gold associated with the island arc stage is hosted in Algoma-type banded iron formations (BIF) and alternating tuffaceous sedimentary rocks and also hosted in volcanogenic massive sulphide (VMS) deposits. The auriferous BIF and the associated auriferous tuffs are spatially associated with the arc/back-arc rock assemblages concentrated towards the northern end of the arc/back-arc belt. However, the auriferous VMS deposits are associated mainly with the bimodal volcanic rocks towards the south of the arc/back-arc belt. The cordilleran-stage gold mineralization occurs as vein-type deposits. The auriferous veins, mainly quartz veins, are hosted in the metavolcano-sedimentary assemblage and their associated granitic rocks, and in sheared ophiolitic ultramafic rocks. Most of the vein-type gold occurrences extend along a NNW-SSE trend coinciding with the arc/forearc belt. From the spatial distribution and the rock association of the gold mineralization in the CED, it can be inferred that the southward progressive opening of the back-arc basin resulted in the formation of the auriferous BIF within the wide ocean basin to the north, while the formation of the auriferous VMS within the rifted proportion of the island arc towards the south. Then, with the formation of the cordilleran margin magmatism the circulation of the hydrothermal fluids resulted in gold mobilization from the early accreted island arc rocks. As serpentinites have the highest gold values in the CED, they could be the main source for gold and that could be the reason why many auriferous quartz veins are located close to serpentinite masses which occur along the western arc/forearc belt.

SESSION NO. 4, 10:50

Monday, 4 October 2010

Strike-slip and transform fault tectonics. Part 1 (*Dogrultu atim ve transform fay tektonigi*)

METU Convention and Cultural Centre, Kemal Kurdas Salon

4-1 10:50 Anderson, Thomas H.

COEVAL GLOBAL EXTENSIONAL EVENTS – AN INDICATION OF TRANSMISSION OF CHANGES IN PLATE MOTIONS IN RESPONSE TO COLLISION, COUPLING, AND CAPTURE

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Episodes of Tertiary extension in western North America are widespread, affecting 1000s of km^2 of crust from the Pacific Ocean to the Rocky Mountains. The episodes commonly are considered to record “post-orogenic collapse”, perhaps driven by gravity. However, the regional structural domains in western North America (NA) - including Basin and Range, and core complexes along the Colorado River and in southern British Columbia - are characterized by systems of strike-slip faults commonly linked by normal faults that accommodate temporally distinct (~15-0 ma, ~31-20 ma, 55-42 ma) extensions with remarkable overall consistency in the directions of tectonic transport (~275°; 240°, 285°). The strike-slip faults include large continental-scale “transforms”, which obey E. M. Anderson kinematics (σ_1< 45° to plane of maximum shear stress). The large faults are generally coeval and kinematically compatible with shorter, right- and left-lateral strike-slip faults, along which normal faults at releasing-steps may result in development of footwalls exposing formerly deep crystalline rocks, i.e. core complexes.

The characteristics of the extensional domains support the hypothesis that convergence followed by collision, coupling, and plate capture may lead to extension. In this model, arrival of buoyant oceanic lithosphere - commonly part of a long segment of spreading center - impedes subduction and leads to collision with the overriding continental plate. During collision, the formerly converging plates couple as the buoyant lithosphere binds against the base of the overriding plate. The length of the sutured former plate boundary will vary depending upon the length of the collided ridge segment. The length of the segment of plate boundary that must be coupled in order to induce crustal stretching is uncertain. Coupling of a ridge segment to the overriding plate leads to “capture”, after which movements of the newly coupled plates are integrated. In western NA coupling of the Pacific plate to the North America plate generally adds a northwesterly component that affects the southwestward-moving North America plate. The net effect of the 15 ma and younger integration of the Pacific and NA plate motions has been westward extension accommodated by the San Andreas fault, and kinematically compatible normal and lateral faults. The western NA extensions are interpreted to be driven by movement of the Pacific plate as it and the margin of western NA are pulled toward western Pacific trenches into which the Pacific plate subducts. The distinct extensional events last until the buoyant oceanic lithosphere cools and begins to sink anew, generally a period of 10 to 15 Ma.

The similarity of ages of Tertiary extensional events in western NA to the multiple episodes of extensional deformation and related plutonism, and metamorphism within the zone of collided, coupled plates extending from the Himalaya to the Alps is remarkable. The correlation leads to the speculation that changes in Pacific-North America plate motions may be recorded at the coupled edges of major plates where collision has taken place (e.g. the Tethys collision belt). This conclusion infers that the suture zone is susceptible to reactivation caused by shifts in plate motions following collision, coupling, and capture.

4-2 11:10 Busby, Cathy J.

BIRTH OF A PLATE BOUNDARY: TRANSTENSIONAL TECTONICS AND MAGMATISM, SIERRA NEVADA MICROPLATE AND GULF OF CALIFORNIA RIFT

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We identify the key conditions that localized active transtensional continental rifts in the Gulf of California (Mexico) and along the eastern boundary of the Sierra Nevada microplate (California), and elucidate the geologic signals of transtensional continental breakup.

Geodetic studies show that the transtensional eastern boundary of the Sierra Nevada microplate (Walker Lane Belt) accommodates about 25% of the plate motion between North America and the Pacific plate (Unruh et al., 2003). This boundary is a reasonable approximation to a "classic" plate boundary, because it is discrete relative to its north and west boundaries, which are diffuse and complex due to structural interleaving by compressional and transpressional tectonics, respectively. The eastern microplate boundary is thus ideal for determining when the microplate formed, and for identifying the timing of features that signal the birth of a microplate. This has important implications for understanding the processes involved in the rupturing of continental lithosphere, similar to the well-funded MARGINS study in the Gulf of California (Lizarralde et al., 2007). Much of the geologic record of the early rift stage of the latter now lies below sea level in the Gulf of California, making it difficult and expensive to study in detail. In contrast, rocks and structures of the early rift stage are superbly exposed on land along the eastern boundary of the Sierra Nevada microplate. Although rifting has not yet succeeded in forming new sea floor there, we suggest that it has many features in common with the Gulf of California rift, including: (1) timing of initiation, at about 12 Ma (2) localization of rifting due to thermal weakening in the axis of a subduction-related arc undergoing extension due to slab rollback; and (3) enhanced thermal weakening in the arc, due to stalling of the trenchward-migrating precursor arc against a thick Cretaceous batholithic crustal profile on its western boundary. Rifting led to seafloor spreading very quickly in the Gulf of California (by 6 Ma), because the spreading center between the plate subducting under Mexico and the huge Pacific plate froze offshore of Mexico; the Pacific plate then pulled the dead slab northwestward, dragging the upper plate of the slab (Baja California) with it. In contrast, continental breakup is still in progress in California.

We use new geologic map data from the central Sierra Nevada to identify features that signal the birth of the Sierra Nevada microplate at ~12 - 11 Ma. This timing is consistent with the plate-tectonic reconstructions of McQuarrie and Wernicke (2005), which show a change from more westerly motion to more northerly motion of both the Pacific plate and the Sierra Nevada microplate, relative to the Colorado Plateau, at 10-12 Ma. Releasing transtensional stepovers (or pull-aparts) along the plate boundary began to control the siting of large volcanic centers by ~ 11 Ma, and continue to do so today (e.g. Long Valley Caldera and Lassen Volcanic Center). Onset of transtension within the axis of the Ancestral Cascades arc at ~ 11 Ma resulted in "flood andesite" eruptions over a >40 km long segment of the new plate boundary, in the Sonora Pass to Bridgeport region (the largely trachyandesitic "Table Mountain Latite/ Formation"). These "flood andesites" were erupted from 6–8 km long fissures within volcano-tectonic depressions that currently lie along the Sierra Nevada range crest and range front. Individual lavas flowed distances up to 130 km, with volumes up to 20 km^3, and the >200km^3 lava flow field was erupted in only 28-230 kyr. The Little Walker Caldera formed at the site of maximum extension in this volcanotectonic lava depression complex, and erupted ~9.5 – 9.4 Ma large-volume trachydacite ignimbrites.

The birth of the Sierra Nevada plate boundary was also signaled by derangement of ancient drainage systems. For much of Cenozoic time, the present-day Sierra Nevada formed the western shoulder of the "Nevadaplano", a high broad uplift formed by crustal shortening during Cretaceous low-angle subduction; this shoulder was crossed by E-W paleocanyons/paleochannels carved into the Nevadaplano, with a drainage divide >230 km to the east. Our mapping demonstrates progressive derangement of this ancient E-W drainage system by N-S plate boundary structures, including: (1) diversion of lavas and pyroclastic flows into N-S grabens at ~11-9 Ma, (2) stream capture at the western edge of the volcanotectonic graben complex, on the modern range crest, at ~9 – 6 Ma, and (3) stream capture at the eastern edge of the volcanotectonic graben, at the base of the range front, by the modern Little Walker River after 6 Ma.

The geologic signals of transtensional continental breakup described here must be taken into account when constructing theoretical, experimental, or geophysically-constrained models for the rupture of continental lithosphere.

4-3 11:30 Dalziel, Ian W.D.

TRANSFORM MOTION ACROSS THE SCOTIA ARC: INFLUENCE ON OCEANIC CIRCULATION

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The Scotia arc is the eastward closing loop of locally emergent submarine ridges joining the southern tip of the South American continent to the northern tip of the Antarctic Peninsula and enclosing the Scotia Sea. South America has moved westward relative to Antarctica at 20-30mm/yr over the past 50 Myr. The present day motion is taken up by transform motion along the east-west trending South Sandwich Fracture Zone in the South Atlantic Ocean basin and by subduction along the north-south trending Andean margin. Across the Scotia arc itself, it is taken up by a combination of transform motions on the North and South Scotia ridges and the Shackleton Fracture Zone which closes off the Scotia Sea to the west.

The North Scotia Ridge transform fault (NSRT) separates the South American plate from the Scotia plate to the south. It extends from the Antarctic-South American-Scotia plate triple junction at the Chile Trench in the west to the South Sandwich trench in the east where the South American plate is being subducted westward. Global Positioning System measurements in southernmost South America (the Magallanes-Fagnano fault system) demonstrate 6.6 ±1.3mm/yr of left-lateral motion is occurring there. Hence the transform takes up 20-30% of the westerly motion of South America relative to the Antarctic Peninsula across the Scotia arc. The remainder is taken up along the South Scotia Ridge transform (SSRT) that separates the Scotia and Antarctic plates and joins the Antarctic Peninsula to a triple junction with the South Sandwich trench and South Sandwich Fracture Zone, and the northwest-southeast trending Shackleton Fracture Zone (SFZ) that bounds the Scotia plate between South America and the Antarctic Peninsula. The Euler poles for the motions of South America-Scotia and of Scotia-Antarctica are closely located, so displacement on the NSRT and SSRT are nearly parallel and the Scotia plate is not deforming or rotating

Although the trace of the NSRT is clearly marked across South America, displacements are difficult to determine because the stratigraphic units and main structural fabric are parallel to the fault. There is a reasonably reliable left-lateral offset of ~25 km measured on an Upper Jurassic volcanic unit. Less certain is an observed 80 km left-lateral offset on the margin of the Mesozoic-Cenozoic Patagonian batholith. To the east along the North Scotia Ridge itself its location is unclear, though a few earthquakes with east-west left lateral motion fault-plane solutions have been recorded. Burdwood Bank, the submerged ridge immediately offshore Tierra del Fuego, is a continuation of the Andean Cordillera. The Davis and Aurora banks and the Black and Shag rocks platform to the east appear to be displaced fragments of the Pacific side of the Cordillera. South Georgia Island (~3000m elevation) is the emergent part of a microcontinental block at the eastern end of the ridge. It has been displaced ~ 1700 km eastward from the Pacific margin. Interestingly there are clusters of earthquake epicenters located at the eastern ends of Burdwood, Davis and Aurora banks, and the South Georgia platform. They appear to form restraining bends along the NSRT. South Georgia collided with the Northeast Georgia Rise on the South American plate at ~ 12-10 Ma. This probably accounts, for underthrusting of the Scotia plate beneath the microcontinent as well as the rollback of the South Sandwich arc to form the active backarc spreading center beneath the East Scotia Sea.

Though complex in detail, the SSRT is marked by a fairly continuous narrow zone of epicenters offset in releasing bends. Powell Basin, which separates the South Orkney Islands continental platform from the Antarctic Peninsula, may represent a Neogene pull-apart basin. The South Orkney block is now within the deforming zone of the SSRT. A number of epicenters are located along the SFZ which is transitional southeastward from the Chile Trench subduction zone to a larger component of strike-slip motion south east of the extinct Antarctic-Phoenix Ridge to the west. At the southern end of the ridge the Elephant Island block, northernmost part of the South Shetland Islands platform, appears to be moving with the Scotia Sea block to the north of the SSRT.

The zone of left-lateral transform motion of South America with respect to Antarctica through the Scotia arc region dates back at least until 84 Ma. It may have been initiated in the Early Cretaceous, ~130 Ma, with the opening of the South Atlantic Ocean basin. During the interval between 30 Ma and 9 Ma most of the motion may have been taken up in the NW-SE opening of the West Scotia Sea with little or none in an east-west direction along the North and South Scotia ridges. This would explain the limited displacement mapped on shore in South America. At this time the Shackleton Fracture Zone was the western boundary of the spreading system. The late Mesozoic-Cenozoic development of the transform zone in the Scotia Sea region played a major role in controlling the development of oceanic circulation in the Southern Ocean. It was critical in the onset and development of the globe-encircling Antarctic Circumpolar Current.

4-4 11:50 Mann, Paul

THE CARIBBEAN PLATE: A NATURAL LABORATORY FOR THE STUDY OF THE STRUCTURE AND SEISMIC POTENTIAL OF ACTIVE STRIKE-SLIP FAULTS

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Although the Caribbean is a relatively small plate, over 5100 km of its plate edges are bounded by strike-slip faults ranging from single continental-style plate boundaries to broader zones of transpressional or transtensional strain partitioning. Steadily-improving GPS data from the Caribbean margins allow for quantitative comparisons between the structure of individual fault zones and the observed style of strike-slip deformation using a variety of onland and submarine mapping methods. Single continental-style plate boundaries like those separating the Caribbean plate from the neighboring North and South American plates exhibit discrete segments ranging in length from 200 to 1000 km that transition with changing plate motion from transtension, to pure strike-slip, to transpression. Transtension in the offshore Honduras area (defined by obliquity of plate motion in range of 5-20°) produces continental borderlands provinces that resemble zones of pure rifting on seismic profiles. Transpression in the range of 5-15° produces elongate, mini-fold-thrust belts in a submarine setting (southern Cuba). Oblique collision in the range of 15-30° as observed on the 3-km-high island of Hispaniola produce a 250-km-wide outer zone of subduction and inner zone of partitioned strike-slip faults. Pure strike-slip deformation produces the simplest pattern of deformation in the form of remarkably narrow and continuous zones of linear strike-slip faults (Cayman trough, El Pilar system). Active strike-slip faults are closely guided along the suture formed by collision of the Caribbean arc against thicker continental crust as well seen by abrupt steps in the Moho between thinner arc and thicker continental crust along the South American margin. The most divergent arrays of strike-slip faults across the widest areas are associated with collisional indentation as observed in northwestern South America as a result of the Panama arc collision. Older strike-slip faults become cryptic when they are overprinted by a younger phase of compression (northwestern South America) or extension (northern Central America). Perhaps the most puzzling active strike-slip faults are those driven as intact but narrow narrow slivers by varying amounts of oblique subduction (Cocos-Caribbean arc, Puerto Rico trench). A common trait shared by all Caribbean strike-slip faults and tragically seen by the 2010 Haiti earthquake is their relatively slow slip rates (7-12 mm/yr range) that allows for strain accumulation over centuries. The seismic cycle of relatively benign strain accumulation is terminated by shallow and destructive M6-7 earthquakes unleashed on unsuspecting populations not accustomed to or prepared for these infrequent events.

4-5 12:10 Wyld, Sandra J.

STRIKE-SLIP TRANSLATIONS IN EVOLVING OROGENS: THE NORTH AMERICAN CORDILLERA EXAMPLE AND IMPLICATIONS FOR PALEOTECTONIC AND PALEOGEOGRAPHIC ANALYSES

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Plate convergence, the driving force of most continental orogenesis, generally occurs at an oblique angle to continental margins. Displacement partitioning resulting from convergence obliquity may lead to a component of margin-parallel strike-slip faulting. Over time, hundreds of kilometers of strike-slip offset may occur and result in substantial margin-parallel translation of outboard crustal fragments (terranes). This process is especially likely where continental margins have a long-lived history of offshore convergence, such as the North American Cordillera. If strike-slip terrane displacements are not taken into account when constructing tectonic and paleogeographic models for the orogen, then substantial errors in interpretation can occur. For example, contractional tectonism in an outboard oceanic arc terrane could be used to argue for an episode of arc-continent collision in that area, but that interpretation would be incorrect if the arc terrane was deformed elsewhere along the margin and only brought to its present location by younger strike-slip faulting. The North American Cordillera is an exceptional example of a continental margin that has experienced abundant, margin-parallel strike-slip displacements, mostly of dextral-sense offset, over a protracted time interval, from at least the late Mesozoic through the Cenozoic. Relations and reconstructions from this system provide insight into processes and consequences with broad relevance for orogenic belts in other parts of the globe.

In this talk, we present palinspastic restorations of the Canadian and U.S. Cordillera that account for major strike-slip offsets of Cretaceous and Cenozoic age (building on Wyld and Wright, 2001; Wyld, Umhoefer, and Wright, 2006; Wright and Wyld, 2007). The resulting reconstructions place many of the Paleozoic and Mesozoic terranes of the Cordillera hundreds of kilometers south of their current locations, with minimum offsets of 700-1200 km since the Early Cretaceous. These displacements are sufficient to translate Cretaceous and older provinces of the Cordillera into positions that are far outside the paleogeographic and paleotectonic realm in which they are currently found. When the offsets are taken into account, linkages between terranes (sedimentary basins, orogenic belts, and magmatic provinces) must be critically re-evaluated, and new interpretations have the potential to solve long outstanding problems and generate exciting new avenues of research. In general, offset analysis in the Cordillera has impacted interpretation of time-space variation in the evolution of basins and orogenic belts, driving forces of sedimentary basin development, sediment provenance, terrane linkages, and tectonic models.

In summary, oblique convergence can lead to margin-parallel, strike-slip terrane transport over distances large enough to render in situ paleotectonic interpretations potentially meaningless. It is thus crucial to account for strike-slip offsets as much as possible when interpreting an orogenic belt. Additional results of our study include: (1) Strike-slip boundaries can be reactivated by younger tectonism or serve as a locus for plutonism, and may thereby become quite obscure. Their presence, however, should be expected in long-lived orogenic belts regardless of whether direct structural evidence is preserved. Many terrane boundaries should thus be considered suspect, particularly when the boundary juxtaposes terranes that can't be readily linked by accordion-style tectonics. Wherever this type of relation exists, it may be fruitful to search along the orogen for other matching terranes or features, and consider what these matches might indicate about cryptic strike-slip displacements. (2) Timing and sense of regional strike-slip displacement can provide important constraints on relative plate motions during development of an orogen, and are a useful compliment to other sources of data (e.g., paleomagnetic) on plate motions. (3) Strike-slip faulting along an active margin can result in a complex distribution of terranes, particularly when multiple fault strands are active and/or when the sense of motion switches over time. In addition, long-lived episodes of strike-slip faulting can result in a deficit of terranes in one part of an orogen and a pile-up of terranes elsewhere.

SESSION NO. 5, 08:30

Monday, 4 October 2010

Landscape, climate and archaeological evolution of the Mediterranean region. Posters (*Akdeniz bölgesinin topografik, iklimsel ve arkeolojik tarihçesi*)

METU Convention and Cultural Centre, Exhibition Hall

5-1 BTH 1 Kucukuysal, Ceren

SWELLING CLAY PALEOSOLS AS INDICATORS OF SEASONAL DRYNESSS DURING PLIO-QUATERNARY IN ANKARA, TURKEY

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Soils are strongly influenced by the agents as precipitation, temperature, parent material, morphology of landscape and time. Paleosols ,the ancient soils, therefore can provide excellent information on climate of the past and can be useful proxies of weathering and climate conditions at the time of formation. In paleoclimotology studies, paleosols and paleosol carbonates are widely used to do such interpretations. Clay minerals, one of the most important components of soils, can be used as a good indicator of long-term climatic fluctuations because the clay mineral compostion of weathering profiles and soils largely depends on the climatic conditions.

In this study, a succession of Plio-Quaternary age from Gölbaþý-Karahamzalý area is selected. The selected fluvial succession includes reddish-brown mudstones with alternating horizons of massive calcretes and channel deposits. Calcretes formed as massive accumulations of carbonates between clasts. Mudstones represent blocky-subangular blocky- prismatic and granular micromorphological structures. Additionally common pedofeatures of clay coatings, ped structures, floating grains and crack systems are well developed within the mudstones. The mineral and rock fragments, voids and dissolution channels are surrounded by carbonate spars which is a typical feature of calcretes. Manganese oxide also rims some grains and also seen as dense compound infillings and loose discontinous clusters within the voids. Voids in paleosols of the Kulu succession can be classified as planar voids observed as crack patterns and chamber connected with channels. Main carbonate mineral of the paleosols is dolomite in the succession. Clay minerals are dominantly smectite and little amounts of detrital illite, chlorite and kaolinite. Smectite contents show an increase up to succession suggesting an increase in aridity.

Dolomitic calcretes occurring within the paleosol have δ18O values ranging from -3.97‰ to -5.02‰ VPDB, reflecting their formation under the infuence of meteoric water and δ13C values between -7.11‰ and -7.8‰ VPDB. The stable isotope compositions of the massive calcretes in the succession is consistent with the clay mineral assemblages. The increase in the frequency of calcretes toward the top of the succession, increase in the smectite content of the paleosols up to the section and the stable isotope data represent the alternating wet and dry seasons.

SESSION NO. 6, 08:30

Monday, 4 October 2010

Magmatism in evolving orogens: Collision to extension. Posters Part 1 (*Aktif orojenik kusaklarda magmatizmanin evrimi: Çarpisma tektoniginden gerilmeli tektonige gidis*)

METU Convention and Cultural Centre, Exhibition Hall

6-1 BTH 2 Barich, Amel

MG-AL RICH ZONE IN THE CONTACT BETWEEN MANTLE ROCKS (PERIDOTITES) AND GRANULITES FACIES ROCKS IN THE BENI BOUSERA MASSIF (INTERNAL RIF, MOROCCO)

BARICH, Amel and BOUYBAOUÈNE, Mohamed Larbi, Earth Sciences Department, Faculty of Sciences, Université Mohammed V - Agdal, 4 Avenue Ibn Battouta, BP 1014, Rabat, 10000, Morocco, amelbarich@yahoo.com

The Beni Bousera peridotite massif (Internal Rif , Morocco) is formed in a major part of Spinel-bearing lherzolite rimed by a layer of garnet-bearing peridotite which is in direct contact with HP-HT granulite metamorphic rocks (16Kbar, 860°C). A shearing contact between these two formations shows the presence of metamorphic ultramafic intercalations underneath the deformed granulites.

Foliation is well distinct and allocates in both rocks with a succession of metamorphic micro-zones with very diverse mineral assemblages. It consists on the spatial arrangement of 3 centimetric zones separating garnet-spinel bearing peridotites from garnet-kyanite bearing granulites:

- Phlogopite, orthopyroxene, spinel zone.
- Corundum, sapphirine, spinel zone.
- Sillimanite, kornerupine zone.

Geochemistry of the different phases shows peraluminous (corundum, kornerupine, sapphirine, spinel) and magnesian (phlogopite, enstatite) assemblages; the P-T conditions estimated using THERMOCALC are 9 to 10Kbars and 700 to 950°C in the saphirine – sillimanite – corundum stability domain.

These thermobarometric conditions reveal that these rocks -forming the top of the peridotite massif- have incurred a metamorphic evolution at high temperatures, which is related to an isothermal decompression after or during the setting up of these rocks at the base of the crust (60 km thick). However, the kornerupine could have formed sequentially under nearly constant P–T conditions (sillimanite stability field) during the infiltration of fluid in the rocks. These hydrothermal processes are also involved and drive the peridotites to a metasomatic contamination at the contact with fluid-rich crustal rocks that leads to crystallization of phlogopite and amphibole. This contact is possibly a shear zone crossing the limit crust-mantle.

The data show that, in the Rif Mountains, the granulites and formerly diamond bearing ultramafic rocks, are uplifted in the same geodynamic environment and give very strong constraints on the Alpine metamorphic evolution of the whole Alboran domain.

6-2 BTH 3 Palinkas, Ladislav

DATING OF NEOTETHYAN INCIPIENT RIFTING MAGMATISM ON THE MID-ADRIATIC ISLANDS JABUKA, BRUSNIK AND VIS, CROATIA

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The Mid-Adriatic island Jabuka, Brusnik and western part of the Vis island, are built of basic rocks placed within the Mesozoic successions of the Adriatic carbonate platform. Jabuka and Brusnik islands are built exclusively of igneous rocks, of two-clinopyroxene gabbros, derived from crystallization of differentiated subalkaline magma. The late stage dykes, with higher content of potassium cross-cut the main magmatic bodies in ductile and brittle manner. The trace elements and the MORB-normalized, spider-diagram support similarity of the gabbros with continental tholeiitic magmas, excluding MORB type affinity, widespread in ophiolitic sequences. The high content of Al_2O_3, alkali elements, major and trace elements are comparable with Triassic magmatic rocks of Alps, Dinarides and Hellenides, developed in the extentional rift environments. Triassic platform carbonates and evaporates on the Vis island are associated with volcanic rocks, which are formed as lava littoral cone. The parent magma is, however, the same. The first radiometric dating, and detailed mineralogical and geochemical study was done on the Jabuka by Balogh et al. (1994). The K/Ar ages obtained on the whole rock and mineral fractions differ insignificantly. The avergage **K/Ar age is 205 ± 6.9 Ma,** and two isochrones gave **200.3 ± 7.9 and 199.5 ± 11.9 Ma** with little amount of excess radiogenic Ar. The dating, however, suggests uppermost Triassic, what does not correspond with the major phase of Triassic rifting, although calc-alkaline character excludes MORB type lithotypes (Balogh et al., 1994). De Min et al. (2008) obtained, by analyzing plagioclase separates on Jabuka and Brusnik, a new **Ar/Ar plateau ages** of **227 ± 5 Ma** and an isochrom **226 ± 3 Ma** for Jabuka**,** and **plateau age 226 ± 3 Ma** for Brusnik**.** The age is shifted toward the Middle Triassic time what is a better fit to the general rifting conditions in the area. Recent research on the Jabuka and Brusnik intrusives (Palinkaš et al., 2010) revealed a plateau age of **273 ± 1.1 Ma** on biotite, from the Jabuka gabbro, with loss of Ar on the **77.2 ± 2.4 Ma**. K-feldspar, from the Jabuka gabbro, shows similar value of **269.4 ± 2.3** Ma, but K-feldspar from the dyke on the Jabuka is dated **254.5 ± 2.0** Ma. Biotite in the Brusnik dolerite is dated at **265 ± 1.1 Ma,** while K-feldspar has **plateau age 214 ± 0.9,** lowered due to release of Ar, during some later thermal episode. K-feldspar separated from the basalt-andesitic fragment in the volcanics from Komiža, Vis island, gave a coherent age with the other magmatic representatives of **276.6 ± 1.7 Ma.** The ages determined on biotites are more consistant, and differ from those obtained on K-feldspars, which was the object of the previous dating. This explains why the former K/Ar and Ar/Ar dating gave ages not compatible with the geotectonic events in the early history of the Tethyan evolution. Upper Permian ages obtained recently correspond to the early intra-continental rifting and the geochemistry of the within plate magmatism.

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6-3 BTH 4 Nouraliee, Javad

CONCEPTUAL MODEL OF KHORHE GEOTHERMAL RESERVOIR

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Mahallat geothermal region (MGR) is one of the promising geothermal regions in Iran which has been selected for further studies almost 10 years ago. This very large region has 51,000 sq km area and is included some parts of Qom, Markazi and Isfahan provinces.

Due to its large size, it was not possible to conduct a systematic geothermal exploration survey. So, in order to assessing of geothermal resources in MGR available data such as geological, remote sensing, water wells temperature, warm springs and aeromagnetic information were used to recognize the most favorable geothermal areas in MGR.

One of the promising geothermal areas in MGR is Khorhe area. It is located in north-east of Mahallat city. According to the available data the first conceptual model of Khorhe geothermal field was produced. Therefore, probable heat source is a large intrusive body which is positioned in the deeper parts of the area. It is believed that Permian formations (mostly carbonates) can play role as reservoir rock and Shemshak formation (Jurassic) which is composed of shale and sandstone can cover the reservoir rocks.

At the south-west of Khorhe field there is a band of Precambrian- Permian carbonate rocks which its width is 4.5 km. Meteoritic waters can penetrate these rocks and transfer toward the geothermal resource. Based on the geothermometery calculations Khorhe geothermal reservoir approximate temperature and its estimated stored thermal energy are 95 °C and 50.1 × 10^7 KJ respectively.

6-4 BTH 5 Eskandary, Amir

MAGMA DYNAMICS INFERRED FROM GEOCHEMICAL MODELING AND QUANTITATIVE TEXTURAL MEASUREMENTS OF IGNEOUS ROCKS FROM SE-BIRJAND (EAST OF IRAN)

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Study area is located 120 km to SE of Birjand (East of Iran). Geologically, this region occurs in Sistan suture zone and is a wing of East Iran colored mélange. This study focused on the division of rocks younger than ophiolitic complex.

Textural analysis techniques and geochemical modeling were used to quantify textural and chemical diversities between shallow level intrusive rocks with quartz diorite - micro diorite and volcanic rocks with basaltic andesite composition. Some of the textural characterisitics such as presence of mafic enclaves, xenocrysts with reaction rims, oscillatory zoning and sieve texture of plagioclases, corroded and embayed quartz grains show evidence of magma mixing as recharge of more mafic and hot magma into open- system magma chamber. Results of major element modeling based on mass balance calculations and trace element modeling based on Rayleigh crystal fractionation models (FC), Assimilation and Fractional Crystallization (AFC), mixing combined with fractional crystallization (MFC) and mixing equations suggest that data trends is more consistent with magma mixing model. However, it seems that other processes also might have played important role in genesis of these rocks. These rocks represent geochemical signatures of adakites such as high Sr/Y and high Cr, Ni contents that suggest a subdaction source but it is possible that role of AFC with ultramafic rocks as assimillant caused this characterisitics.

Using quantitative textural measurements including crystal size distributions (CSD), Crystal Shape (S) and spatial distribution pattern (SDP) of plagioclases, some of the physical processes ongoing in the magma chamber modeled as Numerous repetitions of cycle of crystal nucleation and growth, injection of basic magma and following textural coarsening (Ostwald ripening) that finally ended by nucleation and growth of fine groundmass crystals but for basaltic andesites only affecting formation factor was kinetic processes of nucleation and growth.

6-5 BTH 6 Farahkhan, Nasrin

MAGMATIC FRACTIONATION MODELLING IN KARAJ DAM SILL IGNEOUS ROCKS

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At the NE of Baraghan, Karaj Dam Sill, intruded between the pyroclastic rocks of Karaj formation. The composition of the Sill changes from gabbro and monzogabbro to monzodiorite. Based on field observations and microscopic studies, the sill was differentiated from margin to center. For geochemical modeling in study area, incompatible elements diagrams such as Zr vs. Rb and Ba vs.Ce have used that sample· s trends are consistent with Fractional Crystallization (FC) process vector and maximum fractionation percentage for samples with high SiO2(65%) are 80%. For determining differentiated mineral and differentiation percentage have used mineral vector diagrams such as Logarithmic bivariant diagram Ba,Sr. results show that samples was formed by Plagioclase, Clinopyroxene and olivine fractionation. Also based on fractionation vectors and numerical modeling, fractionation ratio for this minerls are approximately (pl/cpx/Ol,55:35:10).

Modeling results shows that Magmatic crystallization based on Rayleigh fractiontion Equation can explained chimecal variations of trace elements. Although not following some elements from fractionation process trend in some samples (like unusual enrichment Ba) show that other process like crust contamination and secondary process like hydrothermal alteration can play important role in chemical variance of elements in study area.

6-6 BTH 7 Remichi, L.

CHARACTERISATION OF THE VOLCANIC SERIEES IN THE DAMRANE (WESTERN OUGARTA, ALGERIA) AND IMPLICATION FOR THE GLOBAL MODEL OF THE WEST AFRICAN SHIELD NORTEASTERN MARGIN

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In the variscan chain of Ougarta (South Algeria), the Proterozoic is only known from some anticline cores, southeastern equivalent of the Anti-Atlas inliers of Morocco; in general, it deals the uppermost ignimbritic levels, assigned to P.III structuro-lithostratgraphic unit. However, more ancient, levels have already been described in the southeastern Ougarta (Sebkha el Mellah and assigned to the P.II unit; by comparison, the lowermost levels underlying the ignimbrites in the Damrane (southwestern Ougarta), have been assigned to this structuro-lithostratigraphic unit (P.II). Moreover, on this basis of their mostly mafic volcanic composition and of the presence of a positive gravimetric anomaly in this area, it was concluded that the western Ougarta was a landmark, between Ahaggar and Anti-Atlas of the West- African Shield. It was thus inferred that is occurred there, first and oceanization and a further obduction and related continental collision.

The detailed studies of the Damrane we present here, lead to challenge most of these conclusions, and demonstrate that:

*) the geostructural origin of both and felsic volcanisms is of late-to post orogenic (compressive) intra- continental type, devoid of any obvious nearby subduction- zone relationships ;

**) it is thus inferred that, during the Middle- Upper Proterzoic, the western Ougarta belong to a thineed continental-crust domain, backwards a hypothecal defined (aborted subduction zone or active margin? rifting?) would at most have occurred in eastern Ougarta (Sebkha el Mellah) or even farther to the east (?). As a result, the Pan-African geosuture, as far as it really exists in Ougarta, is to be searched in this direction, not in the Damrane, which at these times was governed by intra-continental crust subaerial conditions.

6-7 BTH 8 Rajabinasab, babak

PROMISING AREA DETECTION USING MULTIVARIATE STATISTICS

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Multivariate statistics methods would be able to Analysis so many data simultaneously, therfore the risk of decisions based on these methods will be highly reduced. The exploration Area is lactated in 120 km of Zahedan city. The intrusion of Subplutonic monsodiorite bodies and diorite dikes in sedimentary sequence has made faulting and wide hydrothermal alteration. In a regular grid, 669 samples from the outcrops have been taken. The samples has been analyzed, using ICP-Ms method for Fe, Cu, Cd ,Bi Be ,As ,Ag ,Zn ,W, Te, Sn, Sb, S ,Pb ,Mo and using Fire Assay for Au. The primary data processes revealed element enrichment in some rock outcrops. The most important paragenesis determined using Hierarchical Clustering analysis. The PCA analysis introduces the most important anomalies(PC1). The location of anomalous areas determined with mapping PC1 variable. The importance of anomalies was investigated with the comparison of erosion surface and probable mineraliztion surface. The promising areas for the following Exploration program introduced.

6-8 BTH 9 Zaeimnia, Fatemeh

SURVEY OF MINERAL CHEMISTRY OF SOUTH AMLASH CLINOPYROXENE, NORTH OF IRAN: AN EVIDENCE OF BI MODAL GABBRO

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South Amlash Gabbroic bodies in eastern of Giulan provenance, according to geological subdivision of Iran is located in Gorgan-Rasht zone. The gabbroic rocks texturally are homogenous and minerallogically and geochemically divided in two distinctive group with two different origin: 1) In Alkaline type the dominant mineralogy is plagioclase, Clinipyroxen (titan-augite) and apatite which are also enriched from LREE and HFSE such as Nb and Ti, virtually shows the characteristic of typical oceanic island basalt. 2) Subalkaline types also have plagioclase and clinopyroxene, with negative anomaly of Nb and Zr suggested the rocks which formed in an island arc. According to microprobe data, clinopyroxene in Alkaline gabbros are enriched of Ti and show alkaline affinity. Occurrence of high Ti clinopyroxene in conjunction with their geochemical characteristics, suggested that this group of gabbros are similar to the basaltic rocks which formed in an enriched-source like as oceanic island. #Mg, high content of Al2O3 and amount of Cr and Ti of these clinopyroxenes indicate that they are crystallized from an enriched basaltic source in low pressure and high Oxygen fugacity. clinopyroxene of sub-alkaline gabbros are Diopside type and #Mg and Ti and Na content equivalent with island arc gabbros. According to their clinopyroxene characteristics, it seems that these gabbros are sourced from a suprasubduction zone and from melting of a mantle which metasomatized with subducted slab fluids.

6-9 BTH 10 Khatib, Mohammad Mahdi

STRUCTURAL CONTROL FOR EMPLACEMENT OF THE ANDESITIC DIKES IN ROMENJAN AREA, SOUTH OF BIRJAND, EAST OF IRAN

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Early Neogene andesitic mass and dikes in the Romenjan area of southern Birjand, east of Iran show evidence that their emplacement was structurally controlled. Andesitic dikes in this area formed by dilating in trans-tensional zones on pre-existing vertical to steeply N-dipping strike-slip faults. Magma propagation along these faults must have required less energy than the creation of a self-propagated fracture at dike dips and the magma pressure must have been greater than the compressive stress perpendicular to the fault surface. NWW- to W-trending ***en echelon*** dikes formed locally and are not obviously attached to the four main dikes in the area. The ***en echelon*** segments are probably pieces of deeper dikes, which are segmented perhaps as a result of a documented rotation of the regional stresses. Alternatively, changes in orientation of principal stresses in the vicinity of each en ***echelon*** dike could have resulted from local loads associated with paleotopographic highs or nearby structures.

We suggest that the change in stresses near the earth's surface played the main rolls for created open space for magma emplacement in this area.

The longest dikes intruded normal to σ***3,*** along pre-existing faults with critical dips and strikes: only NNW steeply dipping planes were injected. To achieve this geometry, magma pressures must have been greater than σ***3,*** and also have exceeded friction across the fault surfaces. Driving pressures were apparently not sufficient to intrude neither along faults of other orientations nor along self-propagated paths. *En echelon* dikes trend at an angle to the fault-conforming dikes, and could have formed during the documented stress-field rotation from east to west.

6-10 BTH 11 Moghaddas, Yousef

METALUMINOUS SUB-ALKALINE GRANITOIDS FROM THE TAKAB AREA, NW IRAN

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The Paleoproterozoic Takab complex is composed of a variety of metamorphic rocks including granulites, amphibolites, gneisses, mafic migmatites and meta-ultramafics, which are intruded by the Cenozoic intrusions of granitoids. The granitoids are mainly granodiorite, Qtz-monzodiorite, monzonite and Qtz-diorite. Chemically the granitoids show a low alumina saturation index (ASI), low concentration of SiO_2 and high FeO, MgO and CaO contents which are typical features for I-type granitoids. Field evidence, petrology and geochemical features lead to propose that the investigated granitoid suites are generated from melting of a crustal source connected to the associated mafic migmatites in the area. High concentrations of CaO, MgO and FeOt and low K_2O/Na_2O values, classify the source of the granitoids as metabasites. Basalts, amphibolites and rarely greywackes are protoliths for the magma generation in the Takab area.

The granitoids show main affinities as syn-collisinal granitoids (syn-COLG). Volcanic arc feature in some samples are most likely related to the features inherited from previous arc-related protoliths.

Magmatic crystallisation pressure and temperature for the quartz-diorite and the granodiorite are estimated to be P~8kbar, T~850°C and P~5kbar, T~790°C, respectively. Subsolidus conditions are consistent with temperatures of ~600°C and ~620°C, and pressures of ~6kbar and ~3.5kbar for the quartz-diorite and the granodiorite, respectively. The responsible magmatic activity in the Takab area occurred in relation to the subduction of the Neo-Tethys during Tertiary during the Alpine Orogeny. Although the accurate timing of collision between the Arabian plate and the Iranian block and associated magmatic activity are highly controversial, recent studies based on structural and metamorphic data suggest that continental collision occurred during Oligocene (see Agard et al. 2005). Widespread Neogene volcanic activities related to the extensional phase of the Alpine orogeny and U/Pb data from the migmatites evidence the Oligocene as the collision time in the Takab area (Hajialioghli, 2007).

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6-11 BTH 12 Saki, Adel

MINERALOGY, GEOCHEMISTRY AND GEODYNAMIC SETTING OF THE GRANITOIDS FROM NW IRAN

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The Mahneshan granitoids intruded the Neoproterozoic-Lower Cambrian regional metamorphic rocks in northwestern Iran. These granitoids consisting mainly of K-feldspar, plagioclase, quartz, muscovite, garnet and biotite display a number of subtypes in terms of structure, texture and mineralogy. Geochemically, they are peraluminous and (or) slightly peraluminous with variable normative corundum contents (0.28– 4.50%), and medium to high potassic with calc-alkaline affinity. Chondrite-normalized REE patterns indicate that these granitoids can be divided into three distinct groups, supported by petrographic data. The REE patterns of the first group are shallow-sloping in LREE relative to HREE ([La/Yb]n=1.37–2.48), exhibiting pronounced negative Eu (Eu/Eu_¼0.23–0.35). The second group granitoids are characterized by strong LREE-enrichment relative to HREE ([La/Yb]n=3–6.20), with positive Eu anomalies (Eu/Eu*=1.15–1.47). The third group of granitoids is depleted in the middle REE relative to other LREE and HREE. These REE patterns suggest the role of plagioclase and hornblende in their source of granitoids for group 1 and groups 2 and 3, respectively. The trends of Eu/Eu_ ratio versus silica contents suggest mixing of mafic material with components formed by crustal melting with a plagioclase-rich residue. Furthermore, thermobarometric estimations indicate that these rocks may have been formed at depths of 15–18 km at relatively low temperatures. The Mahneshan granitoids are S-type and may have been emplaced in a syn- to post-collisional tectonic setting.

1. GEOCHEMISTRY

1.1. Major and trace elements

These granitoids have SiO2 contents between 69-76.8 wt %, low MgO and very low abundance of high-field strength elements (Nb, Ta, Zr and Hf). For example, Nb is generally lower than the average value of felsic I-type (21 ppm) granites from Lachlan Belt of southeastern Australia (Chappell and White 1992). The chemical compositions of the rocks are plotted on the total alkali versus silica diagram of Middlemost (1994). The samples plot in the granite field of this diagram. Using AFM diagram of Rickwood (1989) and TAS diagrams of Irvine and Baragar (1971) and Cox et al. (1979), all samples present a subalkaline composition and are plotted on the calc alkaline field . The SiO2 versus K2O plot yield a medium to high-potassic calc-alkaline characteristics. Based on the aluminium saturation index (ASI) of (Shand 1947); the Mahneshan granitoids are peraluminous to slightly peraluminous and have S and I-type tendencies.

1.2. Rare earth elements

Based on chondrite-normalized REE patterns (normalization values from Sun and McDonough 1989), Mahneshan granitoids can be subdivided into three distinct groups. The REE patterns of the first group (are shallow-sloping in light rare earth elements (LREE) relative to heavy rare earth elements (HREE). The samples exhibit moderately fractionated REE patterns ([La/Yb)n=1.37-2.48), flat heavy REE patterns, and a large negative europium anomalies (Eu/Eu*=0.23-0.35; the depletion of Eu/Eu* ratios reflects melting with residual plagioclase and/or plagioclase as a major fractionating phase (Mark 1999). Therefore, the chondrite-normalized REE patterns and the Eu/Eu* ratio versus silica contents, display the role of hornblend and plagioclase minerals in their source, which probably suggests that the Mahneshan granitoids may be originated by partial melting of crustal material with different compositions.

1.3. Tectonic and geodynamic setting

Compared with the typical Lachlan S- and I-type granites (White and Chappell, 1983), the Mahneshan Granitoid rocks have higher Na_2O but similar K2O content. The I-type affinities shown in a few of the Mahneshan granitoid samples may result from hydrothermal alteration or even may be due to weathering, which are reflected in the variation of K_2O/Na_2O ratios and Na2O>K2O. Secondary minerals, such as sericite, some muscovite and cloudy feldspar are resulted from late hydrothermal activities.

Discrimination diagrams R2 [6Ca+2Mg+Al] vs. R1 [4Si-11 (Na+K)-2(Fe+Ti)] indicates that the Mahneshan granitoids represent syn- to post- collisional granites. Furthermore, these granitoids using the geotectonic classification of Pearce et al. (1984) and Pearce (1996) are classified as syn- to post- collisional granites similar to those of recent syn- to post- collision granites (high-Rb, low-Zr, Hf and Sr contents). The (Hf, Rb/10, Ta*3) diagram after Harris et al. (1986), in Figure 2k clearly shows a collisional tectonic setting for the studied rocks.

2. CONCLUSION

-The geochemical characteristics, mineralogy and petrography of these granitoids are comparable with typical S-type granites and were emplaced in syn- to post- collisional tectonic setting.
-Magmatic origin from water-saturated, heterogeneities source rocks (i.e. crustal material having different compositions) under low pressure conditions are suggested to the Mahneshan granitoids origin.

6-12 BTH 13 Chiu, Han-Yi

ZIRCON U-PB AGE AND GEOCHEMICAL CONSTRAINTS ON THE MAGMATIC AND TECTONIC EVOLUTION IN IRAN

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This study reports new zircon LA-ICPMS U-Pb and whole-rock Ar-Ar age data, coupled with geochemical analyses, for magmatic rocks from different areas or continental fragments of Iran, including the Urumieh-Dokhtar magmatic arc (UDMA), Sanandaj-Sirjan structural zone (SSSZ), Alborz Range, Central Iran, Lut and Sistan suture zone. Our analytical results, combined with literature data, allow us to better constrain the magmatic and tectonic evolution of Iran and neighboring regions. As part of an ongoing project focused on Cenozoic pre- to post-collisional magmatism in the Caucasus/Iran/Turkey orogenic belt, this study also identifies the occurrences of several Paleozoic-Mesozoic magmatic events, such as Cambrian (518-511 Ma) granite and rhyolite from Bafq area in the Central Iran, Triassic (~203 Ma) granites from Binalud area in NE Iran, and Jurassic (~165 Ma) granitoids in the UDMA, SSSZ and Lut Block. While the first belongs to the widespread late Neoproterozoic-Cambrian magma suite in Iran affiliated with subductions along the margin of Gondwana, the third affirms the notion that the Neotethyan subduction and resultant UDMA started evolving from at least middle Jurassic. By dating a large number of Cenozoic igneous rocks in Iran, this study that would form a main dataset to explore the magmatic evolution before and after the Arabia-Eurasia continental collision reaches to following major conclusions: (1) the pre-collisional, calc-alkaline magmatism in the UDMA appears to cease southeastward, taking place in the late Oligocene (~27 Ma) in Tabriz, the middle Miocene (~16 Ma) in Esfahan and the late Miocene (~7 Ma) in Kerman areas; (2) the magmatism in the Alborz Range occurred in two stages, dominantly in the Eocene (peaked at ~50-38 Ma) and subordinately in post-late Miocene (<7 Ma), with a long magmatic quiescence; (3) the voluminous volcanism that occurred within the Lut and Sistan suture zone mainly erupted from the middle Eocene to Oligocene (44-25 Ma); and (4) the post-collisional magmatism, of small-volume though widespread, started from 15-11 Ma with intraplate basalts in Tabas and Neh areas, eastern Iran and from ~11 Ma with absarokites in Urumieh area, NW Iran.

6-13 BTH 14 Lin, Yu-Chin

GEOCHEMICAL CONSTRAINTS ON THE PETROGENESIS OF EOCENE TO QUATERNARY VOLCANIC ROCKS IN ARMENIA

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Cenozoic magmatism in Armenia took place in two main stages, i.e., an early one from Eocene to Oligocene and a late one from late Miocene to Quaternary, which, respectively, pre- and post-date the onset of the Arabia-Eurasia collision. In contrast to the general consensus that attributes the early stage magmatism to the Neotethyan subduction, how did the late stage occur as voluminous post-collisional volcanic eruptions (~11 Ma to Recent) in the vast region covering much of the Caucasus, Northwestern Iran and Eastern Anatolia (hereafter named as the CIA magmatic province) has long been an issue of debates. This study reports geochemical data of 10 samples from the early stage and 34 others from the late stage from NW and central parts of Armenia. The former that range from basaltic to dacitic compositions show medium-K calc-alkaline nature, while the latter composed of basalts to rhyolites that constitute a high-K calc-alkaline suite. Although all these rocks show LREE-enriched rare earth patterns, basalts from the early stage, which contain La of 15-28 ppm and $(La/Yb)_N$ of 3.5-7.9, are markedly less enriched than those of the late stage [La=24-63 ppm and $(La/Yb)_N$=5.8-20]. In the multi-element diagram, such secular variations are observed also for other highly incompatible trace elements (e.g., Rb, Ba, Th, U), despite all the basalts display apparent depletions in the high field strength elements (e.g., Nb, Ta, Ti). These geochemical features, similar to those of many coeval volcanic rocks from the CIA magmatic province, support the existence of a subduction-modified lithospheric mantle that prevails in the Lesser Caucasus and nearby regions throughout the Cenozoic. The Armenian rocks show rather uniform Sr-Nd isotopic compositions, with the early stage having $^{87}Sr/^{86}Sr$=0.7040-0.7047 and $^{143}Nd/^{144}Nd$=0.5137-0.5129 and the late stage having $^{87}Sr/^{86}Sr$=0.7042-0.7046 and $^{143}Nd/^{144}Nd$=0.5128-0.5129, similar with the isotopic compositions reported in other CIA magmatic province. Moreover, the Sr-Nd isotopic compositions do not change with SiO_2 contents, suggesting FC, rather than AFC, processes in the petrogenesis or magma differentiation. We performed REE modeling for the Armenian basaltic magma generation and the results suggest that the pre- to post-collisional magmatism resulted from changing degrees of partial melting of a shared mantle source, with the melting degrees being larger in the early stage (5-15%) and smaller in the late stage (1-6%).

SESSION NO. 7, 08:30

Monday, 4 October 2010

Ophiolites, blueschists, and suture zones. Posters Part 1 (*Ofiyolitler, mavisistler ve kenet kusaklari*)

METU Convention and Cultural Centre, Exhibition Hall

7-1 BTH 15 Rebay, Gisella

DEFORMATION-METAMORPHISM RELATIONSHIPS IN THE ECLOGITISED RODINGITES OF THE UPPER VALTOURNENCHE (ZERMATT-SAAS ZONE, ITALY)

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The Zermatt-Saas Zone is a remnant of the Piedmont-Ligurian oceanic lithosphere, trapped in the suture zone of the Western Alps on the occasion of the Alpine subduction and collision. A major extensional fault (e.g Sartori & Thelin, 1987; Ballevre & Merle, 1993), whose recognition is grounded both on lithostratigraphic and metamorphic evidence (e.g. Bearth, 1967; Caby *et alii*, 1978; Dal Piaz, 1974; Kienast, 1983; Marthaler & Stampfli, 1989), puts it in contact with the Combin Zone. A structural analysis has been performed in a portion of the Zermatt-Saas Zone mainly consisting of mafic and ultramafic rocks of oceanic derivation and well known for its high- and ultrahigh-pressure mineral assemblages (e.g. Chinner & Dixon, 1973; Ernst & Dal Piaz, 1978; Reinecke, 1991; Xu-Ping *et alii*, 2004). Zermatt-Saas eclogites generally recorded high-pressure mineral assemblages formed by omphacite-garnet-chloritoid-talc-zoisite or omphacite-garnet-kyanite- clinozoisite ± talc (e.g. Barnicoat & Fry, 1986); eclogites are retrogressed into epidote amphibolites ± garnet.

The investigated rocks are mainly rodingites, associated with serpentinites, minor metagabbro and chlorite-schists. The mesostructural analysis allowed recognition of four groups of superposed ductile structures three of which are syn-metamorphic.Both D_1 and D_2 are correlated to the development of high-pressure parageneses. Mineral and textural relics older than these phases have been recognised and are correlated to the serpentinisation and rodingitisation processes ascribed to oceanic metamorphism.S_1 is a relic foliation recorded only in rodingite dykes and lenses, preserved in the millimetre thick microlithons of D_2 crenulation cleavage and as internal foliation of garnetI porphyroblasts; it is marked by pyroxene and amphibole SPO.

S_2 is the dominant fabric in rodingites and metagabbros; in rodingites it is underlined by alternating chlorite- and amphibole-layers and trails of small garnet$_2$.

In metagabbros pre-D_3 relics are garnet, omphacite, rutile and glaucophane + phengite and, successively, barroisitic amphibole, zoisite, Mg-chlorite, phengite and ilmenite.

D_3 structures are the most pervasive in serpentinites and gabbros, consist of a crenulation cleavage type foliation associated with open metric folds and are correlated to post-P peak greenschist facies retrogression. S_3 in rodingites is marked by Fe-chlorite, replacing zoisite. Both S_2 and S_3 affect the reaction rim underlying the serpentinite and rodingite boundaries, which consists of chloritic schist.

The last group of ductile structures is D_4 metric open folds with a sub-horizontal axial plane.

Structural mapping allowed the correlation of HP fabrics between metagabbros and rodingites, making possible to identify the HP assemblages in S_1 and S_2 fabrics in eclogitised rodingites: S_1- garnet$_1$, Mg-chlorite$_1$, epidote-clinozoisite$_1$, clynopiroxene$_1$, vesuvianite$_1$, titanite$_1$ + amphibole; S2 – Mg-chlorite$_2$, vesuvianite$_2$, clinopyroxene$_2$, epidote-clinozoisite$_2$, garnet$_2$ (in veins), titanite$_2$. These results highlight that vesuvianite forms together with chlorite, epidote, garnet, clinopyroxene HP assemblages and syn-D_2 recrystallization is associated with Al-increase.

Pre-D_3 PT conditions estimated in metagabbro of P ≤ 1.2 GPa for T ˜ 550°C suggests that these can represent the minimal pressure for vesuvianite recristallisation under HP conditions.

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7-2 BTH 16 Malatesta, Cristina

THE HIGH PRESSURE VOLTRI MASSIF (LIGURIAN ALPS, ITALY) AND 2D NUMERICAL MODELS: AN INSIGHT INTO EXHUMATION MECHANISM

MALATESTA, Cristina[1], GERYA, Taras[2], FEDERICO, Laura[1], SCAMBELLURI, Marco[1], CRISPINI, Laura[1], and CAPPONI, Giovanni[1], (1) Dip.Te.Ris, University of Genova, C.so Europa 26, Genova, 16132, Italy, cristina.malatesta@unige.it, (2) Institute of Geophysics, ETH Zentrum, Sonneggstrasse 5, Zürich, 8092, Switzerland

High-pressure ophiolite massifs usually outcrop in the internal position of an orogenic chain. In the Ligurian Alps we studied a kilometric massif in which plurimetric to pluridecametric lenses of metagabbro and metabasites are surrounded by highly sheared serpentinite and metasediments. The massif is made of two tectono-metamorphic units (Palmaro - Caffarella and Voltri) which record distinct metamorphic histories with peak conditions ranging from the blueschist to the eclogite facies. The study of some metagabbro lenses outcropping in such massif revealed that a strong strain partitioning acted between the lenses and the host-rock (serpentinite or metasediment) and between the core and the rim of the lenses: in the cores the magmatic textures are preserved whereas tectonitic and mylonitic textures are often visible in the rims. In the Voltri and Palmaro - Caffarella units both the metamorphic peak (eclogite and blueschist facies, respectively) and the later greenschist facies retrogression are syn-kinematic.

Coupling the conventional petrographical analysis with P-T pseudosections (PERPLE_X; Connolly et al., 1990) we have been able to define the metamorphic history of each analyzed sample. The Palmaro-Caffarella metagabbros record peak metamorphic conditions of 10<P(kbar)<15 and 450<T(°C)<500 typical of the blueschist facies. The Voltri metagabbros reach peak metamorphic conditions in the lawsonite stability field, varying from about 21 kbar

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and 450-490 °C to 22-28 kbar and 460-500 °C. All the analyzed samples were subject to a clockwise P-T trajectory, which includes an almost isothermal exhumation path.

To study the mechanism for exhumation of the Voltri Massif we performed a series of 2D numerical simulations (Gerya & Yuen, 2003): the starting set up depicts an oceanic basin of prescribed amplitude surrounded by continental margins. To best reproduce the intra-oceanic subduction that started in Mesozoic time inside the Ligurian-Piedmontese branch of the Western Tethys, we defined an oceanic lithosphere with a non-layered structure typical of slow and ultra-slow spreading ridges; gabbros form discrete bodies inside the serpentinized lithospheric mantle and a discontinuous basaltic layer covers the latter.

We tested two different rheologies of serpentinites (Gerya et al., 2002; Hilairet et al., 2007) and in both cases slab dehydration causes formation of a viscous serpentinitic channel in the mantle wedge. Ductile deformation of serpentine (Hilairet et al., 2007) favors the mixing of sediments in the serpentinitic channel also during the initial stages of subduction. Furthermore the serpentinitic mélange includes slices of subducted oceanic lithosphere which are scraped from the slab; in this way serpentinite deriving from the mantle wedge hydration are therefore closely associated with slab-derived serpentinites. The serpentinitic mélange is finally exhumed thanks to the buoyant effect of the ultramafic rocks that decreases the bulk density of the high-pressure terrains below the mantle value (Hermann et al., 2000).

The P-T paths predicted by the model for the exhumed metagabbro and metasediments are comparable to the clockwise P-T path obtained for the Voltri Massif. The peak metamorphic conditions vary from P= 12,5 kbar and T=250°C to 20<P(kbar)<25 and 420<T(°C)<500 and the exhumation path is almost isothermal. In addition the size of exhumed units in the model grossly fits the size of the different rock bodies actually cropping out in the Voltri Massif.

Such evidence suggests that buoyancy could be considered an effective mechanism that contributed to the final exhumation stages of the high-pressure rocks of the Voltri Massif.

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7-3 BTH 17 Farahat, Esam S.

NEOPROTEROZOIC EGYPTIAN CENTRAL EASTERN DESERT ARC-BACK-ARC SYSTEM AS EVIDENCED BY SUPRA-SUBDUCTION OPHIOLITES

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Ophiolites are broadly distributed in the Central Eastern Desert (CED) of Egypt, occurring as clusters in its northern (NCEDO) and southern (SCEDO) segments. They show supra-subduction zone geochemical signature with prevalent island-arc and minor boninitic affinities in the NCEDO and MORB/island arc association in the SCEDO. Mineralogical and geochemical data on the volcanic sections of Wizer (WZO) and Abu Meriewa (AMO) ophiolites as representative of the NCEDO and SCEDO, respectively, are presented.

The WZO volcanic sequence comprises massive lower part of more MORB-like compositions intruded by minor boninitic dykes and thrust over island-arc metavolcanic blocks in the mélange matrix, pointing most likely to formation in a protoarc-forearc setting. Chemical compositions of primary clinopyroxene and Cr-spinel relicts from the WZO volcanic section further confirm this interpretation. Such compositional variability in the WZO crustal sequence is comparable with its mantle section that varies from slightly depleted harzburgites of MORB/IAT affinities to highly depleted harzburgites of IAT affinity containing small dunite bodies of boninitic affinity. Source characteristics of the WZO different lava groups indicate generation via partial melting of MORB source progressively depleted by melt extraction and variably enriched by subduction zone fluids. MORB-like magma may have derived from ~20% partial melting of an undepleted lherzolite source, leaving slightly depleted harzburgite as a residuum. The generation of island-arc magma can be accounted for by partial melting (~15%) of the latter mantle source, whereas boninites may have derived from partial melting (~20%) of a more refractory mantle source previously depleted by melt extraction of MORB and IAT melts, leaving ultra-refractory dunite bodies as residuum.

On the other hand, the AMO volcanic unit occurs as highly deformed pillowed metavolcanic rocks in mélange matrix. They can geochemically be categorized into LREE-depleted (La/Yb_{CN}= 0.41-0.50) and LREE-enriched (La/Yb_{CN}= 4.7-4.9) lava types that show a MORB/within plate to island arc geochemical signature, signifying back-arc basin setting, consistent, as well, with their mantle section. Source characteristics indicate depleted to slightly enriched mantle sources with overall slight subduction-zone effect as compared to WZO.

Such polarity in geologic and geochemical characteristics of the NCEDO and SCEDO, along with the abundance of mature island-arc metavolcanics which are close in ages (~750 Ma) to ophiolitic rocks, systematic enrichment in HFSE of ophiolites from north to south, and lack of crustal break and major shear zones, is best explained by a geotectonic model whereby the CED represents an arc-back-arc system above a southeast-dipping subduction zone.

SESSION NO. 8, 08:30

Monday, 4 October 2010

Strike-slip and transform fault tectonics. Posters (*Dogrultu atim ve transform fay tektonigi*)

METU Convention and Cultural Centre, Exhibition Hall

8-1 BTH 18 Esat, Korhan

DETERMINATION OF MAIN STRAND OF A STRIKE-SLIP FAULT BY USING SUBSIDIARY STRUCTURES: ESKISEHIR FAULT ZONE AS A CASE STUDY

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Eskisehir Fault Zone is one of the important neotectonic structures of Turkey and extends from Bursa-Inegol to the west of Tuzgolu. Although most studied section lies between Bozuyuk and Eskisehir, there is no consensus on the structural style of the Eskisehir Fault Zone in this region. Some of the recent studies report the Eskisehir Fault as a transtensional structure whereas others suggest that earlier strike-slip faulting superimposed by younger normal faults.

On the contrary, our field observations on the subsidiary structures indicate an active right lateral strike-slip regime. Between Bozuyuk and Eskisehir, Riedel shear surfaces, overturned fold axes, small thrust surfaces, calcite filled open fractures and dyke systems indicate a theoretical main strand of strike-slip fault trending N 60-80 W. When this result is taken into account, two segments of the main strike-slip fault have been recognised between Bozuyuk and Eskisehir. In the NW of Inonu town, Sarisu Cayi is diverted 4.5 km right laterally by Bahcehisar segment. Further to east, the course of Sarisu Cayi is again deflected 18 km right laterally by en echelon Cukurhisar segment. Toward south, Porsuk river is also diverted right laterally by Kizilinler, Gokcekisik and Akcapinar segments. It is clear that E-W trending normal faults are not compatible with NW-SE trending right lateral strike-slip system. Indeed E-W trending Inonu fault is cut by N45W trending right lateral R shear in the Turkish Aeronautical Association Training Centre and the right lateral strike-slip faults control the drainage system of the region. All these data indicate that the E-W trending normal faults must belong to the earlier extensional tectonics and the region is under the influence of the current strike-slip tectonics.

This working hypothesis should be tested by geophysical methods especially on the Cukurhisar segment which is highly important to evaluate seismic risk of Eskisehir settlement.

8-2 BTH 19 Isik, Veysel

GEOLOGY OF THE SAVCILI FAULT ZONE, CENTRAL TURKEY

ISIK, Veysel[1], CAGLAYAN, Ayse[1], SEYITOGLU, Gurol[1], UYSAL, Tonguc[2], ZHAO, Jianxin[3], SOZERI, Koray[4], and ESAT, Korhan[1], (1) Department of Geological Engineering, Tectonics Research Group, Ankara University, Tandogan, Ankara, 06100, Turkey, isik@eng.ankara.edu.tr, (2) Earth Sciences, University of Queensland, Queensland, Brisbane, QLD 4072, Australia, (3) Centre for Microscopy and Microanalysis, The University of Queensland, Brisbane, 4072, Australia, (4) Department of Geological Engineering, Ankara University, Ankara, 06100, Turkey

Understanding the nature of fault zones is sometimes essential to interpret their regional geology. There are two contrasting tectonic models proposed for origin of the Savcili fault zone. One view has been that this zone is characterized by the development of structures typically associated with crustal contraction. The others have interpreted that this zone refers to crustal extension.

The Savcili fault zone is one of the significant structural features exposed in the western portion of the central Anatolian core complex. It contains numerous parallel to sub-parallel thrust/reverse faults mainly a WNW-striking and SW-dipping and is cross-cut by later normal and strike-slip faults. Along the zone, the faults mostly places metamorphic and granitoidic rocks over Paleogene sedimentary rocks, which are overlaid by Miocene-Pleistocene deposits. It is therefore inferred that movement along the SFZ was ceased by Miocene.

The Savcili fault zone possesses a well-developed zone of brittle deformation, called here cataclastic zone, in both the hanging wall and footwall. The cataclastic zone is characterized by two main architectural components; core and damage zone. The core is characterized by cohesive and non-cohesive fault rocks (mainly cataclasite and gauge). The damage zone surrounding the core consists of a well-developed fracturing and cohesive and non-cohesive fault rocks (mainly breccia). Kinematic indicators include steps, fractures, trains of inclined planar structures and asymmetric cavities, suggesting that hanging wall block has moved up approximately northwards with respect to footwall block.

The models for evolution of the Savcili fault zone advocated in the literature do not fit our integrated field and microstructural data providing evidence of episodic cataclasis and diffuse mass transfer deformation mechanisms.

8-3 BTH 20 Çinar, Seray

KINEMATICS OF THE GANOS FAULT, NW TURKEY: IMPLICATIONS LATERAL EXTRUSION OF THE ANATOLIAN BLOCK SINCE LATE MIOCENE

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Ganos Fault, is a right lateral strike-slip fault, represents the further western segment of the dextral North Anatolian Fault Zone and has about 100 km length. It is namely the Gaziköy-Saros segment and connects the western Marmara Sea and Aegean Sea in continent around the Gulf of Saros. Ganos Fault has been active both in historical and instrumental periods. Historical earthquakes (M>6) occurred in 542, 824, 1063, 1343, 1344, 1354, 1542 and 1766. Besides in last century, 1912 Mürefte (M=7,3) earthquake occurred on the Ganos Fault was the largest and most destructive. The aim of this study is to present the kinematic characteristics of the Ganos Fault. According to kinematic measurements on fault planes and some earthquake focal mechanism solutions, Ganos Fault is regarded as an active and right lateral strike-slip fault with a normal component. Kinematic analysis results or inversions of these fault-slip data show an active transtensional tectonic regime and presented the maximum horizontal stress (σ_1) axis as NW-SE and minimum horizontal stress (σ_3) axis as NE-SW. Rm value is smaller than 0.5. This result is thought to be related with the continental collision in eastern Anatolia, slab-pull forces on African plate in SW Turkey and combined effect of the Anatolian extrusion to the west since late Miocene time.

8-4 **BTH 21** Cicek, Ceren

IMPLEMENTATION OF A ROCKFALL HAZARD RATING SYSTEM TO THE CUT SLOPES ALONG KIZILCAHAMAM-GEREDE SEGMENT OF D750 HIGHWAY

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A rock fall hazard rating system (RHRS) was implemented to the cut slopes along Kizilcahamam-Gerede segment of D750 (Ankara-Istanbul) Highway. The RHRS developed by the Tennessee Department of Transportation was assessed for thirty five cut slopes which were selected based on a reconnaissance survey along D750 highway, between Kurtbogazi Dam (50 km northwest of Ankara) and Aktas village (15 km to Gerede town of Bolu province).

The stages of the investigation consist of project conception, field investigations and application of this system, assessment and presentation of data. The cut slopes were classified by implementing the method which requires a scoring on an exponential scale assigned to various parameters related to the site and roadway geometry and geologic characteristics. The rating process was completed at two stages: Preliminary and Detailed Rating. Based on the Tennessee RHRS, nineteen cutslopes were assessed according to these two stages while the other sixteen cut slopes were able to be classified only with the preliminary rating stage. Different modes of slope failure (planar, wedge, toppling, rock fall with differential weathering, raveling) throughout the selected segments of the highway were investigated and the slope and highway related parameters such as slope height, ditch effectiveness, average vehicle risk, road width, percent desicion site distance and rockfall history were identified for these nineteen cut slopes. After the scoring process was completed all cut slopes were classified based on their hazard ratings from the point of the problems that they may cause in transportation.

Among these thirty five cut slopes, nineteen of them are rated as “A” slopes which are considered to be potentially hazardous, while a total of seven are rated as “C” slopes which pose no danger. In placing a slope into a “B” category, it is considered that they are not as prone as A slopes to create a danger and a total of nine B slopes are detected. The detailed rating is accomplished for these nineteen “A” slopes and as a result of the scorings, it has been seen that the final RHRS scores range from 164 to 591. The slopes with scores over 300 (both additive and multiplicative) can be counted as more hazardous slopes since they get very high scores both from site and roadway geometry and geologic hazard part.

8-5 **BTH 22** Parlak, Oktay

THE RELATIONSHIP BETWEEN ELDIVAN-ELMADAG PINCHED CRUSTAL WEDGE AND NORTH ANATOLIAN FAULT ZONE: AN APPROACH TO THE AGE OF CENTRAL NORTH ANATOLIAN FAULT ZONE

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Recently determined, NNE-SSW trending Eldivan-Elmadag Pinched Crustal Wedge (EPCW) has thrusted eastern and normal faulted western margins. This neotectonic structure is created due to NW-SE compression created between North Anatolian Fault Zone (NAFZ) and Kirikkale-Erbaa Fault Zone (KEFZ). In the north of Cankiri, the EPCW has arc shape geometry and its trend changing to NE-SW and further to east it becomes ENE-WSW that is nearly parallel to NAFZ. In the north of Cankiri, the Korgun fault constituting western margin of EPCW is clearly a normal fault evidenced by undulated fault surfaces. The eastern margin of EPCW has complex thrust faults. The both margins control deposition of Pliocene-Pleistocene clastic Deyim Formation. The arc shaped connection of EPCW to the NAFZ, the strain analysis of GPS data and focal mechanism solutions of micro-earthquakes demonstrate a genetic link between EPCW and NAFZ. Ilgaz and Tosya basins located in the NAFZ contain upper Miocene – Pliocene basin fill in which syn-sedimentary normal faults are observed. The strikes of these normal faults are incompatible with right lateral NAFZ. Therefore, it can be speculated that development of these basins was not related to NAFZ and its initiation must be post Pliocene which is also in agreement with the activation age of EPCW.

8-6 **BTH 23** Rashidi, Mohadese

STRUCTURAL INVESTIGATION OF NAYBAND FAULT(MIDDLE PART) BY USING SATELLITE IMAGE PROCESSING

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The studied area is located in East of Central Iran Micro continent (CEIM) and East of Dasht-e Lut, were the Nayband fault located as an old index of tectonic structure. The Nayband fault, with a length of 104 km, known as a right lateral slipping fault, and in some parts with a normal dip slip component.Using satellite image processing methods, we can study some structures such as Releasing bends that caused basaltic eruption and some Quaternary volcanic activities and even some outcrops of salt domes along the Nayband fault system. And also the displacement of the channel & its measurement is detected, that shows the new tectonic activity along the Nayband fault system on this area .

8-7 **BTH 24** Toori, Moosarreza

NEOTECTONICS OF ZANJAN (CENTRAL IRAN): A LEFT LATERAL STRIKE-SLIP SYSTEM AND RELATED STEPOVER STRUCTURES

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Escape tectonics developed in the collision zones and strike-slip faults are the main tectonic elements. Arabia- Eurasia continental convergence is continuing in Iran according to seismic and GPS data. This N-S convergence cause right lateral (Tebriz, Zagros) and left lateral (Dashte Beyaz, Elburz) strike-slip systems. Zanjan (Zengan) is located between Tehran and Tebriz and its neotectonic structures are not well determined. In this area, Sultaniye, Geydar and Tarim mountains are located as NW-SE trending highlands parallel to the Zagros and Elburz mountains where the pre-Neogene rocks come to contact with Quaternary deposits occupying the lowlands. Our morpho-tectonic studies indicate that active E-W trending left lateral strike-slip faults control the morphology of the Zanjan area. They are evaluated as western continuation of main left lateral Mosha-Shahrud fault that is the main structure of Elburz mountain. The left and right stepping of the left lateral strike-slip faults creates pull-apart basins and push-ups. Kazvin basin is an example of pull-apart basin and Sultaniye is located on the push-up region where the rivers flow opposite directions towards NW and SE. In the restraining bends single or double vergent thrust faults trending NW-SE is developed and deformed Quaternary sediments. This explains NW-SE trending highlands in the region. Geological record of this uplift is lying in the Upper Miocene-Quaternary alluvial and fluvial sedimentary deposits around Sultaniye. Lower part of coarse clastic sedimentary succession is composed of fragments of Eocene units whereas that of upper part contains metamorphic rock fragments that its original outcrops are located in the core of Sultaniye mountain. The uplift of the NW-SE trending highlands and related strike slip system is operational since Late Miocene. Maximum displacement of the geological units in the area is 25 km. If GPS data of 4mm/year is considered, it is clear that most of the deformation must be absorbed in the sidestep and restraining bends.

8-8 **BTH 25** Gürbüz, Alper

PULL-APART BASIN FEATURES IN 2D AND 3D

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Pull-apart basins are depressions associated with geometrical irregularities of strike-slip faults. However, many uncertainties complicate the interpretations of their geometrical aspects. This study presents a review of current literature and a new data set from the pull-apart basins along the North Anatolian fault zone about the angular and scale characteristics of these basins to understand their geometries in 2-D and 3-D. Angular data in literature that attained from the natural cases, experimental and numerical studies represent a mean acute angle of 33° between the master faults and diagonal faults. Pull-apart basins along the North Anatolian fault zone also present the similar acute angles. As represented by experimental studies, this value is a result of overstep geometry. Some declinations may be observable in pull-apart basins located at zones controlled by composite regimes. Scale characteristics of pull-apart basins from all over the world indicate a good 2-D relationship between basin length and width as firstly suggested by Aydin and Nur (1982). A similar relationship between length and depth data has also been proposed by Hempton and Dunne (1983). In this study a comparison among the length, width, and depth parameters of pull-apart basins in 3-D from the well-known active and ancient pull-apart basins suggests that there may be an empirical relationship. This relationship would be most cheap and useful method to predict sediment thickness of pull-apart basins which are one of the important reservoirs for economic resources. Independent from the type of potential resource (oil, gas, ore deposits, or groundwater), sedimentary thickness is the most important parameter in understanding the attainability of the resource. The application of the proposed relationship to the pull-apart basins along the North Anatolian fault zone and some other basins around the world predicts new sediment thicknesses. By the addition of more sediment thickness data by drilling and geophysical methods to current literature, the accuracy of the regression and predicted values will increase.

SESSION NO. 9, 08:30

Monday, 4 October 2010

Subduction, collision and orogeny. Posters Part 1 (*Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez*)

METU Convention and Cultural Centre, Exhibition Hall

9-1 **BTH 26** Dokukina, Ksenia

ARCHAEAN AGE AND PETROLOGY OF GRANITOIDS FROM GRIDINO AREA (BELOMORIAN ECLOGITE PROVINCE) AS LIMIT IN THE TIME OF HIGH-PRESSURE PROCESSES

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Last years eclogites were found in the Belomorian mobile belt (location – Gridino and Salma). It is considered that in the Gridino eclogite-bearing zone (Northern Karelia) the eclogites have got two ages of formation: Archaean and Paleoproterozoic (Volodichev et al., 2004). Lenses of Archaean eclogite (2720.7±8 Ma) are in the felsic gneissic matrix as strongly deformed pods or layers and it is considered that they were formed in the enviroment of “warm” subduction of oceanic crust. Other type of “local” eclogite displayed in undeformed and deformed mafic dikes. Geochronology studies of mafic high-pressure metamorphic dykes gave Archaean dates coupled with Paleoproterozoic (2.35-2.42 Ga). Geochemical and petrological investigations of the both types of eclogites displayed a likeness in the chemical composition and the united step-by-step metamorphic P-T trend for all mafic rocks (from eclogite to amphibolite through HP-granulite). We dated Zircons (SHRIMP II) from granitoids which cross-cut the mafic postulate Paleoproterozoic dykes. New geochronology data permitted to determine the Archaean age of high-pressure metamorphic event.

The first sample was collected from a Phen-Fsp-Qtz leucosome developed at the continuation of the granulite gabbro dike, which was subjected here to deformation, amphibolization and migmatization. Petrological studies of the leucosome showed high-pressure magmatic relicts: Ba-bearing phengites (3.17 cations Si per 11 atoms O), K-Ba feldspar, mirmekite and near solidus symplectic intergrowths of Czo, Phe and Qtz. The conditions of leucosome crystallization are 16-20 kbar for 650 °C. Evidences of change the eclogite to granulite conditions are: Bt replaces the Phe; grossular Grt and Cpx replace the Czo-Qtz symplectites; Pl breaks down with antiperthite forming. The granulite stage was at 750-800 °Cƒn and 10-12 kbar. Last superposed amphibolitic metamorphic event fixes new mineral forming (600 °C at 8 kbar): Hbl replaces Cpx, new Bt and Czo with Ep forming. Zrns the Phen-Qtz-Fsp leucosome subdivide into some crystal faces. First routine Zrn group is brownish subhedral 100 x 200 µm grains, with clear core-rim structures in CL images. The cores display a relic oscillator zoning with underwent an alteration and a metamict. It is typical for magmatic Zrns with high-content of uranium (more 3000 ppm). One analysis of the least metamict core of the same Zrn gives concordant age 2713±6 Ma. The Zrns have a distinctive chemical composition characterized by low Th/U ratio (0.05), much enriched REE concentrations than others Zrns (summa REE=1205 ppm) and have smaller negative Eu (Eu/Eu*=0.57) and positive Ce anomalies (Ce/Ce*=1.62) at a relative flat chondrite-normalised REE pattern (Lu_N/Sm_N=21; LuN/SmN = 131). Second extended Zrn group is colourless ovoid 100x150 µm grains show core-rim zoning. In general Zrns are characterized a high-uranium (522-935 ppm) structureless cores. Some Zrns have a fir-tree zoning which is typical for high-pressure Zrns. The cores vary by Th/U ratio (0.11-0.32) and their age 2707±20 Ma. The REE pattern of such Zrn is characterized by a positive Ce anomaly, a negative Eu anomaly (Eu/Eu*=0.33), and low enrichment in HREE with respect to MREE (Lu_N/Sm_N=13, Lu_N/La_N=135). In rare instances the inner core display fine magmatic oscillatory zoning; external core has properties corresponding cores of second group. One point from inner oscillator core gave older age 2793±14 ($^{207}Pb/^{206}Pb$). All Zrns are surrounded by narrow structureless cracked low uranium (66-155 ppm) rims. Concordia age 1938±35 Ma and corresponds to the Svecofennian Orogeny, when imbricate thrusting brought deep-seated rocks of the Belomorian belt to shallower amphibolite levels (Bibikova et al., 2004). The rims are depleted in all the trace elements, except Hf and much low Th/U ratio (0.00-0.01). The REE pattern of rims is characterised by positive Ce anomaly, a negative Eu anomaly (Eu/Eu* = 0.41-0.51), and enrichment in HREE with respect to MREE and LREE (Lu_N/Sm_N=17-79, Lu_N/La_N=89-392).

Second geochronological sample was collected from enderbite vein cutting an eclogite gabbronorite dyke. Mineral composition of enderbite is Grt-Bt-Opx-Cpx-Pl-Qtz equilibrium paragenesis. There are no petrological evidences of amphibolite transformations in the enderbite. PT-path estimation of enderbite forming is 721 °C at 10 kbar. Zrns from the enderbite are subdivided into two groups. First group is subhedral grains with fine-scale oscillatory zoning, magmatic Th/U ratio (0.55-0.85) and ages about 3 Ga corresponding of the time of tonalite forming. Second Zrn group is subhedral structureless black in CL grains and rims around the core of the first type. They are characterized low Th/U ratio (0.03-0.04). Average weighted age ($^{207}Pb/^{206}Pb$) is 2719±39 Ga.

Thus the isochronous ages of granitoids are the upper age limit of Archean mafic dike intrusion and Archean high-pressure metamorphism. We believe that traditional interpretation of the age of mafic magmatism and emplacement of dikes (~2.4 Ga) is invalid. The high-pressure complexes of the Gridino zone were presumably formed during a continent–continent collision which took place about 2.71 Ga.

SESSION NO. 10, 08:30

Monday, 4 October 2010

Tectonic, magmatic & geomorphic evolution of high plateaus. Posters (*Yüksek platolarin tektonik, magmatik ve jeomorfik evrimleri*)

METU Convention and Cultural Centre, Exhibition Hall

10-1 **BTH 27** Abbasi, Madjid

THE STUDY OF CRUSTAL STRUCTURES FOR THE IRANIAN PLATEAU BY TERRESTRIAL GRAVITY DATA

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Terrestrial gravity data are relatively sparse in the Middle East region. In Iran these data are mainly furnished by Bureau Gravimetric International (BGI) and Iranian National Cartographic Center (NCC). These data seems to be enough for studying the large-scale crustal structures in Iran.

A considerable data preparation phase is needed to correct the data for blunders. Complete Bouguer anomalies are computed over the region by taking account of the Earth's curvature for topographic correction. Some special problems like negative heights of Caspian Sea level shore have to be treated with more precautions. There are also some marine gravimetric data over Persian Gulf and Oman Sea. The corresponding Bouguer anomalies are computed for these regions as well.

Bouguer anomalies show a minimum value of -289 mgal over Zagros Mountains. This region has the thickest crust in Iran. The maximum value of Bouguer anomlies is seen in the southern part of Caspian Sea. A positive anomaly is also seen in the south east of Iran in the northern part of Oman Sea. Rigorous interpretation of these Bouguer anomalies needs a comparison with other data sources like seismic data.

SESSION NO. 11, 13:30

Monday, 4 October 2010

Keynote Talk 2

METU Convention and Cultural Centre, Kemal Kurdas Salon

11-1 13:30 Mulch, Andreas

MIOCENE TO PLIOCENE PLATEAU DEVELOPMENT AND PRECIPITATION PATTERNS IN CENTRAL ANATOLIA

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Long-term stable isotope records of continental depositional systems represent increasingly important tools for paleoenvironmental, paleoclimatic, and paleoaltimetric reconstructions within continental interiors. A rapidly growing number of studies within the Earth's major mountain ranges has demonstrated that the growth of topography and orogenic plateaus profoundly influences local, regional, and hemispheric climate and hence precipitation patterns. In contrast, such records are almost absent for the Anatolian plateau, an important topographic element in the Alpine-Himalayan chain and an area most likely to be strongly affected by future climate change and water scarcity.

Here, we present oxygen, carbon, and hydrogen isotope data from Neogene-to-recent fluvio-lacustrine and pedogenic environments, stream and lake waters with the ultimate aim of reconstructing past precipitation changes, plateau aridification and ideally surface uplift histories of the Neogene Central Anatolian Plateau (CAP). Our long-term objective is to assess the role of climatic and orographic factors that have governed the distribution (and isotopic composition) of precipitation across the CAP from the Neogene to recent. Such data is fundamental for our understanding of the geodynamic and sedimentary history of orogenic plateaus in general and for the role of surface uplift along the plateau margins in the Pontide and Tauride mountains. Our approach is to cross-calibrate modern patterns of isotopes (oxygen and hydrogen) in precipitation with pedogenic carbonate oxygen and carbon isotope data across topographic barriers that today strongly control the distribution of rainfall along the plateau margins and within the plateau interior. We then compare these patterns with Miocene-to-Pleistocene lacustrine and pedogenic records to assess a) the role of late Neogene (ca. 8-0 Ma) surface uplift in the Pontide mountains, b) the importance of rain shadow development in the lee of the plateau margins, and c) the potential effects of Mediterranean aridification during the Messinian (at ca. 5.9 to 5.5 Ma).

Based on ca. 200 hydrogen and oxygen isotope data from modern streams and rivers we can document the orographic effect of the southern plateau margin onto the hydrogen and oxygen isotopes in precipitation with apparent oxygen isotope lapse rates that fall within the global average (0.2-0.4 ‰/100 m) and a leeward decrease in the oxygen isotope ratios of ca. 3-4 ‰ compared to sea level.

Miocene-to-recent lacustrine and pedogenic carbon and oxygen isotope profiles from the southern plateau margin into the plateau interior (Ermenek, Ankara, Cankiri, Kastamonu basins) document that to first-order similar-to-modern lake isotope records characterize the late Neogene with strongly evaporative lake systems dominant in the Pliocene. We specifically focus on fault-bounded basins in the Ecemis basin immediately behind the southern plateau margin. Here, our data indicate that surface uplift of the souther plateau margin (and hence the Pontide Mountains) most likely occurred in a time-transgressive fashion with the western termination clearly characterized by a phase of relatively young (8-5 Ma) surface uplift. This pattern is less obvious further East where lacustrine and pedogenic isotope records are consistent with a phase of earlier (Early to Mid-Miocene) rain shadow development. Based on our current long-term stable isotope data we preliminarily conclude that surface uplift of the Central Anatolian Plateau occurred at different rates and magnitudes along the Pontide Mountains which places indirect constraints on plate boundary and mantle dynamics but also hosts a series of questions regarding animal and plant migration, changes in precipitation-controlled plant communities and ecosystems as well as late Neogene biodiversity in the Eastern Mediterranean region.

The data presented here are part of the ESF Eurocores TopoEurope inititiative: “Vertical Anatolian Movements Project”.

SESSION NO. 12, 14:30

Monday, 4 October 2010

Landscape, climate and archaeological evolution of the Mediterranean region. Part 2 (*Akdeniz bölgesinin topografik, iklimsel ve arkeolojik tarihçesi*)

METU Convention and Cultural Centre, Salon B

12-1 14:30 Felis, Thomas

MEDITERRANEAN CLIMATE VARIABILITY DOCUMENTED IN OXYGEN ISOTOPE RECORDS FROM NORTHERN RED SEA CORALS

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Annually banded reef corals from the northern Red Sea provide a high-resolution archive of past climate variations at the southeastern rim of the Mediterranean basin. Subseasonally resolved oxygen isotope records derived from the carbonate skeletons of these massive colonies robustly document seasonality and interannual to decadal climate variability. These proxy records of climate, supported by analyses of instrumental data and model simulations, reveal the prominent role of the Arctic Oscillation/North Atlantic Oscillation (AO/NAO) in controlling eastern Mediterranean/Middle East climate on seasonal, interannual to decadal and orbital timescales, most pronounced during winter. Variability at interannual periods of 5-6 years evident in the coral records is indicative of AO/NAO-like atmospheric variability over the Northern Hemisphere and its influence on eastern Mediterranean/Middle East climate during the last centuries, the late Holocene and the last interglacial period. The coral oxygen isotope records, which are recording temperature and surface evaporation in the northern Red Sea, are linked via AO/NAO-controlled atmospheric circulation changes to variations in temperature and precipitation throughout the Mediterranean and Middle East region.

12-2 14:50 Cosentino, Domenico

LATE MIOCENE GEOHISTORY OF THE MUT AND ADANA BASINS (SOUTHERN TURKEY): INSIGHT FOR UPLIFT OF THE SOUTHERN MARGIN OF THE CENTRAL ANATOLIA PLATEAU

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The Mut and the Adana basins developed on top of the Tauride units as late Oligocene-Miocene wedge-top basins. Their upper Oligocene-lowermost Miocene continental deposits recorded the last compressional phases associated with the Tauride orogeny in the area. Starting from the Burdigalian, a general increase in the subsidence rate provided enough accommodation space for sedimenting thick lower Miocene-Pleistocene successions. These deposits, which are mainly marine, sedimented across the present day southern margin of the Central Anatolian Plateau (CAP). This margin separates the uplifted area (CAP, Mut Basin) from downthrown and more subsiding sectors (Adana Basin).

The magnitude and timing of uplift of the southern margin of the CAP helps to define a critical phase of plateau development. Along the southern margin of the CAP, late Miocene marine deposits of the Mut Basin capping the basement rocks of the Taurides are almost undeformed. These deposits, which crop out at elevations higher than 2,000 m, are useful to define the age for plateau margin uplift. In the adjacent Adana Basin, located SE of the uplifted area of the CAP, a quite similar Middle-Late Miocene stratigraphy shows a general connection between these two basins. Recent field work carried out on these two basins allowed us to better constrain the major stratigraphical changes that occurred in those sedimentary basins starting from their onset, and consequently to reconstruct a more detailed geohistory for both basins.

Our new data from the Adana Basin better constrain the Tortonian-Pliocene interval. The stratigraphy of the Adana Basin recorded the Messinian salinity crisis (MSC) of the Mediterranean Sea in a marginal setting. We recognized two major unconformities (Messinian Erosional Surfaces; MES 1 and MES 2), which distinguish different phases of the MSC of the Mediterranean area (evaporitic, early post-evaporitic, and late post-evaporitic phases). The evaporitic phase was recorded by the cyclical deposition of anhydrite/sapropel couplets (Lower Evaporites), resting conformably on pre-evaporitic Messinian marls. Above the MES 1, which affects the Lower Evaporites and the Messinian pre-evaporitic deposits, resedimented gypsum beds, mainly due to debris-flows processes, with thick intercalations of marls, define the early post-evaporitic (p-ev1) phase of the MSC. The MES 2 separates the p-ev1 from the late post-evaporitic sediments (p-ev2), which in the Adana Basin are mainly characterized by coarse-grained deposits (fluvial conglomerates of the Handere Fm). According to the Messinian stratigraphy from other sites in the Mediterranean area (i.e. northern and central Apennines, Italy), these unconformities are well dated: MES 1 = 5.6 Ma; MES 2 = 5.45 Ma.

Using surface and subsurface data, we determined the geohistory of these two basins through a reconstruction of their subsidence curves. The Early-Middle Miocene geohistory is quite similar for both basins. Some differences are recognizable at the Middle Miocene/Late Mocene transition, likely due to the different position of the two areas with respect to the Arabia/Eurasia collision zone. At that time (late Serravallian, 12 Ma), the Adana Basin was uplifted and an erosional surface developed in the area cutting down to the deep marine marls of the Güvenç Fm (mainly Serravallian). Lower Tortonian continental sediments were deposited just above this erosional surface. In contrast, the Mut Basin was not so clearly affected by uplift, and sedimentation continued in a fully marine environment.

Our biostratigraphical and Sr-isotope analysis carried out on the highest marine deposits of the Mut Basin capping the southern margin point to a late Tortonian age, suggesting that uplift of that region is younger than late Tortonian. More precise indications about the uplift of the southern margin come from the stratigraphy of the Adana Basin. The subsidence curve for the Tortonian-Messinian interval of the Adana Basin shows an increase in the subsidence rate of the basin at about 5.6 Ma, corresponding to a period of increasing in the sedimentation rate (debris flows of resedimented gypsum deposits) just after the draw down of the Mediterranean base level (MES 1). However, a major increase in the subsidence rate is recorded at about 5.45 Ma, with the sedimentation of more than 1,000 m of fluvial deposits (conglomerates and marls of the Handere Fm) pertaining to the p-ev2 stage of the MSC of the Mediterranean (5.45-5.33 Ma), and containing late Messinian Lago-Mare fauna with Paratethyan immigrants (Loxocorniculina djafarovi Zone). In the Adana Basin, this event corresponds to a rapid deposition of clastics coming mainly from crystalline and sedimentary rocks of the Taurides. We interpret this as denoting a rapid uplift of the northwestern margin of the basin (southern margin of the CAP).

12-3 15:10 Currano, Ellen D.

RECONSTRUCTING PALEOLANDSCAPE, PALEOCLIMATE, AND PALEOECOLOGY OF THE LATE OLIGOCENE CHILGA BASIN, NORTHWESTERN ETHIOPIA

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Late Oligocene (28 – 27 Ma) strata from the Chilga Basin of northwestern Ethiopia provide a unique opportunity to reconstruct a tropical Paleogene ecosystem using evidence from multiple proxies. These fossiliferous deposits occur at a critical time in the geologic history of Africa: after flood basalt eruption and global climate changes of the Early and Middle Paleogene, but before influx of Eurasian fauna or development of the East African Rift. Geochemical, sedimentological, and paleontological studies of these strata have yielded data that provide a detailed understanding of ancient landscape, paleoclimate, and biotic communities. Here, we summarize the techniques and results of our multi-proxy paleoecosystem analysis.

Abiotic parts of the paleoecosystem were documented by geologic mapping and sedimentological studies. The Chilga Beds are divided into two units: (A) a lower ~80 m thick sequence of drab colored fluviogenic mudstones with abundant coals and paleosols and (B) an upper ~40 m thick sequence of buff to dusky-red interbedded fluviogenic mudstones and cross-bedded sandstones. Paleosol profiles in the lower Chilga Beds include Protosols, Gleysols, and Histosols, and in the upper Chilga Beds include Protosols, Histosols, Gleysols, Vertisols, and Argillisols. These data suggest that the lower Chilga Beds were deposited in a poorly drained, swampy landscape, whereas the upper Chilga Beds represent an open landscape dominated by braided and meandering fluvial stream systems with variable, but generally better, soil drainage.

Quantitative paleotemperature and paleoprecipitation estimates are derived independently from geochemical and paleobotanical techniques. Carbon, oxygen, and hydrogen stable isotope values of pedogenic kaolinite, smectite, sphaerosiderite, and calcite indicate warmer soil temperatures (29±3°C), higher rainfall, and different atmospheric circulation patterns than modern-day Ethiopia. Paleobotanical climate estimates were obtained using overlapping distribution analysis and foliar physiognomy, and give a mean annual temperature of 24±3^{o}C and mean annual precipitation of 1300-1600 mm/yr. Thus, all these methods provide statistically overlapping estimates and indicate warmer temperatures and more equable rainfall distribution than today.

Fossil plant remains are abundant in the Chilga strata. Plant fossils preserved in ash beds document transient pioneer communities dominated by ferns, legumes, and palms. Plant species preserved in overbank and pond deposits are characteristic of diverse, heterogeneous lowland or submontane forests. *In situ* silicified trees indicate a canopy height of 24-30 m. The forests are dominated by trees with affinities to relatives found today in Central and West Africa or the Eastern Arc and coastal forests of East Africa, and they differ from their modern counterparts by the common occurrence of palms, which today are rare or absent. Fossil insect herbivore damage on the Chilga leaves is dominated by specialized feeding types, particulary galls. These results suggest that although the Chilga plants were well-defended against generalist herbivores, they were susceptible to specialized herbivores.

12-4 15:50 Gjani, Eleni

PALYNOSTRATIGRAPHY, PALEOECOLOGY AND PALEOCLIMATOLOGY OF TERTIARY MOLASSE BASINS AND THE PERI-ADRIATIC DEPRESSION IN ALBANIA AND PALEOGEOGRAPHIC IMPLICATIONS

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The Albanides are part of the Alpine orogenic system that encompasses the Dinaride-Hellenide mountain belt in the Balkan Peninsula and have evolved as a result of the oblique collision between Adria and Eurasia during the latest Mesozoic-Cenozoic. The *External domain* of the Albanides includes Paleogene and younger lithostratigraphic units of, from east to west, the Krasta-Çukali, Kruja, Ionian, and Peri-Adriatic Depression (foredeep) that are all affected by pre-Pliocene contractional deformation, manifested in west-directed folds, reverse to thrust and strike-slip faults. The *Internal domain* to the east consists mainly of Paleozoic-Mesozoic basement units, locally overlain by Paleogene-Quaternary molasse basins and alluvial depocenters. Pliocene and younger extensional normal faults and transtensional, dextral strike-slip fault zones are common in the Internal domain and played a significant role in the development of a series of basins and sub-basins as graben and half-graben systems, which are interspersed with local horst structures. In this study, we have examined the palynostratigraphy of the Peri-Adriatic Depression (PAD) in the External domain and several major inter-mountain basins in the Internal domain, and have identified paleoclimatic and paleoenvironmental changes using dinocysts, spores and pollen assemblages.

The PAD deposits consist mainly of conglomerate and mudstone rocks interbedded with sandstone, siltstone and lithothamnium limestone. Sandstone layers consistently become finer-grained from east to west. Gypsum horizons are abundant in the Messinian. Pliocene deposits consist of an argillaceous facies tapering out eastward and a conglomeratic facies pinching out westward. We have identified five dinoflagellate cysts zones and six spore and pollen assemblages in the Langhian to Pliocene strata in the PAD. Calibration is provided by planktonic foraminiferal biozones.

The Tertiary inter-mountain basins we have examined include the Korça basin in southern Albania, Librazhdi and Burreli basins in central Albania, and the shallow Erseka, Pogradeci, Tropoja, Kukesi and Peshkopia basins in eastern to northern Albania. The *Korça basin* includes basal conglomerates at the bottom overlying the ophiolitic ultramafic rocks, and coal and coral formations. The middle Oligocene-middle Miocene molasse section higher up starts with sandstone deposits intercalated with clay horizons. There are five dinoflagellate cysts zones within the middle Oligocene and Langhian strata. Tertiary deposits in the *Librazhdi basin* are made mainly of red-coloured, massive conglomerate and coarse sandstone locally grading upwards into siltstone. The spore-pollen assemblage is represented by only one Pliocene sample. The *Burreli basin* strata are made of massive conglomerate and coarse sandstone, and contain a Messinian–Pliocene sporo-pollen assemblage. The molasse deposits in the shallow *Erseka basin* lie transgressively on the Oligocene rocks and are made of sandstone, siltstone with sand pebbles, and argillite that contains rich, coal-bearing horizons. The sporo-pollen also occurs in the Pliocene strata. The molasse deposits of the *Pogradeci basin* lie transgressively on a Triassic limestone and include sandstone-siltstone units with commercially exploited coal-bearing horizons. The sporo-pollen assemblage belongs to the Pliocene. The molasse deposits in the *Peshkopia basin* onlap the Paleozoic rocks of the Korabi zone and contain a sporo-pollen assemblage in the Pliocene strata. The molasse deposits in the *Kukesi basin* in northeastern Albania onlap the Mesozoic deposits of the Mirdita zone and include conglomerate-sandstone units with a Pliocene sporo-pollen assemblage. The molasse deposits in the northernmost *Tropoja basin* also onlap the Mesozoic rock units of the Mirdita zone and contain conglomerate-siltstone sequences with a Pliocene sporo-pollen assemblage.

We have recorded a high diversity of dinoflagellate species in the Oligocene strata of the Korça basin, although its Miocene and Pliocene strata are lacking any dinoflagellate. Dinocysts are common in the Serravallian rock record of the Peri-Adriatic Depression, indicating warm temperatures and marine conditions during the middle Miocene. We observe a major change from cysts-rich palynomorphs in the Serravallian to pollen-rich palynomorphs the Messinian strata of the PAD. The majority of dinoflagellate cysts also disappear in this time frame, and their limited diversity suggests an open shallow marine environment during the late Miocene. The observed enrichment of grass plants in the Pliocene record indicates a temperate climate. The poor presence of dinoflagellate in the lower Pliocene is an indication of shallow marine conditions, whereas a rich dinoflagellate assemblage higher in the Pliocene sequence is an indication of a deeper marine basin in the beginning of the Quaternary. We interpret these palinostratigraphic, paleocological and paleoclimatological data from the Tertiary inter-mountain molasse basins and the Peri-Adriatic Depression within the framework of the Cenozoic geodynamic evolution of the Albanides and the Balkan Peninsula.

12-5 16:10 Yilmaz, Ismail Omer

EVOLUTION AND STEPWISE DROWNING OF A RAMP-TYPE CARBONATE PLATFORM IN THRACE BASIN, NW TURKEY (LATE MIDDLE EOCENE –OLIGOCENE)

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The Sogucak Limestone is an Eocene shallow marine carbonate unit in the Thrace basin in northwest Turkey. The Formation has been studied in Pinarhisar, Catalca, Kirklareli, Karaburun and Samlar areas in the north, and Mecidiye, Pirnar, Murefte, Besyol in the south of the basin. The studied successions display a transgressive character including siliciclastic near shore and fluvial deposits on the basement rocks and platform carbonates and patch reefs at the top. The patch reefs display back and fore reef facies with limited extension.

Inner ramp is characterized by dasyclad algae, pecten, gastrapoda, miliolid foraminifera association and display bioturbated silty mudstone, bioturbated calcareous bioclastic sandstones, dasyclad algal, miliolid foraminiferal wakestones/packstones. In the inner ramp, lagoonal facies with limited extension characterized by ostracoda, gastrapoda, miliolid foraminifera association display dark colored mudstones and wakestones. Siliciclastic fluvial and beach facies have been observed in inner ramp environment in association with poorly sorted polygenic sandstone and cross-bedded conglomerate and well-sorted quartz sandstones.

Middle ramp is characterized by association of nummulitids, orthophragmines, and red algae. Coral patches and nummulite banks are observed as discontinuous features. Path reefs are composed of reef core, back and fore reef facies. Reef cores are composed of bufflestones, framestones, and bindstones. Back reefs display red algal, foraminiferal packstones, grainstones, wackestones. Fore reefs are composed of poorly sorted red algal, coral debris and poorly sorted polygenic carbonate breccia.

Outer ramp is characterized by association of rhodoid nodules, bryozoa, red algae, orthophragmines and display pelagic marls, porous chalks and fore reef talus in some places.

Patch reefs in the Thrace basin present a transgressive distribution from south (Early Bartonian) to north (Priabonian) and increase in abundance in the north.

Transgression of platform carbonates over the elevated basement metamorphics (paleohighs) without basal clastics in the north take place in the Early Priabonian and infill the Neptunian dykes.

In the Late Priabonian/Early Oligocene, drowning of the platform took place and characterized by bryozoan accumulations, iron and glauconite bearing surfaces on bioturbated bioclastic limestones with planktonic foraminifera, echinid, orthophragminid fragments and overlying pelagic marls with planktonic foraminifera and glauconite.

In the Oligocene, in some places, local unconformities overlie the platform carbonates. This may imply sudden uplift and tilting of blocks after drowning event, and abundance of dissolution porosities in platform carbonates take place beneath the unconformity surface.

12-6 16:30 Catalano, Stefano

THE EFFECTS OF LATE QUATERNARY CLIMATE CHANGES ON THE STRATIGRAPHY OF THE M. ETNA VOLCANO (SOUTHERN ITALY)

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At Mt. Etna Volcano, in eastern Sicily, relics of ancient volcanic edifices are largely exposed at the base of the eastern flank of the modern (< 40 ka) strato-volcano. The older volcanics are represented by subalkaline lavas, interleaved within Middle Pleistocene marine clays, which crop out along the Ionian coast of the region. In the same area, the first subaerial products, which are represented by a sequence of alkaline lavas ranging in age from 220 ka to 121 ka, are exposed. A major erosional surface grading to the OIS 5.5 (125 ka) marine terrace has been recognised within the volcanic succession. Finally, volcanic horizons showing radiometric ages from 105 to 93 ka are exposed in the walls of a large caldera depression (Valle del Bove) located along the eastern slope of the modern edifice. A major unconformity is modelled at the top of this sequence. Also the modern stratovolcano sequence is marked by a main unconformity, separating the pre-15 ka volcanics from the younger horizons.

As a whole, the volcanic succession of Mt. Etna, together with the marine terrace deposits, provides several chronological data, useful to detail the stratigraphy of the end of the Middle Pleistocene and the entire Late Pleistocene.

Recent investigation, consisting of 1:10.000 field mapping caried out on the entire eastern flank of the Volcano, integrated with information from several bore-holes, have evidenced the occurrence of distinct, several tens of meter thick, clastic horizons within the volcanic succession. These deposits exhibit textural features typical of epiclastic (debris-flow) horizons. These are made of plurimetric matrix-supported *conglomerate* in a well cemented muddy-sandy matrix and by fine tuff with rare centimetre-sized conglomerate elements. Generally they are associated with coarse grained, poorly sorted and unconsolidated *breccias,* composed of a wide range of angular to sub-rounded lava blocks and scoriae, in a poorly consolidated matrix, indicating a debris-avalanche origin. The older clastic horizons infill deeply entrenched valleys modelled on the pre-Tyrrhenian volcanics, being covered at the top by the marine terrace of the OIS 5.5. A further clastic horizons mark the unconformity at the top of the 93 ka old volcanic deposits. Finally, very thick conglomerate horizons, showing dm-sized boulders, are related to

M O N D A Y

an impressive alluvial fan that conceals the topography modelled on the pre-15 ka volcanics, being covered by several historical and pre-historical lava flows.

The geometric relation between dated lava horizons and analysed clastic deposits indicates that the latter actually developed in very short periods, in the order of 1 ka, during which gravity-induced mass transport and alluvial processes have remobilised huge volumes of detritus. In this periods, coinciding with major deglaciations accompanying the sea-level rises towards the OIS 5, 3 and the Holocene, the exogenous processes were largely prevailing on lava flows accumulation. This evidence confirms that the maximum effectiveness of agents on the landscape have characterised in the past the periods of rapid sea-level rise rather than the entire periods of the sea-level highstand, thus suggesting that the increase of precipitation and the recurrence of heavy rain falls have been strctly related to climate crises induced by the main deglaciation processes.

SESSION NO. 13, 14:30

Monday, 4 October 2010

Ophiolites, blueschists, and suture zones. Part 2 (*Ofiyolitler, mavisistler ve kenet kusaklari*)

METU Convention and Cultural Centre, Salon A

13-1 14:30 Okay, Aral

DEEP SUBDUCTION OF A PASSIVE CONTINENTAL MARGIN: COMPARISON OF THE TAVSANLI ZONE AND OMAN

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The Tavsanli Zone in northwest Turkey provides one of the best examples of continental crust subducted to a depth of 80 km and exhumed, while preserving to a large extent the prograde high-pressure - low-temperature (HP/LT) mineral assemblages. The Tavsanli Zone consists mainly of a passive continental margin sequence of Triassic to Cretaceous sedimentary rocks, which have undergone metamorphism at ~24 kbar pressure and 430-500 °C temperature during the Late Cretaceous (~80 Ma). They are tectonically overlain by an oceanic accretionary complex (ophiolitic mélange) of basalt, chert, pelagic shale and limestone, which shows only an incipient blueschist facies metamorphism. Farther up in the tectonic stack is an ophiolite, which at present is represented mainly of peridotite (>%90) with minor gabbro and pyroxenite all cut by isolated diabase dykes. Although ophiolite outcrops are isolated at present, most likely they were once part of a very extensive Anatolian ophiolite emplaced over the Anatolide-Tauride Block during the Cenomanian/Turonian. All these tectonic units are intruded by Lower to Middle Eocene granodiorites, and are overlain by Lower Eocene marine limestones. The generation of blueschists is related to the burial of the northern margin of the Anatolide-Tauride Block in an intra-oceanic subduction zone during the Campanian; the blueschists were exhumed during the ongoing subduction and prior to Paleocene continental collision through a thrust fault at the base and a normal fault at the top.

The Tavsanli Zone shows similarities to the Semail ophiolite and the underlying HP/LT metamorphic rocks in terms of tectonic setting, geological evolution and in the timing of the deformational and metamorphic events. The Semail ophiolite has a length of over 400 km and a width of 150 km, its thickness prior to emplacement is thought to be 15-20 km; the thickest part of the ophiolitic sequence (8-12 km) is made up of peridotites. The zircon ages from the plagiogranites of the Semail ophiolite (95.4-94.5 my) and the radiolarian ages from the cherts overlying the ophiolite show that the Semail ophiolite is Cenomanian in age. The ~93.5 Ma hornblende Ar-Ar ages from the subophiolite metamorphic rocks show that within 2 my following the formation of the Semail ophiolite at a mid-ocean ridge, it was emplaced, probably along a transform fault, over the neighbouring oceanic crust. The Ar-Ar ages from the base of the Anatolian Ophiolite are also in the range of 95-90 Ma. The Semail ophiolite was first emplaced over an oceanic crust and then over the continental margin of Arabia. During its emplacement over the Arabia margin, it bulldozed the continental margin sequences in its front. These continental margin sequences, which crop out southwest of the Semail ophiolite, are known as the Hawasina nappes and show close similarities to the Lycian Nappes in the Taurides. The Arabian continental crust under the Semail ophiolite underwent HP/LT metamorphism during the Campanian (82-79 my), which is of the same age as the HP/LT metamorphism in the Tavsanli Zone. The blueschists and eclogites under the Semail ophiolite are unconformably overlain by the marine Eocene deposits, as in the Tavsanli Zone. The main difference between the Tavsanli Zone and Oman is that in the Tavsanli Zone the ophiolite emplacement was followed by the continent-continent collision, whereas no continental collision has occurred in Oman, where Indian ocean lies north of the Semail ophiolite. Another difference is that the Semail ophiolite is thrust over the Arabian platform, whereas the Anatolian ophiolite over the Anatolide-Tauride Block, a relatively small terrane, which has rifted off from Arabia during the Triassic.

13-2 14:50 Pourteau, Amaury

ALPINE SUBDUCTION-RELATED GEODYNAMICS OF WESTERN TO CENTRAL TURKEY: INSIGHTS FROM PETROLOGY OF HP METASEDIMENTS AND 40AR/39AR GEOCHRONOLOGY

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In Western to Central Turkey, the closure of a Neotethyan oceanic branch resulted in the accretion of a Gondwana-related continental fragment, known as the Anatolide-Tauride Block, to southern Eurasia. As a result, the northern continental passive margin of the Anatolide-Tauride Block was tectonized and metamorphosed between the late Cretaceous and the early Cenozoic. Based on differing lithostratigraphy and metamorphic histories, several metamorphic units, referred to as Anatolides, are generally considered as follows. From north to south, they are the Tavsanli Zone, the Afyon Zone, the Menderes Massif and the Ören Unit. From the Aegean Coast to Cappadocia, blueschist-facies mineral assemblages were reported in coherent sedimentary series from all these units. Moreover, the Cycladic Blueschist Unit, which crops out mostly in the Aegean, is also recognized west of the Menderes Massif.

The timing of the subduction-related metamorphism is variously contrained from one unit to the other. Radiochronologic studies (using Ar/Ar and Rb/Sr on phengite and glaucophane) showed that HP metamorphic event occurred in middle Late Cretaceous (88-82 Ma) in the Tavsanli Zone, and in Eocene (45-40 Ma) in the Cycladic Blueschist Unit. In contrast, no radiometric but only vague stratigraphically-constrained metamorphic ages, were published for the HP metamorphism in the Ören Unit, the Menderes Massif cover and the Afyon Zone while accurate ages would constitute strong clues for understanding the evolution of Western and Central Turkey and its correlation with the Aegean Domain.

At the GSA Meeting "Tectonic Crossroads: Evolving Orogens Eurasia-Africa-Arabia" (Ankara, October 2010), we will present new results of ongoing Ar/Ar geochronologic and metamorphic petrological works from the Anatolide HP belts, and discuss their implication in understanding the evolution of the Eastern Mediterranean.

13-3 15:10 Whitney, Donna L.

LAWSONITE VORTICITY AND SUBDUCTION KINEMATICS (SIVRIHISAR, TURKEY)

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Documenting deformation in high-pressure (HP) rocks of exhumed subduction complexes is critical for understanding the relationship of metamorphic reactions to seismicity and release of water to the mantle wedge in active subduction zones. In addition, the rapid exhumation of HP rocks from depths of >50 km poses the question of the mechanisms that enable rapid, large-magnitude transport of HP rocks to shallower depths. Evidence for HP deformation within subduction complexes is typically overprinted by low-P deformation, heating, and hydration reactions, complicating efforts to interpret processes that operated at depth. The exceptional preservation of HP rocks near Sivrihisar, Turkey, including lawsonite in eclogite and blueschist, allows evaluation of HP deformation and exhumation using kinematic analysis of a HP index mineral.

In the Sivrihisar Massif, layering and foliation typically dip gently to moderately, and steepen toward a fault contact with a metamorphosed ultramafic/mafic complex. The strong foliation carries a prominent oblique stretching lineation that is oriented E-NE. Marble displays columnar aragonite pseudomorphs that are systematically inclined relative to foliation, consistent with top-to-E shear. All rock types in the massif show top-to-E or NE sense of shear that developed at HP conditions; the planar and linear fabrics formed in uniform normal/dextral oblique shear across the terrain.

Kinematic vorticity analysis of lawsonite can be used to document the relative components of pure and simple shear in a subduction complex at HP, the strain that accompanies and accommodates exhumation, and the mineral fabrics and anisotropies that develop in HP rocks. For this analysis, ten samples of lawsonite-bearing blueschist and eclogite were collected from the NW part of the massif, including 2 samples from the bounding fault zone. We evaluated kinematic vorticity (Wm pure shear = 0, Wm simple shear = 1) using the shape fabric of lawsonite crystals in blueschist layers and meter-scale eclogite pods. Textural relations indicate that lawsonite behaved as a rigid grain in both glaucophane- and omphacite-dominated rocks. EBSD data show that the (010) lawsonite crystallographic axes correspond to the orientation of the presumed vorticity axis; i.e., thin sections preferentially contain the short and long axes, represented by (100) and (001), respectively, and vorticity parameters derived from 2D analysis are valid proxies of 3D rotation.

Pods record dominant simple shear (Wm > 0.8) in their eclogitic core and at pod margins partially transformed to blueschist; map-scale blueschist layers record a large component of pure shear (Wm = 0.4-0.6), consistent with oblique extrusion at depth, and local simple shear (Wm = 0.8) at the fault contact with serpentinite. A combination of oblique unroofing from beneath a weak serpentinized hanging wall and pure shear extrusion in the subduction channel accounts for rapid exhumation along a low geothermal gradient and the rare preservation of lawsonite eclogite during exhumation. Footwall rocks were not translated rigidly upward but were deformed by a large component of pure shear that was capable of accelerating exhumation by squeezing the HP rocks out of the subduction zone.

If material is pinned at some depth, the pure shear component may add a significant upward motion to the translation of material achieved by simple shear. This effect can be quantified using plane strain analytical modeling. For vorticity values obtained on blueschist layers (Wm = 0.4-0.6), the amount of pure shear extrusion has the effect of multiplying the simple shear translation several times. This component of strain adds significantly to the upward trajectory of HP rocks.

In addition, the transformation from (omphacite) eclogite to (glaucophane) blueschist during ascent results in significant weakening of the subduction channel. Flow of blueschist around meter-scale rigid eclogite pods reflects this weakening. Therefore, a positive feedback likely develops between decompression and weakening of the subduction channel. The channel is rapidly exhumed by translation from beneath the serpentinized overlying plate and by pure shear extrusion in a dextral-normal shear system, perhaps assisted by aggressive erosion at the Earth's surface, preserving lawsonite blueschist and eclogite.

Lawsonite vorticity analysis is a powerful new method to investigate deformation and exhumation mechanisms in subduction complexes. Results of this and other studies of HP and ultrahigh-P terrains show that material weakening during decompression may be the origin of strain localization of major discontinuities and patterns of vorticity partitioning that favor rapid exhumation. This type of exhumation may be necessary for the preservation of some HP mineral assemblage at the Earth's surface.

13-4 15:50 Rebay, Gisella

TI-CLINOHUMITE IN THE ECLOGITISED SERPENTINITES OF THE UPPER VALTOURNENCHE (ZERMATT-SAAS ZONE, ITALY): THE TECTONIC RECORD OF UHP IMPRINT?

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The Zermatt-Saas Zone is the widely eclogites portion of the Thethyan oceanic suture in the Western European Alps buried during Alpine subduction. The presence of pre-Alpine relics shows that this oceanic crust was variously affected by oceanic metamorphism before subduction (Dal Piaz et al., 1980, Li et al., 2004).

Serpentinites with lenses and dykes of metagabbro and meta-rodingite displaying a metamorphic imprint in the eclogite facies, or greenschist facies, outcrop in upper Valtournenche. On the occasion of a detailed structural mapping three superposed foliations associated to different parageneses in all these rocks, followed by D_4 folding, has been recognised. In metabasites, S_1 and S_2 foliations are associated to high-pressure low-temperature parageneses, whereas S_3 is associated to a later re-equilibration in the greenschist facies. In serpentinites S_2 is the pervasive foliation, and it may be parrallel to bands rich in clinopyroxene$_2$ + amphibole$_2$. S_1 is recognised where S_2 is less pervasive: here relic Ti-clinohumite –olivine veins, up to 4 cm thick, boudinaged and folded in S_2 foliation, are found. Sometimes they have a white clinopyroxene rim toward serpentine.

Serpentinites mainly consist of serpentine with minor magnetite, but where S_1 and S_2 foliations are pervasive, metamorphic olivine is found, together with Ti-clinohumite and clinopyroxene.

The stable mineral assemblage associated with D1 is serpentine$_1$, clinopyroxene$_1$, opaques, titanite +/- amphibole$_1$, chlorite$_1$, olivine$_1$, Ti-Clinohumite$_1$, orthopyroxene, ilmenite. The assemblage stable with D_2 is serpentine$_2$, clinopyroxene$_2$, opaques, Ti-clinohumite$_2$, olivine$_2$, +/- chlorite$_2$, amphibole$_2$, titanite. Ilmenite and perovskite rim olivine and Ti-clinohumite. The assemblage associated with D_3 structures is serpentine$_3$, opaques, +/- chlorite$_3$ and amphibole$_3$.

Compositionally, serpentine associated to D_1 structures is more Mg-rich than that in D_2 structures. Olivine, clinopyroxene and chlorite do not have large chemical changes, though when associated to D_1 structures they may be more Mg-rich than when associated to D_2 structures. Ti-chumite$_1$ is slightly Fe-richer than Ti-clinohumite$_2$ and may have less Ti.

Veins consisting of olivine, pyroxene, Ti-clinohumite can predate or be contemporaneous to D_2 structures: post-D_2 veins never contain Ti-clinohumite, olivine and pyroxene. This conclusion, drawn on the evidences gathered through the detailed structural mapping, alows to constrain the timing of Ti-clinohumite growth to S_1 and S_2 foliations, contradicting the interpretation of Li et al., (2004) that interpret the veins as post D_3 or linked to ocean-metamorphism predating Alpine metamorphism. This result is coherent with what observed by Scambeluri & Rampone (1999) and Groppo & Compagnoni (2007) in other parts of the western Alps.

PT conditions estimated for S_1 and S_2 parageneses have been evaluated with preliminary calculations of a PT grid in the MASH system, using end-members (fosterite, talc, enstatite, antigorite, clinohumite, clinochlore, spinel and sudoite).

A PTtd path suggests that these rocks underwent pressures > 2.2 GPa for temperatures between 600° and 750°C, implying that they have been forged in a cold subduction zone characterised by a T/depth of ~6°C/Km. The late greenschist facies re-equilibration implies exhumation. It is characterised by a small T-decrease, indicating a thermal regime compatible with the thermal relaxation consequent to continental collision. Radiometric ages (Rubatto et al., 1998 and Lapen et al., 2003) suggest ages of 50-43 Ma for the P peak and ages of 36-40 Ma for the greenschist facies retrogression, suggesting exhumations rates between 0.6 and 2.7 cm/y for this part of the Zermatt-Saas unit.

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13-5 16:10 Bröcker, Michael

NEW TIME CONSTRAINTS FOR HP METAMORPHISM AND EXHUMATION OF MELANGE ROCKS FROM THE SISTAN SUTURE ZONE, EASTERN IRAN

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The Sistan Suture Zone in the eastern part of Iran documents the closure of a Neotethyan oceanic basin due to convergence between the Central Iranian and Afghan microcontinents [1]. This Cretaceous–Tertiary orogenic belt (ca. 500 x 100 km^2) exposes a well-preserved subduction zone complex, which includes a tectonic mélange consisting of disrupted meta-ophiolitic rocks within a low-grade matrix of chlorite-talc schists, mica schists and greenschists. Large slabs of ultramafic rocks and meta-gabbros record low-grade metamorphism, but some smaller metabasic blocks (<200 m) were affected by high-pressure and/or epidote amphibolite facies conditions. Understanding of the petrological and geochronological record of these rocks plays a key role in unraveling the geodynamic evolution of the Sistan ocean. Radiolaria in pelagic cherts from the mélange document that the Sistan ocean existed already in Early Cretaceous time (Aptian to Albian) [4], but the closure history is yet poorly constrained.

Metamorphic conditions recorded by samples from different HP blocks vary considerably. P–T estimates for the eclogite and blueschist-facies stages indicate pressures of ca.1.5–2.4 GPa at temperatures of ca. 450–650 °C, whereas pressure conditions of ca. 0.5–0.7 GPa at temperatures of 520–590 °C were reported for epidote amphibolite facies rocks [2]. Previously published Ar–Ar data for a phengite-paragonite mixture from an eclogite and paragonite from a blueschist indicated apparent ages of 122.8 ± 2.2 Ma and 139 ±19 Ma [3]. Phengite and barroisite from amphibolites yielded Ar–Ar ages of 124 ± 13 Ma, 116 ± 19 Ma and 124 ± 10 Ma, respectively [2]. All Ar–Ar ages were interpreted as cooling ages that date post-epidote amphibolite facies stages of the exhumation path, implying that both HP metamorphism and the epidote–amphibolite-facies overprint occurred prior to 125 Ma. However, caution is warranted in assigning geological significance to this data set, because the presence of excess Ar leading to geologically meaningless dates was documented for many HP and UHP occurrences.

In order to evaluate the importance of the Ar–Ar data and to obtain a more detailed picture of the metamorphic evolution, we use a multimethod geochronological approach (Rb–Sr, Sm–Nd, Lu–Hf, U–Pb). Samples representing HP blocks and matrix were collected in the Ratuk Complex near Gazik, Gurchang and Sulabest within a NNW-SSE trending belt spanning a distance of ca. 95 km that exposes the major occurrences of HP rocks and epidote amphibolites. First Rb–Sr results (internal mineral isochrons comprising several grain size fractions of white mica, ± epidote, omphacite, glaucophane) for 5 samples indicate a regional consistent age pattern (86.1 ± 1.0 Ma, 86.6 ± 0.6 Ma, 84.3 ± 4.7 Ma, 84.7 ± 0.7 Ma, 85.7 ± 0.7 Ma) with considerably younger ages than indicated by Ar–Ar geochronology. This observation is consistent with assuming variable amounts of extraneous argon in the white mica, and suggests that the Ar–Ar data do not provide reliable ages. The Rb–Sr ages are in accordance with field and biostratigraphic observations and document subduction of the Sistan ocean in Late Cretaceous time. Additional Sm-Nd and Lu–Hf studies (work in progress) will help to understand the exact meaning of the age difference and to further constrain the time of HP metamorphism in the study area.

Textural evidence indicates that epidote amphibolites represent completely overprinted HP rocks. Understanding the geological significance of white mica dates of multiply metamorphosed rocks is often not free of ambiguity, due to incomplete resetting or mixing of different growth generations. To avoid such complexities, the age of the overprint is best determined by dating of texturally well-constrained, newly formed phases. Phengite and omphacite of eclogite sample 5611 from an outcrop near Sulabest yielded an 85.7 ± 0.7 Ma age for the HP stage. In the same sample, the lower pressure overprint is recorded by the occurrence of epidote, biotite and plagioclase that formed as breakdown products of garnet and omphacite ± phengite. Rb–Sr dating of the retrograde mineral assemblage provided an apparent age of 78.3 ± 0.8 Ma, indicating the time of cooling below ca. 300–350 °C.

The new metamorphic ages for HP rocks from the Ratuk Complex do not provide support for previously published Ar–Ar data. The results obtained so far underline the necessity to apply several geochronometers for unravelling the age information of HP rocks.

[1] Fotoohi Rad et al. (2005), Lithos 84: 1–24; [2] Fotoohi Rad et al. (2009), Geological Journal 44: 104–116; [3] Tirrul et al. (1982), Geological Society of America Bulletin 94: 134–150. [4] Babazadeh & De Wever (2004), Geodiversitas 26: 185–206.

13-6 16:30 Omrani, Hadi

GEOCHEMISTRY OF SHANDERMAN ECLOGITES; CONSTRAINS ON NATURE OF PALEOTETHYS OCEANIC CRUST

OMRANI, Hadi[1], MOAZZEN, Mohssen[1], OBERHANSLI, Roland[2], MOAYYED, Mohsen[1], TSUJIMORI, Tatsuki[3], and BOUSQUET, Romain[2], (1) Geology Department, University of Tabriz, Bolvar 29 Bahman, Tabriz, 5166616471, Iran, omrani@tabrizu.ac.ir, (2) Potsdam University, Institute for Geosciences, Karl-Liebknecht-Strasse 24/27, Potsdam, 14476, Germany, (3) Institute for Study of the Earth's Interior, Okayama University, Misasa, Tottori, 682-0193, Japan

Shanderman eclogites are exposed at west of Shanderman town, Talesh Mountains in the north of Iran. Shanderman eclogites have experienced blueschist facies condition on their prograde P-T path. Some hydrous phases such as glaucophane, zoisite and paragonite were stable at the peak of metamorphism. Amphibolite and Greenschist related minerals are formed during exhumation and subsequent fluid influx. Protolith of these rocks had basaltic composition. Geochemical studies indicate that most of the samples have tholeiitic features. Mg# versus Cr and Ni show that the original magma experienced olivine and clinopyroxene fractionation. Spider patterns show more fractionation of olivine compared to clinopyroxene. Behavior of relatively compatible trace elements versus major oxides show that major oxides had no significant (except for Na2O and to some extent FeO) variation during alteration and subsequent metamorphism. Based on REE, eclogite of the Shanderman can be divided into two groups. The first group shows PREE= 31.1 ppm and (La/Lu)N=0.6. The second group have PREE= 139.2 ppm and (La/Lu)N=2.3. Chondrite REE normalized patterns show that they are comparable with N-MORB and E-MORB. This indicate that either Shanderman eclogites parental magma source was not homogenous or it experienced melting with different degrees, indicating a change from low spreading to fast spreading oceanic crust.

SESSION NO. 14, 14:30

Monday, 4 October 2010

Strike-slip and transform fault tectonics. Part 2 (*Dogrultu atim ve transform fay tektonigi*)

METU Convention and Cultural Centre, Kemal Kurdas Salon

14-1 14:30 Niemi, Tina M.

ACTIVE TECTONIC DEFORMATION ACROSS THE NORTHERN SHELF OF THE GULF OF AQABA/EILAT, DEAD SEA RIFT SYSTEM

NIEMI, Tina M.[1], BEN-AVRAHAM, Zvi[2], AL-ZOUBI, Abdallah[3], TIBOR, Gideon[4], HARTMAN, Gal[2], ABUELADAS, Abdel-rahmen[3], AL-RUZOUQ, Rami[3], and AKAWI, Emad[3], (1) Department of Geosciences, University of Missouri - Kansas City, Kansas City, MO 64110, niemit@umkc.edu, (2) Department of Geophysics and Planetary Sciences, Tel Aviv University, Tel Aviv, 69978, Israel, (3) Al Balqa' Applied University, Al-Salt, 19117, Jordan, (4) Israel Oceanographic and Limnological Research, Haifa, 31080, Israel

New geophysical data of the northern part of the Gulf of Aqaba/Eilat (GAE), Dead Sea Rift were collected during two marine surveys in Oct/Nov. 2006 and February 2010 as part of the "High Resolution Marine Geophysical Imaging of Active Faults in the Aqaba-Eilat Region" project funded by MERC. Multibeam sonar data were used to generate the first detailed bathymetric map with a 2 m resolution across the entire northern Gulf of Aqaba/Eilat in Israel and Jordan. In total more than 1400 km of geophysical data lines including Sparker seismic reflection, magnetics, side-scan sonar, ground penetration radar, and electrical methods were acquired in the GAE and within the greater Aqaba municipality.

From interpretation of these geophysical data, we mapped the location of six previously unknown faults with varying degrees of seismic activity in the offshore and traced their potential continuation on land beneath the densely populated cities of Eilat and Aqaba. The Eilat and Aqaba faults along the margin of the gulf are zones of predominantly normal faults that accommodate subsidence of the basin. The most active strike-slip fault is the Evrona fault that projects from the shelf landward into the lagoon and hotel district of the city of Eilat. If the age model for the subsurface layers based on application of global sea level curves and climate variations is correct, then most of the recent plate motion is concentrated on this fault. This fault is also the most likely to have the largest amount of surface rupture in a future earthquake. Four faults appear to project from the offshore into the city of Aqaba.

The GAE shelf is oriented at a high angle to the main trend of the Dead Sea transform boundary. The shelf sedimentary sequence is cross-cut by several, subparallel faults that flank the east and west margins of the basin and faults that trend obliquely across the basin. These faults divide the gulf head into the Eilat and Aqaba subbasins separated by the Ayla high. West of the high, the Eilat subbasin receives a large amount of sediment that is transported to the deep basin by slumping and gravity sliding along the Eilat submarine canyon. Seafloor lineaments defined by slope angle analyses suggest that the Eilat canyon and the eastern boundary of the Ayla high align along northwest-striking fault systems. The shelf-slope break that lies along the 100 m isobath in the Eilat subbasin and shallower in the Aqaba subbasin is offset by approximately 150 m along the east edge of the Ayla high. Our preliminary interpretations of these data suggest block deformations with localized depocenters that migrate as the blocks adjust to changes in the localized strain. Submarine failures, identified from the high-resolution image of the seafloor, appear to be highly concentrated on the west side of the GAE and may be associated with the higher seismic activity on the Evrona fault. Submarine failures are likely triggered by earthquakes and could potentially produce local tsunami hazards. These data are particularly important for the safety and monitoring of marine infrastructure (*e.g.* the port and pipelines) and in future planning of infrastructure (*e.g.* Red Sea-Dead Sea canal, desalination plants, etc.) in the region.

14-2 14:50 Hubert-Ferrari, Aurelia

LONG-TERM EVOLUTION OF THE NORTH ANATOLIAN FAULT

HUBERT-FERRARI, Aurelia[1], VAN DER WOERD, Jerome[2], KING, Geoffrey[3], VILLA, Igor Maria[4], ALTUNEL, Erhan[5], and ARMIJO, Rolando[3], (1) Geography, University of Liege, Sart Tilman, Allée du 6 aout 2, Liege, 4000, Belgium, aurelia.ferrari@ulg.ac.be, (2) Institut de Physique du Globe de Strasbourg, Strasbourg, 67084, France, (3) Institut de Physique du Globe de Paris, Paris, 75005, France, (4) Isotope Geology, Institute of Geology, University of Bern, Baltzerstrasse 3, Bern, 3012, Switzerland, (5) Eskisehir, Turkey

The right-lateral North Anatolian Fault (NAF), together with the conjugate East Anatolian Fault (EAF), accommodates the westward extrusion of the Anatolian block toward the Aegean Subduction Zone. This process started most probably 12Ma ago during a late phase of collision between Arabia and Eurasia. The Karliova triple junction between the NAF and the EAF is a pivotal region making the transition between continental shortening to the east and the extrusion regime to the west. Volcanism younger than 7 Ma covers nearly entirely the region and provides an ideal marker to record deformation. We focus here on the relationship between faulting and volcanism at the Karliova Triple Junction to further constrain the evolution of the Anatolian Extrusion.

Along the NAF, we are able to reconstruct a single volcanic edifice from two offset volcanic structures by a left-lateral displacement of 50 km. Both structures have similar 2.5 to 3.5 Ma ages distinct from the surrounding volcanism. In addition the offset volcanic structures have an undistinguishable geochemistry considering major or trace elements, quite distinctive from the surrounding volcanism. In the same area, we use the volcanism along the EAF to further constrain the NAF age to be younger that 4 Ma and its total offset to be about 20 km as already proposed.

Those constrains confirm that the Anatolian extrusion indeed developed in two phases. The Anatolian extrusion first occurred between the NAF and a proto EAF. A second extrusion phase then started about 2.5 Ma ago, with the activation of the EAF followed by the eastward jump of the TJ to its present location near Karliova. The following scenario is fully compatible with the overall evolution of the Karliova Triple Junction modeled in a plate-tectonic framework and constrained by fault geometries, total offsets and ages presented here.

14-3 15:10 Zitter, T.A.C.

FLUID SEEPAGE ALONG THE NORTH ANATOLIAN FAULT, IN THE SEA OF MARMARA, IN RELATION WITH TECTONICS AND SEDIMENTARY ENVIRONMENTS

ZITTER, T.A.C.[1], GRALL, C.[1], HENRY, P.[1], GÉLI, L.[2], CAGATAY, M.N.[3], OZEREN, S.[3], DUPRÉ, S.[2], TRYON, M.[4], and BOURLANGE, S.[5], (1) CEREGE, Europole de l'Arbois BP80, Aix-en-Provence cedex 4, 13545, France, zitter@cerege.fr, (2) Marine Geosciences Department, Ifremer, Plouzané, 29280, France, (3) Geology Department, Istanbul Technical University, Faculty of Mines, Maslak, Istanbul, 34469, Turkey, (4) Scripps Institution of Oceanography, 9500 Gilman Dr., 0244, La Jolla, CA 92093-0244, (5) CRPG, 15 Rue Notre Dame des Pauvres, Vandoeuvre-les-Nancy, 54501, France

Along the submerged section of the North Anatolian fault system within the Sea of Marmara, the Main Marmara Fault (MMF) is a case study on coupled fluid and deformation processes. Indeed, numerous sites of fluid venting occur in association with the active deformation at this major transcurrent plate boundary. Recent surveys combining visual observations, acoustic sounding, sampling, and long term instrument deployments permitted us to relate fluid outflow with geomorphologic and tectonic features.

Since the Izmit earthquake in 1999, a wide range of marine datasets were acquired in the Sea of Marmara. Multibeam bathymetric data image seafloor traces of active faults, as well as significant mass wasting processes affecting the steep slopes of the Sea of Marmara. Seafloor deformation and fluid emissions were observed with ROV during the Marmarscarps cruise (2005), with manned submersible during the Marnaut cruise (2007), and recently with AUV during Marmesonet cruise (2009). Various structural contexts were surveyed: strike-slip localized on a single linear fault (e.g. Western High), releasing and compressive jogs on the main strike-slip fault (e.g. Kumburgaz basin and Central High), fault segments with combined strike-slip and normal slip (N Cinarcik scarp), en-echelon normal fault system (S Cinarcik basin), and a basin edge with minor transpressive deformation (NW Tekirdag). Manifestations of fluid seepage are diverse and range from highly focused brackish water outflow emitted from authigenic carbonate chimneys to more extensive and diffuse fluid seepage areas. Fluids are mainly from relatively shallow basin consolidation and gases are mainly of biogenic origin, however several fluid emission sites expel fluids originating from deep within the sedimentary basin and include thermogenic gas, oil, and brines, and possibly, mantle He.

Mapping of seep distribution indicates that fluid emissions are primarily associated with deep-rooted active faults. In particular, gas emissions are found in Cinarcik Basin above a buried transtensional shear zone, which displayed aftershock activity at its eastern end after the Izmit earthquake. In most areas where it is observed, the main strike-slip fault trace presents reflectivity anomalies indicative of fluid outflows. However, secondary extensional (normal faults), compressional structures (anticline axes), and, in some occurrences, Riedel shears also influence the distribution of seepage sites. Gas emissions are observed on NE-SW trending anticlinal ridges a km or more away from where the main fault trace crosses the ridge. Some of the emission sites are not obviously correlated with active faults. In particular, gas emissions are generally present at the base of the slopes along the edges of the basins, but these do not systematically correspond to an active fault trace. Furthermore, observations also suggest that the sedimentary environment plays a role in providing pathways for fluid expulsion, mainly in the case of diffuse seepage and water outflow. Fluid emission sites are observed in close relationship with mass wasting deposits (turbidites, debris flow) or at the toe of destabilized slopes. In the NE Cinarcik basin, fluid seepage has been observed at the base of a scree slope with meter-sized boulders. Avalanche debris and coarse sandy turbidites provide high permeability conduits to drain fluid from the basin towards the active fault scarp.

14-4 15:50 Lisenbee, Alvis L.

THE DAVUTOGLAN WRENCH FAULT: INTRA-ANATOLIAN PLATE, NEOGENE DEFORMATION, ANKARA PROVINCE, TURKIYE

LISENBEE, Alvis L.[1], UZUNLAR, Nuri[1], and TERRY, Michael[2], (1) Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St, Rapid City, SD 57701, alvis.lisenbee@sdsmt.edu, (2) Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57702

Approximately 100 km west of Ankara, the northern margin of the Haymana Basin is disrupted by a 12-km wide series of ENE-trending faults, anticlines and monoclines, the largest of which is the topographically expressed, 18-km long Davutoglan wrench fault. These structures deform Miocene fluvial and lacustrine strata north of Cayirhan and the Davutoglan fault crosses beneath Davutoglan village.

Right strike-slip on the several strands of the Davutoglan fault zone is indicated by slickenlines and mesoscopic, fault-surface features, an associated train of right-echelon folds and thrust faults (in a restraining bend), in-line horsts and grabens, and overlapping faults with an associated transfer ramp. Horizontal displacement is less than one kilometer: Vertical offset across the zone is as much as 250 m, down to the north. Offset within the fault zone decreases to the east where deformation continues as an anticline whose axis is of similar trend: To the west the faults merge into a single strand and offset decreases to zero.

Individual faults are well exposed as discreet, polished surfaces in the siliceous limestone and may have a clay-smear character in the mudstone units. These faults acted as fluid conduit, are commonly strongly iron-stained, and locally contain chalcedony veins. The enclosing grey- to green mudstones are bleached to a buff or pale orange-tan color for many meters outward from the fault surfaces.

The Davutoglan fault zone represents deformation within the Anatolian Plate, about 70 km south of the bounding North Anatolian Fault (NAF). The type of deformation, timing, and right-lateral offset suggest an origin under similar regional stresses as those of the NAF. The zone lies along the eastward projection of the Late Cretaceous-Paleocene, northern margin of the Izmir-Ankara suture beneath the Miocene deposits: It may indicate local reactivation of a part of that feature.

14-5 16:10 Koral, Hayrettin

THE NORTH ANATOLIAN FAULT ZONE IN NW TURKEY: INFERENCES FROM NEOGENE STRATIGRAPHY TO EARTHQUAKE RUPTURES

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The North Anatolian Fault (NAFZ) is a major tectonic feature of the Marmara region and NW Turkey. It follows an ancient suture zone and comprises three prominent splays. These splays delimit several Neogene basins.

The Neogene basins indicate a sedimentary sequence extending from the Oligocene to Quaternary with noted interruptions in the stratigraphy. The sequence begins with a thick and gently folded limestone that overlies disconformably a pre- Oligocene magmatic/metamorphic basement. It continues with marl-mudstone-tuff intercalations which have an age of the Upper Oligocene-Lower Miocene. The sequence continues with a distinct unconformity and is overlain by lignite bearing marl and fine clastics. It is then cut by volcanics overlain by clastics of both sedimentary and volcanogenic origin. Pleistocene clastics and a thick Holocene alluvium overlie the older units with an angular unconformity.

The sedimentary sequence in NW Turkey indicates a large inland basin modified by tectonic events as evidenced by differing depositional conditions and noted unconformities. The orderly map pattern of Neogene units suggests temporal and spatial modification of Neogene faults possibly dissimilar to the present.

The 1999 earthquakes of the Marmara region caused a surface rupture reaching to a length of over 150km. The rupture included simple as well as complex rupture geometries and slip modes. It extended largely through Quaternary deposits. This rupture pattern is considered to be representing the modern NAFZ with a rather simple through-going geometry. However, details of the rupture appear to bear many influences of the Neogene faults and Neogene fault geometry.

14-6 16:30 Esat, Korhan

NEOTECTONICS OF NORTH CENTRAL ANATOLIA: A STRIKE-SLIP INDUCED COMPRESSIONAL REGIME

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North Central Anatolia is mainly dominated by strike-slip tectonics. Right lateral the North Anatolian (NAFZ), the Kırıkkale-Erbaa (KEFZ), and the Eskisehir Fault Zones (EFZ) are major strike-slip neotectonic elements in the region. The triangle shaped area bounded with these fault zones has many contractional structures such as tectonic wedges, folds, and blind thrusts.

The Eldivan-Elmadag Pinched Crustal Wedge (EPCW), having a thrusted eastern and normal faulted western margin and composed of the Neo-Tethyan suture zone rocks, is a main NNE-trending contractional structure in the area between the NAFZ and the KEFZ. The EPCW has been active since Late Pliocene as indicated by the age of the syn-tectonic Deyim formation and the seismic activity. The other NNE-trending wedge structure called Abdusselam Wedge (ASLW), having a thrusted eastern and normal faulted western margin similar to the EPCW, is located between Ayas and Kazan in west of Ankara. The ASLW deforms the Middle Miocene-Pliocene sedimentary rocks. The normal faults on the western margin of the ASLW create drag fold synclines whereas on the eastern side thrusts and blind thrusts produce a NNE-trending large-scale folding. Apart from these major wedges, asymmetrical folding on the Oligocene sedimentary units probably created by the NNE-trending blind thrusts is seen at the east of the EPCW around Bagdatli. All these contractional structures are limited by the regional strike-slip faults namely the NAFZ, KEFZ and EFZ. They are compatible with the recent GPS based regional geodetic strain analyses and microseismic activity which indicate active NW-SE compressional regime in North Central Anatolia.

SESSION NO. 15, 14:30

Monday, 4 October 2010

Tectonic, magmatic & geomorphic evolution of high plateaus. Part 1 (*Yüksek platolarin tektonik, magmatik ve jeomorfik evrimleri*)

METU Convention and Cultural Centre, Salon C

15-1 14:30 Mo, Xuanxue

CENOZOIC MAGMATISM IN GANGDESE, SOUTHERN TIBET: RECORDS OF COLLISION AND SUBDUCTION BETWEEN INDIA AND ASIA

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The geological record of Cenozoic magmatism in Gangdese (Lhasa terrane), southern Tibet, provides unique information on the collisional and postcollisional processes following the collision and partial subduction of India beneath Asia. The Linzizong volcanic succession (LVS, ~65-45 Ma) and the coeval batholiths (~60-40 Ma) of andesitic to rhyolitic composition represent a magmatic response to the India-Asia continental collision, which began ~70-65 Ma and culminated at ~45-40 Ma with convergence continuing to the Present. These syncollisional felsic magmatic rocks are widely distributed along much of the 1500 km long Gangdese Belt immediately north of the India-Asia suture (Yarlung-Zangbo) in southern Tibet. Our study of the Linzizong volcanic rocks from the Linzhou Basin (near Lhasa) suggests that syncollisional felsic magmatism likely accounts for much of the continental crustal growth in this collision zone. These volcanic rocks show a first-order temporal change from the andesitic lower Dianzhong Formation (64.4–60.6 Ma), to the dacitic middle Nianbo Formation (~54 Ma), and to the rhyolitic upper Pana Formation (48.7–43.9 Ma). Our detailed geochemical study suggests that the remarkable compositional similarity between the andesitic lower Dianzhong Formation and the modal bulk continental crust corroborates our proposal that continental collision zones may be the sites of net crustal growth (juvenile crust) through process of syncollisional felsic magmatism (Mo et al. 2007, 2008). Undeformed, subaerial LVS volcanic strata unconformably overlie the strongly deformed Cretaceous strata in the Gangdese Belt, providing an important temporal constraint for the timing of widespread volcanism in the region. Recent 1:250,000-scale geological mapping of the Gangdese Belt (Pan et al. 2004) revealed that the LVS occurs widely, extending E-W for more than 1500 km and taking up ~50% of the outcrop area in the entire Gangdese Belt. This unconformity goes with the LVS throughout the entire Gangdese Belt, suggesting a major tectonic event, which, together with the geochronological data (Dong, 2002; Mo et al., 2002, 2003; Zhou et al., 2004; Mo et al., 2006, 2007 allows us to advocate that the unconformity, which is ≥65 Ma, represents the onset of the India-Asia collision, supporting the inferred timing of initial collision at ~70–65 Ma by Yin and Harrison (2000) based on a multitude of observations. Postcollisional potassic and ultrapotassic rocks (28-8 Ma) reveal the mantle contribution to their source regions and the involvement of recycled subducted Indian continental material in response to the post-collisional lithosphere delamination (Mo et al., 2006; Zhao et al., 2009). The 14-18 my old volcanic rocks and adakitic ore-bearing granite porphyries, on the other hand, possibly represent the products of partial melting of the thickened lower crust of the plateau. The chronological order and geochemical characteristics of these magmatic events point to the processes of Tethyan oceanic crust subduction, followed by India-Asia collision and subsequent continental subducting/underthrustion of India beneath southern Tibet. This tectonic scenario is reminiscent of that of the eastern Mediterranean region, involving the collision of Africa with Eurasia in the late Cenozoic, offering new insights into the magmatism and crust accretion associated with continental collision, which may also suggest a common tectono-magmatic pathway for the evolution of continental collision zones.

15-2 14:50 Zhao, Zhidan

HIDDEN CRUST-DERIVED MAGMATISM REVEALED BY THE ~23 MA POTASSIC MAGMATISM IN THE WESTERN LHASA TERRANE, TIBET: INSIGHT FROM ZIRCON U-PB DATING AND HF ISOTOPES

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The postcollisional potassic and ultrapotassic magmatism in western Lhasa terrane has been well-studied in the past decade. The magmatic pulse during 21-25 Ma has been particularly well recognized by Ar-Ar dating in Shiquanhe, Xiongba, Bangba and Wenbu areas (Miller et al., 1999; Ding et al., 2003; Williams et al., 2004). Here, for the first time, we present our new zircon LA-ICPMS U-Pb dating and Hf isotope data on new potassic extrusive rock occurrences in the Xiongba and Bangba areas of the western Lhasa terrane, to further constrain their age and nature of their melt source regions. These rocks are high-K calc-alkaline dacite and shoshonitic trachyte, with their SiO_2 content ranging from 63 to 69 %, MgO from 0.6 to 2.5 %, and K_2O / Na_2O from 1.5 to 6.2.

One hundred zircon grains from seven potassic samples in Xiongba and Bangba give concordant LA-ICPMS U-Pb ages of 23-24 Ma. These zircon separates yield $^{176}Hf/^{177}Hf$ ratios ranging from 0.282273 to 0.282531, corresponding to $\varepsilon_{Hf}(t)$ values of -17.1 to –8.0. Their Hf depleted-mantle modal ages (T_{DM}) and crustal model ages (T_{DM}^{C}) are in the range of 1.0–1.4 Ga, and 1.6-2.2 Ga, respectively. These data collectively suggest that magmas of the alkaline rocks were derived mainly from a source region with significant contributions from mature crustal materials.

We also found two major clusters of inherited zircons with concordant U-Pb ages in the potassic rocks. The first (39 zircon grains) yields a peak age of ~90 Ma (MSWD = 2.0), with positive $\varepsilon_{Hf}(t)$ values ranging from ~0 to 6. Such zircon $\varepsilon_{Hf}(t)$ values are significantly lower than those of the contemporaneous granite (86.4 Ma) near Quxu in central Gangdese batholith (ε_{Hf} = 10–13, Ji et al., 2009), implying that the ~90 Ma magmatism with contributions from depleted mantle materials also exists in the western Lhasa terrane without outcrops yet recognized. The second cluster (10 zircon grains) yields a peak age of ~152 Ma, with negative $\varepsilon_{Hf}(t)$ values of -11 to -5.2, suggesting the presence of Late Jurassic magmatism in the same area. Contemporaneous granitic magmatism (152 and 159 Ma) with different $\varepsilon_{Hf}(t)$ values (10-15) was recently reported in Dazhuqu, central Gangdese batholith by Ji et al. (2009).

Our preliminary results reveal that the ~90 Ma and ~152 Ma magmatic events with different source regions to the central Gangdese batholiths probably volumetrically significant in the western Lhasa terrane. We interpret the hidden ~90 Ma magmatism as having generated by partial melting of the lower continental crust, whereas the ~152 Ma magmatism was derived largely from anatexis or remelting of the middle-upper crust with mature continental materials beneath the western Lhasa terrane.

15-3 15:10 Zhu, Di-Cheng

EARLY CRETACEOUS SUBDUCTION-RELATED ADAKITE-LIKE ROCKS FROM THE SOUTHERN MARGIN OF THE LHASA TERRANE, TIBET: PRODUCTS OF SLAB MELTING AND SUBSEQUENT MELT–PERIDOTITE INTERACTION?

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Conflicting geodynamic models have been proposed for the generation of the widespread Cretaceous igneous rocks in the central and northern Lhasa subterranes. To contribute this issue, we present SHRIMP U-Pb zircon data and geochemical and Sr-Nd-Pb-Hf isotopic data for the Mamen andesites from the southern margin of the Lhasa Terrane, Tibet. The Mamen andesites, emplaced at 136.5 Ma, are sodic (Na_2O/K_2O = 1.2–2.3) and have geochemical characteristics typical of adakites (i.e., high Al_2O_3, high La/Yb ratios and Sr contents, low Y and HREE contents, and positive Eu anomalies), except for high Cr, Ni, and MgO contents. The andesites have initial $(^{87}Sr/^{86}Sr)_t$ ratios of 0.70413–0.70513, positive eNd(t) values of 3.7–5.8, and $(^{206}Pb/^{204}Pb)_t$ ratios of 18.37–18.51, $(^{207}Pb/^{204}Pb)_t$ ratios of 15.59–15.65, and $(^{208}Pb/^{204}Pb)_t$ ratios of 38.43–38.72. *In situ* Hf isotopic analyses of zircons that had previously been dated by SHRIMP yielded positive initial $e_{Hf}(t)$ values ranging from +11.0 to +15.5. A model calculation using trace element and Sr-Nd-Pb isotopic data indicates that several percent of subducted sediment is required to generate the Mamen andesites, which were derived via the partial melting of subducted Neo-Tethyan slab (MORB + sediment + fluid) and subsequently hybridized by peridotite in the mantle wedge. Our data indicate that the Neo-Tethyan ocean floor was subducted northward beneath the Lhasa Terrane during the Early Cretaceous at a high angle. Our results are inconsistent with a tectonic model that advocates the low-angle or flat-slab subduction of Neo-Tethyan ocean floor in generating the widespread Cretaceous magmatism documented in the Lhasa Terrane.

15-4 15:50 Bartol, Jeroen

THE CENTRAL ANATOLIAN PLATEAU: NEW INSIGHTS FROM THERMAL-FLEXURAL MODELLING

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In the Middle to Late Miocene several seemingly unrelated events occurred nearly simultaneously in central Anatolian, Turkey: (1) onset of widespread volcanic activity with a mantle signature (2) disruption of a late Oligocene-lower Miocene paleo-drainage system in the Western Taurus and (3) significant increase of erosion in the Bolkar mountains (south-east Turkey). The last two observations suggest a sudden uplift (>1000 meters) of the central Anatolian plateau by a mechanism which also triggered widespread volcanic activity. In the eastern Anatolian plateau, comparable events are attributed to delamination of the lithospheric mantle. Seismic wavespeeds are slow below the crust of the eastern and central Anatolian plateau. Results from tomography suggest that the (deeper) Bitlis slab was laterally continuous below the eastern and central Anatolian plateau. We therefore propose that the scenario developed for eastern Anatolian plateau also applies to central Anatolian plateau. In this scenario, delamination started in both east and central Anatolian along the Izmir–Ankara-Erzincan suture zone possibly induced by remnants of a northern Neotethys slab. As the lithospheric mantle (negative buoyancy) separates from the crust (positive buoyancy) it sank into the asthenosphere and was replaced by hot mantle material.

If true, delamination is expected to have had a thermal and isostatic imprint. Using a three-dimensional thermal and flexural model, we aim to quantify the possible imprints in the geological record of the central and eastern Anatolian plateau. With the lithospheric mantle being replaced by the hot asthenosphere partial melting of the crust could occur. The high temperature will also influence the rheology of the lithosphere and consequently the effective elastic thickness and flexural response. Our model takes the changes of the effective elastic thickness due to thermal perturbation into account and calculates the potential volume of crust that could melt.

Model results show that the present day elevation of both plateaus can be explained by delamination of the lithospheric mantle; 1500 meters of uplift is predicted for the central Anatolian plateau while an uplift of only 1000 meters is predicted for the eastern Anatolian plateau. This large difference in uplift is caused by variations in crustal thickness with a thick crust (eastern Anatolian plateau) resulting in a limited uplift while a thin crust (central Anatolian plateau) in a large uplift. The initial uplift is followed by a gradual thermal subsidence, which continues today, between 0.8-0.4 meter/kyr with the central Anatolian plateau having the highest subsidence rate. For the present day surface heatflow, our model predicts an average of 76 mW/m2 with a maximum of more than 80 mW/m2 predicted in the south. This is, to a very first order, in agreement with the observed surface heatflow. The average surface heatflow increases with time reaching a maximum of 84 mW/m2 , 30 Myr after delamination. Based on the model results, we expect to see a clear crustal signature within the erupted volcanic products in eastern Anatolian were our model predicts significant crustal melting. In central Anatolia, crustal melting is substantially less and consequently we expect to see less or even no influence of the crust in the erupted volcanic products.

15-5 16:10 Yildirim, Cengiz

LATE NEOGENE UPLIFT ASSOCIATED WITH THE NORTH ANATOLIAN FAULT IN THE CENTRAL PONTIDES; THE NORTHERN MARGIN OF THE CENTRAL ANATOLIAN PLATEAU, TURKEY

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In the context of the margin evolution of the Central Anatolian Plateau, we address the mode and timing of the uplift in the Central Pontides. We present morphometric analyses, interpret published geodetic and seismic reflection data as well as structural and geomorphic field observations. Our regional morphometric analyses reveal regional topographic anomalies, steep channel gradients, and local high relief areas as proxies for ongoing differential surface uplift, which is higher in the western sector of the Central Pontides. The results from NAF-normal components of geodetic slip vectors indicate that regional stress is accumulated in the broad restraining bend of the NAF, and seismic reflection and structural field data indicate a deeper structural detachment horizon that creates an active orogenic wedge with a northward polarity and a positive flower structure geometry across the Central Pontides. Our tectonic concept implies that the NAF is the main driving force for wedge tectonics and uplift in the Central Pontides. The syn-tectonic deposits within the inverted basins and deeply incised gorges of the Kızılırmak and Filyos rivers imply that the formation of relief, changes in sedimentary dynamics, and >1400 m and 1200 m, respectively fluvial incision were the consequences of accelereated uplift starting in the early Pliocene. The Central Pontides thus provide an example of the initial to intermediate stage of continental plateau evolution, when the role of surface breaking faults plays a critical role in margin growth and sedimentary basin evolution.

15-6 16:30 Schildgen, Taylor F.

UPLIFT OF THE SOUTHERN CENTRAL ANATOLIAN PLATEAU FROM 87SR/86SR STRATIGRAPHY AND CRN DATING OF RIVER TERRACES

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The Central Anatolian Plateau is at the crux of one of the most complicated tectonic regions on Earth, bounded by the Aegean extensional province to the west, enigmatic subduction to the south, the Bitlis-Zagros collisional zone to the east, and the continental-scale North Anatolian Fault Zone (NAFZ) to the north. Although several mechanisms have been proposed to explain the high elevation of the Eastern Anatolian Plateau, little attention has been given to the Central Anatolian Plateau. Critical for understanding the mechanism of surface uplift and how it fits within the regional tectonic setting is determining the temporal framework and pattern of surface uplift. The southern margin of the plateau, which is extensively overlain by Miocene marine sediments uplifted to ~2 km elevation and contains well-preserved fluvial terraces within the Mut Basin, offers excellent potential to explore the history of surface uplift.

Our data provide constraints on uplift that followed initial deformation and uplift of the Tauride belt along the southern plateau margin. We present $^{87}Sr/^{86}Sr$ data on the highest and youngest marine sediments that presently cap the margin, and onlap older Tauride units at the southeastern and southwestern edges of the margin. Analyzed samples, including oysters and foraminifera, cover a region of > 150 km along the southern margin, from the Antalya Basin to the Mut/Ermenek Basin. Measured ratios average 0.708888 in the west (1450 m elevation), 0.708832 at the middle site (1885 m elevation, ~200 m below the highest marine sediments), and 0.708813 at our eastern-most site (1845 m elevation). Comparing these values to the global sea water $^{87}Sr/^{86}Sr$ curve (LOWESS IV) suggests ages of ~10 Ma in the west, ~12.5 Ma at the middle site, and ~13 Ma in the east. However, a potential complication concerns the Miocene Mediterranean sea water $^{87}Sr/^{86}Sr$ curve, which shows a major departure from the global $^{87}Sr/^{86}Sr$ curve when the Mediterranean became restricted from global ocean circulation (e.g., McCulloch and De Deckker, 1989). This interpretation of the Mediterranean Sr isotope curve would imply ages of ≤ 10 Ma at the western site, ≤~8 Ma at the middle site, and ≤ ~7 to 8 Ma at the eastern site. If the latter interpretation of our Sr measurements is correct, which is suggested by biostratigraphic constraints from the same sections, this indicates a post-middle Tortonian phase of uplift that was nearly simultaneous along the southern margin of the plateau, or slightly earlier in the west.

We suggest a regional tectonic framework that can explain this uplift pattern. Initial westward extrusion of the Anatolian microplate likely led to localized uplift along restraining regions of the bounding faults, such as the nearly N-S striking Kirkkavak fault near Antalya. Later uplift across the southern margin may have resulted from a change in the deformation pattern, with Central Anatolia undergoing counter-clockwise rotation. Such a pattern of modern deformation is supported by paleomagnetic rotation data as well as GPS velocity data. This deformation pattern should have produced a compressional or transpressional regime throughout the southern margin.

To determine the most recent uplift history, we analyzed cosmogenic exposure ages of fluvial clasts preserved on river terraces of the Göksu River (Mut Basin). Sampled terraces range from ~30 to 140 m above the present river. Model exposure ages of chert clasts from the terraces are derived from cosmogenic ^{21}Ne and ^{10}Be measurements, while exposure ages of carbonate clasts are calculated from ^{36}Cl measurements. Initial ^{21}Ne results suggest a model exposure age of ~160 ka for the upper terrace level, however, complications in the interpretation of the age with respect to initial inherited cosmogenic nuclides and surface erosion will be tested as additional analyses are completed. Nonetheless, if our initial model ages are even approximately correct, this implies that the latest Quaternary was characterized by a relatively rapid

M O N D A Y

phase of uplift. This more rapid uplift was probably driven by different mechanisms, which may have included deeper crustal or lithospheric processes.

SESSION NO. 16, 09:30

Tuesday, 5 October 2010

Crustal motions, mantle dynamics & GPS velocities in continental collision. Part 1 (*Kitasal çarpismalarda kabuk hareketleri, manto dinamigi ve GPS hiz dalgalanmalari*)

METU Convention and Cultural Centre, Kemal Kurdas Salon

16-1 09:30 Spakman, Wim

MANTLE DYNAMICS OF THE MIDDLE EAST INFERRED FROM TOMOGRAPHY

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Seismic tomography results in today's structure of the mantle expressed in 3D seismic wave speed variation. Mantle structure reflects ongoing mantle dynamics which still involves remnants and evidence of past processes, e.g. past lithosphere subduction. Our latest tomography model will be presented showing deep mantle structure of the Middle East involving evidence for past and current subduction and possible evidence for mantle upwelling.

16-2 09:50 Govers, Rob

HOW THE SUBDUCTION CONTACT CONTROLS THE RESPONSE TO CONTINENTAL COLLISION

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Anatolia is an assemblage of terranes that were accreted during various collisional events. Continental collision may actually result in a wide range of tectonic responses. In search of the controlling conditions and parameters, we start from the results of our previous work, which demonstrated that the properties of the plate contact are important for the dynamics of convergent plate margins. We distinguish two fundamental types of subduction plate contact: one based on a fault and the other based on a subduction channel. We investigate how the plate contact affects the initial stage of continental collision. We use a finite element method to solve the heat and the time-dependent momentum equations for elastic, (power-law) viscous and plastic rheologies. For the same rheological properties and driving forces, varying the nature of the plate contact leads to three types of responses. The presence of a subduction channel promotes coherent and, when the boundary conditions allow it, plate-like subduction of the continental margin. In models with a subduction fault, coherent subduction of the incoming continental lithosphere occurs when the colliding passive margin has a gentle slope. The approaching continental sliver starts to subduct and the subduction is characterized by a non-plate like behaviour—slower subduction velocity than in channel models and strong slab deformation. If the continental margin is steep and the strength of the incoming continental crust is high, fault models result in locking of the trench, eventually leading to slab break-off. If the crustal strength is relatively low, shear delamination of part of the crust is expected. In the channel model, this type of delamination never occurs. The tectonic settings used in our experiments (prescribed plate velocity of the subducting plate versus fixed subducting plate corresponding to a landlocked basin setting) do not significantly influence the nature of the model response. We conclude that initial stages of continental collision are strongly affected by whether the subduction contact is a fault or a channel. Neither the slab pull magnitude nor the tectonic setting is very important to the overall geodynamics at this stage. The plate contact type, along with the slope of the incoming passive margin and the rheology of the continent, controls whether the incoming crust (1) subducts entirely; (2) separates partially or entirely from the lithospheric mantle or (3) blocks the trench, likely leading to slab break-off.

16-3 10:10 Sandvol, Eric

THE SEISMIC STRUCTURE OF THE ARABIAN PLATE AND THE SURROUNDING PLATE BOUNDARIES

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Much of the Cenozoic geology and the present lithospheric and upper mantle structure of the Arabian-Eurasian collisional belt including the Anatolian and Iranian plateaus are the result of the collision and suturing of the continental Arabian plate to the Eurasian and the escape of the Anatolian plate to the west. This process of collision, suturing, and escape was strongly influenced by three active structures in the region: the Caucasus mountains, the Zagros mountains, and the Dead Sea fault system. In order to address upper mantle dynamics in this region we review the variations in the seismic wave velocity structure across the Anatolia plate and the African-Arabian-Anatolian plate boundaries. Recent techniques are giving us a new view of the seismic velocity structure across these important tectonic provinces and thus important insights into their evolution.

The northern portion of the Arabian plate appears to be relatively thin (~120 km) and in places relatively since there is circumstantial evidence to suggest regions of partial melting. Specifically along the Dead Sea Fault System we observe some evidence for a hot and possibly thin lithosphere. In general these anomalies coincide with Cenozoic volcanism. The adjacent Eurasian and Anatolian lithosphere, however, is even more anomalous. There appear to be large regions of the Anatolian plateau and Lesser Caucasus where there is very little, if any, lithospheric mantle. Using seismic records collected from 54 broadband stations located in the region were used to develop a new three dimensional shear wave velocity model we determined the fundamental mode Rayleigh wave phase velocities at periods between 20 and 145 seconds. We used the method of Yang and Forsythe (2006) that models the network variations in phase and amplitude of teleseismic Rayleigh waves to map the variations in phase velocity. We observe a relatively high velocity zone located in the upper mantle under the Kura basin and the western part of Caspian Sea that is continuous to the Moho. This high velocity may either be a subducting slab or a thick lithospheric mantle root beneath the basin. We observe a separate high velocity body beneath the Lesser Caucasus that appears only in our longer period (> 100s) phase maps. We believe that this may be the remnant Neo Tethys slab that broke off after the initiation of continent-continent collision between the Arabian and Eurasian plates. Also our images show very low velocities implying the existence of a partially molten asthenospheric material underlying a very thin lithosphere beneath most of the Anatolian plateau. Our surface wave results are broadly consistent with teleseismic S-wave receiver functions across the eastern Anatolian plateau and Lesser Caucasus that show a very shallow (60-80 km) Lithosphere-Asthenosphere Boundary (LAB). The shallow LAB, young alkaline volcanism, and recent plateau uplift are all consistent with a recent break-off of the Neo-Tethys oceanic slab.

In terms of shear wave splitting across the northern Middle East, nearly all stations in central and eastern Anatolia have a NE-SW fast direction and lag time similar to that observed from temporary broadband stations within the Anatolian plate, indicating that the anisotropic fabric may be relatively uniform throughout the upper mantle beneath the Anatolian plate. The extensive young basaltic volcanism, regional travel time tomography, and regional phase attenuation tomography all indicate that observed anisotropy is from existing finite strain, not a preserved lithospheric mantle anisotropic fabric. Furthermore, we have also obtained the depth extent of the azimuthal anisotropy beneath the eastern Anatolian plateau and Lesser Caucasus using Rayleigh wave phase velocities. We have found that beneath eastern Anatolia the fast directions do not vary significantly with depth. We have found that the magnitude of the anisotropy is relatively (small ~2%) and also does not vary strongly with depth down to depths of 200 km Unless exceptionally high (approximately 12%) anisotropy exists in the thinned lithosphere, the main contribution to the observed delay times (of order 1 s) must therefore be asthenospheric and thus reflect recent asthenospheric flow patterns. Furthermore, the lack of correlation between surface deformation and the observed shear wave splitting parameters would suggest that the measured anisotropy is primarily asthenospheric. The measured fast directions across the major fault zones in the region do not change significantly, clearly not reflecting the change in lithospheric or crustal strain [*McCluskey et al*., 2000]. The lone exception appears to be a change in the fast direction across a region of concentrated extension in western Anatolia. We observe a change in the orientation of the splitting to be somewhat consistent with the direction of crustal extension.

16-4 10:50 Wortel, M.J. Rinus

THE ROLE OF CONTINENTAL COLLISION IN THE SEPARATION OF ARABIA FROM AFRICA AND THE FORMATION OF THE DEAD SEA FAULT

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The separation of Arabia from Africa has been proposed to result from the collision induced stress field in the NE corner of the former African plate (see Bellahsen et al., ESPL, 2003). Using this proposed mechanism as a starting point we numerically model the lithospheric stress field resulting from the collision induced changes in boundary forces, with emphasis on temporal and spatial variations. The collisional segment of the Africa/Arabia–Eurasia plate boundary gradually increases in length in E-SE direction. The stress field results show overall SW-NE tension in Arabia just prior to collision, followed by a drastic reduction in tensional stress upon collision. In the vicinity of the Owen Fracture Zone, however, tensional stresses remain high. At the same time the stress level in the Red Sea region is very moderate, thus not indicating simultaneous rifting. Since the initiation of rifting postdates the collision, we consider the high tensional stresses (after collision) at the eastern boundary to have started rift formation (in the present-day Gulf of Aden) towards the Afar region.

Upon incorporation of a propagating rift the model results show two important changes: (1) near the tip of the propagating rift, stress concentration leads to high tensional stresses, and the rifting process appears to becomes self-sustaining; (2) the orientation of the tensional stress axis rotates clockwise with the changing boundary conditions along the plate contact during ongoing collision and rift propagation. When the rift arrives in the northern part of the Red Sea area, the direction of the tensional stress axis has rotated towards NW-SE, promoting rifting in the Gulf of Aqaba, rather than in the Gulf of Suez region. By a simultaneous increase in the magnitude of the compressional axis the rift is possibly redirected to form the Dead Sea transform.

We further pay special attention to the following three questions: (a) Was collision induced rifting able to create the present-day Dead Sea Fault as a new plate boundary, over its entire length all the way to the collisional front in the North, at the Africa-Arabia-Anatolia triple junction ? (b) Did the stress field evolution favour a northward continuation of the southern part of the Dead Sea Fault into an off-shore direction to the northwest? And: (c) What is the relation between the Cyprus Arc and the Dead Sea Fault?

16-5 11:10 Abdelsalam, Mohamed

THE MAKING OF A DIVERGENT PLATE BOUNDARY: THE ARABIA-AFRICA PLATE BOUNDARY WITHIN AFAR, ETHIOPIA

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The triangular-shaped Afar Depression in Ethiopia, Eritrea and Djibouti is considered from global plate kinematics a classical rift-rift-rift triple junction where the Red Sea, the Gulf of Aden and the Main Ethiopian Rift meet and separate the Arabian, Nubian and Somali Plates. This depression is surrounded by the rising escarpments of the Ethiopian plateau in the west and the Somali plateau in the south where elevation drops from ~2 km to reach -160 m below sea level in northern Afar. The Afar triple junction was formed in response to extension following the out-pouring of ~30 Ma basalts when the Afar mantle plume reached the base of the Arabian-Nubian Shield. Subsequently, the Red Sea and the Gulf of Aden were formed as continental rifts at ~24 Ma but transitioned into oceanic spreading centers at ~10 and ~5 Ma, respectively. The Main Ethiopian Rift joined the two oceanic rifts within Afar ~10 Ma. However, the two oceanic rifts (the Red Sea and the Gulf of Aden) do not directly connect within Afar. Rather, the Red Sea spreading center stepped onto Afar at the Gulf of Zula forming the Red Sea propagator which is manifested by spectacular active rifts and shield volcanoes. Similarly, the Gulf of Aden spreading center stepped onto Afar at the Gulf of Tadjoura forming the Gulf of Aden propagator which is equally characterized by active rifts and shield volcanoes. The Red Sea and the Gulf of Aden propagators (respectively propagating in a southeast and northwest directions) enclose a ~120 km wide overlap zone characterized by deep northwest-trending grabens (such as the Dobe graben) surrounded by horst structures. The horst structures within the overlap zone are currently rotating in a clockwise direction due to dextral shear exerted by differential spreading of the Red Sea and the Gulf of Aden propagators. The southern extension of the Red Sea propagator in Afar is represented by the ~50 km wide, northwest-trending Tendaho graben which is surrounded by northwest-trending normal faults deforming ~2 Ma old basaltic rocks. The age of the basaltic flows becomes progressively younger towards the center of the graben reaching ~35 ka. Recent magnetic and gravity studies show that the extension within the Tendaho Graben is magma-assisted and it is maintained by a ~10 km wide zone of basaltic diking. The magnetic pattern across the Red Sea propagator is similar to those observed on mid-ocean ridges where the magmatic diking zone is characterized by normal polarity flanked by reverse polarity. Correlation of the magnetic pattern to geochronological data suggests that the magmatic dikes were emplaced between ~800 ka and ~35 ka. Additionally, these data suggest that extension across the Tendaho graben has slowed considerably in the past ~800 ka and the bulk of the strain might have been transferred to the northeast to be accommodated within the northwest-trending grabens of the overlap zone as indicated by the cumulative ~12 mm/year extension. Magnetic and gravity surveys across the Dobe graben show a pattern that is fundamentally different from that across the Tendaho graben in which these data do not support the presence of magmatic diking under Dobe. It is possible that the Dobe graben is currently mechanically stretching as supported by continuous occurrence of earthquakes indicating northeast-southwest extension. Hence, we suggest that the plate boundary between Arabia and Africa (Nubia and Somalia) within Afar is currently in the make and it is characterized by a defused zone of extension passing through the Red Sea propagator, the Dobe graben, and the Gulf of Aden propagators. Extension within the Red Sea and the Gulf of Aden propagators evolved into magma-assisted extension whereas the extension within the Dobe graben is still maintained through mechanical stretching.

16-6 11:30 Jackson, James

ACTIVE TECTONICS OF THE SOUTH CASPIAN REGION

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The South Caspian Basin is an important element in the accommodation of the convergence between Arabia and Eurasia at the longitude of Iran. Most of the basin is underwater, yet it is largely aseismic, flat and probably relatively rigid. Its motion within the collision zone, and its tectonic significance, must therefore mostly be assessed from the deformation observed on its edges, in the very active seismic belts that surround it on all sides. Since the last major review of the active tectonics of this region in 2002, much improved new data have emerged from GPS, earthquakes and an increasing knowledge of the active faulting and Quaternary geology. As a result, we now have a better understanding of how the current motions in these belts relate to the wider collisional configuration, though other uncertainties and controversies remain, especially in the timing, duration and onset of large-scale features in the Tertiary geology. This talk will review the new information in this region, built up principally by sustained fieldwork in Iran and a re-examination of the earthquake information. The tectonics of the South Caspian basin is probably representative of a more general process within collision orogens, in which trapped basins become surrounded by thrust belts on all sides that eventually consume them; but the processes involved are very three-dimensional, likely to involve rotations about vertical axes and to change rapidly with time, and leave behind them a rather complicated and confusing geological record.

16-7 11:50 Klein, Elliot

THE QUESTION OF LONG-TERM FAULT STRENGTH ACROSS DEFORMING ZONES IN TURKEY

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In this study we make an inverse approach to the problem of fault strength distribution in major deforming zones in Turkey. We use a simple frictional model defined for a thin-sheet lithosphere. Although we are aware that the width of the deforming zone around even geometrically simple strike-slip faults increases with depth and that the physics of the phenomenon is not exactly represented by a thin-sheet approach, we believe that this simple approach can produce first-order quantitative clues on the problem . We treat the body forces for separate cases where we use seismologically determined crustal thicknesses, a large-scale standard crustal model and another simple model where Airy isostasy is almost satisfied. We also use different values of long-term pore pressure to see the overall effect of the variation of this parameter. Using a variational approach we solve the linear force balance equations where the forcing is simply the horizontal gradients in gravitational potential energy per unit area (GPE). This is similar to calculating the Green's function for the Stokes equations for a viscous, non-accelerating thin-sheet continuum. We then exploit the linearity of the problem to solve for the stress boundary conditions to reach a style match between the stress and the strain rates (calculated using a GPS dataset) within the domain. In this preliminary work we assumed Airy isostasy and assumed no lateral density variations within the crust. The seismogenic thickness in Anatolia rarely exceeds 18 km and especially in western Turkey most of the deformation is known to be occurring seismically. Still, the brittle-ductile transition depth might change place to place. Rather than spatially varying the stress integration depths, we assumed uniform stress integration depth but experimented with various depth values. One interesting outcome of our calculations is that, for all reasonable stress integration depth, the fault friction coefficients in the Marmara zone are larger than the rest of NAF to the east. As the stress integration depth increases, the zone that characterizes the "large friction" Marmara zone extends slightly to the east. Assuming a brittle-ductile transition depth of around 15-17 km, we see that the faults in western Turkey have friction coefficients of around 0.1-0.2 (under long-term hydrostatic pore pressure conditions) which is similar to most of the findings in San Andreas fault zone whereas in the eastern part of NAF the values are around 0.1 or less. Coincidentally, eastern portion of NAF is also characterized by less seismicity during the instrumental epoch but this might be due to lack of high density observational coverage there. When we look at the fault strength, rather than solely the friction coefficient, we see a stronger variation in the rest of the NAF, strong Sinop zone being confined from the west and from the east by less strong zones.

16-8 12:10 Özbakir, Ali Deger

THE NATURE AND LOCATION OF THE PLATE BOUNDARY BETWEEN THE ANATOLIAN AND AFRICAN PLATES

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Overall convergence of the African, Arabian and Eurasian plates, and the westward escape of Anatolia has resulted in an evolving plate boundary zone since the Miocene. In the Eastern Mediterranean, the current location and nature of the plate boundary between the Anatolian and the African plates is difficult to trace due to the scattered crustal earthquakes, and the absence of deeper earthquakes. In this study we aim to better constrain the nature and the location of the plate boundary, in particular the transition region from Hellenic arc to Cyprus arc.

GPS-derived velocity field and stresses from earthquake mechanism solutions comprise the datasets which short time scale (elastic) models can be compared to. We model the stresses and deformation on the overriding plate by incorporating convergence of Africa and Arabia towards stable Eurasia, and rollback of the Hellenic trench. Investigation of the plate boundary consists of constraining the directions of motions over the segments which make up the boundary. We assume various types and locations for the plate boundary within the observational limits. We use a spherical plane stress finite element model to test these possibilities.

We find that stresses and displacements are sensitive to both the location and the nature of the plate boundary. Our models favor the plate boundary via Pliny/Strabo trench, Anaximander mountains, Eratosthenes seamount, Latakia/Larnaka/Kyrenia ridge. We obtain the minimum misfit with the data in a model where we assume the following: (1) Pliny/Strabo and Anaximander mountains have both down-dip and fault parallel motions, whereas the western edge of Rhodes basin is pure strike slip (2) the connection between the Cyprus arc and Arabia-Eurasia collision zone, Latakia - Larnaka - Kyrenia ridges, is pure strike-slip and (3) collision of the Cyprus arc. We found slip rates of 6 - 16 mm/yr along the Anaximander seamountains, highest rates being near to the western end. In all our models, a southeast directed pull force on the east Hellenic trench is required to explain the velocities in southwest Anatolia. This force may be related to return flow around the lateral edge of the Aegean slab.

SESSION NO. 17, 08:30

Tuesday, 5 October 2010

Keynote Talk 3

METU Convention and Cultural Centre, Kemal Kurdas Salon

17-1 08:30 Reilinger, Robert

SUBDUCTION DRIVES ARABIA/AFRICA PLATE CONVERGENCE WITH EURASIA AND PROVIDES A UNIFYING, DYNAMIC MECHANISM FOR MEDITERRANEAN/MIDDLE EAST TECTONICS

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To constrain plate driving forces and the dynamics of inter-plate deformation, we use geodetic and plate tectonic observations to determine the tectonic evolution of the Africa (AF)-Arabia (AR)-Eurasia (EU) plate system. In the Late Oligocene/Early Miocene (~25 Ma), the initiation of continental rifting, and the separation of AF from AR along the Red Sea and Gulf of Aden caused an ~50% slowing of AF-EU convergence, presumably due to a reduction in the slab-pull force transferred from the Bitlis-Zagros-Makran subduction system to the AF Plate (McQuarrie et al., 2003). The rate of AR - EU convergence remained constant as determined from plate tectonic reconstructions, and is indistinguishable from the present-day rate determined from GPS observations. A second major change occurred in the configuration and rate of motion across the AF-AR plate boundary at 11 ± 2 Ma, including an additional ~50% increase in the rate of AF-AR motion, and a corresponding decrease in the rate of AF-EU convergence (ArRajehi et al., 2010; McClusky et al., 2010). We relate these changes in plate rates and the configuration of the Red Sea (AF-AR plate boundary) at 11 ± 2 Ma to the initiation of ocean spreading in the Gulf of Aden that completely severed the continental lithosphere at this time, causing a further reduction in the N-S component of the slab-pull force transferred to the AF Plate. The timing of the initial slowing of AF-EU convergence (~25 Ma; Late Oligocene/Early Miocene) corresponds to the initiation of extensional tectonics in the Mediterranean Basin (Alboran, Central Mediterranean [Tyrrenian, Balearic], and Aegean basins), and the second phase of slowing to changes in the character of Mediterranean extension reported at ~ 11 Ma (Tortonian). Based on theoretical considerations indicating that, all else being equal, buoyancy forces on the subducted lithosphere are proportional to the rate of subduction (Turcotte and Shubert, 2002; pg. 242-244), we hypothesize that the slowing of AF-EU convergence caused an imbalance in the dynamic equilibrium of the subducting Neotethys oceanic lithosphere beneath the Mediterranean segment of the plate boundary, resulting in foundering of the subducted plate, and associated southward migration of the trench system. Southward trench migration resulted in contemporaneous ~N-S extension within the Mediterranean Basin. The detailed configuration of these extensional basins likely reflects the segmentation and geometry of the subducted lithosphere (Wortel and Spakman, 2000; Grovers and Wortel, 2005; Dilek et al., 2009). Furthermore, all plates converging with EU along its > 15,000 km long southern margin (AF, AR, India, Australia) rotate counterclockwise in a roughly coherent manner with rates increasing from west to east, corresponding to an increase in the width of the subducted Neotethys lithosphere since 150 Ma. We conclude that pulling by the subducted ocean lithosphere is the dominant force driving plate convergence with EU, and provides a unifying, and conceptually simple, dynamic mechanism for post-Late Oligocene (~30 Ma) tectonic deformation in the Mediterranean/Middle East zone of plate interaction.

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SESSION NO. 18, 09:30

Tuesday, 5 October 2010

Magmatism in evolving orogens: Collision to extension. Part 1 (*Aktif orojenik kusaklarda magmatizmanin evrimi: Çarpisma tektoniginden gerilmeli tektonige gidis*)

METU Convention and Cultural Centre, Salon B

18-1 09:30 Seghedi, Ioan

GEOCHEMISTRY AND TECTONICS OF CENOZOIC MAGMATISM IN THE CARPATHIAN-PANNONIAN REGION

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Carpathian - Pannonian Region (CPR) geodynamic system made of two microplates: Alcapa and Tisia (Tisza)-Dacia is a result of the Cretaceous to Neogene collision of Africa with Europe that modified the mantle lithosphere with various subduction components. Early Miocene to Quaternary magmatic rocks of highly diverse compositions were generated in response to complex post-collisional tectonic processes, as back-arc extension, in response to interplay of compression and extension (e.g. subduction with roll-back, collision, slab break-off, delamination, strike-slip tectonics, core complex type extension and block rotations breakup). At the climax of competition between the different tectonic processes melting was triggered at various levels in the lithosphere and asthenosphere, as mirrored in variations of the associated magmatism. No volcanic activity directly related to pre-collisional subduction is recorded.

Major, trace element and isotopic data of lavas and mantle xenoliths attests that subduction components already preserved in the lithospheric mantle after the Cretaceous-Miocene subduction were reactivated by various processes. Changes in the composition of the magmas through time are linked to the evolution of the Alcapa (1) and Tisia-Dacia (2) and their boundary relations:

1a. In the main Pannonian Basin, magmatism occurred in a back-arc setting producing calc-alkaline felsic volcanic rocks at 21-18 Ma, felsic - intermediate at 18-8 Ma and ended with Na-alkalic basaltic rocks at10-0.1 Ma. Rock geochemistry suggests a change through time in source from a crustal to a mixed crustal/mantle ending with a mantle one. Extrusion tectonics, block rotation and continental collision triggered partial melting by delamination and/or asthenosphere upwelling. Na-alkalic magmatism suggests a north-east-directed mantle flow which triggered magma generation at the base of the lithosphere along NW-SE strike-slip faults; counterclockwise rotation and push of the Adriatic microplate was responsible. Continuous volcanic activity in central Slovakia, as calc-alkaline (16.5-11 Ma), transitional (11-8 Ma) and as Na-alkalic basalts (8-0.13 Ma) supports a mantle plume scenario;

1b. Westernmost Styrian basin contains felsic and intermediate calc-alkaline, K-alkalic and ultrapotassic volcanic rocks generated at 17.5-14 Ma. They were related to extension and extrusion tectonics and core-complex generation at 21.9-13.4 Ma that produced strong mantle perturbations. Na-alkali basalts at 4-1.8 Ma suggest Adria push to cause a north-east directed mantle flow and melt generation.

1c. 15-9 Ma felsic and normal calc-alkaline volcanism in the north-easternmost Transcarpathian basin, is situated at a triple junction between Alcapa, Tisia and the European foreland. It resulted via counter-clock extensional rotation of easternmost Alcapa, causing core-complex exhumation. Geochemical studies indicate a heterogeneous lithospheric mantle as main source followed by fractionation-assimilation in crustal magma chambers. Melting was triggered by rotational extension and asthenosphere uprise;

2a. Calc-alkaline magmatism at 12-8 Ma in the northern part of the Tisia-Dacia microplate follows an important transcurrent fault and is entirely intrusive, ranging from basalts to rhyolites. Each body evolved independently with fractionation, crustal assimilation and/or magma mixing processes; decompression melting of the local heterogeneous mantle lithosphere is suggested. Sinistral transtensional stress regimes at 12-10 Ma controlled the generation and emplacement of the intrusive bodies that further were strongly uplifted and exposed by erosion.

2b. Normal and adakite-like calc-alkaline magmas were erupted in the Apuseni Mountains at 15-9 Ma. Lithosphere breakup during extreme westernmost Tisia rotations (~60 degree) was responsible for extension with core-complex formation. This led to decompression melting of an enriched heterogeneous lithospheric source. Volcanism ended with small volume Na-alkalic basalts (2.5 Ma), K-alkalic (1.6 Ma) and ultrapotassic (1.3 Ma) magmas. Inversion tectonics along the South Transylvanian fault triggered melt generation via decompression melting of diverse lithospheric and asthenospheric sources;

2c. Calc-alkaline Călimani-Gurghiu-North Harghita volcanic chain occurred at 10-3.9 Ma along the easternmost margin of Tisia-Dacia with a southward diminishing age and volume. Magma generation was associated with progressive break-off of the slab and asthenosphere uprise. Fractionation and crustal assimilation were typical;

2d. At ca. 3 Ma, magma changed in South Harghita to adakite-like calc-alkaline until recent times (< 0.03 Ma) interrupted at 1.6-1.2 Ma by simultaneous generation of Na and K alkalic varieties in nearby areas, indicative of various sources and melting mechanism. Two main geodynamic events were responsible: (a) slab-pull and steepening, with opening of a tear-window in the Vrancea lithospheric block hanging into the asthenospheric mantle (forming adakite-like magmas) and (b) inversion tectonics along reactivated fault systems allowed decompression melting of various asthenospheric and lithospheric sources;

18-2 09:50 Prelevic, Dejan

POSTCOLLISIONAL MANTLE DYNAMICS OF AN OROGENIC LITHOSPHERE: LAMPROITIC MAFIC ROCKS FROM SW. ANATOLIA, TURKEY

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Several mantle-derived ultrapotassic occurrences of lamproitic affinity are exposed in southwestern Anatolia, mostly intruding the Menderes massif. Their origin was poorly understood, including the accurate timing of emplacement and their relation with the more voluminous shoshonitic volcanism that occur in the region. To elucidate these issues, the rocks from all lamproite occurrences have been dated using the Ar-Ar method on phlogopite, leucite, and glass, and are characterized using their mineral and whole rock major and trace element geochemistry, as well as their Pb, Sr, Nd and Hf isotopic compositions.

From north to south, the volcanism shows increasingly younger ages ranging between 20 and 4 Ma which are coeval with more voluminous shoshonitic, K-calk-alkaline and ultrapotassic volcanoes in the Simav-Selendi, Usak, Kirka, Koroglu, Afyon and Isparta-Golcuk areas. Sr, Nd, Pb and Hf initial isotopic compositions, together with major, trace and rare earth element analyses in whole rocks and Cpx phenocrysts, show that the southward decrease of the ages goes along with changes in geochemical composition, in particular with a decrease of $^{87}Sr/^{86}Sr$, $^{207}Pb/^{204}Pb$, Zr/Nb, Th/Nb, and an increase of $^{143}Nd/^{144}Nd$, $^{176}Hf/^{177}Hf$, $^{206}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$ and Ce/Pb, i.e., systematic changes from crust-like to convecting mantle-like signatures. In contrast, K_2O abundance remains relatively invariable around 7%.

The SW Anatolian volcanism suggests that magma genesis is controlled by postcollisional extensional events initiated after major lithospheric thickening. It can be explained in terms of the P-T relationships of mineral stabilities, mantle solidi and geothermal gradients. The geochemical constraints suggest that the SW Anatolian mantle dynamics underwent complex multistage processes:

i) The first episode leeds to ultra-depletion of the mantle and subsequent metasomatic enrichment, which enabled the coupling of ultradepleted harzburgite with crust-derived sediments. We think this happened during the final stages of southern Neotethyan ocean closure and accretion of forearc oceanic lithosphere as shallowly subducted material to already assembled Anatolia.

(ii) The second episode is related with postcollisional tectonics, most probably with the collapse of the orogenic belt and extension originating horst-graben structures. Our data suggest polybaric partial melting of the phlogopite-bearing harzburgitic lithospheric mantle. Geochemical resemblance of the lamproites with more voluminous coeval magmas implies that the shoshonitic and ultrapotassic volcanic rocks are derived from mantle that had been affected by similar processes. The spatial and temporal variations in the isotopic signatures reflects the increasing contribution of the convecting mantle component in the younger volcanic rocks.

Our data are incorporated into a geodynamical model that explains the overall distribution of volcanism in SW Anatolia, using lamproites as a proxy for mantle dynamics. During the Tertiary extensional tectonics, lithospheric mantle underwent intense astenospherization due to reaction to southward delamination and increase of intensity of lithosphere-asthenosphere interaction. These mantle processes are tightly associated with the major Menderes uplift episodes. Our petrogenetic model has implications for the melt generation and interaction between sublithospheric mantle and the SCLM.

18-3 10:10 Catlos, Elizabeth

LINKING MICROCRACKS WITH MINERAL ZONING OF DETACHMENT-EXHUMED GRANITES TO THEIR TECTONOMAGMATIC HISTORY: EVIDENCE FROM THE SALIHLI AND TURGUTLU PLUTONS IN WESTERN TURKEY (MENDERES MASSIF)

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Microcracks demonstrate the mechanical behavior of rocks, and can form under a variety of conditions, including thermal contraction during cooling, stress, and relaxation during uplift. Granitic plutons are ideal for microcracking and fracturing studies: they are common in continental crust, predominantly contain only a few key minerals, can be nearly chemically homogenous and structurally isotropic over large areas, and develop vein and crack systems related to their latest stages of cooling. Here we use microcracks to understand the structural evolution of two well-studied granitic plutons in the central Menderes Massif in western Turkey (Salihli and Turgutlu). Both plutons were likely generated in a volcanic arc and have been affected by compressional and extensional deformation. The granitic rocks of which this pluton consists show microcracks and other microtectonic features. We consider these features to be a physical library that records crack generation under submagmatic conditions, migration of the plutons through the crust and their fault-driven exhumation history. Microtectonic features in the rocks were identified using optical microscopy, high-resolution backscattered electron (BSE), secondary electron (SE) and cathodoluminescence (CL) imagery. To discover if mass transfer was accomodated by microcracks during deformation, X-ray element mapping was also employed. The combination of imaging techniques facilitates observation and interpretation of the rocks' microscale features.

Multiple generations of microcracks, some annealed, within the Salihli and Turgutlu granites provide evidence that the rocks experienced pulses of extension. Microcracks are thicker and more common in Ca-rich zones of plagioclase cores than rims, and the outermost rims of plagioclase are in general myrmekitic. Based on the differences in plagioclase zoning and crystal sizes, the Turgutlu and Salihli granite bodies may have been affected by magma mixing under varying chemical and thermal conditions. Many of plagioclase grains in the Salihli and Turgutlu granites show a range of zoning types (patchy, normal, reverse, oscillatory), grain sizes, and deformational features (microcrack types, microstructures) within a single thin section. Granites that show differences in plagioclase grain size and zoning types are likely the result of magma mixing, a process stated to be "ubiquitous" in arc magmas, but difficult to recognize in granitic assemblages, which undergo late magmatic and subsolidus modification of feldspar compositions and grain sizes.

After plagioclase and K-feldspar crystallized in the Salihli and Turgutlu granites, myrmekite formed at grain boundaries: this was likely facilitated by fluids. Myrmekite forms via exsolution or replacement, and is a common breakdown product of K-feldspar during retrograde metamorphism and metasomatism. In these plutons, myrmekite has partly consumed plagioclase. Changes of the wavelength of CL at grain boundaries and within microcracks in feldspar grains, and the presence of calcite in many of the samples testify to late stage mass transfer by fluids. Deep red CL indicates Fe^{3+} in albitic compositions and replacement of blue-CL in rims and regions of K-feldspar grains. The presence of calcite likely reflects CO_2-bearing fluids, which replace An-rich zones of magmatic plagioclase. Fluids enter plagioclase cores via microcracks and/or along twin surfaces. Late stage microcracks reflect brittle fracture. These are transgranular cracks that cut the entire fabric of the rock. However, some of these cracks are sealed with minerals like biotite, suggesting the presence of fluids as well at this stage.

We've targeted granitic assemblages to elaborate the understanding of the extensional dynamics and assembly of western Turkey. Models for Aegean extension in general center on subduction roll-back as a driving force for the exhumation of core complexes. How this process evolved through time is debated. Extension may have initiated in the Rhodope massif of northeastern Greece and southern Bulgaria and progressively transferred to the south towards the Kazdag, Cycladic, Menderes and Crete Massifs. Granitoid bodies are commonly found deformed within and/or cut by major detachments in many of these core complexes. The microstructures, especially microcracking and microveining, are key features of low-T deformation of the Turgutlu and Salihli plutons, and granitoid rocks elsewhere in the Aegean may have comparable records. Bulk geochemistry and dating techniques that rely on mineral separation mask the significant reworking of these rock types that show abundant tectonic features in their microstructures.

18-4 10:50 Tokcaer, Murat

VOLCANIC ROCKS FROM FOCA-KARABURUN AND AYVALIK-LESVOS GRABENS (WESTERN ANATOLIA) AND THEIR PETROGENIC-GEODYNAMIC SIGNIFICANCE (FOCA-KARABURUN VE AYVALIK-MIDILLI GRABENLERINDEKI (BATI ANADOLU) VOLKANIK KAYALAR VE ONLARIN PETROJENETIK-JEODINAMIK ÖNEMLERI)

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The Foça-Karaburun and Ayvalık-Lesvos grabens (western coast of Anatolia, Turkey) are two important NW−SE-trending extensional areas generated in response to the Early Miocene−Holocene extension of the Western Anatolian region, related to the opening of the 'unconventional' back-arc basin of the Aegean Sea. The abundance of geo-structural evidence and the occurrence of volcanic rocks representing all the stages of the Aegean-Western Anatolia volcanism render the Foça-Karaburun and Ayvalık-Lesvos Grabens key localities to exemplify the petrogenetic and geodynamic evolution of the area. In this context, the Foça-Karaburun and Ayvalık-Lesvos grabens, possibly formerly a single graben, formed along an original NE−SW-trending extension, later dissected by E−W-trending transtensional faults, are investigated to constrain the petrogenetic and geodynamic evolution of the whole Aegean region. Calcalkaline and shoshonitic volcanic rocks with scattered ultrapotassic-shoshonitic or lamproitic lavas and dykes represent the orogenic phase of the magmatic activity, while the younger K- and Na-rich alkaline basaltic rocks are the result of later magmatism characterized by an intraplate geochemical signature reflecting progressively decreasing subduction rates. While the tectonic lineaments and the structures of the study area allow the reconstruction of the tectonic evolution of Western Anatolia and Aegean Sea, the volcanic rocks from the different stages of Neogene volcanism within the two studied grabens and surrounding areas permit a precise record of the geochemical evolution of the magma sources.

18-5 11:10 Kadioglu, Yusuf Kagan

TEMPORAL RELATION OF KARAKAYA (ESKISEHIR) GRANITE WITHIN THE FELSIC INTRUSIVE ROCKS OF NW ANATOLIA: GEOLOGY AND PETROLOGY

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The granite and granodiorite of NW Anatolia are represented the Tertiary magmatic products of the Sakarya and Anatolide collision rock unit after the closure of Northern branch of Neotethyan ocean. These granitic rocks have medium K content, calcalkaline character and they plot on collision related volcanic arc granite area on the tectonic discrimination diagram.

Karakaya granite of NW Anatolia crops out at the eastern part of the region is differing from the other granitic rocks in the view of geology, petrography and geochemistry. Karakaya granite has holocrystalline granular texture and mainly composed of quartz, orthoclase, oligoclase, biotite, tourmaline, ± allanite, ± zirkon. Karakaya granite characterise by the presence of nepheline bearing enclaves as angular to sub angular in shape and ranging from 1 cm upto 50 cm in size. It has calkalkaline, high K content, schoshonitic magma nature and they plot on syn-collision granite area on the tectonic discrimination diagram.

ORG normalized elemental patterns of Karakaya granite reveal that they are enriched in LREE (Rb, K, Ba, Th) with respect to HFSE (Zr, Hf, Sm,Y). LREE contents show a clear enrichment with respect to HREE. Geology, petrography and geochemical features of Karakaya granite reveal a partial melting of crustal components with a mantle signature nature.

18-6 11:30 Agostini, Samuele

SUBDUCTION-RELATED AND INTRAPLATE-TYPE VOLCANISM IN CENTRAL ANATOLIA: AN OVERVIEW

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In Central Anatolia Neogene volcanic rocks largely outcrop. In the region enclosed among Ankara, Konya, Adana and Sivas, large ignimbrite sheets (reported often as Kapadokyan Ignimbrites) and continental sedimentary rocks are found intercalated with lava flows, stratovolcanoes, volcanic domes and plateau lavas.

Some of these products have calc-alkaline affinity and the typical geochemical characters of subduction-related rocks, whereas some others are alkaline, strongly SiO_2-undersaturated and reveal an intraplate-type mantle source.

Calc-alkaline basalt, andesites and dacites are mainly found between Nevşehir and Niğde, around Kayseri and in the volcanic edifices of the two big stratovolcanoes of the region, the Hasan Dağ and the Ercyies Dağ, whereas basanites and alkali basalts occur as monogenetic cones in Karapınar, as eccentric monogenetic cones north-west of Hasan Dağ and as plateau lavas to the north-west of Nevşehir, south of Sivas, and west of Sivas, around the town of Şarkışla.

The occurrence of subduction-related and intraplate-type volcanic products in the same region is a common feature with surrounding areas in Aegean-Anatolian region. However, Central Anatolian lavas and pyroclastics have some peculiarities. Indeed, these two kind of lavas may be found in the same area, but have usually different time distribution: for instance in Western Anatolia, Central Aegean and Thrace calc-alkaline products are remarkably older than alkali basalts. Here, calc-alkaline basaltic to rhyolitic rocks and alkaline lavas (basanites, tephrites and alkali basalts) mostly have the same age (2-0 Ma) and sometimes are closely space-time related, especially in the northern portion of Hasan Dağ volcano, and around the city of Nevşehir. Moreover, alkali basaltic plateau lavas are sometimes remarkably older than calk-alkaline lavas and ignimbrites, as those around Şarkışla, dated by K-Ar method at 15.7-14.0 Ma ago, and those south of Sivas, which gave ages of 5.1-4.8 Ma ago.

In addition, mantle sources of subduction-related and intraplate-type lavas are easily distinguished by their Sr and Nd isotope ratios in Central-Eastern Mediterranean region: alkali basalts usually have $^{87}Sr/^{86}Sr$ around 0.7030-0.7035 and calc-alkaline and shoshonitic rocks show distinctly higher values, with $^{87}Sr/^{86}Sr$ varying from ≈0.7050 to ≈0.7080. Once again, in Central Anatolian volcanic products this sharp distinction is totally lacking, because both alkaline rocks (basalts and basanites), and calc-alkaline ones (basalts, andesites and dacites) vary in a quite small range of $^{87}Sr/^{86}Sr$ (0.7035-0.7055).

The different volcanism of Western and Central Anatolia may be linked with the different tectonic setting of the two regions: extension in Western Anatolia in a backarc position with respect to the Aegean subduction at Crete trench, and compression in Central Anatolia in the backarc of Cyprus arc subduction system.

18-7 11:50 Boztuğ, Durmuş

TRACE ELEMENT AND SR-ND-PB- ISOTOPIC CONSTRAINTS ON THE GENESIS OF CRETACEOUS GRANITOIDS IN CENTRAL ANATOLIA, TURKEY

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There are numerous late Cretaceous (Cenomanian-Turonian to Campanian-Maastrictian) granitoids derived from protracted magmatism, generated in a post-obductional extension-related geodynamic setting. This extensional regime followed a continent-intra-oceanic island arc collision in central Anatolia in the Cenomanian, during the Neo-Tethyan evolution of Turkey. Textural and whole-rock geochemical data indicate that the central Anatolian granitoids (CAG) consist of (1) high-K, calc-alkaline, peraluminous, S-type, biotite- or two-mica leucogranite association, (2) high-K, calc-alkaline, metaluminous, I-type, quartz monzonitic-granodioritic association, and (3) high-K, alkaline, metaluminous, A-type, bi-modal, monzonitic-syenitic association. The S-type, calk-alkaline leucogranitic association was formed from purely crustal-derived felsic magmas. The I-type, calc-alkaline quartz monzonitic-granodioritic association was derived from a high-K, metaluminous, hybrid magma source, generated by mixing of coeval mantle and crustal derived melts. These rocks show imprints of subduction zone metasomatism with respect to trace and REE geochemical composition. The A-type, alkaline, bi-modal monzonitic-syenitic association has the same characteristics as I-type granites in terms of trace element geochemical composition. Radiogenic (Sr-Nd-Pb) isotope geochemistry data reveal an apparent crustal origin for the S-type granites, while a lithospheric mantle involvement appears likely for the genesis of hybrid magma sources of the I- and A-type granites. The mantle material was accreted into the collision zone as tectonic slices during the continent-oceanic island arc collision. During the post-collisional extensional regime, these mantle slices were remelted to give rise to the mafic magma source in the genesis of hybrid magmas.

18-8 12:10 Imer, Ali

GEOLOGY, GEOCHEMISTRY, AND GEOCHRONOLOGY OF THE ÇÖPLER PORPHYRY-EPITHERMAL GOLD DEPOSIT, CENTRAL EASTERN TURKEY

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The Çöpler deposit is located about 120 km west of the city of Erzincan in central eastern Turkey, and it consists of a subeconomic porphyry-type Cu-Au mineralization overlain by paragenetically later low-sulfidation epithermal-style Au mineralization. The porphyry-epithermal mineralization is spatially related to middle Eocene intrusive rocks, which have been emplaced into a succession of Permian-Cretaceous metasedimentary and carbonate rocks within an ENE-WSW-trending structural window exposed in the northeastern part of the Tauride-Anatolide orogenic block.

The intrusive suite at Çöpler consists of different phases of diorite porphyry which contain phenocrysts of plagioclase and hornblende ± biotite, set in a groundmass of quartz and plagioclase. Major and trace element data suggest an I-type calc-alkaline magmatic affinity for the diorite porphyries with strong resemblance to magmatic rocks formed in continental arc settings.

$^{40}Ar/^{39}Ar$ dating of fresh hornblende and biotite phenocrysts from diorite porphyries yielded ages between 43.75 ± 0.26 Ma and 44.13 ± 0.38 Ma. $^{40}Ar/^{39}Ar$ ages of hydrothermal biotite (43.84 ± 0.26 Ma) and sericite (44.44 ± 0.28 Ma), combined with Re-Os ages from two molybdenite samples (43.9 ± 0.2 Ma and 44.6 ± 0.2 Ma) reveal that the copper-gold mineralizing hydrothermal system was coeval with magmatism. The short life span (≤1 m.y.) of the magmatic-hydrothermal events at Çöpler is consistent with age relationships at similarly-sized porphyry-epithermal systems globally.

Although weakly developed, the porphyry-style mineralization at Çöpler displays characteristic alteration patterns of classical porphyry Cu systems, with a central zone of potassic alteration surrounded by successive zones of phyllic and propylitic alteration. Early potassic alteration is mainly developed in the intrusive rocks, and is characterized by the presence of secondary biotite, and lesser amounts of K-feldspar, and magnetite in close association with quartz ± magnetite ± chalcopyrite ± pyrite ± molybdenite veins, whereas phyllic alteration is characterized by an assemblage of sericite-quartz ± pyrite, and is commonly associated with quartz ± pyrite veinlets.

Superimposed epithermal-style mineralization, on the other hand, is mainly localized in zones of carbonate alteration, and occurs either as carbonate-sulfide veinlets or as manto-type replacement bodies of sulfides along the basal contact of the overlying Munzur limestone. In epithermal assemblages, gold appears to be mainly in solid solution within arsenical pyrite, which is accompanied by lesser arsenopyrite, chalcopyrite, tennantite/tetrahedrite, galena, sphalerite, realgar, and orpiment. Supergene oxidation of the sulfide mineralization following uplift and unroofing of the Çöpler window was critical for the formation of high grade and easily processed gold mineralization at Çöpler.

New geochemical and geochronological data presented in this study demonstrate that the intrusive rocks at Çöpler were formed through remelting of previously subduction-modified lower crustal sources, following Cretaceous arc magmatism and Paleocene continent-continent collision along the northern Neo-Tethys suture in Anatolia. Thus, the Çöpler deposit may belong to the recently recognized group of postsubduction porphyry and epithermal deposits, which tend to be relatively Au-rich compared to their arc-related counterparts.

SESSION NO. 19, 09:30

Tuesday, 5 October 2010

Mélanges and mélange–forming processes. Part 1 (*Melanjlar ve melanj olusturan mekanizmalar*)

METU Convention and Cultural Centre, Salon A

19-1 09:30 Cloos, Mark

MELANGES AT CONVERGENT PLATE MARGINS: THE FRANCISCAN COMPLEX OF CALIFORNIA

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Melanges are mapable bodies of fragmented and mixed blocks in a matrix. Melanges with a matrix of shale or serpentinite are commonly associated with subduction zone settings and of debated origin. Processes proposed include chaotic sedimentary mass flows (olistostromal), tectonic faulting and/or flowage, and diapirism. The most problematic melanges are the extensive shale-matrix terranes found in California, Alaska, Japan, and Indonesia. These mixed terranes are very poorly exposed where weakly lithified. The California example, the Central

Belt of the Franciscan Complex, is especially noted for the inclusion of "exotic" blocks of garnet-bearing blueschist and rare eclogite. Field relationships, best seen in coastal exposures near San Simeon, reveal ductile flowage was concentrated in the shale matrix with all block types displaying gradations of pinch-and-swell to complete separation into elliptical boudins. There is a remarkable dichotomy in grain-scale deformation mechanisms operative during boudinaging. Masses of graywacke distorted primarily by particulate flow. Clastic quartz grains float in a clay-sized groundmass generated from the destruction of lithic and feldspar grains. In striking contrast, mafic greenstone and blueschist distorted via intense cataclasis concentrated along the block margins and along small shear zones that penetrate into the interiors. These microtextures indicate most of the deformation occurred while the graywacke blocks and shale matrix were essentially unlithified: fluid contents were high (20%±) and fluid pressures were at or very near lithostatic values. Concurrent with boudinaging, the mafic blocks were altering to low-temperature (<150°C) mineral assemblages. The formation of the Franciscan melange belt and similar terranes is best explained as due to tectonically-driven flowage and upwelling of thick piles of shale-rich sediment along the top of subduction channel shear zones. The distinctive microtextures would be obliterated with heating to temperatures above about 250°C. It is likely that some, and perhaps many, schist terranes containing lenticular masses of various lithologies were once Franciscan-like melanges metamorphosed during subduction-terminating collisional tectonism.

19-2 09:50 Festa, Andrea

MELANGE AND MELANGE-FORMING PROCESSES: CASE STUDIES FROM THE APENNINES, APPALACHIANS AND NEW ZEALAND

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Mélange-forming processes (tectonic, sedimentary, and diapiric) commonly operate in tandem and locally synchronously in various discrete tectonic settings, but rarely in isolation. They are linked through complex and mutual interactions and occur in partial superposition. In the geological record of mélanges we commonly observe the artifacts of the last and/or more pervasive process as the best-preserved evidence. In most cases, the latter is consistent with tectonics, although few examples in which sedimentary or diapiric processes have also been described in the literature.

We present here a comparative analysis of on-land examples of mélanges and tectonic environments where mélange-forming processes are currently operating. Main types of deformational mode leading to mélange formation include extensional, strike-slip, convergent margin/collisional tectonics, and intra-continental deformation. We discuss: (1) possible relationships between various mélange types and their tectonic setting of formation; (2) contribution of mass-transport versus contractional deformation processes at the onset of mélange formation, and (3) nature of the "continuum" and transition from broken formations to true tectonic mélanges.

Mélange formation commonly develops through the interaction and/or overlapping of several mechanisms and processes acting during a "continuum" of stratal disruption. This phenomenon defines a broad spectrum of products, represented by two end-members consisting of undeformed stratigraphic successions and block-in-matrix bodies. Different sedimentary, tectonic, and diapiric mélange types developed in this "continuum" of deformation conceptually represent discrete evolutionary stages of stratal disruption processes constrained by the geodynamic setting of their formation, state of consolidation of the original coherent succession/metamorphic degree, rheological contrast between component layers, strain rate, shallow vs. deeper deformational mechanisms. We show that some notable examples, mainly from the Apennines (Italy), Ordovician Taconic belt in Eastern USA, and Hikurangi margin in New Zealand, display clear structural evidence for the operation of different mélange-forming processes and mechanisms at different scales and in different tectonic settings during their formation. These processes appear to have interacted with each other and reworked in turn their products, leading to the genesis of several types of mélanges recognizable in other orogenic belts.

19-3 10:10 Pini, Gian Andrea

OLISTOSTROMES, MASS-TRANSPORT DEPOSITS AND THE ORIGIN OF MÉLANGES

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The terms olistostrome and olistoliths have been introduced by G. Flores (4th World Petroleum Congress, 1955, Rome) to respectively indicate 1) sedimentary bodies with a chaotic block-in-matrix fabric intercalated between layered sequences in the Tertiary succession of Sicily and 2) the individual masses included in the matrix. Both terms soon became extensively used by the international geological community worldwide. With the extended usage, they evolved to generally indicate stratally disrupted to chaotic complexes and "exotic" bed packages, which originated by mass-transport events. Olistostromes are, therefore, part of the more general category of mass-transport deposits (MTD). In their extended meaning, they are complex bodies, often involving the entire spectra of mass-transport processes.

Mass transport processes lead to stratal disruption up to block-in-matrix fabric and the complete chaoticization of sediments. They are also a powerful tool for mixing of rocks of different ages, state of consolidation, diagenetic and metamorphic degrees, and provenance. Because of this, en-mass transport is theoretically considered as the sedimentary end-member of melange-forming processes.

Mass transport deposits (MTD), often named to as olistostromes, have been recursively proposed as consistent part of mélanges worldwide, even if strongly deformed by post-depositional, tectonic and/or mud-diapiric processes. These interpretations have been, however, often sustained by general considerations on regional geology and tectonic setting and not by studies on the mélange structures and fabric. Moreover, the mechanisms of internal deformation and stratal disruption, and the origin of the matrix in MTD are not completely defined so far. The mechanism and structures related to the post-sedimentary reactivation of MTD are still not completely clear, as well as their rheological behaviour and the relationship with fluid overpressure.

Moreover, in the sedimentary record of collisional chains, the majority of fossil MTD, including olistostromes, originated during the stages of intracontinental deformation, having been deposited in foreland and wedge-top basins. In some cases, collisional orogeny has allowed MTD related to extensional tectonics and passive margin to become exposed. This contrasts with the observed abundance of present-day MTD, which prevail in passive and divergent margins and along the flanks of volcanic islands. The present-day submerged contractional margins, however, do not show a significantly high concentration of MTD, apart from the erosional margins off the coasts of Peru. Basin-wide MTD are only present when catastrophic events occur, as in the case of the subduction of seamounts and volcanoes. This also contrasts with the suggested possibility that several mélanges in fossil accretionary wedge originated as MTD.

There are more, possibly concomitant, explanations to these discrepancies: 1) the method of investigation might prevent the imaging of geometrically complicated MTD in present-day submerged active margins; 2) the large scale MTD originated in the passive margins completely lack of preservation because of the intense tectonic reworking during the stages of subduction, collision and intracontinental deformation, and, 3) the MTD originated in passive margins and accretionary wedges are still present in the geological record of collisional chains, but their presence has been disregarded so far.

A complete and integrated sedimentological study of the "olistostromes" can: 1) add a wider spectra of internal structures and flow mechanisms to the sedimentological knowledge of mass-transport processes, 2) give a benchmark for sedimentary-related, melange-forming processes, 3) might help in explaining the discrepancies about the present-day vs. fossil MTD distribution.

19-4 10:50 Federico, Laura

DEVELOPMENT OF TECTONIC MÉLANGES DURING SUBDUCTION AND EXHUMATION PROCESSES: CASE-STUDY FROM THE LIGURIAN ALPS (ITALY)

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Mélanges are mappable chaotic bodies of mixed rocks, with different ages and origin, embedded in an argillitic, sandy, or ophiolitic matrix. Their development in the context of subduction zones have been recognized in different convergent settings all over the world (e.g. Wilson et al., 1989; Froitzheim, 2001; Federico et al., 2007), and many different mechanisms may be involved in mélange formation in a subduction zone, e.g. tectonic erosion, diapirism, underplating, etc.

Recent numerical models (e.g. Gerya et al., 2002; Stöckhert and Gerya, 2005) actually predict the development of a mixing zone between the subducting and the overriding plates in a convergent margin. The growth of this "subduction channel" (that can be interpreted as a "mega-mélange") is controlled by the progressive hydration (and consequent serpentinization) of the mantle wedge; widening of the subduction channel results in the onset of forced return flow. A tectonic intermingling of fragments of the previously subducted crust, hydrated upper mantle slices and lower crustal rocks of the upper plate is therefore envisaged. The size of these fragments is a function of the viscosity contrast between the coherent slices and the serpentinite matrix; the model predictions include an array of diverse P-T paths for subduction-related metamorphic complexes.

In our study we focus on the High-Pressure (HP) metaophiolites of the Ligurian-Piemontese units of the Ligurian Alps (Western Alps). Such units are known in literature as Voltri Massif, that encompasses blueschist and eclogite facies rocks: we discuss the interpretation of the Voltri Massif as a kilometre-scale tectonic mélange developed in a subduction channel.

In the Voltri Massif two decametre-scale tectonic mélanges occur and have been studied (Vissers et al., 2001; Federico et al., 2007). The first mélange is hosted in country serpentinites and encloses blocks of various types of metabasites and metasediments, not occurring in the surrounding Voltri Massif. The mélange matrix is a chlorite-actinolite schist, produced by blackwall reactions between serpentinites and enclosed blocks. The blocks equilibrated under different peak metamorphic conditions and record different segments of a typical subduction P-T path, with peak conditions ranging from eclogite- to garnet-blueschist-facies and prograde lawsonite-blueschist-facies assemblages. The matrix is widely retrogressed in greenschist facies, but it contains rare relics of Na-amphibole. Both structural evidences and P-T paths of the different blocks suggest coupling between blocks and matrix in the blueschist facies. By $^{39}Ar/^{40}Ar$ dating on phengite (Federico et al., 2007), one eclogitic metasediment records peak equilibration at 43.2 ± 0.5 Ma; two metabasites record blueschist equilibration at 39.95 ± 0.37 Ma and at 43.4 ± 0.5 Ma, respectively. These results are interpreted as diachronic metamorphic trajectories resulting from independent tectonic evolution of the different slices inside a subduction channel.

The second mélange zone have similar lithologic and structural features (Vissers et al., 2001) and can be interpreted in the same way.

As the eastern sector of the Voltri Massif is made of blueschist and eclogite facies metabasites and metasediments dismembered and enclosed in serpentinites, our question is: is it possible to extend this interpretation to a larger scale, i.e. to the whole eastern Voltri Massif?

This option is currently being tested through structural and petrologic investigations combined with a numerical modeling approach (Malatesta et al., 2010 and this congress). Such hypothesis predicts that the Voltri Massif originated in the subduction channel developed during Alpine subduction and was subsequently exhumed when subduction was still active or later on during continental collision and/or transpressional tectonics. To check this option we discuss geochronological data presently available for the Voltri Massif, together with petrographic and structural constraints.

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19-5 11:10 Pandolfi, Luca

A RECORD OF FRONTAL TECTONIC EROSION IN A FOSSIL ACCRETIONARY WEDGE: THE EXAMPLE OF THE BOCCO SHALE MÉLANGE, INTERNAL LIGURIDE OPHIOLITIC SEQUENCE (NORTHERN APENNINE, ITALY)

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In the Northern Apennines (Italy), the Internal Liguride units are characterized by an ophiolite sequence that represents the stratigraphic base of a Late Jurassic-Early Paleocene sedimentary cover. The Bocco Shale represents the youngest deposit recognized in the sedimentary cover of the ophiolite sequence. The deposits belonging to the Bocco Shale can be subdivided into two different groups of deep sea sediments. The first group is represented by slide, debris flow and high density turbidity current-derived deposits, whereas the second group consists thin bedded turbidites. Facies analysis and provenance studies indicate, for the former group, small and scarcely evoluted flows that rework an oceanic lithosphere and its sedimentary cover.

According to their overall features, the Bocco Shale can be interpreted as an ancient example of a deposit related to the frontal tectonic erosion of an accretionary wedge. The frontal tectonic erosion was probably connected with subduction of oceanic crust characterized by extensive topographic reliefs. The topographic reliefs were probably originated by reactivation of former Jurassic faults during the bending of the oceanic lithosphere as it was approaching the trench. The frontal tectonic erosion resulted in a large removal of material from the accretionary wedge front reworked as debris flows and slide deposits, i.e. the Bocco Shale, directly sedimentated on the faulted lower plate.

The occurrence of debris flow- and slide-derived deposits at the top of the ophiolite sedimentary cover is a common feature of the oceanic units from Apennine, Corsica and Western Alps. We propose for all of these deposits an origin related to frontal tectonic erosion, that represented a common process during the convergence-related evolution of the Ligure-Piemontese oceanic basin in the Late Cretaceous-Early Tertiary time span.

19-6 11:30 Perotti, Elena

SEDIMENTOLOGICAL AND GEOCHEMICAL FEATURES OF CHAOTIC DEPOSITS IN THE VENTIMIGLIA FLYSCH (ROYA-ARGENTINA VALLEY- NW ITALY)

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The Ventimiglia Flysch is a Upper Eocene-Lower Oligocene turbidite succession deposited in the SE part of the Alpine foreland basin, truncated at the top by the basal thrust of the *Helminthoides* Flysch, a Ligurian tectonic unit that presently covers part of the Dauphinois and Briançonnais successions of Western Ligurian Alps.

The Ventimiglia Flysch is made of alternations of sandstones and shales. The upper part is characterized by chaotic deposits showing the classic block-in-matrix fabric. These deposits are constituted by:

- hm-sized intraformational blocks (i.e. portions of Ventimiglia Flysch slid down);
- hm-sized extraformational blocks (i.e. portions of Cretaceous sediments of the Dauphinois Domain, and portions of sediments of the Alpine foreland basin such as Nummulite Limestone);
- km to hm-sized exotic blocks (portions of succession derived from other tectono-stratigraphic units, i.e *Helminthoides* Flysch).

The matrix of the larger blocks is made up of conglomerates with block-in-matrix fabric interpreted as debris flow deposits.

Debris flow clasts show:

- different sizes, ranging from metre to centimetre;
- different shapes, from rounded to subangular;
- different lithologies referred to Ventimiglia Flysch, Nummulite Limestone, *Globigerina* Marl and *Helminthoides* Flysch alike the larger blocks of the chaotic complex.

The clasts of debris flow deposits are disposed randomly into a chaotic matrix that consists of a dark mudstone in which submillimetre- to millimetre-sized lithic grains, with the same compositions of larger clasts, are present. Locally the matrix consists of sandstones with quartz and feldspar grains and fragments of nummulitids that suggest reworking of unlithified Eocene sediments.

Cathodoluminescence observations allow the distinction of two kinds of clasts: clasts with the same orange luminescence as the matrix that may be interpreted as soft mud clasts that were cemented together with the matrix, and dull-luminescing clasts that underwent a cementation before the formation of conglomerates.

Debris flow deposits are cross-cut by a network of crumpled and broken veins, 10's mm to cm-large, filled with orange luminescing calcite and locally with quartz. Their complex cross-cutting relationships with clasts and matrix show that several systems of veins are present, that may be referred to different fracturing events.

Some clasts are crossed or bordered by veins that end at the edge of the clasts. These veins show the same features as those that crosscut the whole rock. This indicates reworking of plastic sediments crossed by calcite-filled veins by mass gravity flows. Polyphase debris flow processes, proceeding along with fluid expulsion and veining, are thus documented.

Ellipsoidal, dm-large concretions also occur in chaotic deposits. Stable O and C isotope analyses, performed also on matrix, clasts and veins, show:

- $\delta^{13}C$ close to normal marine values (-3 to 0 $\delta^{13}C$ ‰ PDB)
- $\delta^{18}O$ markedly negative (-9 to –7 $\delta^{18}O$ ‰ PDB) that could be related to precipitation from relatively hot waters (60-70 ° C).

Concretions consist of cemented pelites without block-in-matrix fabric: this aspect indicates that they are not the result of early cementation of chaotic deposits. Similar lithological features and absence of biostratigraphically significant fossils make difficult to ascribe these concretions to Ventimiglia Flysch or *Helminthoides* Flysch. In both cases these concretions document a phase of concretionary growth within homogenous pelites caused by an upward flow of relatively hot waters and subsequent involvement in the mass gravity flow.

The block-in-matrix fabric and the variable composition and size of blocks show that these sediments are a sedimentary mélange related to mass wasting processes involving both extrabasinal and intrabasinal sediments. These gravitational movements took place along slopes of submarine tectonic ridges created by transpressional faults (Piana et al., 2009) that juxtaposed tectonic slices of different paleogeographic domains (Dauphinois, Briançonnais, Ligurian Units) in Late Eocene-Early Oligocene times, and involved both rock fall processes of huge blocks of lithified, older formations, and debris flows of unlithified intrabasinal sediment. Faults also acted as conduits for an upward flow of hot fluids supersaturated in calcium carbonate. These fluids reached shallow buried sediments where caused a localized concretionary cementation and formation of vein swarms within unlithified sediments prone to subsequent mass wasting.

19-7 11:50 Alonso, Juan Luis

PROCESSES OF STRATAL DISRUPTION IN THE PORMA MELANGE: SOURCE AND SIGNIFICANCE OF THE "NATIVE" AND "EXOTIC" BLOCKS

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The Porma Mélange is a formation up to 1,5 km thick, underlying a nappe stack and overlying a flysch formation, in the Variscan foreland of the Iberian Peninsula. It is an apparently chaotic mixture of shales and scattered blocks of harder sedimentary rocks. The blocks are extremely diverse in size, from centimetric to kilometric size, and derive from formations ranging in age from Cambrian to Upper Carboniferous.

The Porma Mélange is composed of two different types of rock bodies. Most of the Porma Mélange (shaly matrix and "native" blocks) is a highly deformed, boudinaged sequence of Upper Carboniferous age, with extension values over 300%. This sequence includes scattered "exotic" blocks, up to kilometric size, with a range of ages from Lower Cambrian to Lower Carboniferous. The different structural features of the Porma Mélange can be explained in terms of the degree of sediment lithification during slumping of a submarine orogenic front. The Porma Mélange is regarded as the result of stacking of submarine landslides (boudinaged sequence) intercalated with individual slid blocks (exotic).

The boudinaged sequence is the result of bed-parallel extension in two perpendicular directions giving rise to a chocolate tablet structure. The almost complete parallelism between the bedding of equant and elongate boudins suggest a coaxial strain path with the XY plane nearly parallel to the bedding. In the matrix, a bedding-parallel scale cleavage evidences layer-perpendicular shortening**.** The source of this boudinaged sequence was a synorogenic shallow marine succession located at the upper part of the highest nappe. These semilithified sediments underwent gravitational spreading during slumping. In the lower part of the boudinaged sequences narrow non-coaxial shear zones have been found, experiencing the highest shear strains, which support the gravitational sliding. The fact that these non-coaxial shear zones have different transport directions is consistent with the flattening strain in the upper part of the sequence.

The Porma Mélange also contains scattered "exotic" blocks with a range of ages from Lower Cambrian to Lower Carboniferous. These blocks came into the basin as individual slip blocks from competent well-lithified formations, originally located at the lower part of the nappe stack, with higher shear resistance and unable to spread. Thus, the significance of the "native" and "exotic" blocks in the Porma Mélange is explained in terms of suitability for slumping in the front of the moving nappes. The larger amount of Pennsylvanian rocks (boudinaged sequence) in the Porma Mélange, as compared to the older preorogenic rocks, can be attributed to the different degree of lithification of the materials located at the nappe toe and potentially collapsible by gravitational forces. Collapse at the nappe toe should be favoured where sediments were incompletely lithified, giving rise to the greater volume of slumped deposits.

The internal structure and size of the mélange blocks may also be related to the degree of lithification of the rocks, since it depends on their age and composition. Greywacke-shale boudins rarely exceed metric scale and display soft-sediment faults in their litharenitic bases that disappear and pass to ductile deformation in the shaly upper part of the beds. Limestone-marl multilayer boudins reach up to hectometric size. Limestone boudins show lesser internal deformation than wacke boudins; their internal faults, if there are any, are in general widely spaced and cut across the whole boudin without noticeable displacement changes recording a more brittle behavior. This different behavior may be attributed to faster lithification of limestone compared with sandstone. Pre-Carboniferous preorogenic sequences provide the biggest blocks, irrespective of whether the rocks are siliciclastic or carbonatic, due to the fact that both of them were well lithified. These blocks are composed, in some cases, of two or more formations and may display kilometric size.

Statistical distribution of blocks ages in the Porma Basin, where blocks are progressively older in the nappe transport sense, suggests early collapse of the upper part of the nappe pile and progressive unroofing through subsequent submarine slides. At an early stage of sliding, Pennsylvanian series were the main source of the Porma Mélange; the pre-Carboniferous succession played an increasingly important role as source of the blocks at later stages.

19-8 12:10 De Souza, Stéphane

THE MÉLANGE – OPHIOLITE CONUNDRUM: INSIGHTS FROM IAPETAN AND TETHYAN OPHIOLITES, CANADA AND ALBANIA

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The association of mélanges with ophiolites has long been recognized from orogenic belts worldwide. The Albanian Mirdita zone and the southern Québec ophiolite belt present such an association, and are here used to study orogenic processes leading to mélange formation. The Mirdita ophiolite is located in the Dinaro-Hellenic fold belt and forms a flat-lying, 4000km2 nappe comprising Tethyan oceanic lithosphere that has been obducted onto Adria (Schmid et al., 2008) and/or a Pelagonian microcontinent (Dilek et al., 2007). The southern Québec ophiolites are rather discontinuously exposed along a linear belt extending for 100's of km in the Québec Appalachians (Tremblay & Castonguay, 2002), and form a composite slab of Iapetan oceanic lithosphere typically represented by the Thetford-Mines ophiolite (TMO).

The age of the TMO is ca. 480Ma (U/Pb on zircon), and its metamorphic sole rocks yield amphibole and muscovite, high-temperature ^{40}Ar-^{39}Ar ages clustering between 471 and 466Ma. The sedimentary sequence overlying the ophiolite belongs to the Saint-Daniel Mélange, and shows an apparent maximum thickness of 3 km. The Saint-Daniel Mélange unconformably overlies crustal rocks and mantle peridotite of the TMO, and locally, the infraophiolitic metamorphic sole as well. The base of the Saint-Daniel is therefore interpreted as an erosional unconformity, which is marked by a ca. 500m-thick discontinuous unit made up of mudstone, chert, sedimentary breccias, debris flows and mélanges. The breccias and mélanges contain fragments of ophiolitic lithologies and micaschists dispersed in an argillaceous to sandy matrix. Well-bedded to strongly disrupted horizons of pebbly mudstone, quartz-rich sandstone and green-to-black argilite constitute the upper part of the Mélange. The lower age limit of the Saint-Daniel is constrained by muscovite ^{40}Ar-^{39}Ar ages of 464-463Ma from micaschist fragments.

U/Pb zircon ages on the Mirdita ophiolite vary between 160 and 165Ma, whereas its metamorphic sole rocks, which are part of the Rubik-Peripheral complex, yield ^{40}Ar-^{39}Ar ages of 171 to 162Ma (Dilek et al, 2007). The sedimentary cover of the ophiolite is distributed in a series of small basins (ca. 20 km^2) that commonly overlie the basaltic volcanic rocks. The base of the sedimentary sequence is locally marked by Late Triassic to Middle Jurassic radiolarian cherts, that are overlain by Middle to Late Jurassic conglomerates and mélanges grading into calcareous-siliciclastic Late Jurassic – Early Cretaceous turbiditic flysch (Bortolotti et al., 2005 & Gawlick et al., 2007). The mélanges and conglomerates comprise various types of ophiolitic and sedimentary rock fragments that consist of ophiolitic gabbro, basalt, peridotite and serpentinite, as well as continent-derived sandstone, chert, volcanics, carbonates and metamorphic sole-like rocks which can be reconciled with those exposed in the Rubik-Peripheral complex. In the Blinisht area, the mélange consists of limestone, sandstone, chert and ophiolite-derived fragments dispersed in a crudly stratified, scaly argillaceous matrix. The mélange grades into a broken formation that consists of turbiditic cherty mudstone and argilite showing slump fold structures, which indicate sliding on an east-facing slope, away from the inferred obduction front and towards the center of the basin. A small basin (1km-wide) located south of Rreshen was also investigated; the base of the supraophiolitic cover sequence is there marked by conglomerate made up of ophiolitic debris embedded in a mafic matrix. This conglomerate grades into mafic lithic greywacke and quartz-rich turbiditic flysch.

In summary, the supraophiolitic cover sequence of the Mirdita ophiolite is characterized, from base to top, by a transition from sedimentary mélanges and conglomerates, to broken formations and well-bedded flysch that were obviously formed in tectonically-active basins. As in southern Québec, Albanian mélanges appear to be derived from the erosion of the underlying ophiolitic and infraophiolitic nappes. It is suggested that the uplifting of a syncollisional (accretionary) ridge during obduction and final emplacement of the ophiolites, led to the unroofing of ophiolitic and underlying continental rocks, and to the formation of mélanges and broken formations due to mass wasting and synsedimentary sliding onto the advancing ophiolite nappe. The increasing input of calcareous/siliciclastic material in both sedimentary sequences suggests the progressive stabilization of the sedimentary basins as obduction proceeded. Supraophiolitic mélanges of southern Québec and Albania are thus interpreted as syncollisional piggy-back basins that formed within ca. 5 to 10Ma during obduction.

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SESSION NO. 20, 08:30

Tuesday, 5 October 2010

Crustal motions, mantle dynamics & GPS velocities in continental collision. Posters (*Kitasal çarpismalarda kabuk hareketleri, manto dinamigi ve GPS hiz dalgalanmalari*)

METU Convention and Cultural Centre, Exhibition Hall

20-1 BTH 1 Sobouti, Farhad

CRUSTAL STRUCTURE IN NORTHWEST IRAN FROM RECEIVER FUNCTION STUDIES

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We have determined the lateral variations of crustal structure in northwest Iran from a receiver function analysis of a temporary seismic network. The network is an array of 11 broadband stations on a 200 km east-west line that run from the western Caspian coast in the west towards the interior of NW Iran, roughly along the N38 parallel. The eastern end of the line covers the Talesh Mountains along the coast of the south Caspian basin. The aim of the study is to determine the moho depth variations, as well as shallower crustal discontinuities, in the region. The receiver functions (RF) were calculated in time domain by iterative deconvolution. A bandpass filter of 0.05 -0.8 Hz was applied before calculating the RFs. The width of the Gaussian filter used in time domain was 0.4. We migrated the RFs from time domain to depth domain. We did this by two schemes; the common midpoint (CMP) stacking, and the common conversion point (CCP) migration. The results show a gently eastward-sloping moho in the western part of the profile. In the western end, the moho is about 42 km deep. The moho deepens to about 50 km just in the west of the Talesh Mountains. Under the Talesh the situation is more complicated. There, an abrupt jump in moho to a depth of 28 km is observed. Furthermore, the moho under the Talesh has a steeper dip. It is believed that the Talesh Mountains are being thrust over the south Caspian from the west. Geophysical evidence also show that the Caspian crust is much thinner than its surrounding regions, and the Caspian coast line is a zone of transition in crustal thickness. For those stations situated in Talesh we observe some dependence of the receiver functions on back-azimuth. This can be suggestive of dipping discontinuities in, or at the base of the crust.

20-2 BTH 2 Taymaz, Tuncay

CRUSTAL STRUCTURE OF TURKEY FROM RECEIVER FUNCTIONS AND AMBIENT NOISE TOMOGRAPHY

VANACORE, Elizabeth[1], SAYGIN, Erdinc[1], TAYMAZ, Tuncay[2], and CUBUK, Yesim[3], (1) Australian National University, Research School of Earth Sciences, Building 61 Mills Rd, Canberra, ACT 0200, Australia, elizabeth.vanacore@anu.edu.au, (2) Department of Geophysics, Istanbul Technical University, The Faculty of Mines - Maslak, Istanbul, 34469, Turkey, taymaz@itu.edu.tr, (3) Department of Geophysics, Istanbul Technical University, The Faculty Of Mines - E308 - Maslak, Istanbul, 34469, Turkey

Here we present preliminary results detailing the crustal structure of Turkey from a combination of receiver function and ambient seismic noise tomography analysis. We use over 250 3-component broadband stations from permanent and temporary networks in Turkey and surrounding regions to image structure in Turkey from a combination of receiver function and ambient seismic noise tomography from crust to upper-mantle.

Receiver functions for teleseismic events during period between 2008 and 2010 have been calculated using frequency domain deconvolution. Using the methodology of Niu and James (2002), the receiver functions are analyzed to joint solve for Vp/Vs ratio and Moho conversion depth. The resulting maps show a highly variable Moho with depths ranging between ~35 km and 58 km depth as well as a variable but generally high average Vp/Vs ratio with median values closer to 1.8 rather than 1.73.

Rayleigh and Love wave group velocities extracted from the cross-correlations of ambient seismic noise are used in a nonlinear iterative tomographic inversion. Then the velocity models from the tomographic inversions are used in a joint inversion to create the Moho depth map of the region. We combine the receiver function results with results from ambient noise tomography to generate a comprehensive interpretation of the Moho and crustal structure of Turkey.

The results mark the complex structure of the region. The seismic images from western Turkey show low velocities possibly linked to the elevated temperatures or fluid content. The images for central Turkey show low velocities for shallow depths but seismic velocity increases with depth; this also coincides with the geothermal potential of the region. The complex wavespeed images for eastern Turkey marks the effects of the ongoing geological processes such as the active collision of Anatolian block and Arabian plate.

20-3 BTH 3 Ozacar, A. Arda

CRUST AND UPPER MANTLE DYNAMICS OF TURKEY INFERRED FROM PASSIVE SEISMOLOGY: IMPLICATIONS OF SEGMENTED SLAB GEOMETRY

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Turkey lies within the Alpine–Himalayan orogenic belt and is shaped by continent-continent collision in the east, slab rollback and back arc extension in the west and westward extrusion of Anatolian plate in between. In this study, passive seismic data are used to analyze the crust and upper mantle structure of the region to test different tectonic models proposed for Turkey and its surrounding.

In Eastern Turkey, continent-continent collision resulted in a topographic high, the East Anatolian Plateau which exhibits a widespread Neogene volcanism. The plateau is characterized by lack of subcrustal earthquakes and predominantly strike-slip crustal seismicity suggesting that the collision is accommodated by tectonic escape. Receiver functions indicate thin crust and lithosphere across the plateau that is inconsistent with a simple Airy compensational mechanism and an anomalously high Vp/Vs corridor along the North Anatolian Fault and near the youngest volcanic units supporting the presence of partial melt in the crust. Tomographic images of upper mantle reveal anomalously slow upper mantle velocities where slab-like fast-velocity anomalies only visible at or below mantle transition zone and support the slab detachment and emplacement of the hot asthenosphere. The western limit of this slab window located most likely along the palaeotectonic Inner-Tauride Suture in central Turkey where sharp mantle transitions are visible.

Across Anatolian plate and Aegean Sea, the most prominent upper mantle structures are related to the northward subducting African oceanic lithosphere. New tomographic results clearly indicate segmented slab geometry beneath Anatolia and these segments define Cyprus and Aegean slabs separated by a left-lateral tear that is occupied by slow upper mantle velocities. The Aegean slab which defines a roughly northward-concave configuration has its eastern termination at the north part of the Pliny and Strabo transforms. The Cyprus slab terminates at the tip of the Isparta Angle in the west and near the gulf of Iskenderun in the east. The lateral continuity of the Cyprus slab is also disrupted by a minor right lateral tear at shallow depths aligning with the Paphos transform fault west of the Cyprus Island. Low seismic activity along the Cyprus trench and the sub-vertical down-dip segmented slab geometry suggest a stagnant Cyprus slab that might have started to detach. We believe presence of continuous cold Cyprus slab underneath the Central Anatolia has a shielding effect on the region and provides important contribution to the relatively undeformed crustal characteristics of this province.

Tomographic images show that the lateral extent of the tear spans nearly the entire width of the Western Anatolia and the trends of the upwelling hot asthenosphere are located directly below late Miocene to Quaternary alkaline Kirka-Afyon-Isparta and Kula volcanic fields. Based on the resolved configuration of slab segments, we favor a STEP model for the segmentation and hence tear formation between the Aegean and the Cyprus slabs. The generation of this STEP geometry is probably related with differential retreat rates between the Cyprus and the Aegean trenches that initiated when a locally thicker continental fragment of African margin, similar to the Eratosthenes Seamount further west, entered in to the Cyprus trench and obstructed the subduction beneath the Isparta Angle.

SESSION NO. 21, 08:30

Tuesday, 5 October 2010

Magmatism in evolving orogens: Collision to extension. Posters Part 2 (*Aktif orojenik kusaklarda magmatizmanin evrimi: Çarpisma tektoniginden gerilmeli tektonige gidis*)

METU Convention and Cultural Centre, Exhibition Hall

21-1 BTH 4 Azimzadeh, Zohreh

MAGMATIC ORIGIN AND TECTONIC SETTING OF THE TERTIARY MAGMATIC ROCKS FROM NORTHWEST OF AHAR- NW IRAN (ORUMIEH-DOKHTAR BELT)

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Ahar area occurs in the Tertiary magmatic Orumieh-Dokhtar belt. The Cenozoic volcanic, volcaniclastic and plutonic rocks produced after the closure of Neotethyan Ocean between Arabia and Central Iran in upper Cretaceous. The Eocene extrusive rocks intruded in Cretaceous sedimentary rocks. Their composition is andesite, trachyandesite, dacite, trachydacite, rhyolite, porphyritic diorite and porphyritic monzodiorite. Upper- Eocene volcaniclastic rocks are breccia and agglomerate. The intrusive rocks intruded volcanic and volcaniclastic rocks in Oligocene. These rocks are consist of monzogranite, granodiorite, monzonite, syenogranite, diorite. The rocks with such composition with spatial and temporal similarities have spreaded in the Orumieh- Dokhtar belt. All types of rock's composition are similar and value of SiO_2 is different from 50% to 70% which shows diffraction processes in initial magma. According to the geochemical diagrams, this area's tectonic environment in Eocene-Oligocene is determined as continental arc setting, thus this area's magmatism is interlocked to Neotethyan post-collision activities. According to mineralogy and geochemistry studies, all of area's magmatic rocks have been derived from unit mantle-derived magma that probably has formed in more than 100 kilometers depths due to partial melting of upper mantle and geochemical diagrams certifies it. The formed magma as the time of rising experience fractional crystallization, magmatic mixing and contamination in crust. Petrography evidences, field observations and geochemistry diagrams affirm magma mixing and contamination processes. Plutonic rocks show sub-solvus, hybrid, cordileriate I type granitoids properties and volcanic rocks have high- K orogenic andesites properties. The enrichment of Th in spider diagrams and high value of K can be related to mantle metasomatism source and increasing the ratio of Y/Ti shows diffraction and mixing processes between initial magma and high Y acidic magma. Depletion in compatible elements is related to magma contamination with crustal rocks. Magmatic series of different types of rocks in the Ahar area is determined alkaline but they seldom shows high-K calc-alkaline and shoshonit properties too that is related to mixing and contamination processes.

21-2 BTH 5 Ünal, Ezgi

HIGH SULFIDATION EPITHERMAL DEPOSITS: A CASE STUDY FROM NW TURKEY, BIGA PENINSULA

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Kartaldağ gold mine, operated by ancient Troy is located to the southeast of Çanakkale city (Biga Peninsula, Turkey). A historic open pit with dimensions of about 200 m long, 10 m wide, 20 m deep, and several galleries with maximum depth of nearly 300 m are all controlled by regional ESE – WNW normal faults. The epithermal system and associated alterations are hosted by dacite porphyry with a hornblende Ar-Ar age of 42.19 ± 0.45 Ma. This age is likely to fall into the age interval during which post-collisional Eocene magmatism was pronounced in the Biga Peninsula. Wall rock alterations observed within the Kartaldağ epithermal system are propylitic, argillic, and silicic alterations. Propylitic alteration refers to assemblage of albite, chlorite-smectite mixed layer, epidote, illite, α-quartz ± calcite. The XRD and SEM/EDX analysis revealed that argillic alteration comprises two spatially distinct mineral paragenesis consisting predominantly of quartz-kaoline and pyrophyllite-alunite-quartz assemblages. The silicification occurs mainly as massive silicification of the dacite porphyry with vuggy quartz centered to the main argillic alteration of Kartaldağ epithermal system.

The assemblage of quartz-kaoline, that could also be referred to as a probable sub-zone in the argillic alteration is characterized by the kaoline (dominantly kaolinite), illite, pyrite, α-quartz ± chlorite. Pyrophyllite-alunite-quartz sub-zone is also termed as the advanced argillic alteration assemblage, and is accompanied by pyrite, covellite and sphalerite. Massive silicification is composed of fine to medium grained quartz crystals displaying mostly vuggy quartz textures typical for the high sulfidation epithermal systems. Euhedral pseudomorphs of the parental grains such as plagioclase and hornblende minerals appear to form the vugs during pervasive leaching of the dacite porphyry. Based on relative cross-cutting relationships of quartz textures, dacitic host rock is noticed to have experienced two phases of silicification as early and late silicification. The textural characteristics of the quartz crystals formed at each phase is different such that early silicification exhibits the vuggy quartz texture with fine grained quartz crystals, whereas late phase silicification is characterized by colloform, banded, zoned, and coarse-

medium grained quartz crystals, and occurs as an overprint on the vuggy quartz. Oxygen isotope analysis performed for the early and late silicification phases separately yield $\delta^{18}O$ values of 7.93 and 8.33 per mil, and of 8.95 per mil, respectively. These successive silicification phases are likely to be formed by two boiling process throughout the hydrothermal evolution that formed the Kartaldağ deposit.

The advanced argillic alteration covers and/or envelopes the pervasively silicified zone (core of residual part of the system), and wall rock alteration can be traced from propylitic at the margins to massive silicification at the center of the mineralized system. This may be in lines of evidence that fluid (ore bearing) was channel through a single conduit close to or within the massive-vuggy quartz zone. The temporal and spatial association of alterations, zoning patterns, predominant clay mineral compositions being pyrophyllite, kaolinite and alunite, vuggy quartz texture, and covellite, pyrite, sphalerite ore minerals can be taken as the key parameters supportive of an argument that the Kartaldağ epithermal gold mineralization is formed by a low pH-oxidizing fluid and classified as high sulfidation type epithermal system.

21-3 BTH 6 Simmonds, Vartan

PETROLOGIC AND PETROGENETIC STUDY OF KIGHAL PORPHYRY STOCK (NORTH OF VARZEGHAN, EAST AZARBAIDJAN PROVINCE, NW IRAN)

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Quartz-monzonite porphyry stock at Kighal is located in ~12 km north of Varzeghan, East Azarbaidjan Province, NW Iran. It has intruded older volcanic units during magmatic activities of Pyrenean orogenic phase and produced Cu-Mo mineralization and hydrothermal alteration zones (potassic, phyllic, argillic, advanced argillic, propylitic and later supergene leached zones) in the region. After its emplacement, numerous cross-cutting dikes, ranging in composition from diorite through quartz diorite, granodiorite, microdiorite and monzodiorite have intruded into porphyry stock. In oxide-oxide (Harker) diagrams, all of the samples analyzed from dykes and porphyry stock show single trends, suggesting a common source for their parental magma and occurrence of mineralogical variations in these dyke suits, proportional to their temporal order of intrusion, in a manner that the first generation dykes (Dk1a) are more felsic and toward to Dk1b and Dk1c, MID and MZD dyke suits, the composition gradually becomes more basic and the silica content decreases. The REE patterns of cross-cutting dykes and porphyry stock in spider diagrams are also similar, which confirm the existence of a common source for their parental magma and occurrence of differentiation in the magma chamber. Additionally, based on chemical analyzes, it has been distinguished that different rock types of this complex have high-K calc-alkaline to shoshonitic nature, and have emplaced in a post-collisional volcanic arc and active continental margin setting. The investigation of geochemical characteristics of these rocks indicates the interference and influence of fluids derived from subducting slab in the evolution of parental magma.

21-4 BTH 7 Maghsoudi, Meysam

STRUCTURAL INVESTIGATION IN SOUTHEAST OF THE BATLAQ-E-GAVKHUNI (CENTRAL IRAN), WITH SPECIAL TO MINERALIZATION OF THE REGION

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The study area is situated southeast of Gavkhuni, west of the Yazd province. The main lithological units of the region are Eocene to Miocene volcanic rocks, although Cretaceous limestone and sandstone and Quaternary deposits are also present in the study area. Geographical position, lithological properties and structural trend indicate that this area is situated in the Orumieh-Dokhtar belt, which is an island arc consisting of Eocene to Quaternary rocks. The Dehshir fault is a major tectonic structure with neotectonic activity in the eastern part of the area. Satellite data processing and field observations show that the Dehshir fault and the Khottab fault in the western part of the area make an 18-km wide dextral shear zone with NW-SE trend. In this regard, compressive structures such as folds and thrust faults also trend NW-SE. Riedel and anti-Riedel fractures form angles of 30° and 70°, respectively, with the Dehshir and Khottab faults in SE of Gavkhuni. The study shows that the Sefidkuh-Khaybar tectonic zone is a major Riedel fracture, and several granitic intrusives are present in this zone. Intrusive activity in Eocene period caused Cu, Zn, Au, Ag and Ba mineralizations with associated propylitic, argillic and silication alterations. It is concluded from the study that the Gavkhuni area is a dextral shear zone and within the Riedel fractures there are indications of mineralization. The results of study suggest that the Sefidkuh-Khaybar zone is tectonically fractured and is potentially-mineralized. The mineralization is associated with acidic volcano-sedimentary and intrusive rocks. Based on the geotectonic setting of the area, the suite of host rocks, alteration and mineralographical studies, mineralization in the Sefidkuh-Khaybar area is categorized as massive sulfide.

21-5 BTH 8 Hadj Mohamed, Nacera

MINERALISATIONS DU HORST DE GHAR ROUBAN (ALGERIE OCCIDENTALE)

HADJ MOHAMED, Nacera, EAU , Environment &Geosciences, Sciences de la Nature et de la Terre, 24, cité des 7 Martyrs n Boumedfa, Ain Defla 44245 Algeria, hadj_nacera@yahoo.fr

Le horst de ghar Rouban fait partie des hauts plateaux dans cette region affleure un paleozoique constitué de schistes , quartzites plissées et metamorphisés au cours de l'Hercynien, et intrudés par un magmatisme composé de granites et cortège filonien: pegmatites, filons de quartz, greisens et tourmaline.la couverture est essntiellement jurassique representée par des calcaires massifs et des dolomies formant des falaises.

La tectonique a structuré la region en horsts et grabens. en consideraaant l'encaissant , la mineralisation peut etre groupée en :

1- filons de quartz de direction N145 , encaissés dans les granites rose et gris, à arsenopyrite et or?

2- filons de barytine encaissés dans les granites

3- filons de barytine encaissés dans les calcaires liasiques

21-6 BTH 9 Abdelhak Boutaleb, A.B.

PRELIMANARY PETROGRAPHIC AND MICROTHERMOMETRIC STUDIES OF THE DOLOMITES AND SPHALERITE MINERALIZATION OF EL ABED ZN – PB DEPOSIT – TLEMCEN – NORTH WESTERN ALGERIA

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El Abed is the eastern part of a broad "Touissit - Boubaker - El Abed: where the two first are in the Morocco territory" district that cover more than 30 kilometers from East to West. This deposit can be attached to large deposits so called "Mississippi Valley Type" or MVT. The deposit is located on the North Western part of Algeria at 70 km southwest of Tlemcen. The mineralization includes "stratabound" and fills of karstic internal sediment. It occurs in Aaleno-Bajocian dolomites. The paragenesis is simple with galena, sphalerite, marcasite, pyrite and chalcopyrite. Gangue minerals are dolomites of different generations, quartz, kaolinite and organic matter. Epigenetic sulphide mineralization occurs as open-space cavity fills and local replacement of internal sediments in carbonate strata. We are particularly interested to study the dolomitization which is exclusively associated to mineralization in "stratabound". Diagenetic dolomites consist to replecment of old calcarenites (allochemes ghost). Greyish dolomite is early, because it is represented by the DI dolomicrite and the DII or zebra dolomite, DIII or dolosparite is replaced by the DIV (dissolution re precipitation phase). Epigenetic Dolomites are represented by the white dolomite which has precipitated in fractures or in vugs DV / DVI. The mineralization is dominant sphalérite with incidentally of the Galena. The preliminary study of primary fluid inclusions of DV and DIV dolomites as well as the sphalerites suggested that the ore fluids that are hot brines (100 to 160°C).

The migration of brines from sedimentary basin transporting metals leached from basement rocks which encountered are trapped in Aaleno-Bajocian dolomites at Oligo-Miocene compression. The structural control and widespread dissolution suggest that the brines were acid and that they were transported into the basin along fractures without much interaction with the carbonate host rock.

21-7 BTH 10 Salehian, Mosayeb

FLUID INCLUSION EVOLUTION AT DARALU PORPHYRY COPPER DEPOSIT, SOUTHEAST IRAN

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Daralu porphyry copper deposit is located 130 km south of Kerman, southeast Iran and lies in southern part of Urumieh–Dokhtar magmatic arc. The deposit is associated with granodioritic intrusive of Oligo-Miocene age which intruded Eocene volcano-sedimentary rocks. The Daralu stock emplacement in several pulses as well as copper mineralization was accompanied by both potassic and silicic-phyllic alterations. Four types of hypogene alteration are developed in the Daralu deposit: potassic, propylitic, argillic and silicic-phyllic. Hydrothermal mineralization studies within the Daralu deposit show four types of hydrothermal mineralization: (1) hypogene; (2) supergene; (3) oxidized and leached; (4) gossan. Three principal types of vein mineralization have been identified: Type I which is characterized by quartz, chalcopyrite, magnetite and pyrite with minor bornite and molybdenite; Type II contains chalcopyrite (as the main copper mineral in the Daralu deposit), pyrite and quartz, with traces of molybdenite; and Type III consisting of quartz and pyrite, with minor chalcopyrite.

Four types of fluid inclusions are present in quartz veins associated with the Daralu deposit: (1) mono-phase vapor, (2) liquid + vapor, (3) vapor + liquid and (4) multi-phase solid. Halite and hematite are the principal solid phases. Fluid inclusion data at Daralu showed that the two-phase liquid-rich fluid inclusions represent lower homogenization temperatures between 127 and 293ºC and low to moderate salinity (1.05 to 12.07 wt. % NaCl equivalent). The two-phase vapour-rich fluid inclusions demonstrate homogenization temperatures from 476 to 486 ºC and moderate salinity (average 21.55 wt. % NaCl equivalent). The multi-phase solid inclusions exhibit moderate to high homogenization temperatures ranging from 231 to >510 ºC and moderate to high salinity (30.4 to 59.66 wt. % NaCl equivalent). The coexistence of vapor-rich two-phase and multi-phase solid inclusions suggests that these fluid inclusions resulted from trapping of boiling fluids. Salinity–homogenization temperature relationships indicate two groups of fluids with early hydrothermal fluids represented by high temperature and high salinity interpreted to have caused potassic alteration and low temperature and low salinity fluids typical of silicic-phyllic alteration.

TUESDAY

21-8 BTH 11 Shahbazi, Somayeh

COPPER, OXYGEN AND SULFUR STABLE ISOTOPE EVIDENCE FROM BASHKAND IRON DEPOSIT, NORTHWEST IRAN

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Bashkand iron skarn deposit is a magnetite-rich skarn occurrence, hosted by Late Proterozoic Kahar Formation in contact-metamorphic aureole of 53.39 ± 0.29 Ma Khorram Darreh tectonized subvolcanic microgranite, southeast of Zanjan in northwestern part of Central Iran structural zone. The mineralizing fluids were probably channelled along foliation planes of meta-dolostone, phyllite and metatuff horizons and possibly along auxiliary faults that are mostly parallel to lothologic contacts.

There are three stages of mineralization: 1) Contact metamorphic occurrence (submicroscopic) including vesuvianite, magnesioferrite, garnet and pyroxene without opaque minerals; 2) Anhydrate bands of silicate skarn zone with a very low width (submicroscopic up to two centimeters) including andradite, diopside and fine disseminated magnetite, metatuff and metasiltstone; 3) Retrograde silicate skarn. The mineralization is dominated by epidote, serpentine (clinochrysotile), talc, garnet and diopside. Mineralization at stages 2 and 3 shows banded structure. The quartz-carbonate veins cut all these stages, carrying some magnetite and pyrite. Major oxides distribution patterns in igneous rocks in the surroundings of the deposit suggest that they were formed in a volcanic arc environment.

Both copper stable isotope data (from chalcopyrite) and sulfur stable isotope data (from pyrite and chalcopyrite) in the exoskarn zone are consistent with a magmatic source for Cu and S. However, oxygen stable isotope data from epidote, magnetite and quartz-carbonate veins in the exoskarn zone imply mixing of magmatic and meteoric sources for O.

21-9 BTH 12 Pickard, Megan

GEOCHEMICAL INSIGHTS INTO MANTLE FLOW BENEATH THE ANATOLIAN PLATE

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Anatolia is a natural laboratory for studying and identifying complex geodynamic processes between continental lithosphere, convecting asthenosphere and subducting slabs. New topographic, tomographic and geochemical studies enable an integrated picture of both regional and small-scale geodynamic interactions in space and time. The complex tectonics of the Anatolian microplate are generally well constrained. The African and Arabian plates currently push Anatolia against the relatively stable Eurasian plate, resulting in WSW-directed 'escape tectonism' over the past 12 Ma that is accommodated by three bounding fault systems: 1) the Aegean-Cyprean arc, 2) the dextral North Anatolian Fault Zone, and 3) the sinistral East Anatolian Fault Zone. There is strong geophysical evidence for slab rollback in Western Anatolia and slab detachment in Eastern Anatolia (e.g. Le Pichon & Angelier 1981; Bozkurt 2001; Keskin 2003; engör et al. 2003); beneath Central Anatolia new tomographic evidence suggests a tear in the slab (Biryol et al. 2009). To gain better insight into the interaction between downgoing slabs and the upwelling mantle in these three environments, we use observed differences in the geochemical signatures of primitive mafic lavas to place constraints on the timing and pathways of mantle flow associated with slab rollback, slab detachment and tear(s) in the downgoing African slab. Late Miocene-Quaternary mafic volcanism throughout

Anatolia preserves the signatures of multiple distinct source regions for basalt genesis. The relative abundances of key incompatible trace elements coupled with new radiogenic isotopic Sr, Nd, Pb and Hf data indicate variable mixing between asthenospheric mantle and other source domains within the lithosphere, including subduction-modified mantle. Specifically, Sr-Nd isotopic values measured on Late Miocene-Quaternary primitive basalts from Western, Central and Eastern Anatolia converge on a common asthenospheric source component that is compositionally similar to the shallow mantle underlying mid-ocean ridges worldwide. The asthenospheric component is not observed in Mid Miocene and earlier volcanism indicating a significant temporal change in available sources. Local involvement of the other source domains produces a unique composition for each volcano and each region of Anatolia. Systematical geographical source variations are clearly observed in Pliocene-Quaternary basalts from the Central Anatolian Fault Zone. Karapinar, the southernmost volcano, displays the most enriched trace element contents (Ba/Nb = 25-50, Th/La = 0.2-0.04; Alici Şen et al., 2004). Sivas, the northernmost volcano, has the most primitive mafic lavas (Ba/Nb = 9-20, Th/La = 0.1-0.25; this study); their trace element compositions require a substantial asthenospheric component. Within Central Anatolia, negative Nb-Ta anomalies, characteristic of subduction-related lavas, decrease from south to north accompanied by decreasing Ba/Nb and Th/La ratios. Isotopic variations within Central Anatolia show similar patterns. Sr-Nd isotopic values are more radiogenic in Karapinar basalts ($^{143}Nd/^{144}Nd$ = 0.51260-0.51265; Alici en et al., 2004) than in contemporaneous Sivas lavas ($^{143}Nd/^{144}Nd$ = 0.51257-0.51280; this study). Interestingly, both Karapinar and Sivas have enriched Pb isotopic compositions ($^{206}Pb/^{204}Pb>18.5$, $^{208}Pb/^{207}Pb>38.5$, $^{207}Pb/^{204}Pb>15.6$) that suggest contribution from a recycled oceanic sediment source component, presumably related to subduction of the African plate. Apparent mixing trends between enriched and depleted source compositions observed in all Anatolian mafic lavas indicate a dynamic interaction between the continental lithosphere, the convecting upper mantle and the subducting slab(s). In particular, the geochemical signature seen in the Sivas basalts requires a contribution from upwelling asthenospheric mantle placing important constraints on the nature of mantle flow around subducting slabs in Anatolia.

21-10 BTH 13 Dönmez, Mustafa

STRATIGRAPHY AND NEW AGE FINDINGS IN THE VOLCANIC ROCKS AROUND, ÇUBUK (ANKARA)-TURKEY

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In the region, Triassic rocks which are concerned as Karakaya komplex of Sakarya Continent, Upper Cretaceous Dereköy Ophiolitic melange and Karadag formation consisting flysch type deposits of Ýzmir-Ankara-Erzincan zone and Tertiary volcanic and sedimentary cover rocks take place.The relation of the rocks of both groups is tectonic and the rocks belonging to Sakarya Continent overthrusted the rocks of Ýzmir-Ankara-Erzincan Zone. The main subject of the study is the Tertiary volcanic rocks which are unconformable/cutting the rocks of both groups. The oldest volcanic rocks of the Çubuk area are Paleocene-Early Eocene Sarýkoz volcanite consisting dacite and graniteporphyry. The radiometric age taken from Sarýkoz volcanite by K/Ar method gives the value of 56.4 ± 2.4 Ma which corresponds to late Paleocene-Early Eocene. Sarýkoz volcanite is overlain by Middle Eocene Kurtsivrisi, Sele, Ömercik, Susuz and Yukarýemirler volcanites respectively. Kurtsivrisi volcanite consisting of andesite, trackyandesite and dacite overlies Sarýkoz volcanite unconformably. The radiometric age taken from Kurtsivrisi volcanite by K/Ar method gives the value of 44.5 ± 1.7 Ma. which corresponds to Middle Eocene (Lutetian). Andesitic Sele volcanite cuts Sarýkoz and Kurtsivrisi volcanite. The radiometric age taken from Sele volcanite by K/Ar method gives 44.8 ± 1.7 and 44.3 ± 1.9 Ma which corresponds to Middle Eocene (Lutetian). Ömercik volcanite consisting basaltic lava and pyroclastic overlies Sele volcanite and is cut by Susuz volcanite consisting rhyolites and dacites. The radiometric age taken from Susuz volcanite by K/Ar method gives 43.1 ± Ma corresponding to Middle Eocene (Lutetian). Therefore, Ömercik volcanite which was active between Sele and Susuz volcanite is Middle Eocene in age. The last Eocene volcanism in the region is the basaltic Yukarýemirler volcanite which cuts Susuz volcanite and flows on it. The radiometric age taken from Yukarýemirler volcanite by K/Ar method gives 43.1 ± 1.7 Ma corresponding to Middle Eocene.The volcanites of the region are alcaline and calcalcaline in character. They have different compositions and characteristics indicating bimodal volcanism. The volcanic activity in the Çubuk region ends with Early Miocene Aydos basalt. The age taken from Aydos basalt by K/Ar methods gives 18.4 ± 0.7 Ma corresponding to Early Miocene.

21-11 BTH 14 Gülmez, Fatma

THE MISSING PART OF NW ANATOLIA OLIGO-MIOCENE VOLCANIC BELT: ALMACIK MOUNTAIN, NEW K-AR AGE AND ISOTOPIC AND GEOCHEMICAL DATA

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The new radiometric age data reveal that the presence of Oligo-Miocene volcanic rocks in Almacýk Mountain similar with Armutlu Peninsula volcanic associations were first reported by Genc et al (2004) and Kürkçüoglu et al (2008). We present new Sr, Nd and Pb isotope data together with the geochemical data and K-Ar age (23.8±1.1) data for Oligo-Miocene volcanic rocks from the Almacik Mountain.

The Oligo-Miocene aged basaltic andesitic lavas comprised mainly of plg (An30-45) + cpx ± opx ± opaque minerals, display calc-alkaline affinity and Medium-K character. Evaluation of Mg # (41.6-45.2), Cr (20.5-34.2 ppm), Ni (0.9-30.6 ppm) and MgO contents (2.02-3.14 %) together, it may be claimed that these lavas are the products of evolved melts. Significant enrichments in LILE coupled with Nb-Ta and Ti depletions on N-MORB normalized diagrams and LREE enrichments (La/Sm: 2.9-4.3) with slightly HREE depletions (Gd/Yb: 1.5-1.7) with respect to the MREE's on Chondrite-normalized multi-element diagrams may also imply that the subduction component and crustal contamination processes had played an important role in the evolution of magma.

Although $^{87}Sr/^{86}Sr_{(i)}$ (0.704918 - 0.705561) and $^{143}Nd/^{144}Nd_{(i)}$ (0.512567- 0.512706) contents of the Oligo-Miocene lavas are comparable to the Bulk Earth and Mantle Array compositions, their Pb ($^{206}Pb/^{204}Pb$: 18.701, $^{207}Pb/^{204}Pb$: 15.621, $^{208}Pb/^{204}Pb$: 38.722), O ($\delta^{18}O$ SMOW: 10.9) isotope values and $eNd_{(i)}$ contents (-0.89 in a sample and range from 0.96 to 1.84 in the other samples), implying that the Oligo-Miocene volcanics were derived from a heterogeneous source which was generated by interaction of continental crust and depleted mantle. Subduction signatures of the Oligo-Miocene volcanics may be inherited from the previous subduction event(s).

Based on our evaluation for the geochemical and isotopic data collectively, we argue that partial melting of the subcontinental lithospheric mantle and variable amount of crustal materials contamination were the main processes for the evolution of the magma that produced the volcanic association of Almacik Mountain, during Oligo-Miocene time.

Considering the geochemical features and isotopic contents of Armutlu-Almacýk region Oligo-Miocene volcanism, we have concluded that it may be the central part of the coeval volcanic belt extend from the Thrace basin and Biga peninsula in the west to Galatian complex in the east.

21-12 BTH 15 Siebel, Wolfgang

SR-ND-PB ISOTOPIC AND AGE CONSTRAINTS ON THE ORIGIN OF LAVAS FROM THE ACIGOEL COMPLEX, NEVSEHIR, CENTRAL TURKEY

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The Acigöl Volcanic Complex is a major late Quaternary rhyolitic centre within the Volcanic Province of Cappadocia in central Anatolia where paroxysmal silicic eruptions resulted in the formation of a caldera, c. 6 km in diameter[1]. The Late Pleistocene evolution of the Acigöl complex initiated with the eruption of pre-caldera Lower Acigöl Tuff and associated rhyolite lavas (Group I: Boğazköy and Taşkesik), a major obsidian source in Turkey. This stage was followed by the caldera-forming eruption of the voluminous Upper Acigöl Tuff and of the coeval Kocadağ rhyolite dome (Group II). Late post-caldera magmatism comprises five rhyolitic domes (Group III) and maars within the caldera floor. The Acigöl caldera is bordered by Quaternary basaltic and andesitic lava flows and scoria cones that are inferred to post-date the rhyolite domes[1] and, altogether, form a typical bimodal magma suite attributed to partial fusion of the crust and input of melts from the mantle. Limited dating is mainly based on obsidian fission track ages that suggest eruption ages between ~190 ka and ~20 ka[2].

Here, we present strontium, neodymium, and lead isotopic data for silicic rocks within the Acigöl complex as well as for peripheral basalts. Aphyric rhyolite lava, tephra, and pumice (Group I-III rhyolites) define narrow ranges in $^{143}Nd/^{144}Nd$ isotope ratios (0.51257-0.51265, or $e_{Nd(t)}$ from –1.4 to +0.2), and show virtually no difference in Pb isotope composition ($^{206}Pb/^{204}Pb$: 18.87-18.88, $^{207}Pb/^{204}Pb$: 15.65-15.67 and $^{208}Pb/^{204}Pb$: 38.94-38.98). In terms of Sr isotopes, Group III rhyolites extend to markedly more radiogenic $^{87}Sr/^{86}Sr$ ratios (0.7065-0.7091) compared to those of Group I and II (0.7059-0.7065). Isotopic ratios correlate with indices of differentiation such as SiO_2, suggesting that Group I to III rhyolites are genetically closely related. More radiogenic Sr isotopic compositions in Group III rhyolites are intriguing as they could reflect isotopic heterogeneity in the crustal sources. Regional basement (Mesozoic granites) has by far too primitive Sr-Nd isotopic compositions for representing a possible protolith of the Acigöl lavas, and therefore more radiogenic source rock must abound at depth. Amongst the basaltic association, the most mafic sample (basalt lava flow) is characterised by $^{87}Sr/^{86}Sr$ = 0.7040, $^{143}Nd/^{144}Nd$ = 0.51280 ($e_{Nd(t)}$ +3.6), $^{206}Pb/^{204}Pb$ = 18.85, $^{207}Pb/^{204}Pb$ = 15.65, and $^{208}Pb/^{204}Pb$ = 38.90. These values suggest a moderately depleted signature for the mantle source. Intermediate compositions between basalt and rhyolite (Group I-III) imply mixing between mantle and crustally derived components. We are further investigating the temporal evolution of the Acigöl Volcanic Complex and the genetic relation between Group I-III rhyolites through detailed zircon geochronology using (U-Th)/He and U-Th disequilibrium methods.

[1]Druitt et al. (1995): J. geol. Soc. London **152**: 655-667

[2]Bigazzi et al. (1993): Bull. Volcanol. **55**: 588-595

21-13 BTH 16 Jacob, Lauren

CATHODOLUMINESENCE (CL) EVIDENCE FOR THE TECTONIC HISTORY OF THE EGRIGOZ PLUTON, NORTHERN MENDERES MASSIF, WESTERN TURKEY

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The Egrigoz pluton is a relatively well-studied pluton in the Northern Menderes Massif of western Turkey. Although much attention has focused on its geochemical and geochronological history, its relationship to major structures and other large plutons in the region are still debated. Some geologic maps show the Egrigoz pluton bounded by the low-angle Simav detachment fault. In contrast, other regional maps show no offsets between the Egrigoz pluton and surrounding metamorphic rocks or adjacent granites. Yet other studies indicate thrust faults may be present near the Egrigoz pluton, between Menderes metamorphic rocks and a meta-rhyolite unit. To gain a better understanding of the tectonic history of the Egrigoz pluton, cathodoluminesence (CL) images of samples from the granite and ArcGIS digital elevation data from the region were obtained to search for effects of micro- to macro-scales of deformation.

The Egrigoz pluton lies near the Alacam and Koyunoba plutons, within the Northern Menderes Massif, between the Simav graben and Afyon-Izmir-Ankara-Erzincan suture. Relief images of the Northern Menderes Massif were produced using 3 arc second (~90m) Shutter Radar Topographical Mission (SRTM) data. We observed numerous E-W trending lineations in the images that parallel the Simav graben and cut the plutons. These lineations may reflect large-scale extension. The Simav graben and its associated high-angle fault are evident in the SRTM data, but no other significant detachment-related basins or structures are shown, including the low-angle Simav detachment. The plutons lack noticeable elevation differences from surrounding areas.

The early Miocene Egrigoz pluton is speculated to have been emplaced syn-extensionally into Oligocene metamorphic rocks. However, reported mineral ages from the pluton range from Late Archean to early Miocene, with other ages between these extremes. The composition of the pluton ranges from calc-alkaline to shoshonitic and interpretations of the tectonic setting varies accordingly. Samples from the Egrigoz pluton plot within the Volcanic Arc Granite (VAG) field (Ozgenc and Ilbeyli, 2008; Ilbeyli and Kibici, 2009) or between VAG and syn-collisional granites (Akay, 2009) on the Rb-(Y+Nb) discriminant diagram. On the Nb-Y discrimination diagram, Egrigoz samples plot within the VAG and syn-collisional fields (Akay, 2009) or between within plate granite and VAG + syn-collisional granite fields (Ozgenc and Ilbeyli, 2008; Ilbeyli and Kibici, 2009). Samples from the granite are metaluminous or peraluminous (Ozgenc and Ilbeyli, 2008; Ilbeyli and Kibici, 2009) but others report only peraluminous rocks (Akay, 2009; Dilek et al., 2009). Both I-type and S-type granites have been reported from the pluton (Ozgenc and Ilbeyli, 2008; Dilek et al., 2009; Ilbeyli and Kibici, 2009).

To document microstructures that might help explain these heterogeneities, CL images were obtained from samples of the Egrigoz pluton. The pluton is comprised of Qtz + Pl + Kfs + Bt + Ms + Ap + Zr + Mnz + FeO + Rt + Ttn. Minerals that show CL in these rocks are predominantly Pl (brown/green) and Kfs (blue/red). Blue-CL is patchy in Kfs grains, consistent with fluid alteration. Some Pl grains show distinct color differences between the cores and rims, indicating either igneous zoning during magmatic evolution, or in some cases, response to late-stage fluids. Many plagioclase grains show significant alteration along outer rims. The CL images also show a range of microcrack and microvein types that cut grains and presumably allowed fluid-access during alteration. Many Pl grains appear to have been in part replaced by Kfs, a common feature of low-T alteration in plutons. The CL images constitute evidence of a complex, multi-stage tectonic history for the region that includes water-mediated brittle deformation.

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21-14 BTH 17 Akçay, Ali Ekber

THE STRATIGRAPHY OF YAMADAG VOLCANIC COMPLEX BETWEEN YESILKALE AND BEKTAS NEW K/AR AGE FINDINGS

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This study comprises the stratigraphy of Yamadag volcanic complex between Yesilkale and Bektas villages and the ages taken from this area. In the investigated area, the Late Oligocene – Late Miocene lavas having compositions varying from basalt to dacite and vertical-lateral transitional pyroclastic rocks are considered as Yamadag Group. Yamadag Group consists Delibayirtepe volcanite, Elmaçati volcanite, Besiktepe volcanite, Agcahüyüktepe volcanite, Göldagi volcanite and Akkoyaktepe volcanite from old to young. K/Ar ages taken from the study area changes from 26.6+0.8 Ma to 10.9+0.4 Ma. The oldest volcanites of the area are Delibayirtepe volcanites and crop out Delibayirtepe north of Yesilkale village. These volcanites consisting basalticandesite, andesite and dacite lavas and pyroclastics of calcalkaline character give 26.6+0.8 Ma K/Ar age. This age corresponds to Late Oligocene.The lavas and pyroclastics of calcalkaline character and consisting dark grey, grey, basalt, basaltic trachyandesite, trachyandesite and pyroxene andesite in composition cropping out near Elmaçati, Dereyurt, Kaymak, Aktepe, and Tasli villages area taken as Elmaçati volcanites. The K/Ar age taken from Elmaçati volcanite is 24.3+1.3 Ma . When the age derived and the stratigraphic setting of the unit is considered, Elmaçati volcanite must be Late Oligocene?-Early Miocene in age. The lavas and pyroclastics of alkaline character and consisting basalt and olivine basalt cropping out around Besik Tepe, Ortabayir Tepe, Yoncalik Tepe, Asagikas Tepe, Fatmayurdu region and west of Akkoyak Tepe are considered as Besiktepe volcanites. From the lava cropping out around Basören village south of study area which similar to Besiktepe volcanite an 16.8+0.5 Ma age was taken by Leo et. al (1974) with K/Ar method. According to this data Besiktepe volcanite must have an Early Miocene age. The altered lavas and pyroclastics of calcalkaline character and consisting light grey, grey and sometimes pinkish-grey andesite and dacite cropping out south and around Yesilkale villages as isolated two small domes are taken as Agcahüyüktepe volcanites. Leo et. al (1974) has taken 14.1+0.4 Ma age from Agcahüyüktepe volcanite by K/Ar method. According to this data unit must have an age of Middle Miocene. The lavas and pyroclastics of subalkaline (calcalkaline/tholeitic) character consisting of andesite and dacite cropping out widely around Göldagi, Kizildag, Karsidag, Yanikdag, Kösoglu Tepe and Boztepe are taken as Göldagi volcanites. The eroded and rounded topography for this unit is very characteristic. The fresh parts of the unit is grey while the altered parts are pink and orange. Göldagi volcanite is interfingering with Akkoyaktepe volcanite and has similar chemical character. An age of 10.9+0.4 Ma was taken from Akkoyaktepe volcanite in this study by K/Ar method. Therefore Göldagi volcanite also must have the age of Late Miocene. The rocks of subalkaline (calcalkaline/tholeitic) character consisting andesite, trachyandesite and dacite cropping out arround Akkoyak Tepe, Asarkale Tepe, Kaletepe and Uzunbez Tepe are considered as Akkoyaktepe volcanites. An age of 10.9+0.4 Ma is taken from Akkoyaktepe volcanite by K/Ar method. Therefore Akkoyaktepe volcanite must have an age of Late Miocene.

21-15 BTH 18 Agrò, Alessandro

ROCK-MAGNETIC INVESTIGATION OF THE KIZILKAYA IGNIMBRITE (CENTRAL ANATOLIAN VOLCANIC PROVINCE)

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The 5 Ma-old Kizilkaya ignimbrite is the youngest large-volume unit of the ignimbritic sequence exposed in the central Anatolian Volcanic Province. A rock magnetic study was carried out in order to evaluate the homogeneity of the ignimbrite through the entire deposit unit, by means of anisotropy of magnetic susceptibility (AMS), magnetic mineralogy and magnetic remanence determinations. Six areal distributed localities were sampled at different stratigraphic height within the devitrified portion of the ignimbrite. A total of 33 sites were sampled and 444 oriented specimens recovered and analyzed.

Both the isothermal remanent magnetization (IRM) acquisition curves and the Lowrie method point to a low-Ti magnetite as the main magnetic carrier; locally, the occurrence of a minor high-coercivity mineral (oxidized magnetite and/or hematite) is suggested by the high field value (B > 0.8 T) needed to reach IRM saturation.

Stepwise thermal and AF demagnetization were systematically performed. The characteristic remanent magnetization (ChRM) was clearly isolated by Zijderveld diagram analyses at some sites. Here, the mean value from 20 sites (D = 175°, I = -42°) is fully consistent with previously published paleomagnetic data (Piper et al., 2002). In other sites, remanence appears more complex. During both AF and thermal demagnetization, the remanence direction moves along a great circle and no stable end-point direction is found. Due to the occurrence of two remanence components with overlapping coercivity and blocking temperature spectra, the mean site ChRM was estimated combining best-fit great circles and lines (McFadden & McElhinny,1998). Here, paleomagnetic directions vary significantly along the stratigraphic section; the magnetic declination ranges from 170° to 210°, the inclination from -34° to -55°. Large deflections from the mean direction occur at sites characterized by the occurrence of oxidized magnetite and or hematite. Besides, at these sites the magnetic susceptibility is one order of magnitude lower than usual. These results suggest that at some sites the Kizilkaya ignimbrite acquired first a thermal remanent magnetization and then, during the final cooling or a short time after, a chemical remanent magnetization component.

AMS measurements detected a well developed magnetic fabric. Magnetic foliation is gently dipping at most sites and its plunge is regarded as a proxy of the flow direction. At four out of the six studied localities, the mean flow direction agrees with the vent location in an area between Derinkuyu Basin and Gollu Dag rhyolitic massif proposed in the literature (Le Pennec, 2000). However, the magnetic fabric changes along the stratigraphic section: the magnetic foliation is nearly horizontal in the central part of the deposit, independently of its thickness.

Notwithstanding Kizilkaya ignimbrite is a single cooling unit, its magnetic properties suffer substantial variations through the deposit and the remanent magnetization characteristics show that the acquisition of remanence results from the overlapping of thermal and chemical processes.

The Kizilkaya case shows that thick pyroclastic deposits should be sampled according a stratigraphical approach, with different sites at different stratigraphic heights at each individual outcrop/location. Otherwise, undersampling may severely affect the paleomagnetic results.

21-16 BTH 19 Deniz, Kiymet

INVESTIGATION OF BUZLUKDAGI (KIRSEHIR-TURKEY) SYENITOIDS BY CONFOCAL RAMAN SPECTROSCOPY

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Alkaline intrusive rocks are products of Late Mesozoic magmatism of Central Anatolia Crystalline complex. Buzlukdagi intrusive rocks are exposed as a small alkaline pluton in the Central Anatolia around Alisar and Tatarilyas villages of the region. The body is typically observed at Buzluk hill as circular in shape and covers an area of approximately 15.75 km^2. Buzlukdagi syenitoid is intruded to the metamorphic rocks of Central Anatolia Crystalline Complex in the composition of foid bearing syenitoid. Migmatite and marble are observe at the outer zone as a product of contact metamorphism. The pluton can be distinguished with its high rough keen tophography in the area. The intrusive body is differentiated into three subunits as a coarse, medium and fine crystalline foid bearing syenite on the basis of textural features and grain sizes. Fine crystalline foid syenites have xenolitic enclaves with contacts and metamorphic texture in hand specimen. All the subunits of the syenite have similar mineral compositions with different mineral proportions and colors. Fine, medium and coarse crystalline foid syenites are pinkish, pinkish gray and gray in color respectively. They are mainly composed of nepheline, K-feldspar, oligoclase, pyroxene, biotite, phlogopite, amphibole with rare amount of garnet, cancrinite, titanite and opaque minerals. Confocal Raman Spectroscopical studies reveal that the garnets of these units are in the composition of uvarovite and andradite.

Whole rock geochemical data reveal that the syenites are peralkaline to metaluminous in character. The Buzlukdagi syenitoids both show enrichment in large-ion lithophile and light rare earth elements (LILE and LREE) with respect to high field strength and heavy rare earth elements (HFSE and HREE).

The geology, petrography and geochemical data suggest that the Buzlukdagi alkaline intrusive rocks are products of silica undersaturated and may derived from crustal thinning of Central Anatolia during the late period of Mesozoic and early Cenozoic.

21-17 BTH 20 Fritschle, Tobias

MINERAL VARIATIONS FROM MEDITERRANEAN LAMPROITES: MAJOR ELEMENT COMPOSITIONS AND FIRST INDICATIONS FROM TRACE ELEMENTS IN PHLOGOPITES, OLIVINES AND CLINOPYROXENES

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Lamproites are the most extreme melting products derived from a multiple metasomatised mantle source. Oligocene to Pleistocene ultrapotassic volcanism in the post-collisional environment of the Mediterranean Region often demonstrates clear lamproite affinity. To illuminate the major puzzling features of lamproitic rocks, samples from the Murcia-Almeria Province (Spain), the Vardar Suture Zone (Serbia) and the Menderes Massif (Turkey) were studied. Major and trace element geochemistry of phlogopite, olivine and clinopyroxene grains was determined using electron microprobe and LA-ICPMS. Samples from Spain are represented by madupitic lamproites from Jumilla and phlogopite lamproites from Fortuna, Serbian samples are covered by olivine-dominated leucite lamproites from Borac and Turkish rocks by phlogopite lamproites from Ilicasu and leucite lamproites from Buçak.

Major element analyses of phlogopites from all localities exhibit Al_2O_3 concentrations below 14 wt. % and evolutionary trends of decreasing Al with increasing Ti and Fe, which are typical for lamproites. Extreme contents of Cr and F indicate the presence of mantle-derived xenocrysts in Serbian and Turkish samples. Trace element data reveal interesting variations among the genetic populations, e.g. for Rb, Sr and Zr, and between the discrete lamproite localities, e.g. for Li, Nb and Ta; furthermore, they allow the distinction of lamproitic phlogopites from those occurring in kimberlites and carbonatites.

Olivines are abundant in Mediterranean lamproitic rocks. They occur as strongly resorbed phenocrysts and mantle xenocrysts. Phenocrysts and xenocryst rims bear inclusions of ultrarefractory Mg-chromite and in some cases of apatite. Contents of Ca are often very low in the xenocrysts, while phenocrysts frequently exhibit high Mg# of more than 94 and NiO concentrations up to 0,8 wt. %. Analyses of trace elements reveal equilibration of relatively primitive olivine with a lamproitic melt rich in incompatible trace elements. Additionally, the received data allow the discrimination of lamproitic olivines from olivines occurring in kimberlites.

Late stage crystallisation of diopside took place ubiquitously. Green-core clinopyroxenes were found in several samples. All of the analysed mineral grains exhibit low Al_2O_3 and TiO_2 concentrations, down to 0,4 wt. % and 0,3 wt. %, respectively, indicating their crystallisation in a lamproitic melt. Trace element analyses display constantly strong enrichment in LREE and distinguish these clinopyroxenes from those in kimberlites and other rock types.

Our study demonstrates that compositional variations of early crystallising minerals such as phlogopite and olivine provide an excellent archive for the discrimination of asthenospheric versus crustal influx into the lithospheric mantle. Moreover, mineral compositions of the early phases in lamproites may support understanding of the melting interactions between a refractory mantle and a heterogeneous lithosphere.

Mantle derived F-phlogopite xenocrysts should be the focus of further research, since they incorporate plenty of trace elements and have the ability to control these at high temperatures and pressures. Therefore, dissolution of mantle xenocrystic phlogopites as well as the dissolution of other refractory mantle generated minerals, e.g. K-richterite, are supposed to represent an integral part of lamproite genesis.

21-18 BTH 21 Prelevic, Dejan

MACROCRYSTAL POPULATIONS RETRIVED FROM LAMPROITES INDICATE ACCRETION OF YOUNG SSZ OCEANIC LITHOSPHERE IN THE ASSEMBLY OF SW. ANATOLIA, TURKEY

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Western Anatolian lithosphere comprises several sutures and major continental fragments with Laurasian and Gondwanan affinities, assembled prior to the Oligocene. One of the major tectonic features – shaping its structure – is the Menderes metamorphic massif, which consists of several assembled and imbricated terrains exhumed in the Late Miocene during the extension that affected the entire Aegean province. The predominant opinion is that the Menderes is a core complex delineated by low-angle detachment faults. An alternative explanation associates the Menderes massif with shallow subduction of Neotethyan oceanic lithosphere that was later delaminated. To distinguish between these possibilities, direct evidence from the Western Anatolian mantle lithosphere would be ideal, because of the compositional differences between continental and oceanic mantle lithosphere. In the absence of mantle xenoliths, mantle-derived volcanics and their macrocrystal populations, offer the only information about the composition of the mantle-lithosphere beneath the Menderes.

In this contribution, we constrain the mineralogy of the lithospheric mantle based on a dataset for Western Anatolian lamproitic lavas and a systematical investigation of the major and trace element distribution in their macrocryst populations. The host lamproites are ultrapotassic, high-Mg mantle-derived rocks, which show geochemical resemblance with the rest of the Mediterranean lamproites. Two types of olivine macrocrysts are recognized: Phenocrystic olivine has high-Fo cores (Mg# up to 94), very high NiO contents (up to 0.8 wt.%), low Cr_2O_3 (<0.18 wt.%), and CaO (≤0.20 wt.%). They have high Li contents (up to 17 ppm) and relatively high Sc (up to 5 ppm) and Mn (up to 900 ppm) contents. This olivine hosts Mg-chromite inclusions with extremely high Cr# (as high as 0.84). Large (>1 mm) mantle xenocrystic olivine contains homogeneous cores with plateau-like compositions (Mg# around 0.92, but NiO and CaO contents <0.4 and <0.1% wt.%, respectively), which abruptly change into compositions similar to phenocrystic olivine, resulting in reversed zoning. Their Li contents, exceeds 2 ppm in all investigated grain profiles, indicating strong metasomatic imprint. Macrocrystal phlogopite also comprises two main populations analogous to olivine: Phlogopite phenocrysts typically have uniform core compositions with Mg# (atomic Mg/Mg+Fe) ≥ 90, Al_2O_3 10.0-15.0 wt.%, and Cr_2O_3 less then 1.00 wt.% plotting in the field of lamproitic phlogopite core compositions. It has elevated Ba and Li contents ranging up to 15000 ppm and 70 ppm, respectively, and low Sr

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(<75 ppm) contents. Mantle xenocrystic phlogopite show core compositions characterized by high Mg#, Cr_2O_3 (up to 2.5 %), relatively high Al_2O_3 and F, and low TiO_2. Their high Cr_2O_3 and MgO contents closely overlap with mantle phlogopites from classical localities like Bear Paw and Finero. Their trace element composition is characterized by considerably lower Ba and Li contents around 1500 and 8 ppm, respectively, and sometimes elevated Sr and Nb concentrations up to 600 and 37 ppm, respectively.

The above complex macrocryst assemblages is used to constrain the lithospheric mantle beneath the Menderes Massif. Phlogopite xenocrysts document metasomatism of the lamproitic mantle source by hydrous K-enriched melts. This extreme K_2O and trace element enrichment is in strong contrast with the ultra-refractory character of olivine-spinel pairs, which reflect the pre-metasomatic ultra-depleted harzburgitic lithospheric mantle. High-Fo (up to 92% Fo) xenocrystic olivine in some samples indicates a depleted mantle source as well. This is a feature which can only be explained by a mantle that experienced an episode of strong depletion in melt components with subsequent K-enrichment. Our data support the interpretation that the mantle under the Menderes massif is a phlogopite bearing ultradepleted harzburgite, requiring a complex multistage geodynamic model to explain the origin of this lithospheric mantle. The first episode resulted in ultradepletion of the mantle in a SSZ environment during the closure of the Neotethyan Ocean in the Mesozoic. The second episode includes shallow subduction, accretion of forearc mantle and its interaction with subducted sediments, during which the observed complex composition of the lithospheric mantle was achieved. If our inferences about the W. Anatolian lithospheric mantle are correct, then the connection between accretion and/or shallowly subducted oceanic forearc lithosphere and uplift of the Menderes Massif may not be coincidental.

21-19 BTH 22 Fischer, Sebastian

ALKALINE INTRUSIVES AND WHAT THEY TELL US ABOUT THE UPLIFT OF THE MENDERES MASSIF, W. ANATOLIA, TURKEY

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One of the most prominent features of Western Anatolia is the Menderes Massif. It is regarded as a section of deeper levels of continental crust exhumed in the Late Miocene during a period of extension that affected the entire Aegean province. The Menderes Massif is widely interpreted as a core complex bordered by low angle detachment faults. More recent studies claim, that the detachment faults were originally steep and experienced subsequent back-tilting. Shallow subduction of Neotethyan oceanic lithosphere and erosion of overlying strata instead of low angle normal faulting were suggested as explanation for the uplift history deduced by thermochronology. Current questions concerning the history of the Menderes Massif pertain to the timing of the onset of uplift, the rate of uplift, the depth at which the magmas intruded and the characteristics of their mantle-source region.

This abstract presents an update on the scientific achievements of an ongoing project, aimed to put more constraints on the origin of the Menderes Massif. Here we present the preliminary geochemical results of investigation of plutonism that cuts the core complex. We are currently investigating mafic intrusive rocks from the northern part of the Menderes massif, which occur mainly as concordant intrusions, with the thickness of individual sills ranging from one to ten metres. The sills extend laterally from a few tens to a few hundreds of metres. Most rocks are porphyritic with phenocrysts of mica, amphibole, clinopyroxene and/or calcite within a fine grained groundmass of plagioclase with or without amphibole and mica. According to their mineralogy, the rocks can be classified as kersantites and andesites, the latter containing mafic enclaves.

Geochemically, the rocks are high-K alkaline and of intermediate (basaltic andesite to andesite) composition. Whole rock SiO_2 contents range from 49 to 60 wt.%, MgO from 3.2 to 8.4 wt.%, Cr 100 – 360 ppm and Ni 20 – 250 ppm. Whole rock Mg# (100 * molar Mg/(Mg + Fe^{2+})) ranges from 37 up to 50. The larger sills show internal geochemical zoning from more primitive (high MgO, Mg# and K_2O, low SiO_2) near the contact to more evolved (lower MgO, Mg# and K_2O, higher SiO_2) towards the centre. Trace element variation diagrams ('spidergrams') of whole rock analyses show a positive Pb and a negative Nb anomaly, which is less pronounced in the most primitive samples, suggesting clear orogenic affinity. Geochemistry of the kersantites demonstrates clear resemblance with ultrapotassic volcanic rocks from the area.

A number of geochemical analyses are in progress, including mineral major and trace elements as well as radiogenic isotope systematics (Sr, Nd and Pb) on the selected samples. Additionally, U/Pb dating of zircon by laser-ablation ICP-MS and fission track dating of apatite will be conducted to investigate the rate of uplift. The new data will be presented at the forthcoming GSA conference, and will provide time-constrained information on mantle dynamics under the Menderes Massif, a P-T history for the mantle-derived magmas, and their relation to the known history of uplifting.

SESSION NO. 22, 08:30

Tuesday, 5 October 2010

Mélanges and mélange–forming processes. Posters (*Melanjlar ve melanj olusturan mekanizmalar*)

METU Convention and Cultural Centre, Exhibition Hall

22-1 BTH 23 Beccaletto, Laurent

GEOLOGY, CORRELATION AND GEODYNAMIC EVOLUTION OF THE MERSIN MÉLANGES, SOUTHERN TURKEY

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Extensive field work and numerous micropaleontological determinations in the infra-ophiolitic mélanges of the Mersin ophiolite (Southern Turkey) lead us to clearly differentiate two mélanges: the Late Cretaceous Sorgun Ophiolitic mélange and the Ladinian-Carnian Hacialaný mélange. We show that these mélanges display the mixed origin of different blocks and broken formations, as summarized below.

(1) The Paleotethyan remnants are common and found exclusively in the Hacialaný mélange as small blocks and few broken formations. Pennsylvanian and Early Permian slope and basin deposits (calcarenites, radiolarites) are unknown from the western Neotethys but were already described in Paleotethyan series in the Lycian Nappes and in the margins of displaced terranes in Iran. Radiolarites of Kungurian age are sometimes associated with large amount of tuffites and are also unknown in the western Neotethyan realm, where the oldest radiolarites have a (late) Wordian age. Kungurian radiolarites and pelagic limestones on tuffs and volcanics are common in the Paleotethys of Iran, where they are related to Early Permian seamounts within the Paleotethys. These Paleotethyan remnants within the HM were most likely reworked as major olistostromes in the Neotethys basin during the Eo-Cimmerian orogenic event.

(2) Neotethyan elements are represented by potential Middle-Late Triassic seamounts and by broken formations containing Neotethyan faunas. The rich occurrence of *Metapolygnathus mersinensis* Kozur & Moix and *M. primitius* sensu stricto in the latest Carnian of the Kocatabur block, as well as the rich occurrence of the middle Norian *Epigondolella praeslovakensis* Kozur, Masset & Moix in the Gâvuruçtugu block indicate a derivation from the Neotethys, but further studies in the latest Carnian to middle Norian interval of the Pindos, Antalya and Huglu units are necessary to exclude the common occurrence of these two species in the Huglu-Pindos Ocean to which belong also the Antalya Nappes.

(3) The main Anatolian elements (upper plate position) are symbolized by sequences belonging to the northern passive margin of the Anatolian terrane (southern margin of the Huglu-Pindos Ocean), outlined by the Late Triassic syn-rift volcanic event (Huglu-type series also found in the Beyþehir-Hoyran Nappes), the early flexuration of the margin (already during the Cenomanian) and the Late Cretaceous obducted ophiolitic sequences. This margin is interpreted as emerging from the collapse of the former Variscan cordillera and opening of major back-arc type basins along the northern active margin of Paleotethys during the Triassic.

(4) The Tauric elements (lower plate position) are represented by Eo-Cimmerian flysch-like and molasse sequences, intercalated in Neotethyan series starting most probably with pelagic Permian sediments totally absent in the Anatolian domain. Other blocks are most probably derived from the parautochthonous sequences belonging to the Taurus-Beydaglarý marginal sequences.

The Mersin Ophiolitic Complex belongs to the South-Taurides Exotic Units, extending from Mersin to Antalya, and which can be widened to the Mamonia "Nappes" in Cyprus. This domain is made of exotic elements of the Anatolian terrane now found south of the Taurus terrane, juxtaposed to elements derived from the Paleotethys/Neotethys/Taurus terrane, and emplaced onto the Taurus southern margin (Mersin) or Beydaglarý domain (Antalya) in Late Cretaceous-Paleocene times. In term of paleotectonic and paleogeography, a direct implication is the need of (roughly E-W) lateral displacements of hundred kilometers scale to explain the present day structural scheme. In conclusion, the ages and distribution of the basin, slope and platform facies found in the mélanges, their faunistic content, the age of the passive margin onto which the ophiolites were obducted, and the evolution of the stratigraphic series demonstrate that several Tethyan oceanic basins were involved in the formation of the southern Tauric ophiolitic nappes. The coexistence south of the Bolkardag of these cosmopolitan units is of crucial importance to decipher the regional paleogeographic and paleotectonic evolution.

22-2 BTH 24 Beccaletto, Laurent

PALEOTECTONIC AND PALEOGEOGRAPHIC SIGNIFICATION OF MELANGES: EXAMPLES FROM THE TETHYAN REALM

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There are two different but complementary ways to study accretion-related melanges, originating in the contexts of convergent margin (subduction/obduction): i) a local and mechanical approach, where the mélange is seen as a structural object; the aim is then to get information on the large-scale melange-forming processes, by unravelling its internal structure and complex organisation, and by explaining the timing of the different deformation phases; ii) a regional and historical approach, where the melange is considered as a witness of the history of the regional geology; the aim is to get as much information as possible on the various lithologies found in the melange, in order to reconstruct the evolution through space and time of the ocean(s) and adjacent margins contemporaneous of its formation.

We want to put the emphasis on this second approach, and on the role of fossil accretion-related melanges from a paleotectonic and paleogeographic perspective. It is then necessary to give them a geodynamic signification, and to go further than the classic descriptive definition. In summary, one can distinguish between three ideal types of mélanges, regarding the origin of the material and their genesis: i) melanges related to the lower plate, reworking lithologies from the subducting oceanic lithosphere into the accretionary prism; ii) mélanges related to the upper plate, reworking lithologies both from the arc and the prism, called here fore-arc type melanges; iii) debris-flow mélanges deposited on the lower plate, and reworking ophiolitic fragments in front of an advancing obducting ophiolite. These three types of melange may be seen as ideal end-members of a simple ternary classification of melanges, based on their geodynamic setting.

Examples of melanges taken from the Tethyan realm (Greece, Turkey, etc…) support this view, and their field recognition appears to be crucial in the determination of their geodynamic environment at the time of formation.

22-3 BTH 25 Ogata, Kei

MASS TRANSPORT-RELATED STRATAL DISRUPTION WITHIN SEDIMENTARY MELANGES

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Mélanges of sedimentary origin are commonly represented by mass transport deposits, which are often defined to as olistostromes. From an outcrop perspective, these "chaotic" units are usually characterized by dismembered and internally deformed slide blocks of different size, lithology and shape, embedded in a more or less abundant fine-grained matrix. Data deriving from geophysical investigations of modern continental margins have permitted the characterization of the overall geometry of many of these deposits, which, however, remain still relatively poorly described in term of meso-scale features, as those recognizable in outcrop.

Results of this work show that in mass-transport deposits an unsorted, strongly mixed, relatively fine-grained clastic matrix almost invariably occurs in irregularly interconnected patches and pseudo-veins, infilling space between large clasts and blocks. We interpreted the appearance of this matrix as typical of a liquefied mixture of water and sediment, characterized by an extremely high mobility due to overpressured conditions, as evidenced by both lateral and vertical injections. On a much larger scale this kind of matrix is probably represented by the seismically "transparent" facies separating slide blocks of many mass transport deposits observed in seismic-reflection profiles. The inferred mechanism of matrix production forecasts a progressive soft-sediment deformation, linked to different phases of submarine landslide evolution (i.e. triggering, translation, accumulation and post-depositional stages), leading to an almost complete stratal disruption of involved stratified sequences.

From our data we suggest that most submarine landslides could move because of the development of ductile shear zones marked by the presence of "overpressured" matrix, both internally and along the basal surface. The matrix shows either fluidal structures related to simple shear, or a structure-less, homogeneous fabric.

The matrix acts as a lubricating medium, accommodating friction forces and deformations, thus permitting the differential movement of discrete internal portions and enhancing the submarine slide mobility. Based on our experience, we suggest that deposits characterized by similar features are quite common in the sedimentary record though still poorly reported and understood. Mutti et al. (2006) have suggested to call these deposits "blocky-flow deposits", i.e. the deposit of a complex flow that is similar to a debris flow, or hyper-concentrated flow, except that it carries also out-size coherent and internally deformed blocks (meters to hundreds of meters across) usually arranged in isolated slump folds. The recognition of the above-mentioned characteristics should be a powerful tool to discriminate sedimentary and tectonic mélanges within accretionary systems, and to distinguish submarine landslide deposits transported as catastrophic blocky flows (and therefore part of the broad family of sediment gravity flows) from those in which transport took place primarily along shear planes (i.e. slumps, coherent slides), also highlighting a possible continuum from slides to turbidity currents. The discussed case studies fall into a broad category of submarine slide deposits ranging from laterally extensive carbonate megabreccias (south-central Pyrenees), to various mass transport deposits with a very complex internal geometry developed in ponded, tectonically controlled basins (northern Apennines).

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22-4 BTH 26 Codegone, Giulia

FORMATION OF MELANGES, BROKEN FORMATIONS, AND MASS-TRANSPORT CHAOTIC DEPOSITS DURING THE ORDOVICIAN TACONIC OROGENY: EXAMPLES FROM CENTRAL AND NORTHERN APPALACHIAN OROGENIC BELT, EASTERN USA

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Different types of unmetamorphosed mélanges related to the evolution of the accretionary wedge-front of the Taconic Allochthon have been studied in the Central and Northern Appalachian orogenic belt (in eastern Pennsylvania, New York and Vermont).

Mélanges, broken formations, and mass-transport chaotic deposits (mélanges *s.l.*) display structural evidences for progressive stratal disruption of a Lower-to Upper Ordovician succession during the subduction-accretion-to collision tectonic episodes of the Ordovician Taconic Orogeny. They represent the products of different processes (tectonic, sedimentary and diapiric) operating during the evolution of the accretionary wedge.

Geologic mapping and stratigraphic-structural observations indicate that different types of mélanges *s.l.* were formed at different structural positions with respect to the wedge front, and that their own type of chaotic arrangements and deformation intensities depend on their origin, evolution, and tectonic position.

Downslope mass-movements, which are consistent with different gravity-driven processes (such as slides, slumps and debris flows), produced mass-transport deposits, including debris flow deposits and/or olistostromes, that were emplaced at the wedge-front as precursors of the advancing Taconic Allochthon providing exotic material into the flysch successions. These sedimentary mélanges were locally overridden by the advancing thrust sheets and incorporated into the shear zones forming an olistostromal carpet. Shearing led to the juxtaposition and mixing of rocks (in some cases including exotic blocks) of various ages, and subsequently to the formation of boudinage, enucleation of isoclinals folds, and phacoidal microshear cleavages.

Broken formations were mainly formed at the base of the wedge-front and Taconic thrust fault systems. During early stages of accretion the layered and still water-rich flysch sediments were locally dismembered by *in-situ* layer-parallel extension caused by tectonic loading and increase of fluid pressure. In other cases stratal disruption appears to be produced by compressional deformation of consolidated sediments through thrusting and shearing at the base of the accretionary wedge-front and/or Taconic Allochthon thrust faults. Both types of broken formations show a gradual transition from originally coherent stratigraphic successions to variously disrupted strata, and, finally, to block-in-matrix arranged units that lack a stratigraphic continuity and do not contain exotic blocks.

Diapiric mélanges containing exotic and/or non-exotic blocks formed by the increasing of sedimentary and/or tectonic load at the base of or within the accretionary wedge that, in turn, induced local over-pressure conditions promoting the upward rise of under-consolidated sediments.

In conclusion, the final mélange products studied in the Central and Northern Appalachian orogenic belt generally preserves the artefacts of the only last process of formation, but may represent the product of a complex interaction of superimposed processes that in many cases are reminiscent of a tectono-sedimentary evolution of a mélange developed in a single geodynamic setting.

22-5 BTH 27 Festa, Andrea

MELANGES AND BROKEN FORMATIONS IN THE EXHUMED MIOCENE-PLIOCENE OUTER ACCRETIONARY WEDGE OF THE CENTRAL-SOUTHERN APENNINES (ITALY)

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The Apennines of Central-Southern Italy result from convergence between the European plate and the westward-subducted Adriatic lithosphere. From the Oligocene to early Pleistocene, shortening at the collisional margin involved progressive folding and thrusting of Mesozoic-Tertiary units and of late Miocene-late Pliocene clastic successions deposited in the eastward-migrating Adriatic foredeep.

The new *Geological-Structural Map of Central-Southern Apennines, Italy* at scale 1:250,000 (Vezzani et al., 2010, GSA Special Paper 469) completes two decades of field research on the stratigraphy, geometry, and structure of the Apennine fold-and-thrust belt. In particular, this geological map embraces a representative portion of the outer accretionary wedge of the Central-Southern Apennines. This is marked by a 10-15 kilometers wide belt of chaotic units (Mts. Frentani mélange) that thrust over the undeformed late Pliocene-early Pleistocene foredeep succession. The Mts. Frentani mélange incorporates the outermost and deepest thrust sheets of the Molise Units and is tectonically imbricated with blocks of Messinian evaporites and early-middle Pliocene sandy- conglomeratic deposits, ranging in size from decimeters-to-hundreds of meters.

Two different types of chaotic units are defined on the basis of their geometric and stratigraphic position, internal organization, and nature of the bounding surfaces:

(1) Tectono-sedimentary mélange corresponding to the late Cretaceous-middle Miocene Argille Scagliose (Varicoloured Scaly Clays) of the Sicilide Units. It consists of a block-in-matrix arrangement with blocks of Mesozoic and Cenozoic limestones, calcarenites, greenish-grey calcilutites, cherty limestones, quartzarenites, and manganisiferous black limestones, ranging in size from decimeters-to-hundreds of meters. The blocks are randomly distributed within a varicoloured mainly brecciated matrix, locally overprinted by a pervasive scaly cleavage.

The chaotic arrangement of this mélange suggests that its emplacement and deformation is consistent with (i) slope and debris avalanches at the external frontal thrusts that produced mass-transport deposits during tectonic deformation, and (ii) folding and thrusting that overprinted the previously formed sedimentary mélange.

(2) Broken formations corresponding to the late Oligocene-early Miocene Flysch Rosso of the Molise Units. It consists of alternating red marly claystones and grey-green-red marls characterized by a structurally ordered block-in-matrix fabric. In the matrix a pervasive scaly fabric is present and often associated to mesoscale S-C shear zones. In spite of an intense stratal disruption that led locally to a block-in-matrix fabric, the original stratigraphy can still be recognized. Tectonic shearing acting at the base of the thrust sheets was probably the main factor in disrupting the originally coherent succession.

Finally, we present a comparative analysis of these two types of chaotic units developed in different geometric and stratigraphic positions with respect to the wedge front. They are characterized by different block-in-matrix arrangements that are consistent with their tectonic setting of formation reflecting the Miocene-Pliocene tectono-stratigraphic evolution of the accretionary wedge of Central-Southern Apennines.

22-6 BTH 28 Ozturk, Alican

GEOCHEMICAL, GEOISTATISTICAL INVESTIGATION OF HEAVY AND PRECIOUS METALS IN THE BOZKIR OPHIOLITIC MELANGE (BOZKIR, KONYA, TÜRKİYE)

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In the Bozkýr region there are three tectonic units with different tectonic, structural, stratigraphic and metamorphic features. These are namely Geyikdagý, Bozkýr and Bolkardag units. Bozkýr Ophiolitic melange of the Bozkýr Unit crops out in the south of Bozkýr and covers approximately 150 km2.

The aim of this study was to determine mineral enrichment processes of heavy and precious metals / minerals in the rocks of the Bozkýr ophiolitic melange, listvenites and in the current placers derived from them. For this purpose 61 rock and 62 placer samples fron the Bozkýr ophiolitic melange were analysed for major oxide (SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO, Cr_2O_3) and trace elements (Co, Mo, Cu, Pb, Zn, Cd, Sb, Sn, Ta, W, Zr, Ag, Au, Hg, Ni, Sc) and PGM (Pd, Pt). Their geochemical and statistical evaluations were made. In the cluster (dendogram) analysis diagram prepared on the basis of coefitic correlation coefficients of elements 5 groups in the rocks and 2 groups in the placers were distinguished. Mineralizations such as barite, galena, Au, Mo, Hg, Ag, Sb observed in the Bozkýr Ophiolitic melange seem to be related to Miocene aged Kiziltepe volcanite.

Apart from higher Fe_2O_3, and lower MgO amounts rock chemistry of ophiolitic rocks are generaly similar to those of Alpine-type peridotites

Chemical analysis and petrographic studies carried out on the placers indicate that heavy and precious metal concentrations are mainly nearby the source rocks, but also seen in few amounts in alluvial placers

In the result of field observations and petrographic studies carried on the Bozkýr ophiolitic Melange alterations such as extensive serpentinization spilitization, carbonatization, silicification chloritization and two different types of silicification (siliceous crust and listvenization) have been distinguished.

22-7 BTH 29 Ülgen, Semih Can

TECTONIC SETTING OF THE OPHIOLITIC MELANGES SOUTH OF THE MARMARA SEA BETWEEN THE IZMIR-ANKARA AND INTRA-PONTIDE SUTURES

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An ophiolitic mélange and associated metamorphic rocks crop out south of the Sea of Marmara in the Mudanya-Zeytinbagý region. The oldest rocks in the area studied are low-grade greenschist facies metamorphics sequence consisting of metabasite, phyllite, metachert and marble. They are tectonically juxtaposed with serpentinite slices and an ophiolitic mélange of greywacke, basalt, diabase, recrystallized limestone, marble and radiolarite. The metamorphic rocks and the melange are unconformably overlain by Paleocene limestone and are in fault contact in the north with a thick Eocene sequence of siliciclastic turbidites and volcanic rocks. The Eocene turbidites contain horizons of olistostromes and debris flows with clasts derived from the ophiolitic melange.

The lithological features of the melange are similar to the Cretaceous subduction-accretion complexes, which crop out widely along the Ýzmir-Ankara and Intra-Pontide sutures. The tectonic setting of the melange and the transport direction are studied through detailed mapping and structural studies. There are two possibilities: the melange could either have been derived from the south from the Ýzmir-Ankara suture or from the north from the Intra-Pontide suture.

SESSION NO. 23, 14:30

Tuesday, 5 October 2010

Crustal motions, mantle dynamics & GPS velocities in continental collision. Part 2 (*Kitasal çarpismalarda kabuk hareketleri, manto dinamigi ve GPS hiz dalgalanmalari*)

METU Convention and Cultural Centre, Kemal Kurdas Salon

23-1 14:30 Scholl, David

ANALOGOUS TO ANATOLIA, COLLISIONAL AND NON-COLLISIONAL PLATE BOUNDARY FORCES EXTRUDE WESTERN ALASKA TOWARD OFFSHORE SUBDUCTION ZONES

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INTRODUCTION: It is conjectured that since the Eocene, and probably the Late Cretaceous, crustal lithosphere has moved counterclockwise around the NE corner of the Pacific Basin in a 600-800-km-wide belt of laterally translating crust. The moving band defines a plate boundary zone separating Pacific and North American lithosphere that extends ~3500 km from British Columbia (Pacific maritime Canada) northward through Alaska and westward to the Bering Sea. The zone of transiting crust is termed the North Pacific Rim Orogenic Stream or NPRS by Redfield et al. (2007). The NPRS is driven northward by transform coupling along the transform, but highly obliquely underthrust, margin of British Columbia. Pacific rim crust in Alaska is

TUESDAY

driven by the northward flow through the so-called "oroclinal bend" of south central Alaska to be expulsed west of the orocline toward subduction zones (SZs) residing in the Aleutian-Bering Sea region. This extra-regional tectonic concept is poorly documented by GPS data. Its viability is strongly based on drawing a tectonic analogy with the geologic- and GPS- established pattern of crustal extrusion of Anatolia toward the Hellenic-Cretan SZ system (Fig. 1)

Figure 1: Extra-regional scale pattern of escape tectonism for Anatolia and Alaska

EXTRUSION OF WESTERN ALASKA: Within the NPRS, slip-lines of regional crustal movement are revealed by a family of continental-scale, right-lateral shears that arc around the northeastern rim of the Pacific Basin. Offset evidence establishes that since the Eocene the combined displacement across these faults is ~1000 km or more. West of the orocline, the fault system fans (expands) outward to embrace the whole of Alaska south of the Kobuk fault. The fault pattern strikes SW toward the Aleutian SZ. Because convergence is directed mostly orthogonal to the SW trend of the Alaska SZ and the inboard family of continental shear zones, extrusion or escape tectonism is implied for western Alaska (Fig. 1).

ANATOLIAN AND ALASKAN TECTONISM: Extrusion of Anatolian crust is coupled to the collisional impact of the Arabia plate with Eurasia combined with the co-tectonic roll back of a pre-existing Hellenic-Cretan SZ system. In contrast, in the Late Cretaceous and early Tertiary, extrusion of western Alaska is linked to coupling across a highly oblique plate boundary zone that reached inland across British Columbia at least 600 km (Fig. 1). To the west, co-tectonic extrusion is posited to have forced the Eocene abandonment of the existing, highly oblique SZ of the Beringian margin and the consequent creation of the new offshore Shirshov and Bowers SZs and, possibly slightly earlier, the Aleutian SZ. Strong activation of the NPRS in the Eocene is connected to the subduction of the Kula-Resurrection spreading system beneath the NE periphery of the Pacific Basin and the consequent heating of the lithospheric mantle and crust above a complexity of slab windows (Haeussler et al., 2003).

IMPLICATIONS OF THE NPRS-EXTRUSION CONJECTURE: The NPRS-driven extrusion concept states:

(1) That the Alaska orocline is not the consequence of a physical or static bending of Alaskan crust in the early Tertiary. The NPRS-extrusion concept requires the dynamic movement of crustal material around and through the NE corner of the Pacific rim and expulsion of transiting material to the west.

(2) That until the late Cenozoic the NE corner of the Pacific rim was a broad, inward bowed margin built by terrane accumulation in the Mesozoic and early Tertiary. This rim was strongly pushed in and orogenically thickened by the Miocene entrance of the Yakutat crustal block into the eastern end of the Alaskan SZ.

(3) That new, offshore subduction zones were created by the drive of extruded crustal material toward an unaccommodating structural barrier, in the example here, the transform to highly-oblique underthrust Beringian subduction zone (Fig. 1; Scholl, 2007).

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23-2 14:50 Mann, Paul

TECTONIC BLOCK ROTATION, ARC CURVATURE, AND BACK-ARC RIFTING: COMPARISON BETWEEN MEDITERRANEAN AND WESTERN PACIFIC EXAMPLES

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The fastest modern-day tectonic block rotations on Earth (up to 9 degrees/Myr) occur in the forearcs of convergent plate margins where a transition from collision of a bathymetric high to subduction of normal oceanic crust occurs. GPS techniques have enabled accurate documentation of the kinematics of these rotations, leading us to develop a conceptual model where the change from collision to subduction exerts a torque on microplates within the plate boundary zone, causing them to spin rapidly about an axis at the collision point. We have investigated geophysical and geological data from several active plate boundaries (from the western Pacific and Mediterranean regions) to document a compelling spatial and temporal relationship between the transition from collision to subduction, plate boundary curvature, and rapid tectonic block rotations. In some cases, these microplate rotations can initiate back-arc rifting. We also present numerical modelling results supporting our conceptual model for block rotations at collision/subduction transition. Our results suggest that the rate of microplate rotation depends on the incoming indentor velocity, and can be greatly enhanced by: (1)extensional stresses acting at the subduction interface (possibly due to slab roll back), and (2) a low-viscosity back-arc. Where viscosity of the back-arc is low, forearc microplate rotation dominates. In contrast, tectonic escape of strike-slip fault-bounded microplates is predicted in areas where the back-arc viscosity is high. Previous workers have suggested that the kinematics of the Anatolian block and back-arc rifting in the Aegean are influenced by some combination of forces associated with Arabia/Eurasia collision, and/or subduction (including slab rollback) at the Hellenic trench. Based on previous work from active western Pacific arcs, we propose that the collision of two separate indentors (Arabian promontory in the east, Apulian platform in the west), is a fundamental tectonic mechanism for large-scale anticlockwise tectonic rotation of Anatolia and the opposing clockwise rotation of western Greece documented from paleomagnetic studies. The recognition of several global analogues for Mediterranean active tectonics may lead to new insights into the dominant forces behind tectonic processes affecting the region.

23-3 15:10 Mocanu, Victor

MANTLE FLOW IN THE CARPATHIAN BEND ZONE? INTEGRATION OF GPS AND GEOPHYSICAL INVESTIGATIONS

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The Carpathian Bend Zone (an area known by its local name, Vrancea) is part of the Carpathian arc, which represents the suture zone between the (east European and Moesian) platforms and (southern Europea) continental units. These units have been amalgamated in the last 20 Ma, post subduction of what was thought to be the eastern part of the Alpine Tethys, an elongated oceanic basin of Triassic-Jurassic age that stretched along the entire southern margin of the Ibero-European continent. Previous mantle tomography research identified remnants of subducted lithosphere that has accumulated at the bottom of the upper mantle beneath the Pannonian Basin. Later stages of oceanic subduction (late Miocene?) may be followed by recent phase(s) of continental collision in the process of suturing of south European continental fragments to the older European margins, particularly in the southeastern Carpathians. Here, the very active Vrancea seismic zone, the recent unusual volcanism of the inner Carpathians (2.25 Ma in the Persani Mountains, 2.0–0.2 Ma in the Harghita Mountains), and vertical motions and folding in the Carpathian foreland basin east of Vrancea probably document the ongoing lithosphere activity.

The unusual strong and persistent intermediate depth seismicity and surface deformation at and around the most tightly curved portion of the Carpathian arc in Central – Eastern Europe, Vrancea Bend Zone (approximate central co-ordinates 45.50N, 25.50E), has been the main target of numerous recent studies. They culminated in a persistent debate on the nature of the processes involved. The possible tectonic scenarios explaining the Vrancea seismicity and surrounding structures invokes (a) subduction of Tethys oceanic lithosphere, a remnant of which is presumed to be just detaching from unsubductible continental lithosphere of the East European and Moesian platforms; (b) oceanic lithosphere subduction ending some time in the late Miocene, and that since then a portion of East European or Moesian platform continental mantle lithosphere has been delaminating along a horizontal mid-lithospheric interface and dripping down into the upper mantle.

In order to add a robust, kinematic component to the ongoing studies, the University of Bucharest in close cooperation with The National Institute for Earth Physics and the universities from Delft, Utrecht and Karlsruhe have shaped and implemented a two decade-long program to use the modern satellite geodesy techniques in order to determine de directions and magnitude of velocity vectors for the area nearby Vrancea. We have carried out 19 GPS campaign and run a network of eight permanent stations used as reference frame in order to get a robust determination of velocity values which are so small that could be considered close to technical boundaries.

The very small deformations imposed a particular data processing. The daily solutions in terms of spatial coordinates are determined for each campaign in respect to an average solution of the independent network. This is done in an iterative mode, by decreasing the weight of the reference stations outside the network, using pre-defined criteria for each component, as a function of the statistical analysis of the GPS data set. The sigma values for the solutions of every location from every campaign have been calculated as a function of the variation interval for the daily solution in every location. In addition, secondary processing effects are being computed and their weight in the final solutions has been diminished. The campaign solutions have been afterwards used to estimate the velocity vectors for every component in each site. The average tendency has been determined for every location, as well as the campaign individual solutions using an offset higher than the pre-defined criterion. This iteration continued until getting the velocity vectors by components. In such a way the authors got a solution within the framework of the ITRF-2000 reference net. For the further geophysical analysis, the Eurasian rotation pole has been computed (56.310º N, 101.732ºW and 0.2569º/Ma) which has been elliminated from the solution. In this way, the resulting GPS velocity vectors are refered to the stable Eurasian continent.

The present outcome show that the ESE part of the Romanian territory gets away in respect to the stable Eurasia, velocity values reaching no more than 2.0 – 2.5 mm/y. In respect to the stable Carpathian vorland the movements are very slow and have to be confirmed by further campaigns to be completed on an annual base. Three sites east of the Carpathian arc show a bit higher velocities and the displacements are decreasing westwards. These differential displacements cannot be triggered by superficial landslides as they are located into perfect planes. However, the displacements are determined in front of the Carpathian arc, close to the intermediate depth seismogenic zone. The vectors could suggest a rapid displacement of the the lithospheric slab in respect to the Moesian Platform. The sites placed at the internal part of the Carpathian arc and within the Transylvanian Basin do not show significant displacements in respect with the east-southeast sites reference net but suggest a small counterclockwise rotation of this area. If we take into account the southeastwards position of the velocity vectors from the central-eastern part of the Moesian Platform, as well as the northwestwards position of the velocity vectors at stations in North Dobrogea and east of the prolongation of Peceneaga-Camena crustal fault system, we coul estimate a pretty robust astenospheric rotation flow around the Vrancea lithospheric slab.

Finally, taking into account the results from the high seismic tomography, seismic attenuation and satellite geodesy studies, we shaped the main kinematics of the Carpathian Bend Zone, suggesting an anti-clockwise displacement of the surface as being a result of deep, mantle flow, accompanied by an advancement of the melting processes at the astenosphere-high velocity body boundaries.

Acknowledgments. This cooperative works has been carried out during more than 15 years with significant support from ISES, Romanian Ministry of Education and Research and National Science Foundation (USA), SFB 461 (Germany), and with a coherent input by a prof. B.A.C. Ambrosius (TU Delft), Dr. Ray Russo (University of Florida) and tens of students from various universities in Europe, mainly from the University of Bucharest, TU Delft, Free University Amsterdam, University of Karlsruhe and others.

23-4 15:50 Amer, Aimen

OFFSHORE CYRENAICA SUBDUCTION; NEW BATHYMETRY DATA, NORTHEAST LIBYA

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The offshore area of northeast Libya has a poor history of bathymetry analysis as a result of insufficient offshore oil and gas exploration. The structural high onshore the northeast flank of the country is known as Al Jabal al Akhdar (The Green Mountain) and is composed of carbonate formations ranging in age from Cretaceous up to Late Miocene. By now, the geological framework of the surface geology is under constant research and is largely understood. However subsurface data is scarce, and offshore bathymetry data is almost not available.

This lack of data led to a search in all the different public and private domains to have a detailed view on the offshore bathymetry of Al Jabal al Akhdar and to relate any of the geological features observed to its development. The data collected and processed utilizes sonar data collected from the 1940s to recent years. This data was compiled with the help of different software packages to produce a detailed bathymetric 3D map. The bathymetry map is the first in this region and was quality checked against neighboring countries bathymetry calculations and seafloor seismic maps. The submarine features revealed by this map gave birth to new geological observations that can help further understand Al Jabal al Akhdar development. The main features are submarine canyons and a submarine trench. The maximum depth of this trench reaches approximately -4096mss 152 km north of Benghazi City, Libya. The bathymetry produced shows magmatic bodies 150 km north of the city and south of the trench, helping identify its polarity. The analysis of this data suggests that the trench is a subduction zone plunging towards Al Jabal al Akhdar structure, indicating that this mountain range is overriding the subducting plate, leading to the uplift and formation of the relief. The axis of the trench diverts to the north toward Italy once it approaches the magmatic rocks and continues until it merges with the Apennines thrust belt. The interpreted trench (subduction zone) was named the Cyrenaica Trench.

Analysis of satellite images over the area suggest that the tectonic plate movement at the uplift has different vectorial angles, resulting in a dextral strike-slip movement across the Cyrenaica trench combined with subduction. Using high-resolution 3D bathymetries, satellite images, and field work, a general investigation of the structural setting of the onshore and offshore area of this mountain range and its structural extensions unravels its complex tectonic history.

23-5 16:10 Sidorova, Irina

INTEGRATED GEOPHYSICAL MODEL OF LITHOSPHERE IN WESTERN UZBEKISTAN

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This paper present results of comprehensive analysis of the geological-geophysical data in Uzbekistan using GIS&RS, whish show in the spatial interrelations between the peculiarities of the Lithosperical structures of the region and geodynamic processes occurring there. Deciphering of structural units of South Tien-Shan territory using space images allows us to reveal regional, deep rooted lineaments, extending in latitudinal direction over Uzbekistan territory and neighboring countries. These lineaments or zone of lineaments with anomalous geological objects widening from 50 up to 250 km are originated from a significant heterogeneity of upper mantle. The lineaments could penetrate the Earth up to deep lithosphere layers, inheriting a position of old fault-lineament systems which origin related to Precambrian to Paleocene tectonic processes. Some of these structural discontinuities are poorly expressed in surface geology, but can be detected by remote sensed methods, as well as by the magnetic and gravity anomalies. This study was made with complex geophysical and geological observations by the DSS-MOVZ profiles, which cross Uzbekistan and revealed a number of features, which are characteristic of the upper mantle rocks, related to morphology of bodies, their physical properties, consisting mainly in their contrasting values for contiguous blocks, and general increased velocity and density of the rocks they contain. Anomalous geological objects in Central Kyzylkum having anomalous high velocity and density values have been mapped at different depths within Central Kyzylkum: Muruntau, Kokpatas, Auminza-Beltau, Kuldjuktau, Darbazatau. The alteration zones, the tectonic lines and the circular structures related to the cones and calderas determined these methods and checked by group truth studies may be target areas to explore for some new deposits. New regional features have been revealed : they include peculiarities of the Earth's crust's deep geological structure and spatial distribution of deposits; they are contact areas of the Earth's crust geoblocks with anomalously high and low seism density parameters. Mapping of these zones helps select new ways in the search for mineral deposits. Construction of the integrated model spatial database using ESRI ArcGIS and RS methodologies, combining (i) a digital elevation model (DEM) on the base of ASTER space images; (ii) 3-D models of basement and Moho from reinterpretations of potential field, DSS and magnetotelluric MT profiles; (iii) tables of existing tectonic, stratigraphic and geochronological data; (iv) geological maps; and (v) any other relevant geological information concerning the Western Uzbekistan.

23-6 16:30 Hosseini, Sayyed Keivan

LITHOSPHERIC DEFORMATION OF NE IRAN INFERRED FROM SHEAR WAVE SPLITTING

HOSSEINI, Sayyed Keivan, RAHIMI, Behnam, and SHOKRAEI, Seyedeh Fargol, Department of Geophysics, Faculty of Fundamental Sciences, Azadi Sq., Ferdowsi University of Mashhad, Earthquake Research Center, Mashhad, 91779-48974, Iran, k-hosseini@um.ac.ir

We have made measurements of seismic anisotropy beneath NE Iran performed on 43 teleseismic earthquakes recorded at seven permanent stations of Earthquake Research Center-Ferdowsi University of Mashhad-Iran. Two distinct parameters of shear wave splitting in terms of fast polarization orientation Ø and delay time δt are measured for each station using SKS and SKKS phases. Average time delays between fast and slow shear waves in Lut zone vary from 0.9 to 1.1s with fast polarization azimuth of 248° to 255° which will have a good coincidence with closing direction of Paleo-Tethys Ocean if 135º anti-clockwise rotation of Central Iranian Microplate has been removed. The closing direction of Ocean have reserved well at north of Darouneh fault with no rotation in terms of fast polarization axis, however most of stations in this region show null measurements that may be due to a large amount of vertical strain caused by the crust and subcontinental mantle deformation. The style of deformation in NE Iran changes from east to west by pure shear to simple shear, respectively. We clearly find that the azimuth of fast axis coherently changes to make parallel with major strike slip active faults –Shahrud fault system- in the former region.

SESSION NO. 24, 13:30

Tuesday, 5 October 2010

Keynote Talk 4

METU Convention and Cultural Centre, Kemal Kurdas Salon

24-1 13:30 Chung, Sun-Lin

A COMPARATIVE STUDY OF THE TIBET/HIMALAYA AND CAUCASUS/IRAN OROGENIC BELTS: MAGMATIC PERSPECTIVES

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The Tibet/Himalaya and Caucasus/Iran orogenic belts, two principal and active mountain ranges on Earth today, result from continental collisions of India and Arabia, respectively, with Eurasia. With the former representing a mature continental collision zone and the latter an intermediate to initial stage example, this study aims at a comprehension of the pre- to post-collisional igneous activities in the two orogenic belts in specific and the whole spectrum of magmatic and tectonic processes through which collisional orogeny evolves in general. In the Tibet/Himalaya orogenic belt, the Neotethyan subduction related arc magmatism started from the Jurassic and lasted until the Eocene. In southern Tibet, the volcanic records are marked with southward migration and intensification at ca. 50 Ma, suggesting rollback and breakoff of the subducted Neotethyan slab at the early stage of the India-Eurasia collision that should have begun by 55 Ma. Post-collisional magmatism, showing either ultrapotassic or adakitic geochemical features, started ca. 30 Ma as a result of removal of collision-thickened lithospheric root. In contrast to other active collision zones that involve broad, diffuse regions of crustal deformation, the Caucasus/Iran orogenic belts has an intriguingly sharp northern boundary defined by the linear trend from the Great Caucasus to Kopeh Dagh, a feature lacking in the mature India-Eurasia collision zone. Although the true continent-continent contact between Arabia and Eurasia seems to have initiated no later than the early Miocene, some large-scale ocean basins such as those in the Black and Caspian Seas are yet closed. However, our new data from Georgia, Armenia and Iran indicate a southeastward younging of termination of the Neotethyan subduction related calc-alkaline magmatism, from the Oligocene in Armenia to the middle Miocene in Esfahan and the late Miocene in Kerman areas along the Urumieh-Dokhtar magmatic arc. These data are consistent with the argument for an oblique Arabia-Eurasia collision and diachronous contact between the two continents along the Bitlis-Zagros suture zone.

SESSION NO. 25, 14:30

Tuesday, 5 October 2010

Magmatism in evolving orogens: Collision to extension. Part 2 (*Aktif orojenik kusaklarda magmatizmanin evrimi: Çarpisma tektoniginden gerilmeli tektonige gidis*)

METU Convention and Cultural Centre, Salon B

25-1 14:30 Jahn, Bor-ming

ACCRETIONARY OROGEN AND EVOLUTION OF THE JAPANESE ISLANDS - IMPLICATIONS FROM A SR-ND ISOTOPIC STUDY OF THE PHANEROZOIC GRANITOIDS FROM JAPAN

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The Japanese Islands represent a segment of a 450 Ma old subduction-related orogen developed along the western Pacific convergent margin, and most tectonic units are composed of late Paleozoic to Cenozoic accretionary complexes and their high P/T metamorphic equivalents. The formation of the Japanese Islands has been taken as a standard model for the accretionary orogeny. According to Maruyama (1997), the most important cause of the orogeny is the subduction of oceanic ridge, by which the continental mass increases through the transfer of granitic melt from the subducting oceanic crust to the orogenic belt. Sengor and Natal'in (1996) named the orogenic complex "Nipponides", consisted predominantly of Permian to Recent subduction-accretion complexes with very few fragments of older continental crust. These authors pointed out the resemblance in orogenic style between Japan and the Central Asian Orogenic Belt (CAOB). The present work uses available Sr-Nd isotopic data to test the statements made by these authors. The isotopic data indicate that the granitoid generation in SW Japan was in strong contrast with that in two celebrated accretionary orogens: the Central Asian Orogenic Belt and Arabian-Nubian Shield. In fact, the Japanese isotopic signatures are more comparable with those observed in SE China and Taiwan, or in classical collisional orogens in the European Hercynides and Caledonides. A large proportion of the granitoids of SW Japan have Proterozoic Sm-Nd model ages, high initial $^{87}Sr/^{86}Sr$ ratios and negative $\varepsilon_{Nd}(T)$ values. This raises questions about the types of material accreted in accretionary complexes, and negates the hypothesis that the Nipponides contains very few fragments of older continental crust. The subduction-accretion complexes in Japan are composed mainly of recycled continental crust, probably of Proterozoic ages. The scenario is comparable with that in Taiwan. The present study argues that accretionary orogens could be distinguished by the nature of the accreted lithological assemblages. Orogens with dominantly island arc assemblage would witness generation of granitoids with juvenile characters. This is best exemplified by the granitoids of ANS and many parts of CAOB. By contrast, orogens with accretionary complexes with a large proportion of recycled Precambrian crust relative to mantle-derived rocks would produce granitic rocks with more crustal signature. This is represented by the Japanese Islands. The Sr-Nd isotopic compositions of Japanese granitoids indicate that the source regions vary from dominantly mantle-derived rocks to an assemblage with a large proportion of recycled Precambrian crust. This implies that the proportion of the eroded Precambrian crust in the trench to the ocean plate stratigraphy was very variable in the subducted accretionary complexes during the Mesozoic. Alternatively, the accreted fragments, including MORB, basalts of seamounts and ocean plateaux, have not significantly participated in the generation of granitic magmas.

25-2 14:50 Lee, Hao-Yang

AGE AND GEOCHEMICAL CONSTRAINTS ON THE PETROGENESIS OF LATE CENOZOIC VOLCANISM IN MYANMAR

LEE, Hao-Yang[1], CHUNG, Sun-Lin[1], YANG, Hsiao-Ming[1], CHU, Chiu-Hung[1], LO, Ching-Hua[1], and MITCHELL, A.H.G.[2], (1) Department of Geosciences, National Taiwan University, Taipei, Taiwan, haoyanglee@ntu.edu.tw, (2) Ivanhoe Myanmar Holdings, Ltd, Yangon, Myanmar/Burma

Late Cenozoic volcanism occurs in the central Myanmar basin, a region that is marked by the existence of the dextral Sagaing fault linking the eastern Himalayan Syntaxis in north and the Andaman Sea in south. Here we report new $^{40}Ar/^{39}Ar$ age results for the volcanic rocks from Mt. Popa and two volcanoes in Monywa, central Myanmar. The results suggest two distinct stages of eruptions, a mid-Miocene stage from ~16 to 13 Ma and a Quaternary stage <1 Ma, with a >10-m.y. magmatic gap in between. While calc-alkaline rocks showing arc lava geochemistry are abundant, an apparent change in magma composition is observed between the two stages. The mid-Miocene rocks are typical of high-K calc-alkaline nature and dominated by intermediate compositions (SiO_2=53-62 wt.%). By contrast, the Quaternary rocks are mainly basalts but show heterogeneous compositions, including (1) high-Al basalts from Mt. Popa: ε_{Nd}=+3.0 to +2.1, ε_{Hf}=+17.4 to +10.7, (2) absarokites and high-Al basalts from Monywa: $\varepsilon_{Nd}\approx+3.6$, $\varepsilon_{Hf}\approx+12.1$ for the former and $\varepsilon_{Nd}\approx+3.0$, $\varepsilon_{Hf}\approx+11.8$ for the latter, and (3) OIB-type alkali basalts from Singu, a locality off the Sagaing fault: $\varepsilon_{Nd}\approx+0.9$, $\varepsilon_{Hf}\approx+3.7$. We interpret the long magmatic gap as a consequence of cessation of the oblique subduction of the Indian oceanic lithosphere beneath this part of Asia that occurred in the mid-Miocene, when the dextral motion of the Sagaing fault system initiated and opening of the Andaman Sea began. All these processes were related to the India-Asia collision that caused plate reorganization in the region and eventually transformed the subduction system from oblique convergence to dextral movement. Under this framework, the Quaternary volcanism renewed owing to small-degree melting of different types of pre-Miocene subduction-enriched mantle domains beneath central Myanmar related to an extensional or transtensional setting created by the stress partitioning along the Sagaing fault system.

25-3 15:10 Zhu, Di-Cheng

THE LHASA TERRANE: RECORD OF A MICROCONTINENT AND ITS HISTORIES OF DRIFT AND GROWTH

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The Lhasa Terrane in southern Tibet has long been accepted as the last geological block accreted to Eurasia before its collision with the northward drifting Indian continent in the Cenozoic, but its lithospheric architecture, drift and growth histories and the nature of its northern suture with Eurasia via the Qiangtang Terrane remain enigmatic. Using zircon *in situ* U-Pb and Lu-Hf isotopic and bulk-rock geochemical data of Mesozoic–Early Tertiary magmatic rocks sampled along four north–south traverses across the Lhasa Terrane, we show that the Lhasa Terrane has ancient basement rocks of Proterozoic and Archean ages (up to 2870 Ma) in its

T U E S D A Y

centre with younger and juvenile crust (Phanerozoic) accreted towards its both northern and southern edges. This finding proves that the central Lhasa subterrane was once a microcontinent. This continent has survived from its long journey across the Paleo-Tethyan Ocean basins and has grown at the edges through magmatism resulting from oceanic lithosphere subduction towards beneath it during its journey and subsequent collisions with the Qiangtang Terrane to the north and with the Indian continent to the south. Zircon Hf isotope data indicate significant mantle source contributions to the generation of these granitoid rocks (e.g., ~ 50–90%, 0–70%, and 30–100% to the Mesozoic magmatism in the southern, central, and northern Lhasa subterranes, respectively). We suggest that much of the Mesozoic magmatism in the Lhasa Terrane may be associated with the southward Bangong–Nujiang Tethyan seafloor subduction beneath the Lhasa Terrane, which likely began in the Middle Permian (or earlier) and ceased in the late Early Cretaceous, and that the significant changes of zircon $e_{Hf}(t)$ at ~ 113 and ~ 52 Ma record tectonomagmatic activities as a result of slab break-off and related mantle melting events following the Qiangtang–Lhasa amalgamation and India–Lhasa amalgamation, respectively. These results manifest the efficacy of zircons as a chronometer (U-Pb dating) and a geochemical tracer (Hf isotopes) in understanding the origin and histories of lithospheric plates and in revealing the tectonic evolution of old orogenies in the context of plate tectonics.

25-4 15:50 Karsli, Orhan

LATE MESOZOIC TO LATE CENOZOIC MAGMATIC EVOLUTION OF THE EASTERN PONTIDES, NE TURKEY

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Anatolia is formed by mainly four major tectonic blocks, separated by three main high-pressure (HP) belts. Eastern Pontides (EP) is a subset of Sakarya zone, which is one of these tectonic blocks. The EP extends for 450 km along the north eastern coast of Turkey. Late Cretaceous to late Miocene magmatic activity yielded several volcanic and plutonic rocks of different age and compositions.

Late Cretaceous is represented by (1) high-K calc-alkaline and calc-alkaline I-type (~75-91 Ma, Ar-Ar on hornblend, U-Pb on zircon and Pb-Th on monazite) and shoshonitic A-type (~75-81 Ma, U-Pb on zircon) plutonic rocks, and (2) calc-alkaline (Turonian-Campanian) and shoshonitic volcanic rocks (80 Ma, Ar-Ar on hornblende). All the rocks are isotopically indistinguishable. Sr-Nd isotopic data for all of the samples display I_{Sr} = 0.70676 to 0.70736, ε_{Nd}(79 Ma) = -4.4 to -3.3, with T_{DM}= 0.94 to 1.36 Ga. The lead isotopic ratios are ($^{206}Pb/^{204}Pb$) = 18.79-18.87, ($^{207}Pb/^{204}Pb$) = 15.59-15.61 and ($^{208}Pb/^{204}Pb$) = 38.71-38.83. All isotopic compositions suggest that the magma has a dominantly mafic lower crustal source, though a minor mantle contribution is possible.

Late Paleocene-Early Eocene are characterized by high-K calc-alkaline adakite-like volcanic and adakite-like granitoid porphyre rocks (~ 50-54 Ma, Ar-Ar on hornblende) having a relative high I_{Sr} (0.70474-0.70640) and low ε_{Nd} (50 Ma) values (-2.3 to 0.8), which is consistent with an origin as partial melts of a mafic lower crust, and spessartite type lamprophyres (~ 48 Ma, Ar-Ar on hornblende). Their relative high I_{Sr} = 0.70429 to 0.71291, ε_{Nd}(48 Ma) = -1.4 to 3.6, with T_{DM}= 0.48 to 2.22 Ga and lead isotopic ratios [($^{206}Pb/^{204}Pb$) = 18.35-18.63, ($^{207}Pb/^{204}Pb$) = 15.51-15.60 and ($^{208}Pb/^{204}Pb$) = 38.29-38.87] accord with partial melting of isotopically and chemically enriched subcontinental lithospheric mantle (SCLM).

Middle Eocene aged rocks are typical of high-K calc-alkaline I-type granitoids (40-45 Ma, K-Ar on biotite, U-Pb on zircon, Pb-Th on monazite and Pb-Th on uraninite) and high-K calc-alkaline and calc-alkaline volcanics. Initial Nd-Sr isotopic compositions for the rocks are ε_{Nd}(43 Ma) = -0.6 to 0.8 and mostly I_{Sr} = 0.70482-0.70548. The Nd model ages (T_{DM}) vary from 0.84 to 0.99 Ga. The Pb isotopic ratios are ($^{206}Pb/^{204}Pb$) = 18.60-18.65, ($^{207}Pb/^{204}Pb$) = 15.61-15.66 and ($^{208}Pb/^{204}Pb$) = 38.69-38.85. These isotopic characters indicate that the magma has a dominantly SCLM, which is chemically enriched, but isotopically depleted in composition, though a minor mafic lower crustal melt contributes to the generation.

Neogene alkaline volcanics (5-13 Ma, K-Ar on biotite and Rb-Sr) are last magmatic products of the EP. The rocks are slightly depleted and homogeneous in isotopic composition, with respect to $^{87}Sr/^{86}Sr$ (ranging 0.705018 to 0.705643) and $^{143}Nd/^{144}Nd$ (ranging 0.512662 to 0.512714) that indicates young Nd model ages (0.51-059 Ga). This may imply that the parent melts tapped a homogeneous and young lithospheric mantle source, metasomatized by subduction-derived sediments during the Late Mesozoic. Pb isotopic compositions ($^{206}Pb/^{204}Pb$= 18.85-18.95; $^{207}Pb/^{204}Pb$ = 15.60-15.74; $^{208}Pb/^{204}Pb$= 38.82-39.25) may also be consistent with a model for an enriched SCLM source.

Geochemical and age data, combined with regional studies, show that the late Cretaceous magmatism formed in a subduction setting resulting from northward subduction of northern branch of Neo-Tethyan oceanic crust beneath the Eurasian plate and that the back-arc extensional period started by least ~79 Ma in the EP. A magmatic gap, coinciding with collision period, is present from late Cretaceous to late Paleocene in the region. After the collision period, first magmatic records, which are adakitic characters in composition, occurred at ~ 50 Ma. The rocks represent initial stage of crustal thinning caused by crustal extensional events in the EP. The spessartite type lamprophyres, having similar ages with the adakitic products, are evidence of initial stage of post-collisional extensional events in the region. From middle Eocene to late Miocene, lithospheric thinning and resultant upwelling of asthenosphere induced by lithospheric extension is responsible to magma generation in the EP. In this regard, the Eastern Pontides recorded a complex history of subduction-, collision- and extension related magmatic episodes from late Cretaceous to late Miocene.

25-5 16:10 Zarrinkoub, M.H.

ZIRCON U-PB AGE AND GEOCHEMICAL CONSTRAINTS FROM THE NORTHERN SISTAN SUTURE ZONE ON THE NEOTETHYAN MAGMATIC AND TECTONIC EVOLUTION IN EASTERN IRAN

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The Sistan suture zone, eastern Iran is generally regarded as a deformed accretionary prism that was emplaced during the destruction in the late Cretaceous-Paleocene of a narrow arm of the Neotethys Ocean separating the Lut and Afghan continental blocks. Based on a detailed field investigation, here we report new results of zircon U-Pb age and whole rock geochemistry of representative magmatic rocks from the northern Sistan suture zone, which allow us to explore the Neotethyan magmatic and tectonic evolution in eastern Iran. The results include: (1) two gabbros in the Sistan ophiolite sequence that yield zircon U-Pb ages of 113±1 and 107±2 Ma, respectively; (2) four granodiorite intrusions that show adakitic geochemical characteristics and yield ages of ca. 86-71 Ma; (3) two A-type granites dated at ca. 56 Ma; and (4) the subsequent, widespread calc-alkaline volcanism that was emplaced from the middle Eocene to late Oligocene (ca. 45-25 Ma) not only within the suture zone but also to the west in the Lut block. Combining the above with literature data, we conclude that between the Lut and Afghan continental blocks the Neotethys Ocean should have closed before ca. 86 Ma, when the adakitic granodiorites started emplaced in the suture zone as a result of the Lut-Afghan continental suturing/collision. The compressional tectonic regime, later, switched to extensional from ca. 56 Ma so that eventually led to the voluminous volcanism in eastern Iran, which we ascribe to an orogenic collapse associated with delamination of thickened lithospheric root. This extensional regime succeeded to cause furthermore lithospheric thinning and asthenospheric upwelling that gave rise to the generation of intraplate basalts from the middle Miocene to Quaternary in eastern Iran.

25-6 16:30 Irannezhadi, Mohammad Reza

TERTIARY MAGMATISM IN ALBORZ MOUNTAINS AND ITS RELATIONSHIP TO THE CONVERGENCE OF EURASIA WITH SOUTHERN PLATES

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The Alborz Mountain Range which is a part of Alpine-Himalaya orogeny and is located in northern Iran at the south of the Caspian depression contains Precambrian to Quaternary sedimentary, igneous and metamorphic rocks. Tertiary magmatism was widespread in Alborz (and also many other parts of Iran), the products of which are numerous plutons, dykes, sills, volcanics and volcanosedimentary rocks. A majority of these magmatic rocks have been attributed to Eocene and Oligocene. Subduction of the Neotethyan Ocean slab beneath Central Iranian plate has played a major role in evolution of the Alborz Tertiary magmatism. Despite their great significance in unraveling the geodynamic setting of this important part of the Alpine-Himalaya range, detailed geochemical investigation has not been carried out on magmatic rocks from Alborz Mountains.

A comprehensive geochemical dataset obtained in the course of the present study show relationship of the Alborz magmatic rocks to subduction and orogenic settings. These rocks show spiked incompatible elements patterns commonly interpreted as evidence for the involvement of a fluid or fluid-rich melt derived from the subducted slab. High ratios of large ion lithophile elements (LILE, Pb) to high field strength elements (HFSE) can be seen in many of these rocks. Trace element patterns of these rocks are more akin to the active continental margin. Although signs of extensional and post-collisional (Miocene ?) magmatism are also found in Alborz, the subsequent magmatic rocks have been affected by previous subduction events.

In this study we try to demonstrate some geodynamic aspects of the Tertiary subduction-related magmatism in Alborz Mountains by combining our geochemical data from Central Alborz with the data from other parts of this belt.

SESSION NO. 26, 14:30

Tuesday, 5 October 2010

Mélanges and mélange–forming processes. Part 2 (*Melanjlar ve melanj olusturan mekanizmalar*)

METU Convention and Cultural Centre, Salon A

26-1 14:30 Kitamura, Yujin

DYNAMIC ROLE OF TECTONIC MÉLANGE IN RELATION TO MEGA SEISMOGENESIS – SPACE AND TIME PARTITION OF DEFORMATION IN SUBDUCTION PLATE BOUNDARY

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Tectonic mélange is essentially a fault rock regarding to its definition. It is, however, difficult to imagine so because of its relatively broad occurrence and complexity of superimposed deformations, which limited us in a way of understanding that the mélange is a passive reproduct by some deformation. We examined different mélanges in the Shimanto accretionary complex in southwest Japan to assess the dynamic role of mélange in subduction plate boundary. Comparing mélanges from different maximum burial depth, we extracted successive change in deformation with subduction. Here we present an integrated result of our recent progress tectonic mélange study from the Japanese subduction zone.

Studied mélanges, the lower and upper Mugi mélange and Makimine mélange, have their maximum temperature of about 150, 200 and 340 °C, respectively. This range of temperature corresponds to up-dip to down-dip limit of seismogenic zone. These mélanges are exposed as a pile of thrust sheets. They are composed dominantly of shale and sandstone showing block-in-matrix structure, and basalt in the bottom of each thrust sheet. Such a deformed pile of ghost ocean stratigraphy suggests that these rocks have deformed in the plate boundary and underplated. Pseudotachylyte was found from the roof fault of the Mugi mélange. Paleo thermal structure reconstructed from vitrinite reflectance study showed that there is no temperature gap at the roof fault, which indicates that the roof fault was active when the fault plane was parallel to the isotherm. Therefore, we conclude that this roof fault was the former seismogenic décollement (Kitamura et al., 2005, Tectonics and Kimura et al., this meeting). The formation temperature of the veins in the sandstone boudin's neck is 125-195 °C (Matsumura et al., 2003, Geology), which indicates that the deformation of sandstone happens around up-dip limit of seismogenic zone.

We performed analyses of anisotropy of magnetic susceptibility (AMS) and boudin size distribution to obtain structural information of shales and sandstones, respectively. Results show that the deformation in the shales is dominantly vertical compaction in the shallow seismogenic zone and changes to simple shear deformation. The size and the aspect ratio of sandstone boudins decrease successively with subduction. These observations suggest that the mélange itself continues to deform within seismogenic zone. On the other hand, formation of the sandstone block is not a single process. Firstly, sandstone layer pinches out because of viscosity contrast, which is followed by cataclastic deformation. When the simple shear component increases, Riedel shear becomes also a sandstone breaker.

Our investigation revealed that the tectonic mélange is a broad fault zone of the plate boundary and keep deforming within seismogenic zone, where the main slip zone is their seismogenic roof fault. Consequently, there is a clear partitioning in deformation between rapid and episodic deformation at the roof fault and slow and continuous deformation in the mélange body. Such a slow and tiny deformation may relate to low frequency swarm in the down-dip limit of seismogenic zone. Also the changing multiple forming processes of the mélange will be a key to understand variety of earthquakes (e.g. very low frequency earthquake).

26-2 14:50 Yamamoto, Yuzuru

THICKENING OF TECTONIC MÉLANGES DUE TO CLAY-MINERAL TRANSITION IN 2-4 KM DEPTH IN SUBDUCTION ZONE: HOTA ACCRETIONARY COMPLEX, CENTRAL JAPAN

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The Initiation of tectonic mélange formation and related-clay mineral variation in aseismic-seismic transition zone along subduction-related thrust were examined by means of investigating onland accretionary complex buried only 2-4 km. The lower to middle Miocene Hota accretionary complex, central Japan, is a unique example of onland accretionary complex, representing initiation of tectonic mélange formation and relation between deformation and physical/chemical properties variation of sediments just prior to entering the seismogenic realm. Two kinds of subduction- related deformations: one is the phacoidal deformation (D1) characterized by rhombus-shaped fragmented mudstone with thin zone of clay-mineral preferred orientation in the outer rims whereas random fabric inside, similar to the primary décollement-zone deformation recovered by ocean drilling toe of modern accretionary prism; the other is deformation characterized by block-in-matrix style deformation (D2) with asymmetric S-C structure and intense clay-minerals preferred orientation, similar to the deformation of tectonic mélange in matured ancient décollement zone, are preserved in the Hota accretionary complex. Considerable-smectite reduction and illite increment were clearly identified inside the D2. Disappearance of weak smectite that has small frictional coefficient, and increment of electric cohesion of sediment associated with porosity reduction and clay mineral preferred orientations during D2 formation lead the shear zone strengthening. Such strain hardening associated with dynamic clay-mineral transition and particle orientation would be the primary mechanism in mélange zone thickening and fundamental mechanical transition just prior to entering the seismogenic zone.

26-3 15:10 Kimura, Gaku

MÉLANGE AS A PLATE BOUNDARY FAULT ROCK- EARTHQUAKE AND SLOW SLIP

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Mélange formation is a key issue to understand the convergent plate boundary processes since it was realized as a fossil Benioff zone in subduction zone during the founding stage of plate tectonics (Ernst, 1970). Although definition of tectonic, sedimentary, or diapiric (injective) mélange was a matter of controversy in the initial period, the research focus shifted more mechano-chemical processes of the mélange formation.

I review a recent research progress of mélange and discuss the plate boundary processes, especially seismogenesis and its updip and downdip limits. Most of on-land mélanges in Japanese islands were once buried beyond 150°C, reached to maximum more than 250-350°C in depth, and came back to the surface. Therefore they record the plate boundary processes in detail in that temperature range, which coincides with the seismogenic zone as suggest by Hyndman and Wang (1993).

Earthquake fault rocks of pseudotachylites have been discovered from several parts of mélange, especially roof thrust of the duplexed mélange packages (Ikesawa et al., 2003). However, the discovered earthqake fault rocks are not only the pseudotachylyte but also fluidized cataclasites with heating evidence. This new type of earthquake fault rocks suggests that thermal pressurization is a key mechanism for dynamic weakening of fluid dominated plate boundaries in subduction zone. Dynamic chemical reaction was also detected from the fault rock. This phenomenon indicates an abrupt change in redox state in association with sudden fluid flow.

Mélange including the earthquake fault rocks is characterized by “block-in-matrix” as traditionally well-known. Deformation mechanisms for the tectonic mélange are dominantly cataclasis with pressure solution. Relationship of these mechanisms with recently discovered slow slip in subduction zone must be a main focus of the next stage of research of mélange.

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Hyndman, R.D. and Wang, K., 1993, J.Geophts. Res., 98, 142039-142060.
Ikesawa, E., Sakaguchi, A., and Kimura, G., 2003, Geology, Geology, 31, 637-640.

26-4 15:50 Wakita, Koji

MELANGES ON GEOLOGICAL MAPS AT A SCALE OF 1:50,000

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The author has conducted the detailed geological mapping on the mélanges in the Jurassic accretionary complexes since 1977. The geological maps of his recent works show the detailed structures of the mélanges based on the understanding of melange formation processes in the accretionary complexes.

The Jurassic accretionary complexes of Japan were composed mainly of Carboniferous to Triassic basalt and limestone derived from ancient seamounts, Carboniferous to Jurassic pelagic chert, P-T boundary claystone, Triassic to Jurassic hemipelagic siliceous shale, and Jurassic to early Cretaceous sandstone and shale of trench turbidite. These components were originally derived from the “Ocean Plate Stratigraphy” which were formed on the past ocean plate moving from ocean ridge to trench, and accreted to the continental margin.

The “Ocean Plate Stratigraphy” was deformed, disrupted and mixed during the accretionary processes to form melange structures. The disruption was caused mainly near the hemiplagic siliceous shale and P-T boundary claystone where decollement was developed during the accretionary processes. Lower part of chert, limestone and basalt were fragmentated and mixed near the P-T boundary claystone, while upper part of chert and trench turbidite were disrupted near hemipelagic siliceous shale. The middle part of chert formed large slabs in mélanges as remnants of disruption and fragmentation.

The structures of mélanges are not completely chaotic. The original structures of “Ocean Plate Stratigraphy” were preserved in the mélanges in some degree. The stratigraphic tops of the large slabs mostly show the same direction in the mélanges. Some of large tectonic slabs in the mélanges kept the original order of “Ocean Plate Stratigraphy” even though they were deformed in various degrees. It suggested that “Ocean Plate Stratigraphy” was tectonically stacked during the offscraping process, and was gradually disrupted along the decollement and out-of-sequence thrusts during the accretionary processes to form the mélange structures.

These structures of the melanges mentioned above were represented in the geological map at a scale of 1:50,000 recently published by Geological Survey of Japan. These geological maps clearly show the melange formation processes during ocean plate subduction along Mesozoic Asian continental margin.

26-5 16:10 Ogawa, Yujiro

RETROGRADE DEFORMATION WITH RETROGRADE METAMORPHISM IN VARIOUS BLOCKS IN MINEOKA OPHIOLITIC MELANGE: COMPARATIVE STUDY TO THE ANKARA AND FRANCISCAN MELANGES

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Origin and setting of melanges are one of the eternal topics. Among the various characteristics, we noticed that most of the blocks in melanges in the subduction zone settings have systematic series of deformation, that is told in a word as retrograde. The last stage is characterized by shearing and brecciation during the final exhumation after the first emplacement from the depths. The best examples of melange in the world, the Ankara melange, as far as mapped, are composed of various kinds of blocks, large and small, ranging from pelagic limestone to amphibolite or greenschist through basalt, chert and sandstone. Those are more or less largely deformaed into breccia. Matrix is of a little amount, and even the serpentinite is not always surrounding the blocks, but is juxtaposed as blocks side by side with other blocks, so that the total mass are said not to be a block-in-matrix relation but rather a kind of a fault belt.

The Mineoka belt in central Japan is situated on the extension of the Izu forearc, and is composed of Cretaceous to Miocene basaltic rocks and pelagic limestone/chert with considerable amount of terrigeous, some volcaniclastic some continental-arc derived fragments as well as ophiolitic materials. Although a large amount of serpentinite (harzburgite in origin) are associated, they are rarely sheared (limited only in a narrow zone around the blocks), but mostly inside is only brecciated. Brecciation is common in metamorphic rocks (2 GPa at maximum) and basaltic or gabbroic rocks of several stages of deformation and metamorphism. Deformation series is from the early mylonitic to later shearing and the last brecciation. Veining of zeolite, prehnite and calcite is also common in basaltic rocks of MORB in chemistry, suggesting various stage hydrothermal deformation since the first emplacement around a spreading ridge setting to strike-slip deformation at later stages. Several stages of such deformation are attributable to strike-slip or transpressional fields, further suggesting most of the multi-stage emplacements are of either transform along ridge-ridge setting, or obudction or even flow mélange-like exhumation along a forearc sliver fault setting.

The Franciscan melange in the San Simeon area on the middle California coast is the classical type locality for the melange study history, and is characterized by various kinds of large to small blocks in muddy matrix. However, our detail mapping indicates that fish or turtle-like shape of blocks suggests Poiseuille flow within muddy (lawsonite-bearing) matrix. Another important mode of deformation is brecciation. Even blueschist, greenschist, basalt and so on are largely brecciated as the last stage of deformation.

In these representative melanges, such modes of shearing, shape of blocks, and inside deformation from ductile to brittle conditions suggests retrograde metamorphism and associated deformation, probably during when those blocks are exhumed along the return flow into flow melanges, some may be within a subduction zone complexes (part of an accretionary prism), some in forearc sliver fault zones.

26-6 16:30 Ukar, Estibalitz

TECTONIC EVOLUTION OF BLUESCHIST-FACIES BLOCKS IN THE FRANCISCAN MÉLANGE AT SAN SIMEON, CALIFORNIA: INSIGHTS INTO SUBDUCTION ZONE EVOLUTION

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The Franciscan mélange exposure near San Simeon contains a small volume (<1%) of mafic blueschist blocks, and an even smaller volume of graphite-schist blocks. Mafic blueschists are of low-T blueschists, and they are of two kinds: lawsonite-Na-amphibole, and epidote-lawsonite-Na-amphibole blueschists. They lack jadeitic pyroxene and, for the most part, also albite. The peak temperatures attained by these rocks are recorded by pre-M2 epidote, and/or actinolitic cores in sodic amphiboles. Actinolite-core-bearing, epidote-free blocks attained peak temperatures of ~300 ºC at 5 kbar, whereas peak temperatures for epidote-bearing blocks are estimated to be on the order of 325-350 ºC. The main epidote-free, blueschist-facies mineral assemblage (M2) preserved in most blocks in San Simeon was recrystallized at about 200-250 ºC and 5 kbar. These blocks record evidence of a counterclockwise P-T path.

Nine of the 34 studied blueschist blocks in San Simeon contain an actinolitic rind. This study is the first report of such rind in low-temperature Franciscan blueschist mélange blocks. As these blocks occur in pelitic-matrix mélange their separation from a terrane with ultramafic rock is evident. Remnants of the metasomatically altered ultramafic as well as mafic parts of the reaction zone developed along block margins are preserved in the San Simeon blueschists. The counterclockwise P-T path and presence of associated actinolitic rinds in low-T blueschist blocks from San Simeon indicates these rocks have a common metamorphic history with high-T garnet-epidote mafic blocks that are distinctive and better studied components of the mélanges from the Central Belt.

This is the first report of graphite-schist blocks in the Franciscan. Graphite-schists were likely derived from a layered shale/graywacke protolith. Lawsonite is present in about one-third of the 30 studied graphite-schist blocks, and several examples of interlayered mafic blueschist and graphite-schists were found, indicating at least some graphite-schist blocks were metamorphosed under similar high-P/low-T conditions as mafic blueschists.

The cessation of ocean floor spreading related to magmatism gave place to the initiation of Franciscan subduction along the margin between the old, cold Farallon plate and the newly-formed CRO-capped lithosphere at about 155-160 Ma. Graywacke sediments that bypassed the forearc basin and were transported to the trench axis along submarine canyons are the probable protolith of the graphite-schist blocks.

During the initial stages of Franciscan subduction in southern California, part of the top volcanic sequence and overlying sediments were underplated at the bottom of the overriding plate and were metamorphosed under high-P conditions soon after initiation of subduction. The age of epidote-bearing low-T blueschist blocks in San Simeon is similar to that of high-T garnet-bearing blocks in the northern mélange terrane (~150-156 Ma), which approximates that of the initiation of Franciscan subduction. Material underplated along the base of the hanging wall became refrigerated and variably retrograded. Actinolitic rinds formed soon after blueschist-facies metamorphism at the bottom of the overriding plate when mafic rock came into contact with mantle that became serpentinized under nearly static conditions. Mafic material continued to be underplated, and low-T dynamic blueschist-facies metamorphism continued to form until at least ~137 Ma.

A model is proposed in which the shallowing of the plate associated with the Laramide orogeny at about 80 Ma played an important role in the exhumation of high-P-blocks and formation of the Franciscan mélange. This shallowing triggered extensional thinning at the surface facilitating the exhumation of coherent metasedimentary terranes of the Eastern Belt as well. The underplated mafic blueschist terrane was brought up to depths of a few km by extension. Blocks were plucked from the bottom of the extended overriding plate and incorporated into the undercompacted shale-rich shear zone forming the plate interface, and brought near the surface during the upward flow of mélange driven by the movement of the downgoing plate. During upwelling extended blocks were boudinaged, and metasomatically altered in the cataclastic zones that developed along necks and margins of the blocks. Dewatering that led to final compaction occurred near the surface.

SESSION NO. 27, 14:30

Tuesday, 5 October 2010

Tectonic, magmatic & geomorphic evolution of high plateaus. Part 2 (*Yüksek platolarin tektonik, magmatik ve jeomorfik evrimleri*)

METU Convention and Cultural Centre, Salon C

27-1 14:30 Gogus, Oguz H.

LITHOSPHERIC DELAMINATION IN AN OROGENIC SETTING: AN EXAMPLE FROM THE EASTERN ANATOLIA COLLISION ZONE

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We examine the role of mantle lithosphere delamination beneath Eastern Anatolia where lithospheric thinning, plateau formation, volcanism and syn-convergent crustal extension have been all suggested. The evolution of delaminating lithosphere (i.e., a peeling away of mantle lithosphere from the crust) is modeled using SOPALE, a geodynamic code that treats the thermomechanical evolution of heterogeneous media. We focus on several observables in the experiments: Surface topography, Moho topography, and crustal structure/deformation rates. A range of convergence rates are imposed during delamination to see the control of lithospheric shortening on surface topography crustal deformation. The models suggest that delamination causes zones of surface uplift (and heating) and subsidence above the mantle lithosphere gap. The subsidence is overwhelmed and an elevated plateau develops in the presence of large-scale plate convergence. In the experiments, contemporaneous delamination and plate shortening at 3 cm/yr produces plateau uplift (in a confined zone of ~600 km) that is consistent with the present day surface topography of Eastern Anatolia along a profile at 42°E. The removal of mantle lithosphere induces distinct regions of contraction/thickening and extension/thinning of the crust. Based on our strain rate calculations, the latter occurs even within a regime of plate shortening, which may explain the development of a ~ 200 km zone of extension in the midst of the Eastern Anatolia at the Arabia-Eurasia convergent plate boundary. The results apply directly to Eastern Anatolia, but may be used to understand similar styles of anomalous topography and syn-convergent extension at the Apennines-Tyrrhenian, Himalayas, Andes and Alboran Sea/Rif-Betics.

27-2 14:50 Toker, Mustafa

SEISMIC AND CRUSTAL IMPLICATIONS FOR EVOLVING ACCRETIONARY WEDGE-BASIN: LAKE VAN, EASTERN ANATOLIA ACCRETIONARY COMPLEX (E-TURKEY)

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Eastern Anatolia Accretionary Complex (EAAC) provides a unique natural laboratory to constrain geodynamics associated with continent-continent collision, subsequent lithospheric delamination, crustal thinning and formation. EAAC is responsible for major growth of the continental lithosphere, through the addition of juvenile magmatic products, but are also major site of consumption and reworking of continental crust through time. It can be broken into retreating and advancing types, based on its kinematic framework and resulting geological character. This research deals with some critical aspects of post-orogenic processes and discusses a prominent example of accretionary orogens in the world and its crustal growth through neotectonic history. An examination and evaluation of multi-channel seismic reflection and high-resolution chirp data cover the geological consequences of the largely Neogene delamination that characterizes the segments of interest, in response to late stage reorganization of the subduction zone, the delamination and break-off of the subducting slab. The aim of this research is to provide a better understanding and overview of post-collisional processes in accretionary orogens and their role in the formation and evolution of the continental crust.

It becomes clearer that questions on evolution of EAAC are answered in tectonic patterns and deformation styles of the accretionary wedge-basins in the region. The peculiar one of these wedge-basins is orogen-parallel Lake Van trough (with 2 km elevation), emplaced at N-end of Bitlis-Pötürge Massive (BP-M) along Muº suture, separating EAAC from BP-M. Lake Van region is a place where no mantle lid exists. Dome-shaped topography of Lake Van is interpreted as indicating asthenospheric upwelling. Lake Van, together with its W-continuation, Muº basin, is generally considered as a prototypical sediment-rich accretionary wedge-basin complex, its tectonic and magmatic evolution is important for understanding accretionary plate margins, the surficial tectonic effects of delamination and decompressional melting magmatism. In multi-channel seismic reflection research of Lake Van, the largely seismic data-based contributions investigate the following special subjects of the preliminary results to exhibit and interpret tectonic and magmatic record of orogeny in Lake Van accretionary wedge-basin. Seismic structural interpretation of overall deformations observed in and along Lake Van leads to clear evidences of basement reactivation, basin inversion, strike-slip deformation, orogen-parallel extension as well as extensional magma propagation, post-magmatic hydrothermal alterations, and magma-hydrothermal sediment deformations. Seismic sections show a late stage of extension-transtension of W- and S-margins of Lake Van, implying that there is a growing appreciation of the role of extensional/strike-slip tectonics in accretionary orogen. This gives an important view that local or large-scale tectonic contacts such as suture complex in orogenic belt have changed. Reflection data also illustrate seismic pattern, external geometry and basinal emplacement of shallow level magmatic intrusions and their cryptoexplosions and reveal clear evidences of dynamics of crustal magma transfer, storage and differentiation. An interpretation of these findings can be extended into an overview of the evolution of the convergent crust beneath the lake. This suggests that extensional magmatism is subject to a series of processes that lead to its differentiation during transfer through and storage within the convergent crust. This provides new insights to the subject of magmatic processes operating within the crust, and remarks important links between subsurface processes and magmatism.

The vast amount of the magmatic cover in the lake suggests a corresponding abundance of alkaline melting materials. These inject into the accretionary complex and there become solidified. The generated partial melts by adiabatic decompression pool under the accretionary structure, penetrate it and begin melting it. This is the first-order mechanism of upper crustal emplacement of rising magmas, confirming extensive marginal distribution of extensional magmatism in the lake. This mechanism builds the crust and drives hydrothermal circulation and consequent melting of the wet accretionary complex rocks, implying basalt-hosted hydrothermal system in Lake Van. This evident the transport of extensional alkaline magmas from the uppermost mantle through the basin-bounding fault zones/suture trends and its cooling and crystallization. Decompressional melting magmatism is correlated with alkaline magmatic surges around Lake Van and clearly appears associated to the present-day area of the crustal thinning defined by the previous studies. It is obvious that the timing of these magmatic surges is related to upwelling pulses from the uppermost mantle, dependent of the extensional and strike-slip tectonic setting of Lake Van. All these considerations deduced from seismic structural observations give a clue to how continental crust forms in E-Turkey and how it begins its journey towards complete consolidation in the form of a continent.

27-3 15:10 Jahangiri, Ahmad

GEOCHEMISTRY OF PLIOCENE/QUATERNARY BASALTS ALONG NORTH TABRIZ FAULT, NW IRAN

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Pliocene/Quaternary volcanism accompanied strike-slip related transtensional deformation along the Northern Tabriz Dextral Fault (NTDF) in the northwest Iran. These volcanic rocks are represented by tephrite, olivine basalts, basdalt, trachi-basalts, trachi-andesite. They can be divided into three different sub-groups on the basis of their mineralogy and geochemical features. Alkaline leucite-bearing basaltic rocks, are characterized with high ratios of K_2O/Na_2O high content LILE and low values of high field strength elements like Ti, Nb and Ta. They are display fractionated REE patterns and based on different discrimination diagrams show similarity with arc related magmas. The olivine basalt studied samples shows close similarity to OIB with high content of TiO_2, Nb, Ta, fractionated REE pattern and primitive mantle normalized spider diagrams. However, compared with a global average of OIB, they are display slightly higher large ion lithophile element (LILE) and lower high field strength element (HFSE) concentrations, features that resemble slightly the arc magmas and suggest that the source of the magmas may have been slightly contaminated by slab-derived fluids. Basaltic to trachy-basaltic rocks have simple mineralogical composition with plagioclase and clinopyroxene without feldspatoied, olivine and k-rich minerals like phlogopite. They are Na_2O rich and their REE chonderite normalized patterns are moderately fractionated. The large variation in the ratios of different incompatible trace elements like Zr/Nb, Zr/Ba and Ba/La also suggest that crustal contamination is affected the magmas during ascent of magma. Pliocene/Quaternary basaltic magmas along dextral North Tabriz Fault is erupted after formation andesitic to dominant dacitic volcanic rocks with adakitic geochemical characteristics rocks such as highly fractionate REE pattern, high Sr/Y ratio. Generation of adakitic rocks may be related to increased temperatures in the subduction zone due to mantle upwelling. This may have also given rise to melting of the subducted oceanic crust in the eclogite field where garnet is stable. Subsequent asthenospheric upwelling could have caused direct melting to produce the alkaline magmas, these melts having the chemical signature of the asthenosphere slightly metasomatised by slab fluids. Rupture of the continental lithosphere by strike-slip-related transtensional deformation might have caused decompressional partial melting of the asthenospheric mantle and generating alkali basalts in northern part of North Tabriz Fault. Probably continental lithosphere rupturing is occurred following of slab breakoff/delamination processes following closure of Neo-tethys and collision of Arabian plate with microplate of Iran.

27-4 15:50 Rezaeian, Mahnaz

EXHUMATION EPISODES IN THE ALBORZ MOUNTAINS WITHIN IRANIAN-TURKISH PLATEAU

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The Alborz Mountains in the north Iranian-Turkish Plateau form a first-order structural system accommodating convergence between Arabia and Eurasia during the Tertiary. In this study we demonstrate the temporal pattern of exhumation in the Alborz coincides with the main phases of deformation within Iranian-Turkish Plateau.

Located between the ultra deep basin of the South Caspian Sea and the micro-continental plateau of central Iran, the Alborz Mountains take up ~ 40% of the crustal shortening due to convergence of the Central Iranian Plateau and Eurasia. This has resulted in the construction of a ~4 km high mountain belt composed of Precambrian-Paleozoic and Mesozoic basement rocks and inverted Cenozoic basin fills. The timing of this construction is particularly important because it may have been coincided with the closure of the Neo-Tethyan seaway linking the Indian Ocean and the Mediterranean Sea, with broad consequences for global ocean circulation. The mountain belt has also interrupted the air flow off the Russian plains and the Caspian Sea, producing a strong climatic gradient with a wet, densely vegetated north flank and a dry, barren south flank. We have used a combination of low temperature thermochronometric and stratigraphic observations to constrain the onset of mountain building in the Alborz and the timing and location of its stepwise exhumation. Apatite fission tracks record a phase of magmatic activity associated with crustal extension during the Middle-Late Eocene, ca. 39 Ma, followed by rapid exhumational cooling during the Eocene-Oligocene transition at ca. 32 Ma. This exhumation phase has caused the deposition of coarse clastic sediments of Lower Red Formation in fringing basins. Accompanied by a switch from submarine to subaerial volcanic activity in southern Alborz, it is interpreted to reflect the onset of convergence and mountain building in north Iran.

This first episode of exhumation recorded in the Alborz coincides with initiation of collision in the Arabia-Eurasia continental collision zone has been constrained by the other studies.

It has been followed by a period with relatively little tectonic activity resulted in deposing of carbonate Qom Formation. This phase of tectonic quiescence lasts for 15-20 My.

The second phase of rapid exhumational cooling has been started at ca. 16 Ma caused the deposition of coarse clastic sediments of Upper Red Formation in the Middle Miocene. It has been interpreted in the literature as the second stage of the collision resulted from the arrival of unstretched Arabian continental lithosphere in the Neo-Tethyan subduction zone.

The Iranian-Turkish Plateau has undergone a main phase of exhumation at NE portion of the Eurasia-Arabia collision zone between 18 and 13 Ma. The second episode of the Alborz exhumation falls within this interval.

The third exhumation pulse, from ca. 5 Ma has been recorded by apatite (U-Th)/He. This episode coincides with a major reorganization of the collision zone occurred at ca. 5 Ma.

27-5 16:10 Abbasi, Madjid

THE STUDY OF CRUSTAL STRUCTURE IN THE IRANIAN PLATEAU BY GRAVIMETRIC DATA BASED ON GEOPOTENTIAL MODEL EIGEN-5S

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Geopotential models provide reliable low frequency gravimetric data. Based on a recent study, one of the best satellite-based geopotential models of gravity field for Iranian region is EIGEN-5S. This model provides the coefficients of gravity potential function of the earth up to degree and order 150 in spherical harmonic development, which correspond to a spatial resolution of 130 km (half-wavelength).

This resolution seems to be enough for determining the large-scale crustal structures in Iran. We computed the complete Bouguer anomalies over the Iranian plateau and the seas adjacent to it using SRTM (the global digital terrain model) and the sea depth maps provided by the National Cartographic Center (NCC). The Caspian is 25.83 m below the geoid. To account for this difference in height, we first added this value to the depth of the Caspian, and then, we treated the 25.83-meter layer as a layer of rock. The Bouguer anomalies show a minimum of –268 mgal over the Zagros Mountains, which have the thickest crust in Iran. A maximum Bouguer value of 70 mgal is observed along the southern shore of the Caspian Sea. This is the region where the thicker continental crust of Iran moves towards the thinner oceanic crust of the Caspian basin.

Next, we attempt to invert the Buoguer anomalies to a moho depth model for the Iranian plateau. We do the inversion in the frequency domain using an iterative scheme to calculate the shape of moho undulations beneath the crust.

27-6 16:30 Sheth, Hetu C.

MAFIC ALKALIC MAGMATISM IN CENTRAL KACHCHH, INDIA: A MONOGENETIC VOLCANO FIELD IN THE NORTHWESTERN DECCAN TRAPS

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Magmatism in Kachchh, in the northwestern Deccan continental flood basalt province, is represented not only by typical tholeiitic flows and dykes, but also plug-like bodies, in Mesozoic sandstone, of alkali basalt, basanite, melanephelinite and nephelinite, containing mantle nodules. Their volcanological context is poorly understood. Based on new and published field, petrographic and geochemical data, we identify this suite as an eroded monogenetic volcano field. The plugs are very shallow intrusions (necks, sills, dykes, sheets, laccoliths), there are local peperites reflecting mingling between magmas and soft sediments, and a well-developed phreatomagmatic vent, made up of lapilli tuff rich in mafic lithic blocks, and injected by mafic alkalic dykes. The lapilli tuff contains basalt fragments, glass shards, and detrital quartz and microcline, and the peperites and the phreatomagmatism are consistent with existing evidence for a humid subtropical climate in Kachchh at ~65 Ma. The Central Kachchh monogenetic volcano field has >30 individual structures and possibly many more if compositionally identical igneous intrusions in northern Kachchh are proven by future dating work to be contemporaneous. The field has important tectonic implications (low-degree, diffuse crustal extension and low-degree mantle melting, unlike significant directed extension and vigorous mantle melting under the Deccan proper region of flood basalts themselves). The field attests to regional volcanological, compositional, and tectonic variability within flood basalt provinces, and adds the Deccan Traps to the list of such provinces containing monogenetic- and/or hydromagmatism, namely the Karoo-Ferrar and Emeishan flood basalts, and plateau basalts in Saudi Arabia, Libya, and Patagonia.

SESSION NO. 28, 09:30

Thursday, 7 October 2010

Aegean geodynamics and extensional tectonics. Part 1 (*Ege bolgesinin jeodinamik evrimi ve gerilmeli tektonikte güncel problemler*)

METU Convention and Cultural Centre, Salon B

28-1 09:30 Ring, Uwe

THE RETREATING HELLENIC SUBDUCTION SYSTEM: HIGH-PRESSURE METAMORPHISM, EXHUMATION, NORMAL FAULTING AND LARGE-SCALE EXTENSION

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The Cenozoic history of the retreating Hellenic subduction system in the eastern Mediterranean involves subduction, accretion, arc magmatism, exhumation, normal faulting and large-scale continental extension from ~60 Ma until the present day. Ages for high-pressure metamorphism in the central Aegean Sea region range from ~53 Ma in the north (Cyclades islands) to ~25-20 Ma in Crete in the south, equivalent to a decrease in age down-section. Younging of high-pressure metamorphism in a southerly direction reflects the southward retreat of the Hellenic subduction zone. The shape of pressure-temperature-time paths of high-pressure rocks is remarkably similar across all tectonic units, suggesting a steady-state thermal profile of the subduction system and persistence of deformation and exhumation styles. The high-pressure metamorphic events were caused by the underthrusting of discrete fragments of continental crust, and these short-term events were superimposed on progressive slab retreat. Most of the exhumation of high-pressure units occurred in extrusion wedges during ongoing subduction and overall lithospheric convergence. At 23-19 Ma this extrusion wedge stage was followed by large-scale lithospheric extension with the development of metamorphic core complexes and the opening of the Aegean Sea basin. This extensional stage caused limited exhumation at the margins of the Aegean Sea but accomplished the major part of the exhumation of ~21-16 Ma old high-grade rocks in the central Aegean (Naxos, Paros and Ios islands). The age pattern of extensional faults, as well as contoured maps of apatite and zircon fission-track cooling ages, do not show a simple southward progression but reflect fluctuations in regional partitioning of extensional deformation and related exhumation from 23-19 Ma to the Recent. Current data suggest that large-scale extension was accommodated by a few low-angle, large-magnitude extensional fault systems. Slip rates on these faults were of the order of 5-10 km/Myr. The pattern, magnitude and slip rates of the extensional faults in the Aegean Sea region are in marked contrast to that in the adjacent Menderes massif of west Turkey. Our review of lithologic, structural, metamorphic and geochronologic data outlines the evolution of the Hellenic subduction system, and supports a temporal link between draping of the subducted slab over the 660 km discontinuity and large-scale extension causing the opening of the Aegean Sea basin.

28-2 09:50 van Hinsbergen, Douwe

A KEY EXTENSIONAL METAMORPHIC COMPLEX REVIEWED AND RESTORED: THE MENDERES MASSIF OF WESTERN TURKEY

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Here I will present a map-view restoration of the Neogene unroofing history of the Menderes Massif, and the relationship with motions of the Lycian Nappes in the Neogene. Exhumation of this massif – among the largest continental extensional provinces in the world – is generally considered to have occurred along extensional detachments with a NE-SW stretching direction. Restoration of the early Miocene history, however, shows that these extensional detachments can only explain part of the exhumation history of the Menderes Massif, and that NE-SW stretching can only be held accountable for half, or less, of the exhumation.

Restoration back to ~15 Ma is relatively straightforward, and is mainly characterised by a previously reported 25-30° vertical axis rotation difference between the northern Menderes Massif, and the Southern Menderes Massif and overlying HP nappes, Lycian Nappes and Bey Dağları about a pivot point close to Denizli. To the west of this pole, the rotation was accommodated by exhumation of the Central Menderes core complex since middle Miocene times, and to the east probably by shortening.

At the end of the early Miocene, the Menderes Massif formed a rectangular, NE-SW trending tectonic window of ~150x100 km. Geochronology suggests unroofing between ~25 and 15 Ma. The north-eastern Menderes Massif was exhumed along the early Miocene Simav detachment, over a distance of ≤50 km. The accommodation of the remainder of the exhumation is enigmatic, but penetrative NE-SW stretching lineations throughout the Menderes Massif suggest a prominent role of NE-SW extension. This, however, requires that the eastern margin of the Menderes Massif, bordering a region without significant extension, is a transform fault with an offset of ~150 km, cutting through the Lycian Nappes. For this, there is no evidence.

The Lycian Nappes – a non-metamorphic stack of sedimentary thrust slices and an overlying ophiolite and ophiolitic mélange – have been previously shown to thrust to the SE between 23 and 15 Ma over at least 75 km. This is contemporaneous with, and orthogonal to stretching along the Simav detachment. I here argue that the amount of SE-wards displacement of the Lycian Nappes was twice the minimum amount of 75 km, which would restore them back on top of most of the Menderes Massif, apart from the ~50 km unroofed along the Simav detachment. A decollement was likely formed by a high-pressure, low-temperature metamorphosed nappe immediately underlying the Lycian nappes in the north – the Ören unit. Latest Oligocene to early Miocene fission track ages of the Menderes Massif, as well as NE-SW trending lower Miocene grabens on the Massif are in line with this hypothesis.

The main implications of this restoration are that 1) the eastern part of the Aegean back-arc accommodated not more than 50 km of NE-SW extension in the early Miocene, and 2) any pre-Miocene exhumation of the Menderes massif cannot be attributed to the known extensional detachments. The restoration in this paper suggests that most of the Menderes Massif already resided at upper crustal levels at the inception of extensional detachment faulting, a situation reminiscent of the role of extensional detachments on the island of Crete

28-3 10:10 Gessner, Klaus

MIOCENE DEFORMATION OF THE MENDERES MASSIF: CONCURRENT FOLDING, FAULTING AND CORE COMPLEX FORMATION CAUSED BY A LITHOSPHERE SCALE WRENCH ZONE

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Within the Alpine orogenic belt the Menderes Massif in western Turkey forms a composite nappe stack that was assembled during Eocene to Oligocene crustal shortening. Whereas subduction and imbrication of continental fragments appears to have ceased in western Turkey around the Late Eocene to Early Oligocene, orogenic activity has continued in the Aegean. This discontinuity in structural evolution along strike of the Alpine orogen requires the existence of a lithosphere scale shear zone between the Aegean and Anatolia. Here we propose that a lithospheric scale wrench zone caused concurrent folding, faulting and core complex formation across the Menderes Massif in the Early Miocene. Since the Early Miocene, the Menderes Massif has been exhumed and extended in an overall N-S orientation. The most prominent extensional structures in western Turkey are Miocene to recent E-W trending grabens controlled by low angle and high angle normal faults. Two of these grabens – the Gediz graben in the north and the Büyük Menderes graben in the south – delimit the Central Menderes Metamorphic Core Complex (CMCC). The CMCC is a syncline structure forced on the Alpine nappe stack by symmetrical footwall uplift below opposite facing low-angle normal faults. The area to the north of the CMCC – the Gediz Massif – displays a pattern of NE-SW trending Miocene basins, and basement highs. South of the CMCC, in the Çine Massif, similar basins trend NNW-SSE. Recent work has suggested that the exhumation of the CMCC is driven by a counterclockwise 30 degree rotation of the Çine Massif relative to the Gediz Massif, which means that the NE-SW basins in the Gediz Massif and the NNW-SSE trending basins in the Çine Massif may have formed in a similar orientation. The NE-SW and the NNW-SSE trending basins appear to have formed contemporary with early ESE striking stages of the ongoing E–W basin formation, but are much shallower and, unlike the latter, have ceased to be active before the Pliocene. Previous studies have suggested that bounding faults or basal detachments controlled the NE-SW striking basins in the Gediz Massif, but there is little direct evidence for this. Here we propose that in the Early Miocene, transtensional folding with a wavelength of tens of kilometers has occurred concurrent with core complex formation and ESE trending normal faulting across a wide structural corridor in the Menderes Massif. Folding caused uplift of basement in the anticlines, while providing accommodation space for the Miocene basins in the synclines. The existence of large granite intruded metamorphic core complexes and widespread volcanic activity in the northern Menderes Massif during the Miocene compared to minor intrusions in the footwall of the CMCC suggest that the crust was much hotter in the north. The combination of folding and faulting, distributed across a wide NE- trending corridor is likely to amount to substantial sinistral offset between the different lithosphere domains in Anatolia and the Aegean. Our model provides an explanation for the geometry and timing of Neogene basins in the Menderes Massif, and may be applicable to marginal zones of other continental backarcs.

28-4 10:50 Bozkurt, Erdin

TIMING OF POST-OROGENIC EXTENSION IN THE GÖRDES MIGMATITE DOME, WESTERN TURKEY: INSIGHTS FROM U-PB AND RB-SR GEOCHRONOLOGY

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The Menderes Massif in western Turkey is a crustal-scale metamorphic core complex and is conventionally subdivided into northern (Gördes), central (Ödemiþ-Kiraz) and southern (Çine) submassifs, where the seismically active E-W-trending Gediz Graben in the north and Büyük Menderes Graben in the south are taken as dividing lines, respectively. The evolution of the massif occurred during two distinct but successive events: (1) continental collision and consequent crustal thickening of pre-Alpine basement during the closure of Neotethys along the Ýzmir-Ankara suture zone and (2) subsequent post-orogenic Neogene extension during which metamorphic rocks of the massif exhumed progressively in the footwall of first ductile, then brittle detachment faults detachment faults. Simav detachment fault around the Simav Graben forms one of the most spectacular structures of the massif. The footwall rocks are composed of high-grade metamorphic rocks, including the migmatites, while the hanging wall is made up of low-grade metamorphics and rocks of the Ýzmir-Ankara suture zone. The supradetachment basins (e.g., Gördes, Demirci, Selendi, Akdere basins)) in the immediate hanging wall hosted

T H U R S D A Y

sedimentation of upper Oligocene to middle Miocene continental clastic rocks attesting the surficial and erosion of footwall rocks. While extensive volcanic activity has been prevailing in the upper plate, the lower plate was intruded by two large bodies of Egrigöz and Koyunoba granites (ca. 20 Ma).

In the present paper we present the results of a recent geochronological campaign (U-Pb on zircon and monazite; Rb-Sr on muscovite and biotite) on the migmatitic, granitic, pegmatitic and cataclastic rocks of the Gördes migmatite dome. The aim was to date the timing of faulting / the extensional deformation and to constrain the history and therefore the evolution of core complex formation in western Turkey. The results argue that extension in the region commenced by ca. 30 and continued till ca. 8 Ma and that core-complex formation in the northern Menderes Massif is complex, occurred in pulses and involved periods of alternating rapid and slow cooling/denudation rates.

28-5 11:10 Faulds, James E.

FAVORABLE STRUCTURAL SETTINGS OF GEOTHERMAL SYSTEMS IN THE AEGEAN EXTENSIONAL PROVINCE OF WESTERN TURKEY

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The Aegean extensional province of western Turkey is a region of abundant geothermal activity currently undergoing significant extension. The geothermal activity is generally associated with enhanced dilation on ~E-W-striking normal faults induced by a complex combination of forces, including slab roll-back in the Hellenic and Cyprean subduction zones and collision of the Arabian plate with Eurasia and resulting tectonic escape of the Anatolian block. Recent magmatism has been relatively sparse in western Turkey; thus, the geothermal activity is generally not driven by magmatic heat sources, at least not within the middle or upper crust. Instead, faults accommodating deep circulation of hydrothermal fluids of meteoric origin are the primary control on the geothermal systems. It is therefore critical to evaluate which type of faults and which parts of faults are most favorable for geothermal activity. Better characterization of the structural controls is needed to enhance exploration strategies, particularly for discovering blind geothermal resources (i.e., with no surface hot springs) and for selecting the most promising drilling sites at individual geothermal fields. We have therefore been analyzing the controls on geothermal activity in several areas across western Turkey, including the Gediz-Alasehir, Simav, and Menderes grabens.

Our findings indicate a variety of favorable structural settings but with several recurrent themes. The two hottest fields in Turkey (Germencik and Kizildere) are focused near the ends of the major normal fault zone that bounds the Menderes graben. We suggest that this fault zone breaks into multiple splays, or horsetails, as it terminates, thus generating a belt of higher fracture density and permeability that accommodates significant fluid flow. The Eynal geothermal system near Simav is hosted by a complex normal fault system with multiple steps and intersections. Several fields, including Germencik and Kursunlu Canyon near Salihli, occur at the intersections between major graben-bounding normal faults and oblique-slip, transversely oriented transfer faults. The Kursunlu Canyon field appears to occupy a small dilational jog, or pull apart, at the intersection of a transverse sinistral-normal fault and currently inactive Gediz detachment fault. However, the main geothermal upwelling for Kursunlu Canyon may lie a few kilometers away from surface springs along a major step in the active, steeply dipping graben-bounding fault zone, where multiple fault splays within the step-over generate a subvertical zone of higher fracture density and permeability. Upon intersecting the detachment fault, fluids in the upwelling may follow permeable carbonate and breccia along the gently dipping detachment rather than rising to the surface directly above the upwelling.

Similar to the Great Basin in the western USA, most systems in western Turkey occupy discrete steps in fault zones or lie in belts of intersecting, overlapping, and/or terminating faults. The similarities in favorable settings between these two active areas of continental extension suggest that conceptual exploration models can be developed for geothermal activity in particular tectonic settings. Further characterization of the structural controls on geothermal activity will help to reduce the risks of drilling while also facilitating discovery of blind geothermal systems.

28-6 11:30 Teyssier, Christian

COEVAL SHALLOW EXTENSION AND DEEP CONTRACTION DURING OROGENIC COLLAPSE: COLLIDING CHANNELS AND DOUBLE DOMES

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Gneiss (migmatite) domes such as the one on the island of Naxos in the Aegean Sea form in a variety of tectonic regimes, from contraction to wrenching to extension, and in some cases form primarily by buoyancy forces. These domes are typically made of a core of variably deformed migmatitic and granitic rocks surrounded by a metamorphic envelope. Physical experiments on diapirism have produced mushroom-shaped domes and finite strain fields that are characterized by vertical stretch (constriction strain) in the stem of the diapir, sub-horizontal flattening in the roof of the dome, and near simple shear (plane strain) at the dome margins. Although dome shape and strain distribution are modified when extension or contraction are involved, deciphering fold-dominated, detachment-dominated, or gravity-dominated domes from their shapes and finite strain fields remains elusive. Many domes reveal an internal architecture composed of two cores separated by a narrow, steeply dipping high strain zone. Examples of double domes include the Montagne Noire (southern France), Naxos (Cyclades, Aegean Sea, Greece), Entia (central Australia), Warwick (N Appalachians, USA), and possibly Thor-Odin (BC, Canada). In some domes, the steeply dipping central high strain zone has been interpreted either in terms of diapiric ascent of migmatites or horizontal shortening and folding.

A series of 2D numerical experiments were carried out to explore the flow of deep crust during extension. These models focus on the strain field within and around domes and build on earlier work that examined the thermal and mechanical implications of the role of partial melting in the development of metamorphic core complexes. The model is 360 km long and 120 km deep. It includes a 60 km thick crust above 45 km of mantle and below a 15 km thick layer of low density, low viscosity material simulating air. To facilitate comparison among experiments, we include a fault-shaped weak element in the upper crust to force the development of a dome at the center of the model. Without this anomaly, stretching and localized strain still occur, but the location changes from one experiment to the next.

Modeling results show that double domes form in an extensional setting as a result of the collision of two channels of laterally flowing, partially molten lower crust that converge below the site of upper crustal necking or faulting. Double domes initiate as recumbent structures by passive shear folding during channel flow and are subsequently rotated into a vertical position into the final dome as the flowing crust fills the space opened by upper crustal extension. A steeply dipping high strain zone marks the contact between the two diverted channels, forming a double dome. Isostasy and buoyancy forces combine to drive upward flow into the dome, which is fed by horizontal Poiseuille flow in the deeper crust; this process is self sustained until crustal extension ceases or the lower crustal channel becomes too thin and depleted.

Although a steady extension rate is applied to the far field in the 2D models, strain regimes in the localized extended region are highly variable in space and time, with coeval extension in the upper crust and contraction in the lower crust. Strain paths are complex as the material is transferred upward from contractional to extensional regions. These features are complicated by 3D flow, oblique tectonics, and lateral heterogeneities in crustal thickness and/or channel topography. Nevertheless, the coeval development of upper crustal extension and lower crustal contraction owing to colliding channels may be a common first-order process of material redistribution and heat transfer during the collapse of orogens.

In Naxos, the N-S elongate migmatite dome consists of two main lobes separated by a subvertical, N-S oriented high strain zone. Foliation outlines subdomes within these lobes, and lineation determined by the anisotropy of magnetic susceptibility is in general close to horizontal and N-S oriented, except in the overturned flanks of subdomes in the eastern lobe, where lineation plunges steeply. The eastern lobe has been dragged by the top-to-N shear that characterizes the Naxos detachment. Results from thermomechanical modeling inspire a new interpretation for the Naxos dome: Extension in a N-S elongate zone in the upper crust, which may have been generated as a jog on strike-slip transfer zones, attracted the rise of channels of partially molten crust at depth. These channels collided beneath the extension zone, ascended, and formed domes of foliation, with a N-S maximum extension and E-W contraction, separated by a subvertical high strain zone. As the domes rose in the extension system, they started responding to top-to-N kinematics, particularly the eastern lobe which developed subdomes overturned to the north.

28-7 11:50 Tortorici, Luigi

NEOGENE-QUATERNARY EVOLUTION OF CRETE: FROM LITHOSPHERIC COMPRESSION TO CRUSTAL EXTENSION

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Following the introduction of Plate Tectonics theory, the recent to present geodynamics of the southern Aegean Region has been soon associated with the African subduction along the Hellenic Arc, while active volcanism, seismicity and subsidence within the Southern Aegean Sea were interpreted as typical back-arc extension-related phenomena. However, with the increasing collection of data and production of results based on many different methodological approaches and investigation techniques, the last two decades of the 20th century have seen the blooming of publications focusing on the Neogene to Quaternary tectonics and geodynamics of the area. This large amount of papers has certainly increased our general knowledge on the geological evolution of the area, but also raised several questions and left open many scientific problems. Numerous models have been proposed since then attempting to unravel and explain the complex evolution of the Aegean Region. Some of these models focus on the present-day kinematics being mainly based on seismicity, geodetic surveys and other geophysical data, while many others are generally grounded on more geological data and consider much longer time periods.

The Island of Crete represents the southernmost and most external outcrops of the whole Hellenic Arc, therefore providing crucial information on the recent (Neogene-Quaternary) geodynamic evolution of the area. In particular, the island contains the record of both the youngest outcropping synorogenic contractional structures and the diffuse normal faulting that at present affects Crete and its surroundings. This research focuses on the timing of the stress regime change, from compressional to tensional conditions.

During Neogene, the central sector of the Hellenic Arc was mainly affected by frontal to oblique convergence and this caused the activation of both major thrusts and wrench zones. The former structures are generally north-dipping, characterised by an arcuate shape showing an almost independent behaviour, while wrench zone are certainly associated with the oblique reactivation of inherited crustal (or lithospheric) structures.

Geological and tectonic investigations carried out along N-S coast-to-coast transects have documented the occurrence of meso- and macro-scale contractional structures, like reverse faults, duplexes, pitted pebbles and folds, clearly affecting Tortonian to Pliocene (and possibly Lower Pleistocene) deposits and characterized by a NNW-SSE to NNE-SSW shortening direction. This deformational event(s), which affects the upper crust, has been associated with the ongoing Hellenic subduction and caused a southwards migrating out-of-sequence thrust system consisting of both reactivated inherited contrational structures and new ones. This event was likely due to a stronger coupling along the overall subduction system and was juxtaposed to the Early-Middle Miocene exhumation phase. Only during Pleistocene the upper crustal extensional regime was resumed in the island and its surroundings affecting the region with diffuse normal faulting active till present. This latter event was probably related to a sudden southwards jump of the basal detachment along the lithospheric African subduction that caused a general stress release in the uppermost crust.

28-8 12:10 Altinoglu, Fatma Figen

DETERMINATION OF CRUST STRUCTURE OF WESTERN ANATOLIA BY USING THE GRAVITY INVERSION TECHNIQUES

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Western Turkey is tectonically one of the most active and rapidly deforming regions of continental crust in the world. The most pronounced structural features of this region are defined by normal faulting in an E–W direction, which creates the boundaries of the Büyük Menderes and Gediz grabens. The Gediz and Büyük Menderes grabens exhibit negative Bouguer gravity anomalies. These anomalies were interpreted using 2D and 3D gravity inversion techniques in order to determine the depth of the crust. 3DINVER.M software program is used to compute 3D geometry of Moho topography. The program based on obtaining the geometry of the density interface related to the gravitational anomaly for three-dimensional extension of the Parker–Oldenburg's method. The study area is locating between 27.00 – 29.50E longitudes and 37.50-38.50N latitudes. The parameters used for the inversion are: density contrast of 0.3 g/ cm^3 (mantle density minus crust density) and a mean depth for the crust–mantle boundary of 15km. The filter cut-off parameters have been chosen as WH=0.01 and SH=0.012. Finally, the truncation window data length established for the cosine taper window is selected as 10% of the extended data length. Convergence of the iterative procedure has been achieved at the third iteration, with a RMS error of 0.0101 km (the convergence criterion had been established in 0.02 km).

The geometry of the inverted interface shows a maximum depth of about 36 km, located at the east part of study field 1 and 35 km located at the center of study case 2, related to Gediz and Büyük Menderes grabens.

The gravity anomaly map obtained from 3DINVER.M due to the interface topography obtained and it's a good correlation with the original gravity input map. The difference between the original and computed anomaly maps is also obtained and are in the range between -0.06 and 0.03 mGal.

In order to compare 3D modelled results with the ones obtained by using a 2+1/2D gravity modeling software GIRIS.FOR and CIKIS.FOR, four gravity profiles, which cross the areas vertically and horizontally, have been selected. It can be observed that the Moho relief obtained from the software produces a gravity anomaly similar in shape to the observed anomaly.

SESSION NO. 29, 08:30

Thursday, 7 October 2010

Keynote Talk 5

METU Convention and Cultural Centre, Kemal Kurdas Salon

29-1 08:30 Hall, Robert

SUBDUCTION, COLLISION AND DEVELOPMENT OF OROGENIC BELTS: A SE ASIAN PERSPECTIVE ON THE TECTONIC CROSSROADS OF EURASIA–AFRICA–ARABIA

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The Mesozoic–Early Cenozoic Tethyan region of the Middle East, especially Turkey, has many similarities to Cenozoic SE Asia. Both were regions of long-term subduction, with large oceans closing as a large continent approached, leading to arc–continent and continent–continent collision. The arrival of continents at the subduction zone did not lead simply to mountain building and termination of convergence: a prolonged and complex tectonic history followed, which in both cases is still incompletely understood.

Because subduction continues to the present-day in and around SE Asia we have some advantages when trying to reconstruct its history. Many features of the surface geology are forming today, or were produced very recently, and therefore can be related to observed motions at the surface, seismicity, and mantle structure. On the other hand, in most places we do not see the deep crust because it is buried beneath young volcanic products and thick sediments. Nevertheless, it does seem that SE Asia is an unusual region. What features may be of importance for understanding the orogenic crossroads of Eurasia–Africa–Arabia?

Around SE Asia the Pacific, Indian/Australian and Eurasian plates are converging and plate tectonics provides a first order explanation of its history. As oceans closed the region has grown principally by addition of continental fragments but, despite a long subduction history, relatively little by magmatism. However, plate tectonics is only part of the story. Today, in many areas the major plates have no clear-cut boundaries and many lines drawn on maps solve an apparent kinematic problem but do not reflect reality. The region cannot be understood simply as multiple small rigid microplates bounded by lithospheric faults. In addition to major plate movements three important factors have influenced what we see today.

First, as result of a long subduction history the region has a weak thin lithosphere, highly responsive to plate boundary forces. Second, the region's history means it has a complex basement structure, with strong and weak parts. It is not a rigid plate and most of the region is really a wide plate boundary zone between a broadly weak continent and surrounding strong lithosphere. Third, the rifting history and consequent shape of continental margins influenced the way in which different parts of the region responded to plate tectonic forces during convergence and collision.

Collisions of continental blocks formed a Sundaland promontory to the Eurasian plate in the Early Mesozoic and other fragments were added during the Cretaceous. These rifted from Australia during the Late Jurassic and Early Cretaceous and are now in Borneo, Java and Sulawesi, not West Burma or Sumatra. Their arrival terminated subduction beneath Sundaland at about 90 Ma, although not north of India, and contributed to emergence of an extensive landmass. At 45 Ma subduction resumed as Australia began to move rapidly north. The shape of the Australian margin resulted in a complex collision history which has caused much controversy and confusion. The first impact of Australia on SE Asia was in the Early Miocene, at about 23 Ma, with collision of the Sula Spur promontory. From 15 Ma there was subduction rollback into the Banda oceanic embayment and major extension. Collision of the Banda volcanic arc with the southern margin of the embayment began at about 4 Ma. After more than 20 million years the Australian–SE Asia collision is far from complete.

Collision and extension have obviously contributed to vertical movements but deformation of the upper crust reflects several processes other than plate movements. Within SE Asia there are remarkable contrasts between strong areas, which include oceanic and continental lithosphere, and adjacent weaker areas. Subduction rollback of strong oceanic lithosphere led to extension and subsidence, but also to continental delamination contributing to rapid uplift. Strong continental areas are little deformed and record only small vertical movements relative to sea level. In contrast, in weaker areas the upper crust appears to be deforming almost independently of the deeper lithosphere and there have been exceptionally high rates of vertical movements, both up and down. A common feature of the region is synchronous rapid uplift of mountains close to areas of major subsidence. These movements have been accompanied by high rates of erosion, and very great thicknesses of sediment have been deposited offshore. It appears that a hot weak deeper crust has flowed in response to tectonic forces, topographic forces and sedimentary loading so that in many areas GPS observations do not record motions of major- or micro- plates but local movements of the upper crust. Models developed in completely different tectonic settings are likely to mislead in predicting features such as heatflow, and rates of uplift, subsidence, erosion and sedimentation. However, the contrasts between weak and strong areas, and the rates and scales of processes observed in SE Asia, may be relevant to understanding older orogenic belts such as those of the Middle East.

SESSION NO. 30, 09:30

Thursday, 7 October 2010

Palaeomagnetic perspectives on the Africa-Arabia-Eurasia plate interactions (*Afrika-Arap-Avrasya levha iliskilerinde paleomanyetik gözlemler*)

METU Convention and Cultural Centre, Salon C

30-1 09:30 Van der Voo, Rob

PERMO-TRIASSIC PANGEA FITS: WHEN DID A PROPOSED 3500 KM MEGASHEAR BETWEEN GONDWANA AND LAURUSSIA HAPPEN, IF IT HAPPENED AT ALL

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It has been noted repeatedly in the last 40 years that Permian reconstructions of the Atlantic-bordering continents in conventional Pangea fits (called Pangea-A type) are not well supported by the available paleomagnetic results. The scale of the misfit (i.e., undesirable overlap between Gondwana and Laurussia) is about 1100 km. While it is widely recognized that the Atlantic Ocean opened from a Pangea-A configuration, rather different Permo-triassic configurations have been proposed that accommodate the paleopoles much better. The so-called Pangea-B fit has Gondwana in a much more east-northeasterly position with respect to Laurussia, such that the Moroccan coast of Africa was adjacent to the southern margin of the East European Craton (i.e., the Ukraine's Black Sea coast). The transformation of Pangea-B into Pangea-A would then have taken place along a 3500 km-long, roughly ENE-WSW, and dextral megashear. The timing of movements along the megashear is uncertain: it could have been in late Early Permian times (as proposed by Muttoni and colleagues in 2003) or in the Triassic (suggested by Irving in 1977and by Torcq and colleagues in 1997). Besides these tectonic solutions to the problem, questions have been raised about the geocentric axial dipole hypothesis, which is so central for paleomagnetism. And lastly, nagging doubts that the paleomagnetic results may be less reliable, in that they do not perfectly reflect the ancient magnetic field, have not gone away. One, now widely accepted reason could be that inclination shallowing occurred in sedimentary rocks, thereby yielding paleolatitudes too close to the equator.

In an attempt to improve upon the available data, especially for the time interval of 280 – 240 Ma where the discrepancy between Laurussia and Gondwana poles is the greatest, we have studied ignimbrite flows (Puesto Viejo Fm., 265 – 240 Ma) from Argentina, late-stage dikes from the Oslo Graben (270 – 245 Ma) in Norway, trachyte dikes (~280 Ma) in Ukraine and ~270 Ma volcanics from Illinois. A fifth and useful result has previously been published for the Esterel volcanics in France (270 – 258 Ma). The new results allow a Pangea-A fit to be constructed without significant (and impossible) overlap of the continental areas of Eurasia and Gondwana for the Late Permian – Early Triassic. A new Euler pole (78.6N, 161.9E, 31 degrees) for the fit of North America w.r.t. Europe brings an improvement as well. This implies that there is no longer any need to invoke a megashear of enormous magnitude for Late Permian - Triassic times, for which there is little or no geological evidence. The question, however, remains whether a Pangea-B configuration may have existed in Late Carboniferous – Early Permian times, if it existed at all. Relevant geological observations from ancient landmasses within the shear zone (e.g., the Caucasus and northern Black Sea area, perhaps Turkey's Pontides and Sakarya, Moesia, Adria, Iberia, Florida, etc.) and improved and well-dated earliest Permian-Late Carboniferous paleomagnetic paleopoles from Gondwana are needed to answer this question.

30-2 09:50 Tatar, Orhan

PALAEOMAGNETIC ANALYSIS OF DISTRIBUTED NEOTECTONIC DEFORMATION AND BLOCK DEFINITION IN THE ANATOLIDES OF TURKEY

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Since final closure of the Neotethyan Ocean in the Eastern Mediterranean with sealing of the Bitlis Suture bordering the Arabian Shield, two forces comprising the continuing northward motion of Arabia into the Neotethyan accretionary collage and westward suction towards the retreating Hellenic Arc have operated during the Neotectonic phase of deformation. Initially post-collisional forces accompanied the uplift of the Anatolian Plateau. Subsequently establishment of the intracontinental transforms comprising the North and East Anatolian Fault zones (NAFZ and EAFZ) by Early Pliocene times has permitted extrusion and rotation of blocks away from the Arabian Syntaxis. We produce an updated summary of Cenozoic palaeomagnetic results from this region which show that deformation has been distributed across the zone between the two transforms. This is expressed by block rotations that vary systematically across Anatolia and range from strongly CCW in the zone of high strain north of the Arabian indenter to near zero in central Anatolia, and then become successively CW in western Anatolia. New palaeomagnetic results from the Cappadocian Ignimbrite Province help to establish the chronology of rotation and permit a comparison with the Sivas Basin to the east where rotation appears to have been concentrated during the Quaternary. The transition of tectonic regimes from compression in the east to extension in the west involves the expulsion of blocks and their rotation along arcuate strike slip faults. In pre-collisional rocks this has compounded earlier rotations imparted during indentation with later rotations linked to tectonic escape. Regional resolution of neotectonic rotation between the Central Anatolian Thrust Zone and the EAFZ identifies comparable rotation across a zone ~200 km wide and suggests that blocks involved in rotation are relatively large away from the influence of the transforms. The weak collage of accretionary terranes sandwiched between the Arabian Indenter and the Eurasian margin appears to have taken up the bulk of the strain imparted by the continuing northward motion of Arabia. This effect has been to expand the radius of the Tauride Arc and the perimeter of extruded crust bordering the limit of the extensional province in western Turkey. The distributed character of neotectonic deformation is illustrated by equivalent polar distributions: both palaeotectonic and neotectonic palaeomagnetic poles show arcuate distributions with poles to best-fitting small circles focussed close to the study area. Differences between the distributed neotectonic deformation resolved from palaeomagnetism and the contemporary GPS record reflect the contrasting time periods being evaluated: the palaeomagnetic record incorporates evolving and changing tectonic regimes whereas the GPS signature has no long term validity within the Anatolian collage; hence the full spectrum of techniques for resolving neotectonic deformation is relevant to unravelling deformation in such regions.

30-3 10:10 Peynircioglu, Ali Ahmet

APPLYING PALEOMAGNETIC CONSTRAINTS ON ROTATION AND DEFORMATION OF THE ARABIAN PLATE SINCE THE EOCENE IN SOUTHEAST TURKEY

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In the Eastern Mediterranean, convergence of the Afro-Arabian and the Eurasian Plates led to the closure of the Neotethys Ocean and to continent - continent collision by the Miocene. The ongoing convergence gave way to the development of the North and East Anatolian fault zones resulting in westwards extrusion of the Anatolian Plate.

To quantify and determine temporal constraints on the vertical axis rotations of the Arabian Plate and the deformation related to collision, we performed a paleomagnetic study at the northern tip of the Arabian Plate in SE Turkey. Such a study is crucial for both establishing a reference frame for the deformation that took place from Eocene onwards in Turkey, and to further constrain Arabian Plate rotation relative to Africa, caused by the opening of the Red Sea.

We collected 851 sedimentary cores from 78 sites from the northern part of the Arabian Plate ranging from the Eocene to Miocene. The sediments consist of limestones and marls which form a key horizon on the Arabian Plate. A field area comprising the entire northern tip of Arabian Plate was covered.

Relatively small and hardly significant counter-clockwise rotations are observed from the north-western part of the Arabian Plate around Gaziantep, which are in line with previously published results from volcanics in this region. Towards the central northern part near Urfa, Diyarbakır and Mardin, however, the results show no rotation on either side of the Bozova Fault and the Akçakale Graben. Further to the east, in the ırnak, Siirt, Hakkari regions, mixed local clockwise and counterclockwise rotations up to 15° are observed likely to be caused by thin-skinned thrusting and deformation of the northern tip of the Arabian Plate.

We therefore suggest that the rotations observed in the western part and northeastern edges of the Arabian Plate represent local fault block rotations and do not represent the rotation of the entire plate. The Urfa, Kocak and Mardin regions, however, show no rotations since the Eocene, and were likely part of the rigid Arabian Plate.

Considering the counter-clockwise rotations in the west and no rotations in the east, we speculate that the opening of the Akçakale Graben is related to these differential block rotations.

30-4 10:50 Tatar, Orhan

PALAEOMAGNETIC ANALYSIS OF NEOTECTONIC ROTATION IN THE ERZINCAN BASIN, EAST TURKEY

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The 50 km long Erzincan basin, which strikes WNW-ESE, is sited close to eastern end of the North Anatolian Fault Zone (NAFZ) and within ~150 km of the confluence of this fault with the East Anatolian transform. Although formerly interpreted as a simple pull-apart basin at a releasing step-over (e.g. ªengör 1979), it is now recognised as a more complex composite basin incorporating the ENE striking left-lateral Ovacik Fault which terminates in the southeast corner of the basin. The basin infill comprises Plio-Quaternary alluvial sediments and the total thickness may exceed 2-3 km. Morphologically-young basaltic, andesitic and locally rhyolitic cones emplaced along the NE margin of the basin provide the opportunity to monitor rotations during ongoing tectonic deformation. Radiometric dating by ourselves and others indicates that this volcanism is entirely younger than 305,000 years in age. Although sites suitable for palaeomagnetic investigation are difficult to locate because coherent lava units occur within morphologically young volcanic cones and within dominantly constructional surfaces mantled by volcanic debris, we were able to sample 43 sites. All were of normal polarity in conformity with the age evidence. Rock magnetic tests show that only titanomagnetite is a significant remanence carrier in these rocks. The mean palaeomagnetic direction is rotated clockwise with respect to the present field (D/I = 16.5/56.4°, R= 34.79, k = 6.4, α_{95} = 9.6°). However, the group mean is dispersed for two reasons: (i) the volcanic cones lie within fault blocks which have rotated differentially with respect to each other and (ii) variable amounts of slumping, either down over-steepened primary slopes or during compaction of the volcanic edifices, has dispersed the magnetic inclinations. Although data are too few to draw positive conclusions, we find that two of the oldest cones show the largest rotations equivalent to average rates of ~4° per ten thousand years; comparable rates of rotation seem to be applicable to four of the cones with ages evidently younger than ~100 ka. We have also investigated Anisotropy of Magnetic Susceptibility in the lava flows and find that the majority of inferred flow directions are northerly or southerly; they appear to reflect the concentration of volcanic activity and the control of the lava conduits by the WNE-ESE fault system defining the north east margin of basin. We suggest that these all tap a single magma reservoir at depth.

30-5 11:10 Langereis, Cor G.

LATE CRETACEOUS TO PALEOCENE OROCLINAL BENDING IN THE CENTRAL PONTIDES (TURKEY)

MEIJERS, Maud J.M., Dept. of Earth Sciences, Paleomagnetic Laboratory Fort Hoofddijk, Utrecht University, Budapestlaan 17, 3584 CD Utrecht, Netherlands, KAYMAKCý, Nuretdin, Dept. of Geological Engineering, Faculty of Engineering, Middle East Technical University, Ýnönü Bulvarý, 06531-Ankara, Turkey, VAN HINSBERGEN, Douwe, Physics of Geological Processes, University of Oslo, Sem Sælands vei 24, Oslo, 0316, Norway, LANGEREIS, Cor G., Paleomagnetic Laboratory, Fort Hoofddijk, Universiteit Utrecht, Budapestlaan 17, Utrecht, 3524WN, Netherlands, langer@geo.uu.nl, STEPHENSON, Randell A., School of Geosciences, University of Aberdeen, Meston Building, King's College, Aberdeen, AB24 3UE, United Kingdom, and HIPPOLYTE, Jean-Claude, CEREGE, UMR-6635 CNRS - Université Aix-Marseille III, BP 80, Europôle Méditerranéen de l'Arbois, 13545 Aix-en-Provence, Cedex 4, France

The Turkish Pontide fold-and-thrust belt formed since the Paleozoic and is an important element in the Africa-Eurasia convergence and the resulting closure of the Neo-Tethys ocean. It has a peculiar arc-shaped geometry in its central part, along the Black Sea coast, which may have resulted from oroclinal bending. We have determined the vertical-axis rotation history of this area using paleomagnetism on Cretaceous to Eocene rocks from 47 sites and critically analyzed previously published data. We applied the same reliability criteria to all data.

Our results show that late Cretaceous sites have clockwise and counterclockwise rotations perpendicular to the structural trend in the central Pontides. In the eastern Pontides, they show only local rotations. Paleocene to Eocene rocks in the central and eastern Pontides show no rotation. We conclude that the central Pontide northward arc shaped geometry results from oroclinal bending in latest Cretaceous to earliest Paleocene times. The timing and scale of geological processes that occurred in the region make it likely that orocline formation resulted from Neo-Tethys closure between the Pontides and the metamorphic promontory of the Anatolide-Tauride Block.

Earlier studies on the southerly located Çankýrý Basin reveal that clockwise and counterclockwise rotations occurred in Eocene-Oligocene times. This implies that the entire region underwent continuous deformation from the late Cretaceous to the Eocene, caused by convergence of the Pontides and the Anatolide-Tauride block, with a southward moving deformation front. Deformation was first localized in the northern part of the central Pontides until the Paleocene, resulting in oroclinal bending, and from at least Eocene times it shifted toward the Çankýrý Basin region.

30-6 11:30 Meijers, Maud J.M.

PERVASIVE PALAEOGENE REMAGNETIZATION OF THE CENTRAL TAURIDES FOLD-AND-THRUST BELT (SOUTHERN TURKEY) AND IMPLICATIONS FOR ROTATIONS IN THE ISPARTA ANGLE

MEIJERS, Maud J.M.[1], LANGEREIS, Cor G.[1], VAN HINSBERGEN, Douwe[2], DEKKERS, Mark J.[1], KAYMAKCI, Nuretdin[3], and ALTINER, Demir[3], (1) Paleomagnetic Laboratory, Fort Hoofddijk, Universiteit Utrecht, Budapestlaan 17, Utrecht, 3524WN, Netherlands, (2) Physics of Geological Processes, University of Oslo, Sem Sælands vei 24, Oslo, 0316, Norway, (3) Dept. of Geological Engineering, Faculty of Engineering, Middle East Technical University, Ýnönü Bulvarý, 06531 Ankara, Turkey

The Turkish Anatolide-Tauride block rifted away from the northern margin of Gondwana in the Triassic, which gave way to the opening the southern Neo-Tethys. By the late Palaeocene to Eocene, it collided with the southern Eurasian margin, leading to the closure of the northern Neo-Tethys ocean. To determine the position of the Anatolide-Tauride block with respect to the African and Eurasian margin we carried out a palaeomagnetic study in the central Taurides belt, which constitutes the eastern limb of the Isparta Angle. The sampled sections comprise Carboniferous to Palaeocene rocks (mainly limestones). Our data suggest that all sampled rocks are remagnetized during the late Palaeocene to Eocene phase of folding and thrusting event, related to the collision of the Anatolide-Tauride block with Eurasia. To further test the possibility of remagnetization, we use a novel end-member modeling approach on 174 acquired isothermal remanent magnetization (IRM) curves. We argue that the preferred three end-member model confirms the proposed remagnetization of the rocks.

Comparing our data to the post-Eocene declination pattern in the central Tauride belt, we conclude that our clockwise rotations are in agreement with data from other studies. After combining our results with previously published data from the Isparta Angle (that includes our study area), we have reasons to cast doubt on the spatial and temporal extent of an earlier reported early to middle Miocene remagnetization event. We argue that the earlier reported remagnetized directions from Triassic rocks - in tilt corrected coordinates - from the southwestern Antalya nappes (western Taurides), are in good agreement with other studies from the area that show a primary origin of their characteristic remanent magnetization. This implies that we document a clockwise rotation for the southwestern Antalya Nappes since the Triassic that is remarkably similar to the post-Eocene (~40º) rotation of the central Taurides. For the previously published results that are clearly remagnetized, we argue that their remagnetization has occurred in the Palaeocene to Eocene.

30-7 11:50 Uzel, Bora

BLOCK ROTATIONS AND STRIKE-SLIP TECTONICS IN WEST ANATOLIAN EXTENSIONAL PROVINCE: PRELIMINARY PALEOMAGNETIC, GEOCHRONOLOGICAL AND STRUCTURAL RESULTS FROM ÝZMIR BAY AREA

UZEL, Bora[1], SÖZBILIR, Hasan[1], KAYMAKCı, Nuretdin[2], LANGEREIS, Cor G.[3], ÖZKAYMAK, Çağlar[1], GÜLYÜZ, Erhan[2], and SARıOğLU, Onur[1], (1) Department of Geological Engineering, Dokuz Eylül University, Buca, TR-35160 Izmir, Turkey, (2) Department of Geological Engineering, Middle East Technical University, TR- 06531 Ankara, Turkey, (3) Paleomagnetic Laboratory, Fort Hoofddijk, Universiteit Utrecht, Budapestlaan 17, Utrecht, 3524WN, Netherlands

The West Anatolian Extensional Province is an important element of the Africa-Eurasia collision. It is dominantly shaped by a series of E–W-trending detachment and high-angle normal faults currently experiencing an approximately N–S continental extension. Field-based studies carried out in Izmir Bay area have revealed a NE-trending crustal scale zone of weakness defined in a region located between Izmir and Balıkesir which is in good agreement with these features: the Izmir-Balıkesir Transfer Zone. It bounds the E-W trending Gediz, Küçük Menderes and Büyük Menderes grabens, the Menderes metamorphic core complex and related detachment faults from the west. Recent paleomagnetic studies have revealed that the area is characterized by incoherent block rotations and is proposed to be the evidence of strike-slip nature of the zone. At least two generations of basins are superimposed in the Izmir bay area. The older basin is represented by a NE-SW trending depression that filled with lower to upper Miocene lacustrine sedimentary units intercalated with calc-alkaline to alkaline volcanic rocks. The younger basin cut across the older one and is characterized by the E-W to NW-SE trending Izmir bay filled with Plio-Quaternary alluvial fan-fan delta to shallow marine sediments. In order to better understand the timing and distribution of deformation and block rotations, we have initiated a comprehensive study in the region using paleomagnetic, geochronological ($^{40}Ar/^{39}Ar$) and structural methods mainly concentrated on the Neogene units including Miocene lavas and sedimentary rocks. In this contribution we will discuss the preliminary results of these studies.

30-8 12:10 Çinku, Mualla Cengiz

NEW CONSTRAINTS ON THE TECTONIC HISTORY OF THE NW ANATOLIAN REGION: PALEOMAGNETIC RESULTS FROM MIDDLE EOCENE VOLCANIC UNITS AROUND THE ALMACÝK BLOCK, TURKEY

ÇINKU, Mualla Cengiz, HISARLý, Z. Mümtaz, and ORBAY, Naci, Faculty of Engineering, Department of Geophysical Engineering, Istanbul University, Avcýlar, 34320, Turkey, mualla@istanbul.edu.tr

We present new paleomagnetic results carried out on middle Eocene volcanic rocks at 25 sites in NW Anatolia, in order to better understand the regional tectonic deformation processes along the North Anatolian fault zone. The mean directions obtained from the Yýgýlca area in the Istanbul zone (*D*=191.5°, *I*=-47.1°, α_{95}=6.2°) indicate no tectonic rotation relative to the reference direction of the stable Eurasia (*D*=191.0°, *I*=-53.2°, α_{95}=5.0°). The paleomagnetic directions in the Almacýk block and the Armutlu region suggest CCW rotation of 21.5° ±7.8° and 14.8° ±14.5°, respectively, relative to Yýgýlca. These findings support the tectonic model, which has been previously suggested that both the Armutlu region and the Almacýk block were emplaced in the same area. Our paleomagnetic results indicate that through the right-lateral strike-slip movement of the northern branch of the NAF, both the Armutlu region and the Almacýk block were rotated in a counterclockwise sense with respect to the Yýgýlca area. In addition, within some parts of the block, an internal deformation with large declination anomalies ranging from 160° to 250° was observed in this and previous studies that could be explained as a result of chemical remagnetisation of hydrothermal events, stress-related magnetisation or small block rotations.

SESSION NO. 31, 09:30

Thursday, 7 October 2010

Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region. Part 1 (*Akdeniz bölgesinin sismik, paleosismik ve arkeosismik evrimi*)

METU Convention and Cultural Centre, Salon A

31-1 09:30 Altunel, Erhan

SEISMICITY, PALAEOSEISMICITY & ARCHAEOSEISMOLOGY OF THE MEDITERRANEAN REGION

ALTUNEL, Erhan, Osmangazi University of Eskisehir, Eskisehir, Turkey, ealtunel@ogu.edu.tr and MEGHRAOUI, Mustapha, Université de Strasbourg, EOST-Institut de Physique du Globe (UMR 7516) 5, rue René Descartes, 67084 Strasbourg, Cedex, France

Active continental deformation in the eastern Mediterranean regions takes place mainly along the North Anatolian Fault Zone, East Anatolian Fault Zone, Dead Sea Fault Zone and the Aegean Extensional province. These active zones are the source of large earthquakes in the region and represent the best locations for implementing geomorphological, palaeoseismic and archaeoseismic research programmes. Recently, new methods (such as InSAR, drilling, LIDAR, GPS etc.) are applied in active fault studies to collect precise data and produce models of crustal deformation. Combination of these investigations along active fault, with the analysis and modeling would enhance our knowledge to understand the seismic behavior of active faults. The results obtained from the study of large earthquakes provide better constraints of the seismic hazard assessment. The aim of this presentation is to introduce updated studies and research along the active faults in the region and discuss integrated methods and results

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31-2 09:50 Brandon, Mark T.

REASSESSMENT OF THE ORIGIN OF THE AD 365 EARTHQUAKE FROM GEOLOGIC AND GEOCHRONOLOGIC RELATIONSHIPS, CRETE, GREECE

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The 365 AD event occurred on a large high angle S-down normal fault, and is not directly associated with subduction. The Earthquake of AD 365 is one of the largest in the greater Mediterranean, and as such is critically important for a broader assessment of the seismic and tsunamigenic hazards associated with Mediterranean subduction zones. The central Mediterranean contains c. 3350 km of subducting plate boundary including the Hellenic, Calabria, and more slowly converging Apenninic systems. What is remarkable is the near absence of definitively documented large-to-great (≥ M 8) subduction earthquakes in this region, especially given historic records spanning nearly three millennia (e.g., Ambryaseys, 2009). The largest known regional event, the July 21, AD 365 earthquake generated widespread structural damage on Crete (e.g. destruction of Kisamos; Stiros & Papageorgiou, 2001) and a regional tsunami recorded in Alexandria, Egypt (Stanley, 2005; Shaw et al., 2008). The AD 365 earthquake is traditionally modeled as a subduction event; although opinions differ as to whether the rupture occurred on the subduction interface or above it on a steeply-dipping splay fault. We present an alternative view of the source structure for the AD 365 earthquake that is most compatible with available topographic, bathymetric, geologic, and geochronologic datasets from Crete.

Physical evidence for the coseismic surface uplift of Crete is preserved around much of the northwestern to southwestern coastline in the form of an uplifted and tilted Holocene shoreline, or bioerosion notch, first reported by Spratt (1865) and examined by many others (e.g. Thommeret et al., 1981), that exists today between 0 and 9 m asl. The presence of this uplifted shoreline constitutes the critical data set utilized in published interpretations suggesting that the AD 365 earthquake nucleated along the subduction interface or on a steeply-dipping splay thrust. Most attribute the maximum 9 m of Holocene shoreline uplift to a single massive earthquake with an epicenter located several tens of km off the SW point of Crete; although this structure has yet to be recognized in the submarine geology south of Crete. Critical to the thrust source model for the AD 365 earthquake is the assumption that much if not all of the up to 9m of uplift recorded in the geometry of the uplifted Holocene shoreline occurred during a single event, and that the magnitude of coseismic uplift is too large for uplift on the footwall of a normal fault due to standard fault-scaling relationships.

We performed a reassessment of all available radiocarbon dates reported in the literature from calcareous marine invertebrates collected from below the maximum elevation of the uplifted "AD 365" shoreline (n > 50) from the northwest, west, and southwest coast of Crete. Radiocarbon ages were corrected for isotopic fractionation and the marine reservoir effect prior to calibration with the Marine09 calibration curve using Calib 6.0 calibration software (Reimer et al., 2009). We find that sessile organisms (e.g. solitary corals, bryozoa, and vermitids) sampled from 0 to 0.3 m below the maximum elevation of the Holocene bioerosion notch consistently provide 2-sigma calibrated ages that are statistically older than samples from 3 to 4.5 m below the maximum elevation of the bioerosion notch at a given locality. For example, at Phalarsana on the west Coast of Crete (where the prominent Holocene bioerosion notch is at 6.6 m above sea level, we find that the weighted means of the "high" and "low" samples (n = 16) are AD 139 ± 112 and AD 422 ± 52, suggesting that there at least two uplift events accounting for the 6.6 m of uplift. An earlier uplift event at Phalarsana, perhaps during the period 64 to 66 AD, is consistent with the geoarchaeologic and sedimentologic evidence indicating rapid sea level fall and evidence for a tsunami as preserved in deposits associated with the uplifted Roman harbor here (e.g. Dominey-Howes et al., 1998).

Wegmann (2008) documented secular Late Pleistocene rock uplift rates from marine terraces from southwester Crete of 1 to 2 mm/yr. Combining the secular uplift rate with estimates of late Holocene sea level rise (c. 0.25 m) in the eastern Mediterranean since AD 365 reduces the amount of coseismic uplift recorded in the uplifted Holocene shoreline from a maximum of 9 m to 5.5 to 7.2 m.

The western Crete escarpment rises precipitously over 6,000 m from the floor West Cretan trough (WCT; -3600 m) to the summit of the Lefka Ori (2454 m). The 175 km long escarpment extends west from the eastern end of the Mesara graben to its intersection with the Ionian trough. The WCT is the underfilled-offshore continuation of the actively extending Mesara graben (e.g. Becker et al.., 2010), with the southwest coastline of Crete and its uplifted Holocene shoreline embedded in the uplifting footwall of a large S-down normal fault(s).

Available data provides evidence supporting the idea that tsunamigenic large historic earthquakes, including AD 365 event, may have nucleated within the upper plate along high-angle normal faults embedded in a zone of rapid rock uplift and left-lateral transtension and that the AD 365 event was likely not as large, in terms of absolute vertical surface uplift or magnitude as previously reported.

31-3 10:10 Niemi, Tina M.

THE 11TH CENTURY COLLAPSE OF AQABA ON THE NORTH COAST OF THE GULF OF AQABA, DEAD SEA FAULT SYSTEM, JORDAN

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The city of Aqaba is situated at the northern end of the Gulf of Aqaba along the southern part of the Dead Sea Transform Fault. Based both on the historical accounts and archaeological excavations, it is clear that earthquakes have played a significant role in the history of the region. The early Islamic city of Ayla was probably founded around 650 A.D., suffered some damage as a result of the 748 A.D. earthquake, and saw extensive reconstruction around the beginning of the Abbasid period (Whitcomb, 1994). Among other evidence of earthquake destruction at the Islamic city of Ayla is the leaning city Sea wall. Stratified pottery collections from our February 2009 excavation of the buttress of the city wall of Ayla strongly suggest a date for revetment construction in the early 11th Century. Based on the fact that the most recent pottery from sealed loci inside the buttress wall is late Abbasid – Fatimid and the absence of handmade pottery often found in the abandonment phases, the buttress was likely constructed after liquefaction damage from the 1033 earthquake. Damage from distant source earthquakes (748 and 1033) in the ancient city was repaired in antiquity. The destruction and loss of life (accounts claim that all but 12 residents who had been out fishing were killed) caused by the 1068 earthquake may account for the relative ease with which Baldwin I of Jerusalem took over when he arrived with a small retinue in 1116 A.D. Paleoseismic trenches in the modern city of Aqaba indicate that at least two earthquakes have occurred after deposits dated to 1045-1278 A.D. A preliminary analysis of the stratigraphy in new trenches in the Taba sabkha north of Aqaba shows at least three separate faulting events, with the most recent event located at a depth of 50 cm below the ground surface. This finding supports the initial ground penetrating radar survey conducted at the southern end of the Taba sabkha by Abueladas (2005). These data document a long period of quiescence since the last phase of intense earthquake activity along the southern Dead Sea Transform and highlight the elevated potential earthquake hazard in the region.

31-4 10:50 Hubert-Ferrari, Aurelia

AN INTEGRATED HISTORY OF PALEOEARTHQUAKES ALONG THE NORTH ANATOLIAN FAULT (TURKEY)

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The North Anatolian Fault is a 1400 km long right-lateral strike-slip fault that accommodates the extrusion of the Anatolian microplate away from the Arabian-Eurasian collision zone. During the 20th century the fault has ruptured over 900 km in a westward propagating sequence of eight earthquakes of magnitude greater than 7. This migrating sequence suggests a simple seismic cycle characterized by nearly equal stress loading and strain release. This view is confirmed by the concordance between the fault slip rate deduced from dated offset geomorphological markers and the crustal loading inferred from geodetic data. However until now paleoseismological data available along the fault were too sparse to confirm if the North Anatolian Fault typically fails in bust of seismicity like the 20th century sequence.

Here we reanalyze selected paleoseismic trenching investigations using Bayesian statistical modelling to determine an accurate record of the temporal probability distribution of earthquakes. The data is then combined with paleoseismic sedimentary records obtained from lakes along or near the fault to check the completeness of the earthquake catalogue. Indeed lacustrine sediments contain a continuous record of all environmental stress including earthquake whereas erosion and/or non-deposition can occur in terrestrial sedimentary trap trenched in classical paleoseimic investigations. The analyze shows that west of the Marmara Sea, the 600 km long fault segment extending between the Erzincan Basin in the east and the Bolu/Gerede towns in the west has ruptured in sequence during the 17th century (1668 earthquake sequence), 13th century, 11th century and 5th century. The seismic behavior around the Marmara Sea is still unclear due to the lack of long-term paleoseimic records available.

31-5 11:10 Avsar, Ulas

SEDIMENTOLOGICAL FINGERPRINTS OF PALEOSEISMIC ACTIVITY REVEALED FROM LAKE SEDIMENTS: A CASE STUDY FROM THE NORTH ANATOLIAN FAULT (NAF), TURKEY

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For several decades, trenching on faults has been the main method applied in order to obtain seismic activity of prehistoric times. During the last decade, paleoseismic investigations on aquatic environments have become more and more popular since they provide relatively continuous and well-preserved sedimentary archives compared to terrestrial environments. Recent lacustrine sedimentary sequences have frequently been investigated to reveal paleoclimatic and paleoseismic records at different locations such as; Chile, Dead Sea and Switzerland. Almost all of the studies in the literature trace the fingerprints of earthquakes in terms of earthquake-induced deformations within lake sediments (e.g. mass-wasting events or in-situ soft sediment deformations). However, earthquakes may have other (indirect?) consequences that can not be observed in terms of sediment deformation. If the lake basin and the catchment are mainly controlled by tectonic activity, the lake may become a potential sedimentary trap, which records tectonic events in terms of primary sedimentation (rather than secondary sedimentary processes). Based on this idea, two shallow/small lakes (Yenicaga and Ladik) located in pull-apart basins on the North Anatolian Fault (NAF) have been investigated for sedimentary paleoseismic records within the scope of a EC-Marie Curie Excellence Grant Project entitled "Understanding

T H U R S D A Y

the irregularity of seismic cycles: a case study in Turkey". Both lakes have maximum water depth of 5 meters and very flat basin geometries. The corresponding segments of the NAF ruptured in 1944 (Ms=7.6) and 1943 (Ms=7.3). Those earthquakes were resulted in approximately 1.5 meters vertical displacement, which is significant for lakes having maximum 5 meters of water depth. A wide spectrum of analyses has been applied on the short gravity cores (~1 m.) and longer piston cores (~4.5 m.). The analyses include ^{210}Pb and ^{137}Cs radionuclide dating, ^{14}C radiometric dating on bulk samples and pollen extracts, Geotek MSCL core logging, ITRAX micro-XRF core scanning, XRD mineralogical measurements, Loss-on-Ignition, C/N atomic ratios, d^{13}C and d^{15}N isotopic ratios. A significant sedimentary event in Ladik Lake is dated to early 1940s by high resolution radionuclide dating. This event almost doubled the sedimentation rate by significant increase in terrestrial organic matter influx. In the piston core from Yenicaga Lake, four significant events are observed similar to the event in Ladik Lake. However, radiocarbon dating on bulk samples and on different organic fractions of the Yenicaga sediments (pollen, seeds, charcoals and phragmites) provides an ideal example of reservoir effect.

31-6 11:30 Kozaci, Özgür

A LATE HOLOCENE SLIP RATE FROM NORTH ANATOLIAN FAULT ON HERSEK PENINSULA IN IZMIT BAY, TURKEY

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Hersek Peninsula has been a strategic location at least for the last two millennia as a result of its location. It extends into the Izmit Bay and creates a shortcut for the Bagdad Road, an important section of the spice route, between Istanbul (Constantinople) and Iznik (Nicaea). It also controls the entrance of the Izmit Bay to Izmit (Nicomedia). Therefore, civilizations have been investing in this location for at least two millennia by building harbors, fortifications, baths, roads, bridges, aqueducts, and temples. The remnants of these historical structures recorded evidence for past destruction of both anthropogenic and tectonic origin. Consequently, from active tectonics point of view, Hersek Peninsula quickly became a key locality for understanding seismic risk in Marmara Region following the M7.4 Izmit earthquake in 1999 since it is the last place that the North Anatolian fault can be studied onland before it enters the Marmara Sea.

We combined both potentials and performed paleoseismic trenching as well as archeoseismologic investigations on Hersek Peninsula in order to investigate seismic hazard in this region. Our paleoseismic trenches north of the Hersek Lagoon provided fault exposures confirming the location of the North Anatolian fault on the peninsula. Furthermore, detailed mapping of a displaced 6th century A.D. Byzantine aqueduct along the projection of this fault exposure revealed a late Holocene slip rate. Although the rapid deposition on the delta plain blankets the evidence of faulting, our trenching in this area provided key insights on the timing of the most recent earthquake that created surface rupture through Hersek Peninsula. This late Holocene slip rate estimate and information about the most recent earthquake at Hersek Peninsula provides invaluable information for the seismic risk calculations and hazard analyses of the Marmara region.

31-7 11:50 Deveci Gürboga, Sule

PALAEOSEISMOLOGICAL RESULTS ON THE SOURCE OF 1970.03.28 GEDIZ EARTHQUAKE

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The Akþehir-Simav Fault System (ASFS) is a 10-30 km wide, 500 km long, and NW-SE-trending discontinuous oblique-slip normal fault system. It is an intraplate seismogenic belt in western Turkey. The seismogenic characteristic of ASFS was proved several times by the occurrence of large historical and recent earthquakes such as the 94, 1766, 1873, 1876, 1896 1921, 1944, 1946, 1969, 1970, 2000 and 2002 earthquakes which caused heavy damages. All of these events occurred on the different segments of the ASFS. The detailed field geological mapping carried out in the study area revealed that the source of the 1970.03.28 Mw = 7.1 Gediz earthquake is the Erdogmuþ Fault.

Two cross trenches were excavated along the ground surface rupture of the 1970 Gediz earthquake in the flood plain deposits of the Kör Stream near west of Erdogmuþ Town, where the morphology of the surface rupture of the 1970 event is still well-exposed. In the first trench (KT–1), the stratigraphy consists of 6 different units. In general, it consists mainly of flood plain deposits at the top, fluvial sediments (colluvial wedge) and lake deposits (limestone-marl) at the bottom. A series of fault arrays were observed inside the trench. The most of displacement was measured along the master fault (source of 1970 event) but minor amount of displacement could also be observed along the second- and third-order faults. In the second trench (KT–2), five different stratigraphic units were identified. They contain more or less same units observed in the KT–1 without only the lake deposits at the bottom. According to structural, sedimentologic and stratigraphic relationships observed on the wall of trenches, at least 2 different palaeoevents, except for the1970 earthquake, were identified. Relative dating was used to determine the order of the events. Because, only one of samples taken for radiocarbon dating could be dated (1060 BP) owing to the pMC (high percentage of modern carbon) amount in them.

Based on the trenching studies, it was found out that the 1970 earthquake was preceded by at least two palaeoearthquakes. Due to the low slip rate (?) along the 12 km long Erdogmuþ Fault, the recurrence interval of large destructive earthquake such as the Mw = 7.1 Gediz earthquake is long. By using the timing of the 1060 and 1970 events sourced from the Erdogmuþ Fault, it can be concluded that the recurrence interval of large earthquake is an approximately 910 yrs.

31-8 12:10 Kazmer, Miklos

DISTINGUISHING DAMAGES OF TWO EARTHQUAKES – ARCHAEOSEISMOLOGY OF A CRUSADER CASTLE (AL-MARQAB CITADEL, SYRIA)

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Data on pre-instrumental earthquakes are provided by historical seismology and by palaeoseismology. Both sciences have rigorous methodology. However, the archaeoseismological method – studying damages to ancient man-made structures – still lacks consensus, therefore the validity of studies is often questioned. We suggest elements for consideration towards the development of a rigorous method in studying damages of ancient masonry structures.

Walls of elongated structures are most sensitive to damaging vibrations at high angles to their orientation. Circular and square buildings (temple domes, stupas, chedis, prangs, donjons, church towers, minarets) might record strong vibrations of any direction. A succession of damaging vibrations have been identified and dated by archaeological survey of failed walls and restoration work.

Medieval Al-Marqab citadel (Latin: Margat) in coastal Syria was built by the Order of St. John (Hospitallers) in the 12-13th century. The hilltop fortification has masonry walls made with and without mortar, using the *opus caementum* technology (Roman concrete). Fallen keystones, V-shaped and U-shaped failures, single-corner and symmetrical corner collapses, in-plane and out-of-plane shift of ashlar masonry walls were surveyed. Dating was attempted by historical and archaeological methods.

Traces of two major, successive earthquakes were identified. A V-shaped extrusion at the top of the Crusader-built donjon indicates NE-SW vibration. This was formed certainly during the Crusader period (1170-1285), as no trace of similar shaking direction is displayed in Muslim-built structures. We suggest that the 1202 earthquake, the largest one ever recorded in the Near East, produced this damage. This quake yielded at least I = VIII intensity at Al-Marqab, higher than previously considered.

A subsequent, NW-SE directed vibration of lesser relative intensity damaged the Qalawun tower, a Muslim fortification, but left no traces on the Crusader donjon. Candidate earthquakes are the 1404 and 1759 events.

One cannot avoid to note that the epicentre of the 1202 earthquake was south of Al-Marqab, in the Mt. Lebanon range. Subsequent major earthquakes had epicentres to the north, in the Aleppo region. This coincidence may indicate that there are cases when a relationship between damage directions and epicentre directions cannot be excluded. (OTKA K67583)

Reference

Kázmér, M. & Major, B. (2010): Distinguishing damages of two earthquakes – Archaeoseismology of a Crusader castle (Al-Marqab citadel, Syria). In: Sintubin, M., Stewart, I., Niemi, T. & Altunel, E. (eds) (2010): Ancient Earthquakes. Geological Society of America Special Paper (in press)

SESSION NO. 32, 09:30

Thursday, 7 October 2010

Subduction, collision and orogeny. Part 1 (*Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez*)

METU Convention and Cultural Centre, Kemal Kurdas Salon

32-1 09:30 Pubellier, Manuel

COLLISION FACTORY IN THE OROGENIC BELTS OF SOUTHERN EURASIA; LARGE SCALE COMPARISON

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A global view at the orogenic belts of Southern Eurasia shows a striking widening toward the east. This geometry mimics the V-shape of the original Paleotethys and Tethys oceans. However the classical "zipper" closure cannot account for the finite geometry. In order to explore this difference, we observe the mechanisms of present-day opening and closure of basins in SE Asia. The different stages all controlled by the consequence of a long lasting subduction which firstly creates marginal basins floored with oceanic crust, and later closes these basins when it is perturbed. The processes of shortening are all illustrated in SE Asia, from the subduction blocking to reversal (e.g. Philippines or Timor), subduction of the back arc basin (e.g. Celebes), transfer to the opposite margin (Makassar) and subduction of the entire basin (NW Borneo). These examples display progressively more advanced phases of collision tectonics with characteristic structural, metamorphic, and magmatic features, prior to the impending Australia-Eurasia continental collision in the future.

In this "collision factory" of the modern SE Asia, basin collapse, ophiolite emplacement, arc collisions, microcontinental accretion and subduction, and crustal shortening have been taking place during the last 45 my. as a complex orogenic prelude to a final continent-continent collision. The mechanisms of these discrete geological phenomena, their imprint on the rock record, the subduction zone geodynamics involved, and the tectonic settings of different crustal and lithospheric entities can still be determined because of the wealth of geophysical, geological, and marine geology data.

If the still visible Neogene or active propagators respects the opening of the large paleo-oceanic domains, they fail to explain the width of the orogenic belts which involves larger continental blocks. It is thus possible that there is a relation between the width of the ocean and that of the crustal blocks, and that the transmission of the extensional strain goes far into the margins, following the increase of the mechanical thickness of the lithosphere.

32-2 09:50 Cloos, Mark

COLLISIONAL DELAMINATION IN NEW GUINEA: THE GEOTECTONICS OF SUBDUCTING SLAB BREAKOFF

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The formation of the island of New Guinea has long been cited as the product of a Cenozoic arc-continent collision. Geologic studies in the Central Ranges of the Irian Jaya Province of Indonesia (near Puncak Jaya, 4884 m) has revealed field and timing relationships which combined with mechanical considerations leads to a refined model for the tectono-magmatic effects of collisional orogenesis.

In west New Guinea, shelf limestone (New Guinea Limestone Group) sedimentation on top of Australian continental basement occurred as recently as 15 Ma. At the top of the ranges (Puncak Jaya), these and underlying strata (Kembelangan Group) are deformed into km-scale open folds with minor reverse faulting. Exposures along the access road to the Ertsberg (Gunung Bijih) Mining District reveal an upright, north-dipping section, at least as old as Devonian, that overlies a basement of greenschist facies slates and phyllites of probable Precambrian depositional age. Regional mapping indicates that the ~ 9 km thick road section forms the northern limb of the 30+ km wide Mapenduma anticline. Apatite fission track thermochronology indicates the mid-slope region has been unroofed at rates of 1-2 km/m.y. since the end of the Pliocene. Extrapolation of this result to the base of the slope indicates unroofing of the Mapenduma anticline began at ~8 Ma. Petroleum exploration drill holes near the southern slope indicate siliciclastic sedimentation began at ~12 Ma and abruptly changed to conglomeratic molasse deposition between 6 to 4 Ma. In the Ertsberg District, intermediate intrusions (4.4-2.6 Ma) cross-cut the axis of a km-scale fold and were emplaced in a left-lateral strike-slip fault system subparallel to the regional structural grain created by folded strata. The little studied northern slope of the Central Ranges is a belt of metamorphosed Australian passive margin strata and the Irian Ophiolite Belt.

The generation of the Puncak Jaya sector of the Central Ranges is explainable by a plate tectonic process we term collisional delamination. Northwards dipping subduction of the oceanic end of the Australian Plate began prior to 20 Ma at a Mariana-type subduction zone. Sediment accretion began once Australian margin strata entered the subduction zone. The top of an accretionary prism broke the surface at ~12 Ma. Jamming of the subduction zone by the underthrusting of Australian continental crust-capped plate occurred at ~6 Ma and was immediately preceded by the detachment and southward displacement (~10-20 km) of the large basement block forming the Mapenduma anticline. The subducted oceanic end of the Australian Plate did not stop and dangle, but rather broke off (see Sacks and Secor, 1990). The tectonic aftermath of subterranean plate rifting between 6-3 Ma included magmatism generated by adiabatic decompression melting of the lower continental lithosphere ± upwelling asthenosphere, and a rapid isostatically-driven vertical uplift of 1-2 km of the collision-generated fold belt.

32-3 10:10 Baldwin, Suzanne L.

FROM SUBDUCTION TO RIFTING: THE LATE CRETACEOUS–CENOZOIC TECTONIC EVOLUTION OF EASTERN PAPUA NEW GUINEA

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Late Miocene–Pliocene high-pressure (HP) and ultrahigh-pressure (UHP) rocks occur in the lower plates of metamorphic core complexes (mcc) in the Woodlark Rift of Papua New Guinea. They form topographic highs, and occur structurally beneath basalts and ultramafic rocks that are inferred to represent remnants of an obducted ophiolite. Petrologic characteristics of these rapidly (>cm a^{-1}) exhumed HP–UHP rocks share similarities with other UHP terranes globally including peak metamorphic conditions of >2.6 Ga and 600–760°C and coesite preserved in mafic enclaves hosted by metasedimentary and granitoid gneisses. However, along strike variations in the transient Australia (AUS)–Woodlark (WDK) plate boundary zone evolution have yielded important temporal and spatial differences now preserved in the geologic, petrologic, and isotopic record that have yet to be demonstrated elsewhere. Presently rifting of a subduction complex transitions along strike into the Woodlark Basin seafloor spreading system. Since ~6 Ma the spreading center rift tip has propagated westward resulting in the separation of the once contiguous Woodlark Rise (northern rifted margin) and Louisiade Archipelago (southern rifted margin).

The Late Cretaceous–Cenozoic evolution of the AUS-WDK plate boundary zone involved northeastward subduction of the Australian passive continental margin beneath an island arc built on oceanic lithosphere. Collision led to metamorphism of Jurassic–Cretaceous sediments and basalts (i.e., Owen Stanley metamorphic rocks), and southward obduction of oceanic crust and mantle to form the 12–16 km-thick ophiolite of the Papuan Ultramafic Belt (PUB). Based on foraminifera in sediments found within the basalts previous studies estimated the PUB crystallization age to be Maastrichtian (71 to 65 Ma; Late Cretaceous). Late Paleocene K-Ar and $^{40}Ar/^{39}Ar$ amphibole ages (58.3 ± 0.4 Ma) have been interpreted to mark the time of cooling of the metamorphic sole following peak metamorphism. The PUB is regionally extensive and is well exposed west of 149°E. However, its continuation to the south and east remains controversial with possible correlative mafic and ultramafic rocks exposed throughout the Woodlark Rift where, in general, they occur in the upper plates of mccs. Dolerite recovered from the Moresby Seamount yielded a zircon U-Pb age of 66.4 ± 1.5 Ma, indicating that crustal extension immediately west of the active sea floor spreading tip is being accommodated in part by normal faulting within latest Cretaceous to early Paleocene oceanic crust.

Within the mcc lower plate rocks, a Lu-Hf garnet-whole rock isochron age (65 ± 6 Ma) from a mafic boudin in mylonitic gneiss within the shear zone carapace bounding the Goodenough Island mcc is interpreted to record garnet growth during prograde metamorphism. This age is concordant with the inferred Late Cretaceous age of the PUB and suggests that zircon crystallization within dolerite, obduction of young (hot) oceanic lithosphere and the onset of subduction zone metamorphism in eastern Papua New Guinea occurred in rapid succession. The subsequent Paleogene–Early Miocene prograde history of metamorphic rocks in the Woodlark Rift has yet to be revealed. However the conditions and timing of peak metamorphism varied from east to west. In the Misima mcc on the southern rifted margin Mid–Late Miocene greenschist to amphibolite facies metamorphism and subsequent exhumation from depths >15 km occurred prior to seafloor spreading in the Woodlark Basin. West of the active seafloor spreading rift tip, and synchronous with seafloor spreading in the Woodlark Basin, blueschists and greenschists formed in the Pliocene and were subsequently exhumed in the Prevost Range mcc of Normanby Island. Late Miocene eclogite facies metamorphic rocks formed and were exhumed from mantle depths and are now found in the lower plates of the D'Entrecasteaux Islands mccs. Outstanding questions regarding the prograde metamorphic history include: What caused the apparent time lag between the onset of collision and HP-UHP metamorphism? Were HP–UHP rocks stored at mantle depths before rapid exhumation occurred? Or are multiple subduction events recorded by the HP–UHP rocks in this plate boundary zone known for complex microplate interactions?

Work in progress aims to determine the age of prehnite-pumpellyite rocks in the Louisiade Archipelago on the southern rifted margin, and the spatial and temporal evolution of volcanism within the rift. Of particular interest are xenocrysts and xenoliths in Pliocene–Recent volcanic rocks from the Woodlark Rise whose composition indicates possible derivation from 1) lower plate gneisses (e.g., garnet amphibolite and possibly eclogite), and 2) oceanic lithosphere (e.g., basalt, dunite and peridotite). These will provide clues regarding the composition of material at depth that the ascending magma has sampled, and help answer remaining questions regarding the relationship between subduction and magmatic processes in the Woodlark Rift.

32-4 10:50 Ringenbach, Jean-Claude

EVIDENCE FOR VARIOUS STAGES OF COLLAPSE IN THE SOUTHEAST ASIAN FOLD-THRUST BELT: BORNEO, PAPUA AND SOUTH CHINA SEA

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Erosion in active orogens involves massive superficial landslides. It is also observed that extension due to bulk forces or to subsequent rifting is the fate of mountain ranges. However, the mechanisms of extension and the rapidity at which compression shifts to extension are not well understood. For example, in the late Mesozoic/early Cenozoic, the South China Sea margin and also rifts related to the Indian indenter-related strike-slip faults overprinted an Andean-type margin with high elevation as seen from the amount of erosion. The presence of a series of Cretaceous molasse basins affected by Tertiary extension indicates that the two mechanisms may be responsible for an abnormally long period of extension. If clear detachments and domes are imaged by seismic data, the Yenshanian Orogeny structures have totally been overprinted in the large zone of extension which led to ocean spreading in the South China Sea.

Western Papua shows an earlier stage of extensional collapse although contractional deformation still dominates in the region. It is a very recent orogenic wedge where the front has ceased its activity 2 m.y. ago, whereas the back-side of the internal zones is the site of a localized and seismically active extension. There, metamorphic rocks (gneisses dated around 5 Ma) are exposed in an elongated dome. The exhumation of these rocks is associated with migmatization, which post-dates the HP event of the wedge. However, the stretching lineations in the metamorphic units are at right angle from the active T axis of the active extension, suggesting that the final stage may be a gravitational event.

The present-day evolution of NW Borneo may be interpreted in relation to an incipient collapse. The construction of the intra-oceanic wedge started in the Eocene but the topography was acquired by the middle Miocene when the South China Sea margin entered the subduction. It was followed by important gravity tectonics at the front of the range. This phenomenon is related to the subduction of a crustal high that induced erosion and delta deposition and subsequent gravity tectonics. However, the shallow thin-skinned extension cannot account for the motion of the front of the topographic wedge detected by GPS data. We present a new model involving a collapse at the scale of the Crocker range but toward the front of the FTB.

32-5 11:10 Bohannon, Robert G.

ENERGY CONSIDERATIONS FOR THE ARABIAN, INDO-AUSTRALIAN, AND ASIAN COLLISIONAL SYSTEMS OF NEOTETHYS

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Plate reconstruction models suggest that the northern edge of the Indian subcontinent contacted the subduction system bordering the southern margin of the Asian continent sometime between 50 and 40 Ma. After 40 Ma India continued its northward drift relative to Asia at a slower rate accompanied by a pronounced anticlockwise rotation resulting in approximately 1200 km of indention into the Asian continental mass. Similarly, Arabia-Eurasia convergence continued after Neotethyn-ocean closure at approximately 10 Ma, all of that coincident with Afro-Arabian divergence in the Red Sea, which began at about 25 Ma. The indention, compressional tectonism, and uplift that resulted from the continent-continent convergence in both regions required a large energy source that is commonly attributed to slab-pull forces. But local slab pull forces, along with associated forces of trench suction, slab roll back and slab suction, cease to be factors once the buoyant continental mass encounters the subduction system. For various reasons, other sources such as ridge push and plate momentum can be discounted as well. This leaves an apparent paradox, especially acute in the Indian case, where the energy needed to drive the post-subduction indention over a time period in excess of 40 million years appears to be locally absent. Less severe, but nonetheless baffling, is the question of how Arabia can be flanked on one side by an expanding ocean and on the other by a compressional mountain belt, also in the apparent absence of local driving forces. The energy question can be easily addressed by considering global, as opposed to local forces. The Arabian and Indo-Australian plates, which include the two large continental masses, together form a large body of lithosphere that has behaved more or less rigidly over the considered time period. The two plates have behaved as a large beam, spanning nearly half the circumference of the globe that rotated anti-clockwise in response to strong forces originating at the descending slabs along its northwest margin from modern-day Burma to Java. Ample far-field energy was available to create the Himalayan and Zagros collisional belts in this case. At the same time, the continental lithosphere of Anotolia was pulled to the west, and that of Asia to the south and east following slab rollback at their respective subduction systems. In this regard it is better to drop the concept of forceful indention of India and Arabia as a driving force for extrusion. Rather slab rollback/suction drives extrusion, allowing room for indention.

32-6 11:30 Ernst, W.G.

MESOZOIC PLATE UNDERFLOW, COLLISION, CONTINENT FORMATION AND HYDROTHERMAL GOLD DEPOSITS ALONG THE NORTH PACIFIC RIM

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Numerous gold vein deposits formed in the Dabie-Sulu belt of east-central China + central Korea + SW Japan + Sikhote Alin, and in the Klamath Mountains + Sierran Foothills of northern California attending ~155-90 Ma subduction of paleo-Pacific lithospheric plates. In eastern Asia, earlier transpression and continental collision at ~305-210 Ma generated a high pressure-ultrahigh pressure orogen, but failed to produce widespread intermediate and felsic calcalkaline, I-type magmatism or abundant hydrothermal gold deposits. Similarly in northern California, strike slip ± minor transtension-transpression over the interval ~380-160 Ma resulted in the episodic stranding of ophiolitic chert-argillite terranes, but generated few granitoid magmas or Au ore bodies. For both continental margin realms, periods of nearly head-on Late Jurassic-Cretaceous subduction of oceanic lithosphere involved long-sustained underflow; on reaching magmagenic depths of ~100 km, the descending mafic-ultramafic plates dewatered due to the breakdown of hornblende, chlorite and serpentine, producing voluminous calcalkaline, I-type arc magmas This process resulted in the abundant formation of sialic crust. Ascent of these plutons into the middle and upper crust released CO2 ± S-bearing hydrothermal fluids and/or devolatilized the contact-metamorphosed wall rocks. Such hot aqueous fluids transported gold along fractures and fault zones, precipitating it locally in response to cooling, fluid mixing, and/or reactions with wall rocks of contrasting compositions (e.g., serpentinite, marble). In contrast, where continental crust was subducted to depths of ~100 km or more, little devolatilization took place, reflecting the thermal stabilities of white mica and biotite. Accordingly, only minor production of S-type granitoid melts occurred, and few major coeval Au vein deposits formed. Thus, the generation of new quartzofeldspathic crust and mobilization of precious metal-bearing fluids in continental margin and island arc environments seems to require the long-continued, nearly orthogonal descent of oceanic—not continental—lithosphere. Continental crustal thickness in such active convergent margins is mainly a function of the rate of generation of juvenile, I-type intermediate and felsic magmas coupled with contractional or extensional deformation, but to a lesser extent depends upon precipitation-modulated erosion. The NS-trending Andes surmount the South American lithosphere above the east-descending Nazca plate. The highest mountains, underlain by ~70 km-thick crust, cap the extremely arid Andean Cordillera at ~25° S. Farther south, the precipitation-drenched Bernard O'Higgins fjordland at ~45° S is underlain by only ~35 km-thick crust. The Cascade + Sierra Nevada ranges in the western U. S. display comparable NS trends and latitudinal rainfall patterns. Westerly winds supply abundant moisture to the Pacific Northwest, but precipitation diminishes southward, producing increased aridity where the Sierra achieves its maximum regional elevation in the Kern Plateau surrounding Mount Whitney. In spite of abundant calcalkaline volcanism and plutonism, island arcs and continental margins rimming much of the North Pacific Basin, including the Japanese Islands, Kamchatka Peninsula, and the Alaska-Aleutians belts, are supported by I-type crust of only moderate thickness; these arcs and continental margins are drenched in rain and snowfall, hence the crustal thickness is at least in part due to the counteracting effect of surface erosion.

32-7 11:50 Hildebrand, Robert S.

ARC, COLLISIONAL AND SLAB-FAILURE MAGMATISM WITHIN THE CORDILLERAN OROGEN OF NORTH AMERICA

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The Cordilleran orogen of North America extends from southern Mexico to Alaska and is generally interpreted to represent an asymmetrical, bivergent, continental margin orogen formed by eastwardly-directed subduction of Pacific oceanic lithosphere beneath North America in which back-arc basin and continental margin rocks were thickened – in part by retrograde thrusting starting in the Jurassic – to spread eastward where they formed a critical-taper fold-thrust wedge with an associated foreland basin. However, this model glosses over much contrary data and so is unlikely to work.

Some of these problems and/or inconsistencies are: (1) the overall paucity of rift volcanics on the Cordilleran margin; (2) robust paleomagnetic data which indicate that much of the Cordillera west of the cratonic terrace did not ultimately dock with the craton until about

60-50 Ma; (3) Mesozoic plutonic rocks of the US Great Basin with isotopic compositions inconsistent with derivation from North American crust; (4) 1.2-1.0 Ga metamorphism and deformation of the Belt-Purcell metasedimentary rocks that are unknown in northwestern North America and suggest long-distance transport; (5) persistent and atypical Paleozoic alkaline magmatism in postulated continental slope-rise rocks from Alaska to Mexico and Belt-Purcell cover in Idaho-Montana; (6) Triassic conglomerate, containing clasts of eclogite and blueschist unconformably overlies rocks of the Cassiar platform and Selwyn basin, indicating thrust emplacement and terrane amalgamation in the Triassic, not the Jurassic; (7) continuous fore-deep sedimentation on the North American platform didn't start until about 124 Ma, indicating that the Panthalassic basin hadn't yet closed; and (8) it fails to adequately account for the voluminous 120-80 Ma Cordilleran-type batholiths, the Laramide thick-skinned belt, and regional Cenozoic extensional tectonism and metamorphic core complexes.

Many of the difficult-to-explain features in the conjectural back-arc model are readily explained and integrated into an actualistic model if the orogeny was caused by failed westerly-directed subduction of the segmented western margin of North America beneath an arc-bearing superterrane, which I call Rubia. Prior to collision, magmatism within the upper plate was highly varied and reflected the complexities of terrane amalgamation. By the Jurassic, the newly consolidated Rubian superterrane became the site of continental arc magmatism, with most eruptions taking place in low-lying areas at or near sea level. This is typical of nearly all modern continental arcs, such as Kamchatka, the Alaskan Peninsula, Central America, Japan, the Cascades, New Zealand, Central America, and Italy, all of which are dominantly low standing, even though individual volcanoes might be very tall. At about 124 Ma – based on widespread deposition of intraplatformal gravels directly beneath the foredeep – the North American platform entered the trench beneath the superterrane, and the sediment-rich distal part of the margin started to dewater, which generated voluminous basalt that rose into the crust to produce the intense magmatic flare-up, crustal reorganization, and uplift typical of Cordilleran-type batholiths. This is in keeping with the observation that even very long-lived subduction of oceanic crust and its veneer of abyssal sediment cannot produce the intense magmatic flux necessary to create Cordilleran batholiths.

By 80 Ma the difficulty of subducting an old craton had slowed convergence such that convection in the asthenospheric wedge stalled and magmatism ceased. Within 5 my the North American plate failed, which not only led to the subduction of the transitional outer crust with its slope-rise sediments and rift-facies rocks; but also to (1) shutdown of the thin-skinned thrusting in the fold-thrust belt; (2) uplift, exhumation and gravitational collapse in the hinterland belt and in the Coast plutonic complex; (3) linear belts of slab break-off magmatism and associated porphyry copper deposits; and (4) thick-skinned basement-involved folding and thrusting within the Great Basin segment. The slab failure magmatism apparently died by 60 Ma, but by 53 Ma new easterly-directed subduction led to magmatism in the Canadian and Sonoran segments of the orogen. Subsequent magmatism reflected the interplay between eastward subduction and collapse of the orogenic highlands during the Miocene to produce the Basin and Range extensional province.

32-8 12:10 Wright, James E.

LATE CRETACEOUS SUBDUCTION INITIATION ON THE EASTERN MARGIN OF THE CARIBBEAN-COLOMBIAN OCEANIC PLATEAU (CCOP): ONE GREAT ARC OF THE CARIBBEAN (?)

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The stratigraphic, magmatic and structural evolution of the Leeward Antilles islands of Aruba, Curaçao, Bonaire, and La Blanquilla, in conjunction with previous investigations of Caribbean geology, suggest an alternative model for the Cretaceous tectonic evolution of the Caribbean fringing arc system. Aruba and Curaçao contain a mafic igneous complex interpreted as representing exposures of the Caribbean-Colombian Oceanic Plateau (CCOP) intruded by 89-86 Ma arc related plutons and dikes. The geologic evolution of Aruba and Curacao is comparable to accreted terranes in Colombia and Ecuador. There Late Cretaceous plutonic rocks and volcanic strata were emplaced into or erupted onto the CCOP. The Ecuadorian, Colombian and Leeward Antilles are interpreted as lateral equivalents of a single Late Cretaceous arc that was constructed on the CCOP. We call this the Ecuadorian-Colombian Leeward Antilles arc (ECLA). There is no evidence for an older Early Cretaceous arc substrate for the ECLA and thus available data indicates Late Cretaceous (~90 Ma) subduction initiation along the southeastern edge of the CCOP.

A number of investigations have concluded that the Ecuadorian and Colombian part of the ECLA collided with the South American margin in the latest Cretaceous (~75 Ma). Following collision, the collided arc and its CCOP basement were obliquely subducted beneath the South American margin giving rise to a post collisional arc that persisted into the Eocene. The Leeward Antillean islands of Aruba and Curacao were not involved in the collision. Curacao did not undergo deformation at ~75 Ma but instead received deep water turbidites derive from both the collided arc and the South American continental margin (i.e. the collision zone). Our U-Pb ages from detrital zircon and $^{40}Ar/^{39}Ar$ r ages from detrital hornblende form the basis of this interpretation. There is neither a deformational nor sedimentary record of this time interval preserved on Aruba. The Leeward Antilles part of the ECLA does not appear to have been directly involved in the accretionary event and thus must have been located North of the collision zone.

In our view, the Late Cretaceous ECLA was linked to the Greater Antilles arc via a Subduction Termination Edge Propagator (STEP fault) that ultimately became the subduction zone that generated the volcanic arc that constitutes the Aves Ridge. La Blanquilla, the only exposure of the Aves Ridge, is composed of two arc related plutons. An older 76 Ma pluton which was intruded by a 59 Ma pluton. During collision of the Ecuadorian-Colombian segment of the ECLA with the South American margin subduction propagated to the North along the STEP forming another arc system between the Greater Antilles and the collided ECLA. The 76 Ma pluton on La Blanquilla may represent the initiation of arc magmatism on what is now the Aves Ridge. The 59 Ma pluton is close in time to the opening of the Grenada Basin when the Aves Ridge became a remnant arc. This marks the inception of the remnant arc/back arc basin/active arc triad represented by the Aves Ridge, Grenada Basin, and Lesser Antilles.

Bonaire has an Early Cretaceous to Paleogene geologic history distinct from the other islands of the Leeward Antilles, and is most likely an arc fragment derived from the Greater Antilles. We suggest that it was derived from the eastern end of the Greater Antilles arc at the junction of the STEP fault that linked the Greater Antilles to the ECLA. Complex tectonic interactions at this junction resulted in the transfer of Bonaire to the proto-Caribbean Plate. Its journey ended when it became attached to the northern South American margin in the Paleocene/Eocene as indicated by the fluvial sediments of the Soebi Blanco Formation with a continental margin provenance.

The geologic evolution of the Leeward Antilles when combined within a broader context of Caribbean tectonics leads us to a tectonic model involving three distinct arcs rather that a single "Great Arc" of the Caribbean as an explanation for the geodynamic evolution of the CCOP and its fringing arc system.

SESSION NO. 33, 08:30

Thursday, 7 October 2010

Aegean geodynamics and extensional tectonics. Posters (*Ege bolgesinin jeodinamik evrimi ve gerilmeli tektonikte güncel problemler*)

METU Convention and Cultural Centre, Exhibition Hall

33-1 BTH 1 Skourtsos, Emmanuel

BASIN SEDIMENTATION, NORMAL FAULTING AND LATE-STAGE EXHUMATION IN EXTERNAL HELLENIDES, SOUTH PELOPONNESUS, GREECE

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Results from mapping along a continuous transect across the southern Peloponnesus, Greece, suggest that records of extension and late-stage exhumation in south Peloponnesus contained within syntectonic sedimentary basin fills adjacent to large structural culminations. In the central and eastern sectors of the transect metamorphic rocks of the lower Phyllites-Quartzites and Plattenkalk Units form two mountain ranges, Mt Parnon eastwards and Mt Taygetos westwards, separated by a terrain lie at lower elevations. New data suggest a two-stage model for the extensional evolution of these sectors. Upper Miocene-Lower Pliocene extension was accommodated by several mappable brittle detachment faults that exhibit a top to the NE-ENE sense of shear on Mt Parnon and top to the SW-WSW on Mt Taygetos. The hanging-wall of the detachment comprises of non-metamorphic rocks of the Tripolitza and Pindos Units. This extensional stage resulted in little topographic expression. Since Upper Pliocene further exhumation of the metamorphic rocks has resulted in the formation of high-angle normal faults overprinting Neogene extensional structures and cut for first time the lowest Plattenkalk Unit. This new fault system tilted the earlier extensional structures and produced a ENE-WSW coaxial deformation. Syntectonic sedimentation within the newly formed Sparta and Vrontamas basins was mainly terrestrial. In Messenia Peninsula, the western sector of transect, Plio-Quaternary movement on NNW-SSE high-angle normal faults and ENE-WSW (to E-W) tranverse faults was superposed on an earlier Lower Miocene imbricate thrust stack as it documented by the fact that sedimentation of the West Hellenic Flysch continued into the Aquitanian. The thrust stuck comprises of the same non-metamorphic units that form the hanging-wall of the detachment faults on Mts Parnon and Taygetos. Marine sedimentation in this area was dominated by the interplay between tectonic uplift and global sea-level change. The central and western sectors are separated from Messenia Peninsula by a series of parallel foreland dipping high-angle normal faults form staircase geometry and control the Messenian half graben. Uplifted Late Pleistocene marine terraces on the footwall of these faults and recent seismic activity suggest that uplift of the internal sectors of transect is still active. Synextensional sedimentation within Sparta, Vrontamas and Messenia basins show that during the Lower to Middle Pleistocene a dramatic tectonic event took place when rapid uplift of the lowest Plattenklak Unit caused deposition within the adjacent basins of sediment-growth packages derived from metamorphic rocks of the mountain ranges. The entire tectonic evolution from the Late Miocene to recent times is mainly controlled by underplating prosecces due to the northward subduction beneath the Peloponnesus, which lead to gradual uplift of the deeper rocks, as new material is constantly accreted, while gravitational collapse occurs at the upper portions of the accretionary prism.

33-2 BTH 2 Bröcker, Michael

DATING OF SHEAR ZONE ACTIVITY IN THE CYCLADES, GREECE: EXAMPLES FROM THE ISLANDS OF SYROS AND ANDROS

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The Attic-Cycladic crystalline belt in the central Aegean region records a complex structural and metamorphic evolution that documents Cenozoic collisional processes and extension-related exhumation. A prerequisite to develop an improved tectonic history of this area is dating of displacement that occurred along major shear zones. We report here results of a Rb–Sr and U–Pb study that focused on tectonic activity on the islands of Syros and Andros.

On Syros, a mélange comprising a wide variety of well-preserved HP rock types (e.g. eclogites, glaucophanites, jadeitites) mostly occurs in a well-defined and mappable horizon that is fault-bounded on top and at its base. Although blocks with blackwall alteration at contacts with serpentinitic rocks are common, the matrix predominantly consists of clastic metasediments. In order to further evaluate the timing of deformation in the mélange, we have studied 8 samples that represent matrix-forming metasediments from the mélange exposed in the northern part of the island. The mineral assemblages of the studied rocks correspond to epidote blueschist facies P–T conditions. Rb–Sr mineral isochrons indicate apparent ages between *c.* 49 Ma and *c.* 42 Ma. Judging from the field relationships and corresponding age pattern, we consider deformation-related and fluid-enhanced mica recrystallization as the most likely interpretation for this age variability. The youngest apparent ages were recognized in samples from block-rich zones that are closely associated with layers of altered ultramafic rocks. These parts of the mélange preferably accomodated deformation in localized domains of intense shearing. The associated transformation of serpentinites into chlorite-, talc- and actinolite-rich schists required not only deformation, but ingress of substantial amounts of fluids, documenting that such zones also represent important fluid conduits. Shearing most likely affected adjoining rock volumes consisting of schistose metasediments, creating favourable conditions for recrystallization processes in zones up to several meters in width. Non-pervasive fluid flow was strongly channelized into horizons with enhanced permeability. The age differences testify to different degrees of dynamic recrystallization and fluid-rock interaction. This study indicates that the Syros mélange experienced a major episode of localized deformation and fluid infiltration at *c.* 42 Ma.

On Andros, the metamorphic succession can be subdivided into two tectonic units, the Makrotantalon Unit and the Lower Unit. The Lower Unit can be correlated with the Cycladic blueschist sequences, which experienced HP/LT metamorphism during the Eocene and a greenschist-facies overprint at *c.* 23-21 Ma. The P–T evolution of the Makrotantalon Unit is poorly constrained, but apparently did not include a HP/LT stage. During the last metamorphic overprint greenschist facies conditions were attained. Previously published Rb–Sr data suggest that the Makrotantalon Unit experienced two periods of Cretaceous metamorphism (*c.* 100–90 Ma and *c.* 80–70 Ma) and a Miocene event (*c.* 21 Ma). Both units are separated by a low angle fault, which is well exposed in some outcrops along the NE coast of Andros, but more difficult to localize in the NW part of the island. Within the broader fault zone of NW Andros, a weak angular unconformity decorated with cm-thick veins of cohesive cataclasites cuts through the metasedimentary succession of the Lower Unit.

Rb–Sr geochronology was carried out on 9 samples from the Lower Unit representing clastic metasediments, calc schists and greenschists that were collected within a distance of <100m to the fault zone. In the NW part of the island, Rb-Sr phengite ages vary between 56 and 30 Ma, with the youngest apparent age representing a sample collected close to the inferred tectonic contact. In the NE area, 4 samples collected at or close to the detachment yielded a relatively narrow range of apparent ages (c. 29– 25 Ma). This age group is considered to closely approximate the time of tectonic juxtaposition and suggests that ductile activity along the detachment is older than previously assumed.

U-Pb dating of detrital zircon indicates maximum depositional ages of *c.* 260 Ma for the Makrotantalon Unit and of *c.* 170–160 Ma for the Lower Unit. These age constraints are consistent with previous interpretations suggesting an inverted tectonostratigraphy – rocks at the top of the succession are older than the structurally lower sequences – implying that the contact between both units originally represented a thrust fault. During large-scale regional extension, this contact was reactivated as a low-angle normal fault.

SESSION NO. 34, 08:30

Thursday, 7 October 2010

Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region. Posters (*Akdeniz bölgesinin sismik, paleosismik ve arkeosismik evrimi*)

METU Convention and Cultural Centre, Exhibition Hall

34-1 BTH 3 Ozkaptan, Murat

DETERMINATION OF THE DELAY TIMES BETWEEN TWO OR MORE INTERFERED BODY WAVE TRAINS USING BY SPECTRAL TECHNIQUES

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Study comprises that using of the some spectral techniques for defining of the delay times of interfered waves, investigating their solution power of these techniques on both synthetic and real data. First of all, theoretical model consisting of more than one signals are evaluated and the spectral methods are tested to determine the delay times. Then these methods are applied to the vertical component seismograms of teleseismic events and also some more regional events occurred in a Mediterranean Sea to determine delays between seismic phases (e.g. pP, sP and PcP phases).

In order to represent seismic phases in our model we use some specific functions (berlage function, etc). For different delay times, cepstral techniques, autocorrelation function and spectral nulls are used on the models. Phase differences between the components of the model are also tested as well as delay times.

Cepstral techniques are used to detect echoes in a signal simple Fourier transform processing methods. They offer natural nonparametric means for estimating general echo patterns in single series. They have been used in as well as in applications to diverse fields such as speech analysis, image processing and radar. The cepstrum is defined as the Fourier transform of log of the spectrum of a time-domain signal and is designed to take advantage of the periodicity that occurs in the power spectrum when echoes are present in the original signal. In principle, the cepstrum can be used to detect the periodicity in the seismic spectrum that is due to the interference of the direct (P) and depth (pP and/or sP) phases. This periodicity is directly related to the depth phase delay time which is in turn directly related to focal depth.

Synthetic teleseismic seismograms are constructed by using berlage function as main seismic phase and its echoes. We use the models with one and two echoes with or without noise. We also investigate phase differences between main wavelet and its echoes by the using spectral techniques.

The results obtained from this study were compared to IASP91 model and tested its reliabilities. On the real data after the effective data processing it is seen that delay times between interfered body wave trains were achieved almost equal to the IASP91 global 1-D model. Cepstral techniques are very efficient to determine arrival times and amplitudes of the wavelet and its echoes. Cepstral – F statistic method also improves the results in case of local network data that an event recorded at various stations in the seismic network.

34-2 BTH 4 Tüfekçi, Nesrin

ESTIMATING SEASONAL GROUNDWATER PUMPING RATE USING INSAR DERIVED LAND DEFORMATION

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Periodic interferometric synthetic aperture radar (InSAR) measurements can detect sub-cm scale ground displacements over large areas. Hence, it has been widely used in investigating the character and future trends of ground-deforming natural hazards. Over the last decade the technique has yielded valuable information for hydrogeological applications, such as mapping, monitoring and simulating groundwater flow, aquifer-system compaction and land subsidence. In areas with significant groundwater pumping, the InSAR signal records changes in land deformation due to periodic aquifer-system compaction and rebound, caused by seasonal changes in pumping. Therefore, InSAR measurements are a potentially valuable source of information to infer groundwater pumping rates over large areas. Here, we present preliminary results of a study aimed at estimating groundwater pumping rates using space-borne InSAR data. Our approach quantitatively links land deformation, subsurface water pressures, and groundwater pumping using subsurface compaction and groundwater flow models. Inverse methods are then used to infer seasonal groundwater pumping rates using InSAR and hydraulic head measurements. Two case studies from the Netherlands illustrate the potential of the methodology.

34-3 BTH 5 Ghods, Abdolreza

DEPTH OF CURIE TEMPERATURE ISOTHERM FROM AEROMAGNETIC SPECTRA IN IRAN: TECTONICS IMPLICATIONS

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Using statistical spectral method corrected for the fractal nature of magnetization, we estimate the depth of Curie isotherm and depth to the top of magnetic layer for Iran. The aeromagnetic data acquired by the Geological Survey of Iran over 7.5 km line spacing is used after revised micro-leveling. To estimate the Curie depth, the depth at which rocks lose ferromagnetic properties, Iranian territory is divided into square blocks of 140x140 km in size overlapping by 80% in both horizontal directions. In each block, the radially averaged power spectra was computed, depths to the top and bottom magnetic layer are estimated for each block and assigned to its centre. The estimated Curie depth ranges between 12 and 24.3 km below the surface. The depth of top magnetic layer varies within a range of 1 to 13 km. The depth of Curie temperature is deeper across the Zagros Mountains and reaches to a maximum depth of 24.3 km in NW of the mountain. In the Alborz Mountains, Curie depth increases west to east towards the Kopeh-Dagh Mountains. In Orumiyeh-Dokhtar volcanic belt, it shallows and varies between 10 and 16 km. Makran subduction zone in SE Iran, the depth of Curie isotherm is about 23 km and increases west to east. In Central Iran it varies between 16 and 24 km, reaches to maximum value of 24 km within the Tabas region where there is a deep sedimentary basin. NW of Iran displays a significantly shallow Curie depth due to widespread volcanic activity.

Confinement of a major part of seismicity to depths above 25 km implies that the Curie depth closely defines the bottom depth of seismogenic layer in Iran.

The thickness of magnetic layer essentially is almost constant over the whole Iran and varies by around 10.5±1.5 km.

Assuming a constant vertical geothermal gradient in the upper crust and using our estimated depth to the top and bottom of magnetic layer and the map of surface mean temperature, we estimate thermal gradient map for Iran. It shows higher values of the thermal gradient over geothermal fields of Sabalan and Damavand Quaternary volcanoes. The thermal gradient map is cross examined with independent data acquired from Sabalan and Damavand geothermal sites.

34-4 BTH 6 Raghaghi, Javad

THE ROLE OF SEISMICITY AND ACTIVE FAULT ZONES ON OPTIMUM SITE SELECTION FOR DESTRUCTED KHANOUK AND REYHANSHAHR TOWNS-EAST CENTRAL IRAN)

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During Fe.22, 2005 southeast Zarand earthquake (Mw = 6.3) Khanouk and Reyhanshahr towns (located 15 Km away from southeast Zarand) experienced MMI intensity about VII and VIII and ancient parts of them were destructed. In the area occurrence of Kuhbanan Active Boundary Fault, it's SE terminations and Second Order Strike Slip faults have created active seismic zones with short time return period destructive earthquakes. Also, field investigations showed the recent earthquake faulting occurred along a pre-existing R type fault. In the other hand, co-sismic shear fractures induce shear stress on structures. Unfortunately, in Central Iran the main shocks often accompanying by co-seismic fractures due to brittle behavior of crust. Therefore, before rebuilding of Khanouk and Reyhanshahr towns active fault zones, especially those are causing co-seismic shear fractures, were mapped and developing sites was proposed on the safe lands far from Active Fault Zones.

34-5 BTH 7 Rezaeian, Mahnaz

IS THE TEMPORAL PATTERN OF SEISMICITY IN THE ALBORZ MOUNTAINS, INFLUENCED BY SEASONAL PATTERN OF PRECIPITATION?

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The Alborz Mountains, a major northern topographic highland of Iran, is a significant climatic frontier between the coastal plains of the humid Caspian lowlands and arid- semiarid Central Iranian Plateau. It produces an intense climate variety with a wide range of precipitation rate. The southern slope demonstrates a highly seasonal pattern in precipitation. The west Caspian lowlands with the greatest amount of precipitation are the wettest part of the Alborz, while the least precipitation occurs in the SE slops where access by the moist air masses appears to be severely restricted.

To constrain the climate forcing of seismicity in the Alborz Mountains, synoptics of precipitation in the range has been employed. Applying daily and monthly precipitation and discharge data derived form gauging stations operated by Ministry of Energy of Iran and Iranian Meteorological Organization measured in a period <40 years, the spatial-temporal pattern of annual-seasonal precipitation and discharge of the Alborz has been computed.

The seasonality is defined as the relative variability of seasonal precipitation proportions evolves with the annual total precipitation. When normalized by the annual total precipitation, the variability of seasonal precipitation is greatest where the annual total precipitation is smallest. Spatial distribution of the variability displays a well defined correspondence with annual precipitation.

In this study, we are looking for evidences of the climatic forcing of seismicity in the Alborz Mountains, northern Iran. Whether the seasonal variations of precipitation in the Alborz can be translated into the temporal-spatial distribution of the seismicity in the mountain range or not?

Institute of Geophysics, Tehran University seismic network, has been monitoring the study area since 1996. The network has a threshold of completeness of 2.5 in magnitude. We use all events larger than 2.5 recorded between 1996 and 2010. To remove the possible bias introduced by aftershocks, we decluster our catalog. Statistical analysis of the 15 years cumulative microseismicity demonstrates that the population of earthquakes in arid south flank of the Alborz is seasonal within the collectively same magnitude range. North flank of the Alborz displays a different temporal distribution with less seasonality. The periodicity of the discharge, precipitation and seismicity is estimated and cross correlated using Least Squares Spectral Analysis (LSSA). Also, we explore the lag time between enhanced precipitation and enhanced seismicity demonstrating spatial-temporal pattern of the precipitation and dynamics of vegetation and run off across the Alborz Mountains.

34-6 BTH 8 Choi, Sung-Ja

PALEOSEISMOLOGICAL STUDY IN GEYONGJU CITY, KOREA

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Gyeongju City, situated in the southeastern part of the Korean Peninsula (KP), and which was the capital city during the Silla Dynasty from 57 BC to 935 AD, and according to the large number of historical earthquake records, is situated in the most dangerous, seismically active, district of the KP. Many active faults have been located in the southeastern part of the KP. Most of the active fault structures characteristically swarm around the Yangsan and Ulsan faults. However, the age of the last faulting episode for the majority of fractures is still unclear because of the absence of effective materials for age dating.

We recently reexamined an active fault site at Jinhyun, a component of the Ulsan Fault swarm,to clarify the time of thelast event and the average slip rate. The host rock is Tertiary granite overlain by a surficial sediment cover of more than 20 m in thickness, which is divided into two sequences. The lower sequence is old Quaternary sediment (OQS) and the other is young Quaternary sediment (YQS), a distinction based upon their respective composition and geometry. The OQS consisted of subrounded to rounded pebble or cobbles with a well-developed stratification that indicates this deposit to be fluvial. The OQS is overlain by the YQS debris flow deposit consisting of mega-sized granite boulders. Theoptically stimulated luminescence (OSL) age of the OQS is 55 ka and the carbon 14 (C-14) age of the YQS is 43 ka. The reverse fault strikes N5-10°E / 70° SE and cuts through the OQS. It is considered unlikely that it penetrates the YQS. The hanging wall of the fault consists of basement Tertiary granite and the overlying debris flow of YQS, whereas the footwall is within the 20 m of superimposed OQS and YQS. Estimation of the throw of the fault was based on the observed displacement between the hanging and footwalls and is at least 10m. The average vertical slip rate of the fault is 0.02 mm/yr, which is one of the highest rates of displacement for active faults in the KP. We concluded that the approximate 10 m of offset indicates an accumulation of fault displacement following the deposition of the fluvial sediments at 55 ka, and is associated with a main fault along the toe of the mountain escarpment. The main faulting led to the deposition of the thick OQSfollowing erosion on the hanging wall after the faulting. Further intermittent movement on the faultcontinued, and induced the YQS.

We concluded that the Jinhyun Fault located in Gyeongju City might not be directly related to the historical earthquakes during the Silla to Chosun Dynasty (57 BC1910 AD), although we observed a terrace surface adjacent to a small bench as apossible fault trace. However, the Jinhyun Fault has a notably large slip rate.

34-7 BTH 9 Ryoo, Chung-Ryul

ACTIVE FAULTS IN GAEGOK-RI, GYEONGJU, KOREA

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Several active faults are found in the central-eastern part of the Ulsan Fault Zone near Gaegok-ri, Gyeongju, Korea. The faults in Gaegok-ri are developed around the contact between Early Tertiary granite and Quaternary gravel deposit which overlies unconformably the granite. They are called from southwest to northeast as Gaegok 1 fault, Gaegok 2 fault, Gaegok 3 fault, Gaegok 4 fault, Gaegok 5 fault, and Gaegok 6 fault. The Gaegok 1 fault strikes N08°W, dips 78° to the east, and two striations are developed; nearly horizontal one with sinistral shear sense and nearly dip-slip one with eastern side up. In the Gaegok 2 fault, strike of the fault plane and fault zone is N02°W, dipping 82° to the west. In the Gaegok 3 fault, strike of the fault plane is N30°E, dipping 65°to the southeast. The fault plane has two different striations, nearly horizontal one related with dextral strike-slip faulting and the other one showing slip along dip direction related with reverse faulting. In the Gaegok 4 fault, the strike of the fault is N30°W-N45°W with dips of 38°-48°to the northeast. In the main Quaternary fault plane, the orientation of striation is 17°, 142°. This fault has a 30-50 cm wide cataclastic shear zone mixed with Quaternary sediments and old fault breccia of granite, indicating a sinistral faulting with some reverse component. There is another striation (08°, 070°) with sinistral strike-slip sense, developed on the subsidiary plane which cuts the main Quaternary fault plane. In the Gaegok 5 fault, the strike of the fault is N25°E-N40°E, dipping 55°-60° to the southeast. The orientation of striation is 55°, 106°, showing reverse-slip sense. The Gaegok 6 fault strikes N02°-22°E, dips 45°-80° to the west. This fault has a 30-50 cm wide cataclastic shear zone with gouge zone, mixed with Quaternary sediments and breccia of granite by old faulting. In the main Quaternary fault plane, the orientation of striation is 17°, 356°, indicating a dextral faulting with some normal component. There is another striation (78°, 278° and 43°, 270°) with reverse-slip sense, developed on the subsidiary plane which cuts the main Quaternary fault plane. The Gaegok 6 fault has a similar orientation, westward dipping geometric pattern, and reverse sensed kinematic pattern with Gaegok 1 fault in the north. We consider that the Gaegok 6 fault is a southern extension of Gaegok 1 fault. In brief, six active faults in Gaegok-ri area juxtapose contact between the granite and the Quaternary gravel deposit. The eastern blocks of faults are mainly uplifted. The striations and movement senses of faults indicate multiple compressional stages in this region. The active faults are developed with an interval of several hundred meters from southwest to northeast in Gaegok-ri, not as a unique active fault, but as several sub-parallel faults forming an active fault zone. A trench survey is done near Gaegok 1 fault. In the trench two Quaternary faults are found. The old one is developed along the contact between Early Tertiary granite and Quaternary lower gravel and sand deposits, and do not continue to the upper sand layer. The younger one is developed between upper channel deposits and humified soil with liquefaction, along which channel deposits are reversely dragged. We describe and discuss also the possibility of surface rupture and liquefaction by earthquake occurred along Ulsan Fault Zone just before the Late Silla Dynasty (779 A.D.).

34-8 BTH 10 Covellone, Brian M.

A COMPREHENSIVE EVALUATION OF EARTHQUAKE SOURCE MECHANISMS WITHIN THE MIDDLE EAST

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The scarcity of reliable earthquake data and the structurally complex nature within the Middle East region requires a thorough examination of obtained earthquake source mechanism solutions and corresponding depths. Localized regions within Iran, the South Caspian basin, Tian Shan, and Hindu Kush represent complex areas of heterogenous continental collision dynamics where small scale faults account for the accommodation of stress within the region and complicate tectonic interpretations. To better address these complexities, we present an accurate and robust earthquake catalog with error assessment to provide a dependable resource for tectonic interpretations and update present wave speed models within the Middle East region.

Earthquake source mechanisms and depths were obtained for 270 events from 1990-2007 with magnitudes greater than 5.5. Using both 1- and 3- dimensional wave speed models, a full-waveform moment tensor inversion was calculated for each event analyzed at periods of 25-400 seconds and 80-400 seconds. Error was assessed using a bootstrap method to directly compare the results between models and period ranges as well as to assess the method's stability. Using results obtained with a 3D model at 25 seconds we observe a 10-40% reduction in variance from initial solutions provided by globalCMT.org and an average cross correlation value of 0.86. The results presented here offer a significant improvement over current velocity models within the study region and provide more accurate grounds for further tectonic interpretation.

Calculated source mechanisms correspond favorably with broad tectonic features within the study region; however due to the nature of localized faults, many earthquakes may reflect motion on either blind faults or the combination of movement on multiple faults with different orientations. Consistent with broad regional plate motions within the Zagros Mountains and northern Turkey, we observe shallow right-lateral slip corresponding to the expected motion along the Main Recent Fault and North Anatolian Fault. NW-SE striking mechanisms suggest regional NE compression and localized tensile stress which trace the locations of numerous interconnected thrust faults traversing though the Caucasus and Apsheron-Balkhan sill, into the Kopeh Dagh range. General NW-SE extension is observed in the Gulf of Aden, with components of left-lateral slip that accommodate the curvature and joining of the mid-ocean ridge system in the Indian Ocean. Two normal faults located in the Makran, on the border of southern Iran and Pakistan, match up to a slow velocity region observed at 50km within the current 3D wave speed model (s29ea) and may be related to present day subduction. Complex normal and reverse faulting is seen in the western syntaxis region of Tibet, where strikes vary nearly 180° trending from the NW to NE.

34-9 BTH 11 Karasözen, Ezgi

EARTHQUAKE FOCAL MECHANISM AND STRESS TENSOR INVERSION ALONG THE CENTRAL SEGMENT OF THE NORTH ANATOLIAN FAULT

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In this study, over hundred events with magnitude ≥ 3, which are recorded during the North Anatolian Passive Seismic Experiment (2005-2008), are relocated and focal mechanism determination, along with stress tensor inversion is carried out. Purpose of this study is to focus to the seismicity associated with relatively less-known central segment of the North Anatolian Fault (NAF).

In the region all relocated earthquakes have shallow focal depth, most occurred in the the uppermost 20 km and widely distributed suggesting a broad zone of deformation in the southern block. Focal mechanism determination is done by FOCMEC program, in which first motions of P- and S- waves are used along with SH/P wave amplitude ratios to obtain more unique solutions. Resultant 109 well-constrained focal mechanisms suggest a dominant strike-slip mechanism in the southern block that correlates with the splays of NAF. Conversely, normal and thrust mechanism solutions can be related to the secondary fault occurrences in the area. Focal mechanism solutions are further used for the determination of *P*- and *T*- axes orientations. Although overall stress filed is highly variable across the region, the orientations of *P*- and *T*- axes are in good agreement with the tectonic regime of NAF's right lateral strike slip motion. The trends of the *P*- *T*- axes show noticeable variations along the main strand of NAF, which is consistent with its' arc-shape geometry, whereas variations in the southern block is mainly characterized by NAF's major splays.

In order to have better understating of the seismicity and its driving forces across the region, stress inversion is performed using well-constrained focal mechanisms. Two different inversion methods are applied, assuming that the stress in the study area is uniform and invariant in space and time. Both inversion methods resulted in same stress orientations: maximum principal stress, σ_1, is found to be subhorizontal striking NW-SE, the intermediate principle stress, σ_2, is vertically orientated and the minimum principal stress, σ_3, is found to be NE –SW striking. Substantial heterogeneity is observed due to the large misfit values, but calculated faulting style represents the characteristic strike-slip motion.

34-10 BTH 12 Cubuk, Yesim

TIME DOMAIN MOMENT TENSOR INVERSION OF BALA-SIRAPINAR (CENTRAL TURKEY) EARTHQUAKES OF 2005-2008

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The goal of this study is to analyse source parameters of Bala-Sirapinar (Ankara) earthquakes occurred during 2005-2008, and to explain the geometry of active fault structures and seismotectonic characteristics in the region by using seismological data. For this purpose, we have analysed 35 earthquakes with magnitudes ranging 3.5 ≤ M ≤ 5.7 occurred between 30.07.2005 and 18.12.2008. Methodology used in this study developed by Dreger (1992), Dreger and Helmberger (1993), and it is known as Time Domain Moment Tensor Inverse Code (TDMT_INVC). Regional Moment Tensor (RMT) method is commonly used to determine source parameters of moderate earthquakes (4.0 ≤ M ≤ 6.0) recorded at regional distances (1° ≤ Δ ≤ 10°), and it is widely accepted technique due to availability of number of high quality broadband stations. With regard to the earthquake history of the region, there is not clear surface ruptures of active faults which can produce a major earthquake. Nevertheless, the study region has been affected significantly from earthquakes generated by North Anatolian Fault located 120 km to the north and cross-cutting fault zones (splay faults) to the south. We have consequently obtained focal mechanism and moment tensor solutions of 27 earthquakes which have good signal-to-noise (S/N) ratios. According to source mechanism solutions, right-lateral strike slip fault characteristics are common in NW-SE direction and left-lateral strike-slip fault characteristics in NE-SW direction. Some mechanisms include normal faulting components and partially E-W directions exist. It has known that the existence of conjugate fault systems are located both in NW-SE and NE-SW in region. In this respect, plenty of NW-SE directions indicate that common characteristics of 2005-2008 earthquake activity in this region could have represented with right lateral strike slip faulting mechanism and source mechanism solutions are consistent with active tectonics and local geological features.

34-11 BTH 13 Galbán Rodríguez, Liber

MODEL FOR GEOLOGIC RISK MANAGEMENT IN THE BUILDING AND INFRASTRUCTURE PROCESSES

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The geologic risk management is processes that require following the recent models of technologic innovation. Today it's necessary to design to model for geologic risk management wish include the necessities of civil the construction systems, and permit the direct, use of tools lake GIS, wombs, cost benefit analysis, etc. Intended to organize and control of the knowledge management and final quality of the buildings and others. Modelling with processes management could be an interesting alternative in front of such objective, in this work is proposing an option of model for geologic risk management in the construction processes using the processes management methodology.

34-12 BTH 14 Rouai, M.

SCALING BEHAVIOR OF AFTERSHOCKS SEQUENCE OF AL HOCEIMA FEBRUARY 24, 2004 EARTHQUAKE (MOROCCO)

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Al Hoceima region (northern Morocco) was struck by an important earthquake (Mw~6.3) on February 24, 2004; inducing a devastating damage and 629 victims.

The time dynamics of the sequence following the main event (838 shocks) has been investigated by non-linear tools. The sequence of the occurrence times of the events with threshold magnitude M ³ 3.2 is characterized by a time-clustering behavior, identified using different fractal methods (Fano Factor, Allan Factor, Hurst exponent, Count-based Periodogram, etc.), well suited to reveal scaling features in point processes. The presence of power-law behavior in the performed statistics indicates the existence of fluctuations on many timescales and therefore of fractal clustering.

The obtained results not only show the presence of memory phenomena and correlation structures in the Al-Hoceima aftershocks, but also furnish quantitatively the estimate of the magnitude of such correlation by means of the estimate of the scaling exponents.

SESSION NO. 35, 08:30

Thursday, 7 October 2010

Subduction, collision and orogeny. Posters Part 2 (*Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez*)

METU Convention and Cultural Centre, Exhibition Hall

35-1 BTH 15 Zack, Thomas

DETRITAL RUTILE AGES FROM THE CARBONIFEROUS FLYSCH OF THE ISTANBUL ZONE, TURKEY: NEW INSIGHTS FOR PROVENANCE STUDIES

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Rutile and zircon are among the most stable heavy minerals in sedimentary environments (erosion, transport and burial). While detital zircon is extensively analysed to gain information of the sediment provenance, the study of detrital rutile is still in its infancy. Nevertheless, it would be highly desirable to collect U/Pb ages of detrital rutile, as rutile records cooling ages of metamorphic terranes, which is another layer of information in addition to U/Pb ages of zircon, which generally record magmatic episodes of its source rocks. We have recently developed a method that allows precise and accurate U/Pb determinations of single rutile grains, employing a LA-ICP-MS, a common Pb correction based on ^{208}Pb and the usage of primary rutile standards (Zack et al., CMP, in revision).

As part of a thorough provenance study targeting the Carboniferous flysch of the Istanbul Zone, Turkey (see Okay N et al., this conference), we started the first pilot study on dating detrital rutiles. The age spectrum of the analysed detrital zircons shows three main age groups (335-390 Ma; 520-640 Ma and 1700-2750 Ma), consistent with an Amorican Terrane source. This is significant, as older sediments in the Istanbul Zone all have a clear Avalonian signature (e.g. a significant zircon population with Grenvillian ages of ca 1000 Ma). The preferred model to explain these results involves docking of the Istanbul Zone as a distant arm of the Avalonian Terrane, with the Amorican Terrane at the time of deposition as the source of the Carboniferous flysch.

In contrast to the results from detrital zircons, detrital rutile U/Pb ages from the Carboniferous flysch of the Istanbul Zone are prominently from only one age population, giving a pooled concordia age of 360 ±7 Ma. With one exception (1 of 30 detrital rutile is ca 550 Ma old), rutiles do not record any event older than the youngest age group of the zircons, e.g. the zircon age group of 1700 to 2750 Ma is not represented. If we follow the interpretation that rutile U/Pb ages represent cooling ages of their source area, the implication is that the source area of the Istanbul Zone flysch has a uniform cooling history.

In the complex Variscan collage, results from detrital rutiles of the Istanbul Zone imply that zircon ages in the age range of 1700 to 2750 Ma, often considered to be of West African Craton origin, by no means have to come *directly* from a distant source. In contrast, they have rather been involved in several metamorphic cycles, with a Variscan metamorphic cycle (360 Ma) in the case of source rocks from the Istanbul Zone flysch. We suggest to systematically search for age spectra of detrital rutile with several age groups, as they seem to be a tell-tale signature of continental scale river systems, therefore greatly helping to improve plate tectonic reconstructions.

35-2 BTH 16 Okay, Nilgun

A MISSING PROVENANCE: SANDSTONE PETROGRAPHY AND DETRITAL ZIRCON-RUTILE GEOCHRONOLOGY OF THE CARBONIFEROUS FLYSCH OF THE ISTANBUL ZONE

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The Istanbul Zone is widely regarded as being part of the Avalonian terranes of central and western Europe. The Lower Carboniferous flysch of the Istanbul Zone of the Pontides is an over 1500-m-thick turbiditic sandstone-shale sequence marking the onset of the Variscan deformation. The petrography of the sandstones and the geochronology of the detrital zircons and rutiles from the Carboniferous flysch were studied to establish its provenance. The sandstones are feldispathic to lithic greywackes and subgreywackes with roughly equal amounts of quartz, feldspar and lithic clasts. The amount of feldspar in the sandstones decreases upwards in the sequence at the expense of quartz and lithic fragments. In the discrimination diagrams 21 sandstone samples lie mainly in the field of dissected arc. 205 detrital zircons and 30 detrital rutiles from four sandstone samples were analyzed with laser ablation ICP-Ms. The detrital zircons show a bimodal age distribution with Neoproterozoic (620 to 550 Ma) and latest Devonian to earliest Carboniferous ages (362 to 355 Ma) ages. There are a few Paleoproterozoic and Neoarchean zircons; absent are Mesoproterozoic and Grenvillan (650-1800 Ma) zircons. The REE patterns and Th/U ratios of the zircons indicate a magmatic origin. The rutile ages are exclusively latest Devonian to earliest Carboniferous. Sandstone petrography and detrital zircon-rutile ages indicate two main sources for the Trakya Formation: a) Neoproterozoic granitoidic basement, b) latest Devonian to earliest Carboniferous magmatic and metamorphic rocks. A granitoidic Neoproterozoic basement is described under the Palaeozoic series of the Istanbul Zone, however, latest Devonian to earliest Carboniferous magmatic rocks are unknown from the Eastern Mediterranean region.

35-3 BTH 17 Sapiie, Benyamin

SOME CONSTRAINT IN TECTONIC RECONSTRUCTIONS OF BIRD'S HEAD REGION, PAPUA, INDONESIA

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The Bird's Head region of Papua, Indonesia is one of the most complex geology and tectonic history among other area in the Eastern Indonesia. Their geologic relationships are poorly understood due to complex tectonic history in both time and space. Tectonic evolution and basin development of region is known as one the most complex in the world. It involves convergent of three major plates: Indo-Australian, Pacific and Eurasia that has been occurring since early Tertiary. This tectonic event was generated several independent tectonic blocks in which their deformation involving rotation and translation in which some involving large displacements resulting from major oblique strike-slip faulting. As a results is very difficult to ramification their tectonic history using only rely on the field geological evidence due inconsistency data both stratigraphy and structural development. The main objective of this paper is to present results of ongoing geology investigation in particular concentrated in developing constraint in tectonic reconstructions of this region.

This study is based on large amount of newly acquired 2D seismic data from several locations surrounding Bird's Head region such as North Salawati Basin, Sorong Fault Zone, Misool Island, Seram Island and Cendawasih Bay. This new interpretation indicating new information leads to generate a new propose tectonic reconstructions model in order to fit the new data. Several regional balancing cross-sections were generated for supporting the development 2D palinspatic reconstructions and strain comparison of several areas within the region.

The results of this study indicates that stratigraphy of the Bird's Head region was varies from area to area which is difficult to correlates. This evidence is parallel by the fact that deformation was also inconsistent indicating by large variation in strain number. Palinspatic reconstructions suggested that deformation had been started as early as Late Mesozoic characterized by several unconformity surfaces. Structural pattern suggested that Bird's Head regions experienced some rotation and also translation resulting from strike-slip faulting deformation. All of these evidences are new for the region for example as comparison with Bird's Body or Northern Australian margin. Therefore, it's demonstrated that a new tectonic reconstructions model should be generated based on the results of this recent study.

35-4 BTH 18 Akbayram, Kenan

NEW U-PB, PB-PB AND RB-SR AGES FROM NORTHWEST TURKEY; RELICTS OF STRANDJA MASSIF BETWEEN ISTANBUL AND SAKARYA ZONE ALONG INTRA-PONTIDE SUTURE

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We provide stratigraphic and isotopical data from the greenschist metamorphic units along Intra-Pontide Suture Zone, which indicate that one of these units once, was probably a part of Strandja Massif. The study area is located south of Sapanca Lake between the Istanbul and Sakarya terranes in northwest Turkey. These two terranes along with the Strandja Massif make up the Pontides. These three terranes show different geological histories, as reflected in their stratigraphic record, and are juxtaposed along the Intra-Pontide suture. The new U/Pb zircon and Rb/Sr mica ages come from south of the Sapanca Lake and Almacık Mountains in northwest Turkey. The Istanbul terrane has a late Proterozoic basement overlain by a sedimentary sequence of Ordovician to Carboniferous age. The Sakarya terrane is characterized by Carboniferous high temperature metamorphism, Paleozoic granitic plutonism, and by the presence of Palaeo-Tethyan subduction-accretion units. The Strandja terrane has a Variscan basement with Carboniferous and Permian granitoids and an epicontinental Triassic to Jurassic sedimentary cover.

South of the Sapanca Lake, three main tectonostratigraphic units have been differentiated. They have steeply dipping tectonic contacts. In the east, an amphibolite-facies metamorphic unit crops out consisting of an intercalation of amphibolite, metaperidotite, metapyroxenite, metagabbro and gneiss representing the Proterozoic basement of the Istanbul Zone. This old basement has a right lateral strike slip contact with a Cretaceous accretionary complex of metabasite, metachert, serpentinite, slate, phyllite sequence metamorphosed in greenschist facies. The third tectonic unit is a metasandstone, slate, phyllite and marble unit metamorphosed in greenschist facies.

Our new U-Pb and Pb-Pb single zircon evaporation geochronological data comes from the metasedimentary unit. The age of deposition and metamorphism of this metasedimentary unit were previously not constrained. The U-Pb ages of the clastic zircons from metasandstones are between 264-504 Ma and the Pb-Pb evaporation ages of the clastic zircons are between 283-557 Ma. These new clastic zircon ages from the metasedimentary unit show that deposition of the sandstones must be later than Permian (264±8,9 Ma). The Rb-Sr muscovite ages from the metasedimentary unit and the accreationary complex give Early Cretaceous (138-111 Ma).

Pre-metamorphic position of the metasedimentary unit is problematic. This unit was interpreted as the equivalent of the Karakaya complex within the Sakarya zone (Robertson and Ustaomer, 2004). We interpret that the metasedimentary unit as a part of Strandja Triassic clastics., the Triassic cover units of the Strandja Massif have a very similar inner stratigraphy, and similar formation (Sunal et al., 2008) and metamorphism ages (e.g.; ~134 Ma of Sunal, 2009). Along with these similarities paleogeographical positions of Istanbul, Sakarya and Strandja Zones during Early Mesozoic interval also plays a crtitical role. Istanbul was the eastern continuation of the Moesian platform before the Late Cretaceous opening of the West Black Sea basin (Okay et al., 1994). Strandja Massif was in the south of the Moesian platform of Balkans. Before the opening of the Black Sea Basin and the formation of the Eocene Balkanide thrust belt; existence of the units of the Strandja Massif along the southern border of the Istanbul Zone is a strong possibility. Indeed in the regional map view of elongated structure of the metasediments south of Sapanca Lake seems continuing through the Strandja Triassics.

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35-5 BTH 19 Sayab, Mohammad

EVENT-WISE COLLISIONAL OROGENIC SEQUENCE OF THE INDIAN PLATE WITH EURASIA DEDUCED FROM PORPHYROBLAST INCLUSION TRAIL MICROSTRUCTURES IN THE NW HIMALAYA

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'Millipede' and 'rotational' microstructures preserved in porphyroblasts have extensively been used for the reconstruction of deformation regimes and associated metamorphic paths in many orogenic belts. In this regard, two, rather three, conflicting kinematic models have been postulated involving porphyroblast rotation (e.g. Jiang and Williams, 2004; Jessell et al., 2009), non-rotation (e.g. Aerden and Sayab, 2008; Bell and Hobbs, 2010) or little relative rotation (e.g. Johnson, 2009). These different interpretations on porphyroblast microstructures have important implications for the tectono-metamorphic growth of orogenic system. For this study, we applied advanced 3D microstructural techniques to examine the orientation of inclusion trail patterns preserved in porphyroblasts in medium to high-grade rocks of the Swat region of NW Himalaya in Pakistan. This area represents Indian-plate rocks that were deformed and metamorphosed during the Himalayan orogeny.

Previous workers in the Swat area and adjacent regions assumed 'rotational' porphyroblast models to calculate shear strain and kinematics of thrust sheets. However, the timing of porphyroblasts preserving different types of inclusion trail patterns with respect to successive deformation regimes that affected the study area have remained poorly constrained. In order to investigate the growth sequence of porphyroblasts and their relationship with the orogenic evolution of the NW Himalayas, we applied two independent techniques namely 'asymmetry switch' and 'FitPitch' for determining the orientation of inclusion trails in 3D developed by Hayward (1990) and Aerden, (2003), respectively. Both techniques are based on the measurements of porphyroblast inclusion trail microstructures from multiple, differently oriented thin sections of single samples. Axes of relative porphyroblast–matrix rotation (FIA: Foliation Intersection/ Inflection Axes) determined via these methods previously in other orogens have systematically revealed regionally consistent orientations of these microstructures that appear to relate to (successive) crustal shortening directions that can, commonly, no longer be deduced from the study of matrix microstructures alone.

Fifty-five samples analyzed using both techniques yield coherent single- and multi-FIA results that demonstrate the existence of four principle sets of FIA in the study area. These FIA sets can be distinguished based on their specific relative timing, and geographic trends. The FIA trend succession, from old to young is SE-NW (FIA set 1), E-W (FIA set 2), NE-SW (FIA set 3) and NNE-SSW (FIA set 4). FIA set 2 can be further subdivided into set 2a (ESE-WNW) and set 2b (ENE-WSW). The FIA succession suggests an anticlockwise rotation of the bulk shortening directions through time, consistent with the collision history of the Indian plate, Kohistan-Ladakh Island Arc (KLIA) and the Eurasian plate since 55 Ma. The orientation of FIA set 2 can be correlated with early-formed E-W trending thrust-related structures, whereas the trend of FIA set 4 is consistent with the younger regional-scale NNE-SSW trending folds and shear zones. FIA set 1 reflects the orientation of primitive structures that marks the trend of initial collision of the Indian plate with the KLIA. Relics of these primitive structures are scarcely preserved regionally due to transposition by later deformations responsible for FIA sets 2, 3 and 4. In addition, each FIA set is marked by distinct metamorphic cycle associated with unique shortening direction. Our combined data for both 'millipede' and 'rotational' types of inclusion trails indicate that all developed during a polyphase deformation history without having experienced significant relative rotations between them.

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35-6 BTH 20 Gogus, Oguz H.

THE SURFACE TECTONICS OF LITHOSPHERIC DELAMINATION FOLLOWING OCEAN PLATE SUBDUCTION: INSIGHTS FROM LABORATORY AND NUMERICAL EXPERIMENTS

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In various geological instances, continental delamination is associated with preceding ocean plate subduction, however the relationship between the two processes has not been recognized. In this work, we present a series of lithosphere scale two-dimensional (2-D) and three dimensional (3-D) laboratory and numerical experiments to investigate the evolution from ocean lithosphere subduction to collision and possible delamination of the mantle lithosphere from the crust. We test how varying the magnitude of plate convergence alters the behavior of the subduction-delamination model. Our experiments show that a converging and retreating plate can develop to continental mantle lithosphere delamination. A negative surface topography is supported at the delamination hinge and this migrates back with the peeling lithosphere. With a high plate convergence, the crust and mantle lithosphere separate at the collision zone in a form of chisel tectonics as oncoming pro-crust is accreted on top of the overriding plate and the converging mantle lithosphere subducts below. Localized high topography develops at this zone of crustal accretion and thickening. The results suggest that delamination may be simply a continental continuation of plate retreat and that lithospheric removal is triggered by the transition from one process to another. Our modeling results can contribute to geological interpretations of the Alpine tectonics particularly in the Mediterranean region and Tibetan plateau where both delamination and flake tectonics is proposed.

35-7 BTH 21 Gedik, Ismet

BERDIGA TERRANE AND ITS ROLE IN THE DEVELOPMENT OF EAST PONTIDE (TURKEY)

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Stratigraphic investigations in East-Pontides reveal that Berdiga Formation, developed in neritic facies, has a stratigraphic range from Callovian to Late Aptian. The regional allocation of this kind of a stratigraphic development has the geographic distribution between: in south ca. Maden (Bayburt) – Reþadiye line; in north Degirmendere-Bridge 23 (ca. 15 km south-west of Maçka-Trabzon); in east Uluçayýr-Yerlice line (ca. 10 km east of Bayburt); and in west ca. Fatsa-Niksar line. This area must have been an oceanic plateau during Callovian – Aptian-Albian time interval, whereas its confining neighbourhoods were deeper marine environments during the same time interval. With the onset of Late Cretaceous collisions between terranes get its start and very strange stratigraphic sequences like Bayburt-cataclastic melange, ophiolitic melanges at different locations, etc. were developed at terrane contacts. The convergent movements between terranes continued during Late Cretaceous and either subduction zones or strike-slip tectonics developed alongside of borders. At the end of Cretaceous most parts of Berdiga Terrane were uplifted and subdued to erosions during Paleocene. With the onset of Eocene some parts of this region were submerged again and Eocene deposits with very different sedimentologic characters developed. Convergent movements between terranes continued further after Eocene and deep-marine sediments and ultramaphic rocks of oceanic crust (indicating a deep environment) were up-thrusted over the confining oceanic plateaus.

35-8 BTH 22 Topuz, Gültekin

EARLY EOCENE OVERPRINT OF A PERMO-TRIASSIC ACCRETIONARY COMPLEX IN THE EASTERN PONTIDES (AĞVANIS MASSIF)

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The Ağvanis metamorphic massif, ~20 km long and ~6 km across, forms a SSE-NNW trending lozenge-shaped horst bounded by the strands of the North Anatolian Fault in the southern margin of the Eastern Pontides close to Neo-Tethyan Izmir-Ankara-Erzincan suture. The metamorphic rocks are made up of metabasite, phyllite, marble and minor metachert and serpentinite, and are intruded by Early Eocene quartz diorite, leucogranodiorite and dacite. The metabasites comprise hornblende/±actinolite, albite, chlorite, epidote, titanite, ±magnetite, quartz and ±biotite, indicative of the albite-epidote-amphibolite facies conditions. The phyllites contain quartz, muscovite, chlorite, albite, ±garnet, ilmenite, rutile, apatite and tourmaline. The peak metamorphic conditions are estimated as ~530 ºC and ~7 kbar. Stepwise $^{40}Ar/^{39}Ar$ dating of muscovite-phengite separates outside the contact metamorphic aureoles yielded steadily increasing disturbed age spectra with the highest incremental stage corresponding to age values between ~180 and 207 Ma, suggesting that the albite-epidote amphibolites facies metamorphism occurred at ≥ 207 Ma (Late Triassic or earlier). Contact metamorphic mineral assemblages, on the other hand, suggest that the present-day erosion level of the Ağvanis Massif was at depths of ~14 km during the Early Eocene. Given a nominal geothermal gradient of 25-30 ˚C/km, the ambient temperatures outside the contact aureoles would correspond to 350-425 ˚C. We therefore suggest that the partial resetting of the Ar-Ar muscovite ages are related to Paleocene-Early Eocene reburial coupled with the igneous activity. The Early Eocene reburial is probably related to thrusting due to the continental collision between Eastern Pontides and Anatolide-Tauride block. Foliation observed in many of Eocene dacite dykes and sills and in one granitic body also indicates major burial and shortening during the Early Eocene

35-9 BTH 23 Amini, Sadraddin

TECTONIC ACTIVITIES EFFECTS ON MINERALIZATION IN HORMUZ ISLAND, PERSIAN GULF, SOUTHERN IRAN

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Hormuz Island as an originally salty-gypsum diapir is located in the Persian Gulf, southern Iran. It includes many types of rocks and minerals ranging in age from Pre-Cambrian to recent. Rocks are not only: igneous, metamorphic, metasomatic, sedimentary and volcanoclastic, but also including many other types of ore deposits, evaporates and hydrothermal veins. Generally the Island is quite active either from diapirism point of view or from plate tectonics activities and plate's movements. Consideration of salty gypsum diapirs in Iran is very important, because Iran is in the first place in this regard. More than 500 salty gypsum diapirs as exposures or hidden could be distinguish in south and Central Iran. Although they are quite different in shape, position and many other characteristics, but based on age they could be divided into two main groups: old group (500-800 my) or south Zagros group, (including Hormuz Island); and young group or Great Kavir group (Tertiary age related diapirs 60 and /or <60 my old). During the last decades many researchers have followed this subject putting their attentions on geological considerations and tectonic studies of the diapirs, but fewer attentions were made on this subject (the title of this paper) particularly in case of Hormuz. Because it is not only a diapir but also it is an island being in direct contact with sea water for a long period of time. It is also one of the most southern diapirs of the Zagros group and close to convergent boundary of the Iran micro plate and the Arabian plate sub-ducting northward beneath the Iran micro-plate. However position, composition and environmental conditions resulted in Hormuz Island unique diapir, not only from tectonic activity but also from many other characteristics point of view. Moreover diversity of rocks in Hormuz could be indication of a diapir with a different type of origin in compare to many adjacent or un-adjacent diapirs. This means that magmatic activity in this area could play an effective role not only in formation of Hormuz, but also in mineralization, ore formation, chemical composition, metasomatism, metamorphism, rock diversity, tectonic movements, geothermal regime, salt- gypsum origin and evolutionary path of the Island.

In general, magmatic and tectonic activities are mainly coincidence in many places, e.g. in mid ocean rifts or divergent boundaries, in convergent boundaries, and so on. However it is yet unknown that, which one is the first and which one is the second (tectonics, or magmatic activities)? It is similar to story of egg and chicken origin!! Perhaps one of the main problems concerning the Hormoz Island is to response to that question. It could be suggested that the whole boundary in WWN –EES trend (the Zagros boundary) was not so active in the past from magmatic point of view, but it was tectonically so active since Cretaceous time.

However there are many un-responded questions about the origin of the Hormuz Island, such as: What is the relationship between diapirism and magmatism? Did magmatism cause diapirism or vice versa?

Beyond to response to these questions, it is obvious that fracturing and tectonic activities have a great effective role in mineralization as a whole and in Hormuz in particular. Because mineralization needs: primary material (composition), space, path to go through, suitable thermodynamics conditions (P, T, t) and geochemical environments (Ph, Eh….), and finally home to crystallize, precipitate, deposit or growth. However diversity of minerals and mineralization in Hormuz are so great that needs too many details studies. Complexity of geochemical and geophysical conditions on one hand and diversity of thermodynamics, tectonic activities, changing of time scale and environmental conditions on the other hand and finally combination of part, parts or all of them under different circumstances: e.g. by changing gradually, quickly, suddenly or extremely, geochemical, geophysical conditions, compositions, space and time scale could had been resulted into the formation of too complicated rocks, minerals, ore deposits and fluids.

35-10 BTH 24 Dadaev, Dmitriy M.

GEOLOGY AND TECTONIC CHARACTERISTICS OF THE NORTH-NURATA FAULT

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The North Nurata Fault is a part of the system of Bukantau-South Ferghana deep faults, which extended for a distance of more, than 1000km from the South Ferghana through the Nurata Mts. in Kyzylkum desert. In plan it is a stepped echelon-like system of parallel displacements. We regard zone of this fault as a major geotectonic and paleogeographical border, which was retained high mobility from the Early Paleozoic up today.

For full length the fault is a compound constructed zone, which is located on junction of two major Paleozoic geostructural elements: the Middle and the South Tien Shan and classified as a sutural zone, generated on the place of closure of paleoocean basin in the Middle Carboniferous.

Structural design of the North-Nurata Fault is rather complicated. Direct near displacements are observed numerous sharply angular blocks and wedges of different size, which are limited by fractures of some orders. In vertical section they are manifested like horsts, grabens, monoclines, graben-synclines and horst-anticlines. Within the zone of the Fault are wide spreaded small fractures, which are formed along displacements monotonous systems. There are two systems of shear fractures and one system of ruptures. For whole zone is characterized numerous dikes of medium composition, as usual within rupture fractures. All above named formations are determined complicated design of the North-Nurata Fault zone and underlined its feather-like character.

Plicative dislocations within fault zone are of very complicate structure as well. Usually are observed asymmetrical, strong and compressed folds of some orders, overturned into counter overlap of southern direction. Often are marked lying folds, which are in overturned bedding. These structures are accompanied by numerous longitudinal overlaps and upthrusts and formed systems of inclinated and deformed wedge scales.

Granitoid intrusives spatially are connected with overlap zones. Intrusives are located direct along overlap zones or at a distance from them. Intrusives are more or less parallel to overlap sutures and, apparently, are submerged together with them.

Specific feature of geological structure of the North Nurata Fault is a thickening of subparallel dislocations, among which are wide spreaded overlaps, which often are complicated with recent srike-slip faults. Strike of subparallel dislocations' system coincides with deep structure' strike.

This system of dislocation breaks up rocks into numerous blocks, lenses and plates of different dimensions (boudinage). Inner structures of plates and blocks are fragments of sections of different formations of various ages. Often they are of different zones and sub-zones and have very mixed lithological composition. It is characteristic, that almost complete absence of normal stratigraphical interrelations between stratified formations, manifestations of products of basaltoid magmatism, development of overthrust structures.

The structure of the North Nurata deep Fault was formed after the packet of covers was overthrusted during Moscovian age. At the same time accumulation of Chormagyz molasses were ended and forming of molasses of Farish suite (Middle-Upper Carboniferous) was begun in back-arc trough.

The North Nurata Suture is a result of prolonged being of subduction zone, which was subsided under the Middle Tien Shan and fixed zone of collision of two continents: Kyrgyz-Kazakh continent (the Middle and the North Tien Shan) and Alai microcontinent (the South Tien Shan. Paleogeodynamic reconstructions (Yu.S.Savchuk) show, that collision of these continental masses was not perpendicular, but slantwise. As a result the suture zone was turned into left-side system of displacements. On this stage (Late Hercinian stage) covers were deformated into synforms and antiforrms – large brachy-structures, often with slipped left wing (Kattaich anticline, Sentyab and Andreev synforms). On the next stage were formed vertical sygmoids. The rocks of covers were dynamic metamorphosed: they were crushed, partly schist-formed, rumpled into small isoclinic folds. In final stage of the Hercinian age intrusives of gabbro-granodiorite composition (Kattaich complex) and then mainly granitoides (Shurak complex) were injected within the southern horst-anticlinorium block of the North-Nurata Deep Fault. As a result neogenetic continental crust was consolidated still more and subsequently it was underwent mainly splitting strike-slip displacements. Hydrothermal fluids, which were injected from below, from relic chambers through channels, provoked metamorphism of rocks (ferruginization, silicification, metasomatism, etc.). In favorable conditions within lithologo-stuctural traps there were ores formation.

In Alpen stage of neotectonical activity the North-Nurata Deep Fault was an active fault again. At present the North-Nurata Deep Fault is the system of overlaps, zones of dislocations, steeply dipping upthrusts-displacements, secondary tectonically dislocations and transversal structures.

35-11 BTH 25 Madanipour, Saeed

EXHUMATION PATTERN IN THE TALESH MOUNTAINS, NW IRAN "CLIMATE FORCING"

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The Talesh Mountains of NW Iran extend between two mountain belts of the Alborz Range in SE and the Lesser Caucasus in NW, forming a narrow gently curved N-trending range west of South Caspian Basin.

The part of the Mountains which stretch out of Iranian border to the Azerbaijan is mainly masked by Tertiary -Eocene- sedimentary and volcanic successions. Within the Iranian border, the Talesh Mountains with about 40-50 km width, display a more complex stratigraphy. It consists of Precambrian to Middle Triassic sedimentary successions deposited along a passive margin of the Palaeotethys Ocean during Early Palaeozoic and, successively, influenced by the opening and closing of the Neotethys Ocean in the Late Palaeozoic-Tertiary. The Eo-Cimmerian event which marks the collision of Iranian Plate with the southern margin of the Eurasia Plate deformed these sequences with large scale displaced nappes. The Shemshak group (Triassic-Jurassic) overlies these nappes with an angular unconformity. The Cretaceous Limestone and volcani-clastic rocks that shows close folds and thrust faults are overlie normally the Late Triassic and Jurassic successions and sealed with Paleocene conglomerate. The Eocene volcanic and volcani-clastic rocks of Karaj Formation succeed the conglomerate and make a main part of Talesh stratigraphic column. These volcanic rocks are reported in literature to be related to active back arc extension of Neo-Thetyan subduction zone.

It is considered that geological evolution of the Talesh Mountain ties closely with the exhumation history of the Alborz Range, and in this study our preliminary assumptions are designed based on the comprehensive studies carried out on the exhumation pattern of the Alborz and its controlling factors.

The general proto-topography of the Alborz and Talesh mountains is assumed to be emerged mainly in Eo-Oligocene ~32Ma when the Eocene extensional tectonic regime converted to the compression, constrained by thermochronomic-stratigraphic data in the Alborz. The stratigraphic evidenced for this event in the Talesh Mountains, in transition of the Upper Eocene to Lower Oligocene strata, has been reported in the literature. It is dominated by fine-grained turbidity current and hemipelagic sediments with slope instability features, which is interpreted to mark the end of rifting and volcanism in the mountains and developing of the Talesh Mountains orogenic wedge as a topographic feature.

The Talesh Mountains with steep slope SW retro-wedge and gentle slope NE pro-wedge provide a solid barrier between the Neogene basins of NW Iran and the South Caspian Basin. There is a strong asymmetry across the range; the NE flank receives, in order of magnitude, more precipitation than the SW flank and erosional unroofing of the mountains must have driven a sediment flux to the adjacent SW and NE depositional basins, which making the area ideal site for studying climate control on erosion and crustal deformation.

This interpretation is compatible with previous study on the climate-exhumation asymmetry in the Alborz Range, located at the SE termination of the Talesh Mountains, displays a higher erosional exhumation rates in the arid-semi arid south flank of the range than in the wet north.

The Talesh Mountains have strong climatic gradients but different lithological gradient between its W and E sides. The Central portion of the mountains is mainly consist of similar erodible rock cover (volcanic and volcani-clastics of the Eocene and Cretaceous) in both retro- and pro-wedge sides. The study will make use of these strong climatic gradients across the Talesh Mountains to constrain effect of the seasonality in exhumation pattern of the orogen. The geomorphic and geodynamic implications of this gradient will be explored, with an emphasis on the possible erosional control on the exhumational and structural evolution of the mountains. Our approach is via combining stratigraphy, structural geology and low temperature Thermochronometric (AFT,AHe) analysis. It's predictable that the western steep flank of the Talesh Mountains has a high exhumation rate with respect to its eastern gentle flank which lasted from late Eocene – Oligocene time in response to low vegetation and high seasonality in retro-wedge steep side of the orogen.

35-12 BTH 26 Alania, Victor Michael

LATE CENOZOIC TECTONIC EVOLUTION OF THE GEORGIA (SW CAUCASUS)

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The tectonic evolution of Caucasus is largely determined by its position between the still converging Eurasian and Arabian plates, within the wide zone of a continent-continent collision. Within convergence zone there existed a system of island arc and back-arc basins etc. characteristic of pre-collisional stage of evolution of the region. The evolution of Mesozoic Greater Caucasus back-arc basin is related to the extensional processes resulting from northward subduction zone. During collisional stage, at the place of back-arc basins were inverted and formed fold-thrust belts of Greater and Lesser Caucasus separated by foreland fold and thrust belt (FFTB). The FFTB which developed formerly as a foreland basin (Oligocene-U. Neogene), is incorporated to the both thrust and fold belts. Georgia as a part of the Caucasus region consists of two major thrust and fold belts: the Greater Caucasus (GC) and Achara-Trialeti (AT). Between GC and AT thrust and fold belts, Paleozoic basement outcrops in the Dzirula massif separates the FFTB into the Rioni and the Kura. Integration of the present-day topography, structural features and section balancing, together with seismic reflection profiles, was used to develop a new tectonic model for the region. Balanced sections suggest that formation of Dzirula basement tectonic wedge structure is related to the southward thrusting of GC accretionary wedge and the presence of basement nappes. These structures were formed during late Alpain time, and characterized by a thick-skinned style of shortening. The amount of displacement of the Dzirula tectonic wedge indicating large horizontal crustal shortening and is accommodated by back thrusting of the Jurassic and Cretaceous strata of the overlying above Paleozoic basement rock. Thrust front of tectonic wedge is linked by backthrust and is structural boundary between AT and GC fold and thrust belts. Seismic reflection profiles show that north and east from Dzirula masiff the Rioni and Kura FFTB of Caucasus are an active thin-skinned fold and thrust belt and they preserve growth strata that record the tectonic and stratigraphic evolution. Analysis of synorogenic (or growth strata) deposits in seismic section documents that evolution of deformation has been continuing during the last ~5-4.5 Ma together with the thrust system kinematics.

35-13 BTH 27 Winn, Robert D.

NEW GUINEA OROGEN: MODEL FOR THE 200 MILLION YEAR OLDER ZAGROS OROGEN OF IRAN

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The Alpine-Himalayan orogenic system, which includes the Zagros Orogen of Iran, extends another 10,000 km southeast to New Guinea. Although having started almost 200 million years later, the New Guinea and Zagros Orogens incorporate similar tectonic elements, including re-attached continental blocks, magmatic arcs, deformation belts, foreland basins, and ophiolites. The orogens are similar because they were constructed by similar events.

The Zagros Orogen bounds the NW-SE suture between the Eurasian and Arabian plates. The Zagros orogenic cycle began with microcontinents (Sanandaj-Sirjan, central Iran, Helmand, other terranes) rifting from the African-Arabian plate margin in the Permian forming the Neotethys Ocean. The terranes moved northward on subducting Paleotethys seafloor toward Eurasia until docking in the Middle to Late Triassic. Northward subduction then jumped outboard, and a Jurassic-Cretaceous magmatic arc, possibly beginning in the Late Triassic, was generated at the Eurasian plate margin. Convergence was also responsible for formation of Mesozoic back-arc basins and for Jurassic and Cretaceous-Paleocene deformation. In contrast, the Arabian continent margin on the other side of Neotethys subsided passively until the Late Cretaceous when the margin became convergent and seafloor was obducted southwestward over the continent edge. Continental collision of Arabian and Eurasia and closure of Neotethys likely occurred during the Eocene to possibly Oligocene. The Neyriz-Kermanshah ophiolite trend marks the suture. Continued convergence formed the Neogene Zagros imbricate zone and fold-thrust belt and was responsible for major Pliocene-Quaternary strike-slip faulting.

Papua New Guinea from SW to NE consists of the Fly Platform, which is an extension of the Australian continent, the Papuan fold-and-thrust belt, the New Guinea Orogen, and several mostly volcanic islands. The New Guinea Orogen in PNG began with separation of microcontinents (Eastern and Papuan Plateaus, Owen Stanley and other terranes) from the Australian continent in the Paleocene, although rifting may have started in the Late Cretaceous. Paleocene-Middle Eocene oceanic crust of the Coral Sea Basin formed during separation. Another ocean apparently opened between detached microcontinents to the north as indicated by inferred Paleocene to Eocene ophiolites (Kami, Uyaknji, Marum terranes) between later re-sutured continental blocks. Mantle and oceanic crust of the Papuan Ultramafic Belt was obducted southward over the Owen Stanley terrane approximately concurrently with Paleocene seafloor spreading creating the Eastern Papuan composite terrane (EPTC).

The Australian plate began moving rapidly northward in the Eocene, and northward subduction began concurrently under the southern edge of the EPTC and an Eocene magmatic arc was generated above. Cretaceous strata and Paleocene-Eocene chert, shale, and deep-water limestone along the southwestern EPTC edge are strongly deformed and likely represent an accretionary wedge associated with the subduction. Continental terranes including EPTC accreted to the north-moving Australian continent starting in the Oligocene. Oligocene accretion is indicated by Oligocene siliciclastics overlapping sutures and by Late Oligocene-Early Miocene radiometric dating of metamorphism and minor magmatism in the orogen. The former subduction zone between the EPTC and the Eastern and Papuan Plateaus is represented by the Moresby Trough. Depression of the continent edge and formation of a foreland basin on the Australian continent edge followed docking with continued compression. The foreland basin includes the Aure Trough above the EPTC suture.

A new south-dipping subduction zone formed outboard of the accreted microcontinents in the Miocene. Melting related to this subduction generated the dominantly Middle Miocene Maramuni volcanic arc. The modern Trobriand Trough is a remnant of the former subduction zone. The Finisterre terrane-Bismarck arc, in turn, collided probably in the Late Miocene-Early Pliocene due to still-ongoing northward subduction at the New Britain Trench. Docking and continued convergence caused faulting and uplift in the orogen and formation of the Late Miocene-Quaternary Papuan fold and thrust belt and a second foreland basin. In addition, extension in the Woodlark Basin since 6 Ma likely is the result of by slab pull of the Solomon Sea plate under New Britain. The Australian plate is currently moving northward and the Caroline and Pacific plates are moving to the northwest. In time, if the motions continue (100 million years?), the Australian plate will collide with Eurasia possibly incorporating additional magmatic arcs and ophiolite slivers, and forming a continent-continent collision zone similar to the Zagros Orogen.

35-14 BTH 28 Konilov, Alexander

ECLOGITES OF BELOMORIAN ECLOGITE PROVINCES: HIGH-PRESSURE OR ULTRA-HIGH-PRESSURE?

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There are two eclogite types in Belomorian eclogite province in the NE Baltic shield. They mark the Archean paleosubduction zone at the boundary between Karelia and Kola cratons. Eclogite forming age is before 2,7 Ga. The Salma eclogites have N-MORB composition, and their protolith is ophiolites. Maximal content of jadeite in an examined omphacite is 30 mole %. Estimation using the omphacite composition of peak of the Salma eclogite metamorphism is 15 kb and 750 °C. Other type of eclogite displayed in mafic pods, lenses and undeformed and deformed mafic dykes in Southeastern part of the Belomorian eclogite province in the Gridino area. Maximal content of jadeite in an examined omphacite (only in quartz-bearing eclogites) reaches up to 34 mole %. Petrological investigations the Gridino eclogite displayed the united step-by-step metamorphic P-T trend for all mafic rocks from eclogite (peak pressure 17,5 kb) to amphibolite (7,9-9,6 kb, 530-700 °C) through HP-granulite (13,9-14,8 kb, 800-810 ºC) facies conditions.

THURSDAY

We discovered petrological observations that probably can be evidences of a much higher pressure at Belomorian eclogite formation:

(1) Were discovered oriented quartz rods in omphacite, which usually interpreted as exsolution structures of a supersilicic clinopyroxene during decompression of ultra-high-pressure eclogites [Katayama et al., 2000; Tsai, Liou, 2000].

(2) Integral composition of omphacite with quartz rods is identical with dendritic clinopyroxene-plagioclase symplectite with a “single grain” structure and have Ca-Eskola end-member about 5 mole percent.

(3) Jadeite content of omphacite corona around a magmatic clinopyroxene in a silica-poor olivine gabbronorite dykes reaches up to 55-60 mole %. Probably in this case the omphacite had a higher concentration of jadeite because external rims of coronas are composed by symplectite of omphacite, oligoclase with corundum and/or spinel.

(4) Equilibrium mineral paragenesis of Grt+Omph+Opx in orthopyroxene-bearing eclogite over silica-poor gabbronorite gave 22,4 kb at 800 °C by using Grt-Opx geobarometer [Harley, 1984].

(5) Lonsdalite was discovered in the eclogite boudin from Gridino area [Volodichev et al., 2006].

SESSION NO. 36, 14:30

Thursday, 7 October 2010

Aegean geodynamics and extensional tectonics. Part 2 (*Ege bolgesinin jeodinamik evrimi ve gerilmeli tektonikte güncel problemler*)

METU Convention and Cultural Centre, Salon B

36-1 14:30 Isik, Veysel

CENOZOIC EXHUMATION AND SEDIMENTARY BASIN FORMATION IN THE MENDERES MASSIF, WESTERN TURKEY

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New studies of the Menderes massif, western Turkey, improve our knowledge on the Cenozoic extension of Aegean region and contribute to understanding of the tectonic exhumation of mid-crustal rocks of the Tauride-Anatolide platform. Yet sedimentary basin formation in western Turkey during the exhumation of the Menderes massif provides important clues about the process; especially, lithological compositions of the boulder and cobble conglomerates indicate geological position of the source rock area. Basically, exhumation of the Menderes massif is controlled by normal faultings along the Datca-Kale main breakaway fault, Simav, Alasehir and Buyuk Menderes detachment faults. These faults juxtapose non-metamorphosed or metamorphosed from low-grade rocks to high-grade metamorphic and intrusive rocks.

The earlier period of crustal extension in western Turkey and exhumation of the Menderes massif have been handled by the Datca-Kale main breakaway fault and its northern continuation Simav detachment fault. In the hanging wall of the main breakaway fault, Oligocene Kale basin fill contains basal conglomerates originated mainly from rocks of the Lycian nappes. The upper sections of the basin fill, however, include fragments of the metamorphites (mainly marble) from Menderes massif. The footwall of the Simav detachment fault consists of high- and medium-grade meta-sedimentary and meta-igneous rocks (e.g. paragneiss, orthogneiss, schist, amphibolite, quartzite and marble) and granitoids with variably mylonitic and cataclastic in nature. Top-to-the N-NE shear sense indicators in the Datca-Kale main breakaway fault and Simav detachment fault suggest that exhumation of the Menderes core complex was initiated as an asymmetric core complex. Furthermore, this indicates that the Menderes massif was exhumed to be a source rock area for Kale basin during Oligocene.

Normal faulting would follow in the Early Miocene. Opposite-dipping two detachment faults, named the Alasehir and the Buyuk Menderes detachments, led to further uplifting the core complex and contributing to exhumation of the central Menderes massif and forming of approximately E-W-trending half-grabens. Early Miocene deposits of these half-grabens and coeval N-trending basins include boulders and cobbles with mylonitic textures representing rocks of the core complex. This shows that the Menderes massif has already been exhumed along Datca-Kale Main breakaway fault and Simav detachment fault and reached up to the erosion level. Post-Miocene basins, therefore, can not be related to the first exhumation stage, even if some of them are located on the corrugations of the Simav detachment.

36-2 14:50 Oner, Zeynep

SYN-EXTENSIONAL FAULT GENERATIONS AND THEIR ROLE ON THE LATE CENOZOIC ALASEHIR SUPRADETACHMENT BASIN EVOLUTION IN THE MENDERES METAMORPHIC CORE COMPLEX, WESTERN TURKEY

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The Menderes metamorphic massif (MM) in western Turkey is the largest core complex in the Aegean extensional province. It includes exhumed high-grade metamorphic rocks of Gondwana origin intruded by metaluminous to peraluminous granitoid plutons. Late Cenozoic structural grabens (Alasehir, Büyük Menderes) bounded by high-angle and seismically active faults crosscut the MM and are filled with Quaternary sediments. The E-W-trending Alasehir basin represents a well-preserved supradetachment basin with the N-dipping Alasehir detachment fault separating metamorphic rocks of the MM and the syn-extensional Salihli granitoid from the overlying Miocene and younger sedimentary rocks. The nearly 100-m-thick cataclastic shear zone beneath the detachment surface contains S-C fabrics, microfaults, Riedel shears, and shear bands, all consistently indicating top-to-the NNE shearing. The Miocene Salihli granitoid intruding the MM and the detachment surface displays mylonitic textures and ductile-brittle structures (microfaults, asymmetric objects, mica-fish, pressure shadows), all consistent with also top-to-the NNE extensional shearing. The oldest sedimentary rocks overlying the Alasehir detachment surface are the Lower Miocene lacustrine shale-limestone units (Gerentas, Kaypaktepe units) overlain by the Middle-to-Upper Miocene fluvial and alluvial fan deposits (Acidere and Gobekli units). Extensive occurrence of these alluvial-fluvial sedimentary rocks indicates a surge of clastic deposition along the northern edge of the core complex associated with the onset of range-front faulting in the MM by the late Miocene. Plio-Quaternary lacustrine-to-alluvial deposits (Yenipazar, Asartepe, and Erendali units) unconformably overlie the Neogene sedimentary units. The continued uplift of the MM provided the necessary relief and detrital material for the Plio-Pleistocene fluvial systems in the Alasehir supradetachment basin (ASDB). Quaternary alluvium fills the modern Alasehir graben bounded by a seismically active N-dipping, high-angle fault. We classify four different fault generations controlling the deposition, basin geometry and internal deformation in the ASDB. The Alasehir detachment fault (F1) is a N-dipping, low-angle corrugated fault plane with turtleback structures at the surface. E-W-striking, km-scale major high-angle faults (F2) crosscut and offset the detachment fault along the southern section of the basin. These faults strongly controlled the deposition of the Upper Miocene-to-Plio-Quaternary sedimentary units and resulted in significant changes in their dip angles and directions due to block rotation and tilting. The E-W-striking, low-angle normal faults (F3) mimic the geometry and kinematics of the N-dipping Alasehir detachment fault, and occur both in its footwall and hanging wall blocks during the basin evolution. Crosscutting relationships between the F2 and F3 fault generations indicate that high-angle normal faulting was a continuous mode of extension as the MCC continued its exhumation during the late Cenozoic. N-S-striking, high-angle scissor faults (F4), which crosscut the MM, the detachment surface and the basinal strata, caused differential uplift between individual rotational fault blocks showing different structural architecture. Strike orientations of sedimentary units adjacent to these scissor faults show significant changes due to rotational deformation along the N-S-striking, oblique-slip, high-angle scissor faults. The Neogene sedimentary rocks indicate higher amount of rotational deformation in the southern section of ASDB. Higher dip angles in the lower to upper Miocene units in comparison to shallower dip angles in the Plio-Pleistocene Yenipazar and Asartepe units are a result of progressive rotational deformation along F2 and F4 faults. Horst-graben structures, extensional drag folds, growth faults and folds are commonly seen in the basinal strata, but no true contractional folds or reverse faults have been observed along the southern flank of the Alasehir supradetachment basin. We interpret a few N-S-striking reverse fault planes as the extensions of range-perpendicular scissor faults. This fault kinematics and the distribution of range-parallel and range-perpendicular faults had a major role in the development of the shape and depth of the accommodation space within the ASDB, and controlled the deposition patterns and fluvial drainage systems. Local unconformities formed as a result of differential extension and uplift rates within the basin. There is no evidence for large-scale contractional deformation or major interruptions in the syn-extensional deposition history of the ASDB, and therefore we rule out the pulsed-extension models that suggest a period of contractional deformation in the late Cenozoic evolution of the MM. We conclude that the late Cenozoic extensional deformation was a continuous process controlled by four different fault generations and their kinematics affecting the syn-extensional deposition and overall basin evolution in western Turkey.

36-3 15:10 Kurt, F. Serap

ALTERNATIVE CENOZOIC EXHUMATION HISTORY OF THE KAZDAG CORE COMPLEX, WESTERN TURKEY

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Kazdag core complex is located on the north of Edremit gulf. The core complex consists of high-grade metamorphic rocks and granitoid intrusions. Detailed field observations and microstructural studies indicate that two different detachment faults play important role on the exhumation of Kazdag core complex.

The first detachment fault, called Selale detachment in the literature, separate from rocks of the Cetmi melange to metamorphic and granitoid rocks and has dominant top- to-the N sense of shearing. The second detachment fault, named as Yesilyurt detachment in this study, is a low angle normal fault at the present. It juxtaposes Lower Miocene Kucukkuyu formation to Cetmi melange. The shear sense kinematic indicators display top-to-the south sense of shearing. This detachment was probably high angle normal fault during the opening of E-W trending Edremit graben and control the deposition of Kucukkuyu formation and then it is rotated to the present low angle position. The basal conglomerates of Kucukkuyu formation contain fragments originated from metamorphic rock of the core complex and rocks of the Cetmi melange, which suggest that the Kazdag massif was already on the surface during the deposition of Kucukkuyu formation. The last tectonic episode is characterised by the strike-slip faults postdating the Yesilyurt detachment fault.

As a result, it can be speculated that the Selale detachment could be related structurally to the Datca-Kale main breakaway fault and its northern continuation Simav detachment. If it is true, the ophiolitic rocks constituting the upper plate attributed to Izmir-Ankara suture zone behave as a rootless unit in the extensional tectonic history of western Turkey.

Keywords: Kazdag, Core complex, Aegean region, Edremit graben, detachment fault

36-4 15:50 Bonev, Nikolay

REGIONAL TECTONICS AND 40AR/39AR TIMING OF CRUSTAL EXTENSION IN THE EASTERN RHODOPE MASSIF, BULGARIA-GREECE, AND MESOZOIC-CENOZOIC GEODYNAMIC EVOLUTION OF THE NORTH AEGEAN REGION

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We synthesize here the Mesozoic-Cenozoic evolution of the eastern Rhodope Massif, and provide a tectonic framework and 40Ar/39Ar age constraints for the processes involved during crustal extension in the north Aegean region. Triassic rifting has its magmatic expression in proto-ophiolitic metamafic rocks of the Serbo-Macedonian and the western Rhodope massifs, whereas it is scarcely represented by Permo-Triassic near-margin sediments in the eastern Rhodope Massif. Triassic-Jurassic rift propagation into the Carpatho-Balkan and Hellenic domains of the Maliac-Meliata oceanic basins and its southward intra-oceanic subduction has created near to the Rhodope margin an Early-Middle Jurassic intra-oceanic arc and established on the upper plate the Vardar ocean in a back-arc setting. Both island arc and associated Triassic-Jurassic sedimentary units were thrust northwards over the Rhodope high-grade basement in the late Jurassic ($^{40}Ar/^{39}Ar$ ages 154-157 Ma) during an arc-continental margin collision. This event contributed to the Mesozoic, paleoalpine crustal thickening. The late Jurassic thrust sheet forms the uppermost Mesozoic low-grade unit (greenschist to sub-greenschist facies) that we correlate with the Circum-Rhodope Belt. Underlying are an upper, high-grade basement unit lithologically heterogeneous unit (diverse in age) and the lower unit of high-grade basement composed of orthogneisses with Permo-Carboniferous protoliths. These two latter units are involved in south-directed ductile nappe stacking in amphibolite facies and related to the subduction (of the Vardar ocean) reversal towards the north since the Middle Cretaceous. Cretaceous nappe stacking further contributed to crustal thickening in the region. The Cenozoic tectonics is dominated by the extensional collapse of the Alpine orogen and the formation of detachment-bounded core-complex type metamorphic domes in Bulgaria and Greece. The domes expose the lower high-grade basement unit in the footwall, with the hanging wall consisting of the upper high-grade basement unit and the Mesozoic low-grade unit. Unmetamorphosed syn-tectonic Paleocene-Eocene sedimentary rocks and post-tectonic Oligocene sedimentary and volcanic units represent cover successions. The Kesebir-Kardamos dome displays NNE-directed ductile to brittle shear fabrics overprinted by brittle extensional shearing in the footwall mylonites and the bounding detachment. The Byala reka-Kechros dome exhibits the same structural pattern as the Kesebir dome in the footwall mylonites and the bounding detachment, but with a SSW-directed extension. This structural feature reveals a partitioned kinematic flow direction, likely related to a transfer fault linking the opposite sense detachment systems in both domes at a high crustal level. In the Byala reka-Kechros dome extension direction inherited the kinematic direction of the Cretaceous nappe stacking. In both domes, the 40Ar/39Ar mica cooling ages span 42.1-34.1 Ma in the hanging walls, whereas ages of the footwalls fall within the interval 38.1-35.5 Ma. The hydrothermal adularia 40Ar/39Ar ages in the range of 34.99-34.71 Ma are indistinguishable from the 40Ar/39Ar ages ranging between 34.69-33.91 Ma for the paleovolcano lavas at the northern Kesebir-Kardamos dome. The 40Ar/39Ar age of 36.5 Ma characterizes hydrothermal adularia in the prospect low-sulfidation mineralization in the Byala reka-Kechros dome. The acid dykes within the domes yield 40Ar/39Ar ages of 32.9 Ma and 31.82 Ma. The dykes of alkaline basalts at 28-26 Ma record latest magmatic pulse of enriched mantle source in the extensionally thinned crystalline basement of both domes. The new geochronology data and the reginal tectonic constraints allow us to delineate the following temporal evolution for the Mesozoic contraction and the Cenozoic extension and exhumation history of the region. Following the Late Jurassic-Cretaceous thrusting and thickening, Cenozoic crustal extension started as late as in the Eocene (youngest Ypresian syn-tectonic sediments) with the initiation of the low-angle detachment faults. Progressive extension led to the regional cooling and exhumation of the hanging wall between 42-34 Ma, followed by cooling and exhumation of the footwall within the interval of 38-35.5 Ma. Continued brittle extension and high-angle faulting in supra-detachment grabens of the hanging wall was followed by hydrothermal alteration at 36-35 Ma and formation of epithermal ore prospects and mineralization that are coeval in their waning stage with the onset of volcanism at 35-34 Ma. The data reveal interplay and overlapping tectonic, hydrothermal and magmatic processes within a narrow time interval with feedback from crustal and mantle (e.g. ductile-brittle basement thinning, hydrothermal activity, magmatism) processes involved in the late-stage extensional history of the eastern Rhodope Massif.

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36-5 16:10 Hajialioghli, Robab

TECTONIC IMPLICATIONS OF THE OLIGOCENE MAFIC MIGMATITES IN THE TAKAB CORE COMPLEX, NW IRAN

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The Takab core complex of NW Iran is Archaean in age. Metamorphism up to granulite facies in the Takab complex has produced mafic migmatites with distinguishable leucosome, mesosome and melanosome parts in mesoscopic and macroscopic scale. The inherited zircons in the melanosome part yield an age of c. 2900 Ma (U/Pb zircon dating). The older ages from this study are comparable to the detrital zircon age of 3140±2 Ma from the Menderes Massif (Kröner and ªengör 1990). The discovery of Archaean crystalline rocks in the study area adds to the plate tectonic scenario of a regionally extensive Tethyan suture zone, extending from western Anatolia (Menderes Massif) through Eastern Anatolia (Bitlis Massif) to western Iran (Takab Complex - Zagros Zone) and the Central Iran Zone. The newly grown zircons in the leucosomes give an age of 26.09±0.82 Ma.

Partial melting in the Takab area was probably the result of crustal thickening related to subduction and closure of the Neotethys ocean and consequent collision of the Arabian plate and the Iranian micro continents during the Tertiary Alpine Orogeny (Agard et al. 2005). A widespread late extensional event leading to lithospheric thinning affected the rocks in the area after the Oligocene crustal thickening (Hajialioghli 2007). K-Ar dating of graphitic schists in the Zarshuran area (Mehrabi et al., 1999), apatite U-Th/He data from the Mahneshan area (Stockli et al., 2004), and ^{40}Ar-^{39}Ar dating of muscovite schists (Gilg et al., 2006) constrain the timing of significant exhumation of the rocks to post-date 20 Ma.

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36-6 16:30 Aissa, Djamel-Eddine

CONTINENTAL COLLISION AND METALLOGENIC RESULTS IN NORTHEST OF ALGERIA

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The territory of North Algeria is part of Maghrebides which represent the southeastern part of the west Mediterranean alpine orogen. It was formed during an oblique continental collision between Africa an Mesomediterranean plate.

In the North-East of Algeria, the crystalline Edough Massif exhibits characteristics of the so-called "metamorphic core complexes", in close relationships with the opening of the Western Mediterranean Sea (Algiers-Provence Basin).

Presently, it is a N50°E antiform basement with a tectonic cover of flysch nappes. These nappes were emplaced in two stages: (i) during Eocene, a first stage of collisional tectonics in the Maghrebides led to the emplacement of a complex of Cretaceous flysch nappes "; (ii) in Late Burdigalian, following a second collisional stage, the Numidian (Oligo-Miocene) siliceous flysch nappe was emplaced.

Antiformal structures are sealed by the emplacement of Langhian (magmatic rocks granite (17 Ma), microgranite (16 Ma) and rhyolite (15 Ma). Magmatism and hydrothermalism occurred under shallower conditions with time, indicating continuous uplift from the onset of magmatism and hydrothermalism in Late Burdigalian. In the Aïn-Barbar area, the uplift rate was estimated to be 0.5 mm.a-1 (Marignac, 1988).

The magmatic and hydrothermal activities have induced several kind of mineralizations (W, Cu-Pb-Zn, Sb, Au) in strong relationship with the continuous uplift.

SESSION NO. 37, 13:30
Thursday, 7 October 2010
Keynote Talk 6
METU Convention and Cultural Centre, Kemal Kurdas Salon

37-1 13:30 Agard, Philippe

ZAGROS CONVERGENCE: A SUBDUCTION-DOMINATED PROCESS?

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This contribution aims at presenting a synthetic view of the geodynamic evolution of Zagros from ~150 to 0 Ma. The Zagros orogen and Central Iran preserve a unique record of the long-standing convergence history between Eurasia and Arabia across the Neotethys, from subduction/obduction processes to present-day collision. I herein combine the results obtained on several geodynamic issues, namely the location of the oceanic suture zone and the age of oceanic closure and collision, the magmatic and geochemical evolution of the Eurasian upper plate during convergence (as testified by the successive Sanandaj-Sirjan, Kermanshah and Urumieh-Dokhtar magmatic arcs), the P-T-t history of the few Zagros blueschists (and their relationship to those from nearby Makran and Oman), the convergence characteristics across the Neotethys (kinematic velocities, subduction zones, obduction mechanisms, thermomecanical modelling constraints), together with a survey of other recent results gathered over the past decade. A geotectonic scenario for the Zagros convergence is proposed, in which I have outlined three main periods/regimes:

(1) long-lasting subduction processes, with kinematic-related changes in arc magmatism (>150-35 Ma) Exhibition Hall

(2) a distinctive period of pertubation of subduction processes and upper-plate fragmentation (115-85 Ma) Exhibition Hall

(3) collision and partial slab tear at depths (~25-0 Ma).

This reconstruction underlines the key role played by subduction throughout the whole convergence history.

SESSION NO. 38, 14:30
Thursday, 7 October 2010
Seismicity, palaeoseismicity & archaeoseismology of the Mediterranean region. Part 2 (*Akdeniz bölgesinin sismik, paleosismik ve arkeosismik evrimi*)
METU Convention and Cultural Centre, Salon A

38-1 14:30 Ghods, Abdolreza

FAULT SEGMENTATION AND STRESS TRIGGERING IN THE 2006/03/31 SILAKHOUR EARTHQUAKE

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The 6.1 Mw Silakhour earthquake occurred on March 31, 2006, in Lorestan province in the Zagros region of western Iran. It was preceded by two relatively large foreshocks of 4.8 and 5.2 mb on March 30 and followed by two relatively large aftershocks of 4.7 and 4.9 mb on March 31, and a large number of smaller aftershocks. The earthquake sequence occurredalong the right-lateral strike-slip Main Recent Fault (MRF). Our moment tensor inversion shows a mostly right-lateral strike-slip faulting with a strike favorably parallel to MRF for the mainshock, the two large foreshocks and the larger aftershock. Using accelorometric stations, we estimate the depth of mainshock and the two large foreshocks to be around 7 km. To understand the spatial relationship between the mainshock and the high level of foreshock and aftershock activity, we relocated the events using a multiple event relocation method. The relocated epicenters of the earthquake sequence lie up mainly on the northeast side of the MRF, and spread parallel to the MRF over a distance of about 55 km.This is much longer than the 10-15 km fault dimension to be expected of a magnitude 6.1 earthquake. The relocated epicenters reveal a segmentation where the MRF steps up to the north, nearby Borujerd. The seismicity of the 2006 sequence is divided into two parts, an eastern patch of 10-15 km on the Borujerd-Dorud segment of the MRF that is directly associated with the rupture of the March 31 mainshock, and a western patch, 20-25 km long, on the Nahavand-Borujerd segment of the MRF. The two patches are offset by about 5 km in the same sense as the MRF, and separated by a nearly aseismic gap. The seismicity on the Nahavand-Borujerd segment, which includes the two largest aftershocks, began almost simultaneously with the mainshock rupture. Our Coulomb stress modeling suggests that seismicity on the this segment have been triggered by static stress changes related to the mainshock.

38-2 14:50 Haque, AKM Eahsaul

SEISMICITY IN THE BENGAL BASIN: POTENTIAL FOR FUTURE MASSIVE EARTHQUAKES

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The 26 Dec,2004 earthquake off the Sumatra coast focused world attention on the Sunda-Arc Subduction Zone, Bangladesh is along the strike of and within a rupture –distance from that enormous M-9.3 earthquake. This country is situated where the India- Sunda subduction zone rises from oceanic depths to subaerial exposure as a result of incipient continent collision where the trench meets the huge sediment accumulation of the Ganges-Brahmaputra Delta (GBD).The Archaean segment between Andaman-Nicobar Island and Bangladesh had been ruptured in the past that have also ruptured the Bangladesh segment. This segment is still active but whether it breaks in great earthquakes is unknown and is a question with complicated hypotheses. Because of huge thickness of sediment comes to Bengal Basin and enters into the seduction zone, this is one of the rare "oceanic" subduction zones where even the deformation front, which is usually along the deep trench, is exposed on land. There have been several active folds, warped reference surfaces and seismicity along the fold belt for current shortening as high as 1-2 cm/year along Myanmar segment. The range of proposed scenarios for the tectonics of the Myanmar Arc will remain very wide unless new data become available. Among the critical missing data sets are geodetic velocities, crustal structure, active fault kinematics, detailed stratigraphy and precise dating of strata and structures. The GBD was traversed by an active plate boundary, yet analyzing how active and whether the motion is aseismic or is taken up by rare earthquakes. From the seismic data, precise modeling of the structural and geodetic foundations for understanding this subaerial subduction zone and accretionary prism has been on the process of better understanding. The modeling will add insight into the mechanical properties of the low-slope over-pressured accretionary prism, and possible distributions of locked and creeping active fault segments.

38-3 15:10 Ruleman, Cal

NEOTECTONIC INVERSION OF THE HINDU KUSH-PAMIR MOUNTAIN REGION

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The Hindu Kush-Pamir region of southern Asia is one of Earth's most rapidly deforming regions and it is poorly understood. This study develops a kinematic model based on active faulting in this part of the Trans-Himalayan orogenic belt. Previous studies have described north-verging thrust faults and some strike-slip faults, reflected in the northward-convex geomorphologic and structural grain of the Pamir Mountains. However, this structural analysis suggests that contemporary tectonics are changing the style of deformation from north-verging thrusts formed during the initial contraction of the Himalayan orogeny to south-verging thrusts and a series of northwest-trending, dextral strike-slip faults in the modern transpressional regime. These northwest-trending fault zones are linked to the major right-lateral Karakoram fault, located to the east, as synthetic, conjugate shears that form a right-stepping en echelon pattern. Northwest-trending lineaments with dextral displacements extend continuously westward across the Hindu Kush-Pamir region indicating a pattern of systematic shearing of multiple blocks to the northwest as the deformation effects from Indian plate collision expands to the north-northwest. Locally, east-northeast- and northwest-trending faults display sinistral and dextral displacement, respectively, yielding conjugate shear pairs developed in a northwest-southeast compressional stress field. Geodetic measurements and focal mechanisms from historical seismicity support these surficial, tectono-morphic observations. The conjugate shear pairs may be structurally linked subsidiary faults and co-seismically slip during single large magnitude (> M7) earthquakes that occur on major south-verging thrust faults. This kinematic model provides a potential context for prehistoric, historic, and future patterns of faulting and earthquakes.

38-4 15:50 Talebian, Morteza

ACTIVE TECTONIC AND SLIP RATE OF BAM EARTHQUAKE FAULT, CENTRAL IRAN

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On 26 December 2003, an Mw 6.6 earthquake struck the city of Bam in the Kerman province of southeast Iran. The intense shaking in the city caused the complete collapse of over 50% of buildings in the central parts of the city and killed at least 25,000 people out of a population of more than 100,000. Bam is located on the eastern edge of the Central Iran. A relatively rigid block of Central Iran moves northward relative to Eurasia and hence relative to Afghanistan which is attached to the Eurasian plate. This motion causes right-lateral shear in eastern Iran with rate, estimated from recent GPS measurements to be 12–14 mm/yr [Vernant et al., 2004]. The resulting right lateral shear in eastern Iran is taken up on two north-south right-lateral strike-slip fault systems located on each side of the aseismic Lut desert.

The Bam earthquake was due to reactivation of hidden faults within the western of the strike slip fault systems bordering the Lut desert. This system has been especially active in recent years, with four major earthquakes between 1981 and 1998 [Berberian et al.,1984; Berberian and Qorashi, 1994; Berberian et al., 2001]. Earlier study of the coseismic deformation revealed that coseismic slip occurred on two sub parallel faults with eighty percent of moment release occurring on a previously unknown strike-slip fault running into the center of Bam (Fielding et al. 2004, Jackson et al., 2006). The remainder occurred on a southward extension of the previously mapped Bam reverse Fault, 5 km to the east.

Unfortunately limited information is available about the slip rates of individual faults in this region. Estimating slip rates of two earthquake faults (the N-S trending strike-slip and blind reverse fault) is the subject of this study. We report optically stimulated luminescence (OSL) ages of samples taken from uplifted plain deposits near the south end of the Bam reverse fault. The OSL ages indicate deposition of alluvial gravels between ~9 and ~19 ka which have been uplifted by about 2.5 m relative to the present river level. These results indicate that the fault-associated-fold is growing in the vertical direction with a rate of about 0.5 mmy-1.

Considering geometric relation between the Bam reverse fault and the south Bam strike-slip fault, we estimate a slip rate of about 2 mm/y for the south Bam earthquake fault. We therefore conclude that return period of large earthquakes on the south Bam fault will be about 1000 years.

SESSION NO. 39, 14:30

Thursday, 7 October 2010

Subduction, collision and orogeny. Part 2 (*Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez*)

METU Convention and Cultural Centre, Kemal Kurdas Salon

39-1 14:30 Garfunkel, Zvi

THE RELATIONS BETWEEN PERI-GONDWANA BLOCKS AND THE INTERIOR OF GONDWANA IN THE LATE NEOPROTEROZOIC AND EARLY PALEOZOIC TIMES

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It is widely accepted that many blocks within the orogenic edifices along the southern margins of Laurussia were located in Late Neoproterozoic and Early Paleozoic times along the periphery of Gondwana. However, the relations between their history and that of the adjacent more internal areas of Gondwana was little studied. Here are examined the relations between the Cadomian-type blocks of Europe and the Middle East and between West and North Africa and Arabia (WNAA) next to which they were most likely located.

The WNAA part of Gondwana was shaped by the assembly and amalgamation of many units and elimination of intervening oceanic areas (with a combined width of perhaps a few thousand kilometers) that was completed 650-620 Ma ago. It is only then that the Late Neoproterozoic configuration could have been established. The earlier positions of the peri-Gondwana blocks are not well constrained, but several lines of evidence suggest that many of them were accreted to WNAA in the late stages of its assembly. When these blocks formed the fringe of WNAA they evolved in an active margin setting, being affected by the Cadomian orogenic phase until the early Cambrian. In contrast, in this time interval the more internal WNAA region was stabilized and was deeply eroded in the aftermath of the Pan African orogeny, and became a stable platform. The tectonic relations between these two domains are not known, so several plate tectonic models of the accretion and development of the Cadomian orogeny can be envisaged. To better constrain them, more needs to be known about the arrangement of magmatic arcs and back-arc basins, and about the transport of detrital zircons in this zone.

Since the Early Cambrian an extensive veneer of northward transported mature silici-clastic sediments accumulated on the WNAA platform. The extension of this cover to the peri-Gondwana domain can be recognized in Anatolia where platformal conditions were established. Sediments accumulated also in more western peri-Gondwana blocks, but in the known ones igneous and tectonic activity of various types continued in the Cambrian and Ordovician times, indicating a different tectonic regime. This activity varied considerably laterally and also in time and was variously interpreted as recording an active margin setting in which rifts and back-arcs formed, and also transtensional deformation, rifting and breakup of the Gondwana margin after subduction along it ended. These events are not obviously related to the evolution and subsidence pattern of the more internal WNAA platform. It is also not clear where the large volume of sediments transported northward from the platform accumulated. The transition from the platform to the more active peri-Gondwana area is not exposed, but it follows that the WNAA platform was not delimited by a passive margin that passed northward into an ocean but by a few hundred kilometers wide belt where tectonic and igneous activity continued at least 80-100 Ma after the platformal sediment cover began to accumulate. A passive margin formed along the edge of this part of Gondwana only after some of the peripheral blocks rifted away and drifted northward.

Thus, the relation between the peri-Gondwana blocks and WNAA provide new insights, and also raise new questions, regarding the history of these areas.

39-2 14:50 Dilek, Yildirim

CRUSTAL ARCHITECTURE AND TECTONIC EVOLUTION OF THE ANATOLIAN-AFRICAN PLATE BOUNDARY AND THE CENOZOIC OROGENIC BELTS IN THE EASTERN MEDITERRANEAN REGION

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The modern Anatolian-African plate boundary is characterized by subduction zone tectonics and is in the initial stages of collision-driven orogenic buildup. The Anatolian microplate itself is made of young orogenic belts (Eocene and younger) that evolved during a series of collisions between Gondwana-derived ribbon continents and trench-rollback systems within the Tethyan realm. The collision of the Eratosthenes seamount with the Cyprus trench since the late Miocene is a smaller-scale example of this accretionary process and has affected the slab geometry and kinematics of the subducting African lithosphere. Pn velocity and Sn attenuation tomography results show that the uppermost mantle beneath much of the young orogenic belts in Anatolia is anomalously hot and thin. This is consistent with the surface geology, which is dominantly controlled by strike-slip and extensional tectonics and widespread volcanism in western, central and eastern Turkey. In all these areas, the extension was well under way by the late Oligocene-Miocene, following the main episodes of continental collisions. Pinning of subduction hinge zones by the accreted ribbon continents arrested slab rollback processes, causing terrane stacking and crustal thickening, and resulted in slab breakoff because of continued convergence of the lithospheric mantle. Slab breakoff-induced asthenospheric upwelling provided the necessary heat and melt to produce the first phases of post-collisional magmatism in these young orogenic belts. Renewed subduction and slab rollback in the Tethyan realm triggered lithospheric-scale extension in the upper plate, and the thermally weakened orogenic crust started collapsing. These processes resulted in rapid exhumation of recently formed high-pressure metamorphic rocks and in the formation of metamorphic core complexes. The Cenozoic geodynamic evolution of the western, central, and eastern Anatolian orogenic belts indicates that the asthenospheric mantle beneath collision zones responds swiftly to crustal tectonics on time scales of just a few million years. Slab breakoff, lithospheric delamination, and slab tearing were common processes that resulted directly from collision-induced events, and caused convective remobilization of the asthenosphere leading to magmatism. Asthenospheric upwelling and partial melting played a major role in a geochemical progression of post-collisional magmatism from initial shoshonitic, calc-alkaline to late-stage alkaline affinities through time. The collision-driven tectonic evolution of the Anatolian-African plate boundary and the young orogenic belts in the eastern Mediterranean region is typical of the geodynamic development of the Alpine-Himalayan orogenic system. Successive collisions of Gondwana-derived microcontinents with trench-rollback cycles in the Tethyan realms of the Alpine-Himalayan system caused basin collapse, ophiolite emplacement, and continental accretion, producing subparallel mountain belts. Subduction of the Tethyan mantle lithosphere was nearly continuous throughout these accretionary processes, only temporarily punctuated by slab breakoff events.

39-3 15:10 Hall, Jeremy

FROM SUBDUCTION TO COLLISION: THE ROLE OF THE ERATOSTHENES SEAMOUNT IN THE EASTERN MEDITERRANEAN

HALL, Jeremy[1], HÜBSCHER, Christian[2], EHRHARDT, Axel[3], DEHGHANI, Ali[2], HÖLZ, Sebastian[4], LOUDEN, Keith[5], AKSU, Ali[1], and SCHATTNER, Uri[6], (1) Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NF A1B 3X5, Canada, jeremyh@mun.ca, (2) Institute for Geophysics, University of Hamburg, Bundesstrasse 55, Hamburg, D-20146, Germany, (3) Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2, Hannover, 30655, Germany, (4) IFM-GEOMAR, Wischhofstr. 1-3, Kiel, 24148, Germany, (5) Department of Oceanography, Dalhousie University, Halifax, NS B3H 4J1, Canada, (6) Dept. of Marine Geosciences, CSMS, University of Haifa, Haifa, Israel

The Hellenic and Cyprus Arcs mark the convergent boundary between the African plate and the Aegean-Anatolian microplate. Subduction of the African plate under the Hellenic Arc is continuous. However, diffuse seismicity and distributed contraction suggest that the Cyprus Arc is in transition form subduction to collision. Eratosthenes Seamount, a continental fragment of the African Plate, is drifting northward towards Cyprus. Its impinging on the Cyprus Arc is partly responsible for the uplift of Cyprus. The results of ODP Leg 160 confirmed this scenario.

Marine geophysical surveys conducted in 2010—gravity, magnetics, multi-channel seismic reflection, wide-angle reflection/refraction seismic, magnetotellurics and swath bathymetry—offer unparalleled insights into the processes affecting Eratosthenes in its interaction with Cyprus. Regional analysis of unconformities indicates shifts in the tectonics at the end of Miocene and in the late Pliocene, which may reflect multiple stages in the development of collision. Our surveys enable us to characterise the early stage of collision of Eratosthenes with Cyprus and point at possible precursors below the Hecataeus Rise.

39-4 15:50 Kaymakci, Nuretdin

HOW MANY SUBDUCTION ZONES AND OCEANS, POST-CRETACEOUS EVOLUTION OF TURKEY: INFERENCES FROM MANTLE TOMOGRAPHY

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The early Mesozoic evolution of Turkey is related to the opening and subduction of strands of the Neotethys ocean and its closure during since the late Cretaceous. Various opening and closing scenarios have been proposed for the region, involving multiple oceanic basins and multiple subduction zones, in many different configurations. These scenarios were based mainly on surface geological and potential field data, and whereas only limited seismic tomographic images are available to test them.

Positive seismic wave-speed anomalies related to lower temperatures in the mantle are normally correlated with subducted slabs, and can be used to identify slabs and other remnants of lithosphere in the mantle. Available high-resolution mantle tomographic images around Turkey from Black Sea to Eastern Mediterranean region do not support multiple simultaneous subduction zone scenarios. Subducted slabs in the region are either still attached to the present oceanic crusts, or are detached form continuous coherent anomalies at depths of more than 1200 km.

In this contribution, we discuss the feasibility of various subduction scenarios proposed previously based on published mantle tomography and geological information, as well as new seismic tomographic images.

39-5 16:10 Axen, Gary

DISTRIBUTED OBLIQUE-DEXTRAL TRANSPRESSION IN THE HIGH ZAGROS MOUNTAINS, IRAN

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The HZ expose Cambrian to Tertiary strata of Arabian affinity that are imbricated by oblique dextral thrusts and cut by dextral strike-slip faults, both related to the oblique collision between Arabia and Eurasia. They are bounded on the southwest against the Simply Folded Belt by the High Zagros fault. On the NE, the Main Zagros reverse fault juxtaposes them against central Iran. Major High Zagros thrusts strike northwest, dip northeast, and carry ~5 km of Paleozoic-Mesozoic strata, locally including Cambrian sandstone at their bases. Although the thrust-belt architecture appears typical we find that many "thrusts" are in fact oblique-dextral faults and that significant dextral strain has been active in the High Zagros, probably since the onset of orogeny in early Miocene or late Oligocene(?) time. Earliest motion is recorded on the Main Zagros reverse fault, which controlled deposition of 3 Bakhtiyari conglomerate units near Shalamzar that are separated by unconformities. The middle unit contains early Miocene (23-17 Ma) marine fossils and pollen; the lower unit is undated but may be late Oligocene. Thus, the MZRF was active by early Miocene or late Oligocene(?) time. Apatite (U-Th)/He (AHe) ages from the two lower Bakhtiyari units are ~19-15 Ma; the younger ages in this range cannot represent detrital-grain ages (erosion in source terrain) because they postdate the youngest possible depositional age. We infer that the Bakhtiyari beds were buried by the Main Zagros thrust sheet to depths below the AHe partial retention zone, then exhumed and cooled from ~19-15 Ma in response to slip on thrusts farther southwest. Dated slip on High Zagros faults shows that the Main Zagros reverse fault is older than thrusts farther southwest, and that thrust timing also varies along strike. Southwest of Shalamzar, the Kuh-e-Lajin thrust is internal to the High Zagros in its northwest part but merges southeast with the High Zagros fault. AHe ages from basal clastic strata northwest of the intersection cluster around 18-15.5 Ma. These ages probably record activity on the Kuh-e-Lajin thrust or a deeper one, either of which may have uplifted the Shalamzar Bakhtiyari. Farther southeast, AHe ages from basal strata of the Kuh-e-Dinar segment of the High Zagros fault and from footwall syntectonic Bakhtiyari conglomerate are concordant, at ~11-8 Ma. An unroofing sequence and generally SW-directed paleocurrents from the Dinar Bakhtiyari indicate a source in the adjacent thrust sheet. The concordant ages suggest that the Bakhtiyari AHe ages are detrital-grain ages reflecting exhumation in their upper-plate source area. It appears likely that dextral transpression was distributed through the HZ in Miocene time, causing penetrative dextral S-C fabrics accommodated by pressure solution/precipitation along the Main Zagros reverse fault, oblique- to strike-slip striations on vertical and "thrust" faults, extension and salt extrusion along northerly striking fault segments, "thrusts" that climb section mainly to the southeast forming dextral duplexes in map view, and southeast-directed fold-accommodated shortening where faults end. The presently active, dextral Main Recent fault system has net offset of ~25 km and apparently developed more recently. The additional north-south convergence accommodated by this distributed oblique-dextral strain is difficult to quantify but may be large enough to account for the discrepancy inferred between plate reconstructions and dip-slip cross section reconstructions that neglect lateral slip components.

39-6 16:30 Sorkhabi, Rasoul

LATE PLIOCENE DENUDATION OF THE HIGHER HIMALAYA: FISSION-TRACK EVIDENCE FROM NEPAL AND IMPLICATIONS FOR TECTONIC EVOLUTION OF THE HIMALAYA

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Elucidating the thermotectonic, structural, uplift, and exhumation of the Himalaya has significant implications for our understanding of how collisional orogens form, and this task, in turn, requires geochronlogical data obtained by various dating techniques and from various parts of the Himalaya. The Higher Himalayan Crystalline Complex (HHC) in the Mount Everest region (Solu-Khumbu Himal) of Nepal is bounded by the Main Central Thrust (MCT) to the south and the South Tibetan Detachment (STD) to the north. Along the Dudh Koshi valley in Nepal, the HHC is a 20-km thick package of amphibolites-facies metamorphic rocks and anatectic leucogranite that has undergone a progressive ductile-to-brittle deformation with a predominant top-to-south sense of shear movement in line with the north-dipping direction of the MCT. Outliers of the HHC also lie as klippen within the greenschist-facies metasedimentary and sedimentary rocks of the Lesser Himalaya further south. Apatite fission-track (FT) ages determined on a topographic profile of 1600-4000 m in the HHC range from 2.1 Ma through 4.5 Ma, mostly clustering at 2.5 Ma and defining the steep slope of an elevation-cooling age curve. We interpret this as acceleration in the denudation of the MCT hangingwall, probably related to a renewed pulse of uplift and upthrust in the Himalaya. The Late Pliocene-Pleistocene sandstone and conglomerate beds of Upper Siwalik molasse in the Himalayan foreland basin support this interpretation; these sediments are fluvial, not glaciogenic. We also determined apatite FT ages on granitic rocks of the Palung area in Nepal, which is a klippe of the Higher Himalaya, presently exposed in the Lesser Himalaya. In contrast to the MCT root zone, the FT ages of Palung are significantly older (10-12 Ma) even though they come from rocks of lower altitudes. This suggests that the MCT root zone has experienced a remarkably different tectonic, denudation and cooling history in post-Miocene times. These data in conjunction with similar Late Pliocene FT ages from the HHC in other parts of the Himalayan orogen probably indicate a more recent phase of uplift and denudation in addition to the much discussed Early Miocene phase based on the Ar-Ar geochronlogy.

SESSION NO. 40, 08:30

Friday, 8 October 2010

Keynote Talk 7

METU Convention and Cultural Centre, Kemal Kurdas Salon

40-1 08:30 Green, Harry W.

SUBDUCTION ZONE EARTHQUAKE MECHANISMS AND EXHUMATION OF ROCKS FROM DEPTHS EXCEEDING 300 KM IN COLLISION ZONES

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Subduction zones are sites of the downwelling in the mantle; most consist of subducting slabs of oceanic lithosphere, which display earthquakes within them down -- to as deep as 680 km. Subduction also can lead to continental collision, of which the collision between India and Asia is the classic modern example. The resulting Himalayan mountain chain has many fossil counterparts in Asia and Europe, most (all?) of which contain rocks showing evidence of Ultra-High Pressure Metamorphism (ie. they contain coesite or other evidence indicating depths of approximately 100 km or deeper. In this talk, I will address the mechanisms whereby earthquakes can occur in subducting lithosphere and show that the evidence strongly suggests subduction zones are dry below 400 km. I will also give examples of UHPM rocks that have surfaced from more than 300 km.

Earthquakes near the surface are caused by frictional sliding on pre-existing faults or, rarely, by creation of a new fault by brittle shear failure. Neither mechanism can function at depths greater than ~30-50 km because pressure strongly inhibits frictional sliding and temperature enhances flow. Experiments show that deeper earthquakes, those in subduction zones, require a mineral reaction that generates a small amount of a new phase with very low viscosity -- a "fluid" -- which could be a real fluid (e.g. H_2O or melt) or a pseudofluid consisting of a polycrystalline material of nanometric grain size. Work over the last 20 years has delineated that fluid-producing reactions like dehydration of serpentine are the likely mechanism for earthquake nucleation above ~400 km and that transformation-induced faulting of metastable olivine is the likely mechanism below 400 km. I will explore the high-pressure shearing instabilities that are probably the underlying mechanisms of these earthquakes and show how they explain the bimodal distribution of earthquakes with depth, why they stop abruptly before 700 km, that metastable olivine is present in at least 4 subduction zones, and that subducting slabs are probably dry below 400 km.

Over the last 40+ years, rocks have been discovered from progressively greater depths in continental collision zones. In particular, in the 1980's coesite was discovered in Italy and Norway and diamonds in sediments from Kazakhstan, giving rise to the field of Ultra-High Pressure Metamorphism, and implying subduction to more than 120 km and return to the surface. More recently, the use of microstructures has extended the evidence in these terranes to much greater depths of 300 km or more. Some are peridotites, for which the trip may be a one-way voyage up; others are rocks that began at or near the surface, rode down on top of a subducting plate, and returned back up the same way they went down. In each case, they carry a combination of mineral phases and microstructures that disclose the depth of their travels. I will give two examples of rocks that have come up subduction zones from more than 300 km, one of which is a pelitic gneiss which at its greatest depth contained large crystals of stishovite (the high-pressure polymorph of quartz that is stable only at depths greater than 300 km). It is virtually certain that greater subduction also has occurred and most likely is responsible for the "continental" geochemical signal in ocean island basalts. Controversy has swirled around the question of how these high-pressure rocks, generally peridotites and eclogites, were transported to the surface. They generally are surrounded by quartzofeldspathic rocks that may show evidence of migmatization but no evidence whatsoever of high pressure. The question has been: Are the white rocks part of the deeply subducted material or have the high-pressure rocks been somehow incorporated into them after they neared the surface. This question has been soundly answered in the affirmative for the Dabie/Sulu terrane of Eastern China where separation of very large numbers of zircons from the white rocks have shown inclusions of coesite. Thus, in at least that case, the white rocks are clearly part of the subducted complex and almost certainly are the "cork" that brought up the denser rocks by buoyant upwelling.

SESSION NO. 41, 09:30

Friday, 8 October 2010

Modern accretionary wedges and ancient analogues (*Güncel ve fosil yigisma-prizmasi kamalarinin iç yapilari ve tektonik evrimleri*)

METU Convention and Cultural Centre, Kemal Kurdas Salon

41-1 09:30 Brandon, Mark T.

DOUBLE-SIDED WEDGE MODEL FOR RETREATING SUBDUCTION ZONES: APPLICATIONS TO THE APENNINIC AND HELLENIC SUBDUCTION ZONES

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We propose a new model for the evolution of accreting wedges at retreating subduction zones. Advance and retreat refer to the polarity of the velocity of the overriding plate with respect to

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subduction zone. Advance indicates a velocity toward the subduction zone (e.g., Andes) and retreat, away from the subduction zone (e.g. Apennines, Crete). The tectonic mode of a subduction zone, whether advancing or retreating, is a result of both the rollback of the subducting plate and the absolute motion of the overriding plate.

The Hellenic and Apenninic wedges are both associated with retreating subduction zones. The Hellenic wedge has been active for about 100 Ma, whereas the Apenninic wedge has been active for about 30 Ma. Comparison of maximum metamorphic pressures for exhumed rocks in these wedges (25 and 30 km, respectively) with the maximum thickness of the wedges at present (30 and 35 km, respectively) indicates that each wedge has maintained a relatively steady size during its evolution. This conclusion is based on the constraint that both frictional and viscous wedges are subject to the constraint of a steady wedge taper, so that thickness and width are strongly correlated. Both wedges show clear evidence of steady accretion during their full evolution, with accretionary fluxes of about 60 and 200 km^2 Ma^{-1}. These wedges also both show steady drift of material from the front to the rear of the wedge, with horizontal shortening dominating in the front of the wedge, and horizontal extension within the back of the wedge.

We propose that these wedges represent two back-to-back wedges, with a convergent wedge on the leading side (proside), and a divergent wedge on the trailing side (retroside). In this sense, the wedges are bound by two plates. The subducting plate is familiar. It creates a thrust-sense traction beneath the proside of the wedge. The second plate is an “educting” plate, which is creates a normal-sense traction beneath the retroside of the wedge. The educting plate underlies the Tyrrenhian Sea west of the Apennines and the Cretean Sea north of Crete. The stretched crust that overlies this plate represents highly thinned wedge material that has been removed or decreted from the wedge. This decretion process accounts for the mean motion within the wedge, from pro to retro side, and the pervasive thinning within the retroside. It also explains how these wedges are able to maintain a steady wedge size with time. An important prediction of this model is that different deformational styles, involving thickening and thinning, can occur within the same tectonics setting. This is in contrast the widely cited idea that tectonic thinning is a late- or post-orogenic process.

41-2 09:50 Rahl, Jeffrey M.

THE TECTONIC EVOLUTION OF THE HELLENIC SUBDUCTION WEDGE IN CRETE, GREECE

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We present a tectonic synthesis of the Hellenic Subduction wedge, Greece, based upon our recent studies into the structural, metamorphic, and thermal evolution of the high-pressure low-temperature rocks exposed in Crete. We focus on the Phyllite-Quartzite unit, a package of Carboniferous to Triassic siliciclastic sediments and minor volcanics that was subducted to a depth of about 35 km at 25 Ma, underplated, metamorphosed, deformed, and exhumed to the surface by 9 Ma. The lithology of the Phyllite-Quartzite is well-suited for both structural and thermochronologic analyses, so the unit is ideal for investigating the deformation and exhumation processes that occur within the subduction wedge.

Ductile deformation in the phyllites that comprise the bulk of the unit occurred primarily by the solution mass-transfer (pressure solution) mechanism. Regional strains estimated using a tensor average approach show a co-axial flattening ductile flow, with sub-vertical shortening of nearly 40% and minor radial extension in the horizontal. All bedrock units in Crete are cut by numerous faults developed after the rocks passed into the shallow brittle part of the wedge. Inversion of fault-slip data from western and central Crete reveals a brittle strain-rate tensor with a co-axial flattening and vertical shortening direction. The geometric similarity of the ductile and brittle strain results suggests the strain field maintains a steady orientation and symmetry throughout the entire wedge. We argue the pattern of within-wedge deformation reflects the mode of accretion; in the case of Crete, the large underplating flux destabilizes the wedge and causes vertical thinning and horizontal extension.

The exhumation of the high pressure rocks of the Phyllite-Quartzite unit from maximum depths of about 35 km will occur by a combination of erosion and tectonic thinning. Published cooling data from the shallowest tectonostratigraphic units in Crete suggest erosion accounted for no more than 6-10 km of exhumation. Modeling of our strain results indicate that ductile thinning contributed to no more than 5-6 km of exhumation. Thus, we conclude that the bulk (~14-19 km) of exhumation was accommodated through brittle deformation. Metamorphic temperature data in central Crete demonstrate a modest thermal offset across the Cretan Detachment Fault, suggesting this structure did not play a dominant role in exhuming the Phyllite-Quartzite unit. We conclude that the bulk of exhumation occurred by pervasive brittle stretching in the upper levels of the subduction wedge.

Because exhumation of the high-pressure units in the Hellenic wedge is controlled by tectonic processes, the rate of exhumation must reflect the pace of within-wedge thinning. In the absence of significant erosion, the deformation rate in a wedge with a steady cross-sectional area scales with its accretionary flux. In the Hellenic wedge, this flux is primarily controlled by the subduction velocity of the African plate. We argue that the Hellenic wedge has been in a flux steady-state since at least 25 Ma, meaning that the volume of material added to the wedge through frontal offscraping and underplating is balanced by the material that leaves, primarily by advection out the rear of the wedge. We discuss a revised cooling history for the Phyllite-Quartzite unit that shows a history of punctuated cooling related to the history of subduction. A period of slow cooling and exhumation beginning at ~19 Ma coincides with a period of slow subduction, while rapid cooling at about 12 Ma reflects with the onset of accelerated rollback. Together, these results indicate the structural, thermal, and exhumational history of wedges is controlled by the material fluxes.

41-3 10:10 Cloos, Mark

SUBDUCTION CHANNEL MODEL FOR ACCRETION, SEDIMENT SUBDUCTION, AND TECTONIC EROSION AT CONVERGENT PLATE MARGINS

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Convergent plate margins display a wide range in tectonic behavior. For example, margins such as Lesser Antilles and Oregon-Washington are sites where broad accretionary prisms have accumulated since the mid-Tertiary. Mariana and Guatemala, on the other hand, are sites where there has been extensive, if not complete sediment subduction and probably even significant subduction erosion during the same time period. Deep-sea drilling and other studies have led to the conclusion that the primary processes that operate at convergent margins are 1) subduction accretion by offscraping at the front of the overriding block and underplating to its base, 2) sediment subduction, and 3) subduction erosion.

The subduction channel model of Shreve and Cloos (1986) is based upon the premise that the descending plate and overriding block at margins where convergence is faster than a few cm/yr are analogous to the guide surface and slide block in a slipper bearing and that subducting sediment is analogous to the lubricant. Complex and varied behavior occurs because the overriding block is not rigid but slowly deforms, the buoyancy of subducting sediment affects the flow, sediment (or upwelled melange) can underplate onto the hanging wall, the sediment supply can vary widely relative to the capacity of the system, and other factors. Quantitative predictions bearing on a wide variety of geological and geophysical observations include the profile of thickness of the subduction channel shear zone, the pattern and speeds of flow in the channel, the stresses exerted on the channel walls, the amount of sediment offscraped and underplated, the zones where subduction erosion is most likely, the amount of sediment subducted to the volcanic arc, the kinematic patterns of flow near the inlet to the shear zone, the formation of subduction melange and other features of convergent plate margins. The subduction channel model does NOT address the same questions as the critical wedge theory of Davis, Dahlen, Suppe and others. Wedge theory and nearly all other quantitative models for convergent margin tectonics focus on the deformation of sediment AFTER its incorporation into an accretionary prism. The subduction channel models focuses on the flow of subducting sediment BEFORE incorporation into a prism or subduction to the depths of arc magmagenesis.

At all margins, some sediment is subducted to the depths of arc magmagenesis and a zone of bulldozer-like action, known as the “zone of compression” is present at the base of the inner trench slope. There are five possible kinematic patterns in the zone of compression (Types A-E), but only three are common. The decollement imaged in seismic reflection profiles is just the lowermost fault in the downward expanding zone of shear. Only fortuitously does it correspond to the boundary separating materials that will become accreted from that which becomes deeply subducted. The amount of bulldozed sediment accreted by is the difference between the amount of incoming sediment (thickness times subduction speed less compaction) compared to the capacity of the margin for dragging sediment past the inlet. The pattern of underplating depends upon the shear stress distribution along the hanging wall, the sediment supply along the channel, and the permeability of the overriding block. Subduction erosion occurs where the incoming sediment supply is sufficiently small that high shear stresses develop on the base of the overriding block and pieces of the block become detached. Whether the state of stress in the overriding block (crystalline overriding plate ± accretionary prisms) is at the point of incipient Coulomb failure for shortening or extension depends upon the magnitude of the shear stress on the hanging wall, the surface slope, and the mechanical properties of the overriding block.

41-4 10:50 Marotta, Anna Maria

DEEP CRUSTAL RECYCLING IN OROGENIC WEDGES FACILITATED BY MANTLE HYDRATION: NUMERICAL MODELING VS. NATURAL DATA

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Studies on high-pressure (HP) and ultrahigh-pressure (UHP) rocks exposed in orogenic belts linked to collisional margin show that nappes of oceanic and continental deeply subducted crust can be exhumed to shallow structural levels. In particular, during ocean-continent-type subduction, the crustal material dragged into subduction channel is composed chiefly by oceanic crust and trench sediments, continental slices belonging to subducting plate microcontinent (Ring and Layer, 2003) or linked to early continental collision (Chemenda et al., 1995) or crustal slices tectonically eroded from the overriding plate (ablative subduction) (Tao and O’Connell, 1992, Marotta & Spalla, 2007). Several models have been developed, during last 20 years, to analyse exhumation of subducted crustal material. They can be resumed on five main mechanisms: a) crust-mantle delamination (Chemenda et al., 1995), b) slab break-off Ernst et al., 1997), c) slab retreat (Ring and Layer, 2003) and roll-back slab (Brun and Faccenna, 2008) and d) decoupling of two main ductile layers (Yamato et al., 2008), in which the exhumation is mainly driven by negative buoyancy and/or faulting and e) subduction-channel flow (Stöckhert and Gerya, 2005) in which the exhumation is driven by the upwelling flow developed a low-viscosity mantle wedge. Only channel flow takes into account recyrculation of crustal slices dragged to high depth by ablation within pre-collisional subduction zones.

The effects of the hydration mechanism on continental crust recycling are analyzed through a 2-D finite element thermomechanical model. Oceanic slab dehydration and consequent mantle wedge hydration are implemented using a dynamic method. Hydration is accomplished by lawsonite and serpentine breakdown; topography is treated as a free surface. Subduction rates of 1, 3, 5, 7.5, and 10 cm/y; slab angles of 30°, 45°, and 60°; and a mantle rheology represented by dry dunite and dry olivine flow laws have been taken into account during successive numerical experiments. Model predictions pointed out that a direct relation- ship exists between mantle rheology and the amount of recycled crustal material: the larger the viscosity contrast between hydrated and dry mantle, the larger the percentage of recycled material into the mantle wedge. Slab dip variation has a moderate impact on the recycling. Metamorphic evolution of recycled material is influenced by subduction style. T_{Pmax}, generally representative of eclogite facies conditions, is sensitive to changes in slab dip. A direct relationship between subduction rate and exhumation rate results for different slab dips; this relationship does not depend on the used mantle flow law. Thermal regimes predicted by different numerical models are compared to PT paths followed by continental crustal slices involved in ancient and recent subduction zones, making ablative subduction a suitable precollisional mechanism for burial and exhumation of continental crust.

Natural data and model predictions are in good agreement: the thermal states simulated for ablative subduction with a hydrated mantle wedge justify the natural PT estimates obtained on continental crust units involved in ocean-continent subduction systems. Similarly, the exhumation rates obtained from analysis of PTt paths are more compatible with natural ones than those obtained from the upwelling flow vector, which could justify only a transient exhumation stage. In general, numerical simulations and natural data show exhumation rates lower then subduction rates.

The good agreement obtained between our model and models developed using different numerical and starting approaches (e.g., Gerya and Stöckhert, 2005; Stöckhert and Gerya, 2005; Faccenda et al., 2008, 2009), except for the exhumation rates, indicates the robustness of the corner-like flow mechanism on precollisional exhumation of the continental crust. On the basis of these results, we propose ablative subduction of the overriding continental plate with corner-like flow as a good alternative, precollisional mechanism for the subduction and exhumation of continental totally decoupling. Thus, ablation decreases and a one-side subduction, characterized by an accrectionary margin, develops (Clift and Vannucchi, 2004).

41-5 11:10 Anma, Ryo

DEVELOPMENT OF TRENCH-SLOPE BREAK NEAR SPLAY FAULT ZONE IN THE NANKAI TROUGH: RESULTS OF SUBMERSIBLE STUDIES

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Aiming to understand distribution of outcrop-scale structures and strain in the accretionary complex of the Nanaki trough, field mappings were conducted using submersible “*SHINKAI 6500*” along the Shionomisaki submarine canyon, off Kii peninsula, Southwest Japan. Outcrops were investigated in the seaward-most part (frontal thrust zone), the landward-most part (splay fault zone) and an intermediate part (imbricate thrust zone) of the complex. Turbiditic sediments in the frontal thrust zone were deformed to form a ridge-scale gentle anticline. Minor normal faults striking parallel to the trough axis developed in the crest of the anticline. As sediments transferred into the imbricate thrust zone, both ridge-scale open anticline and outcrop-scale open to tight folds were developed in the turbiditic sequence. Brittle thrust faults that accompany tight folds and development of shear fabrics were also observed.

An out-of-sequence thrust (splay fault) was then developed in frontal part of the landward-most ridge comprised of thick Pliocene to Recent (< 4.3 Ma) turbidite sequences. Sandstones just above the splay fault were cemented by carbonates. Behind the cemented zone, bifurcations of the splay fault were distributed in the sandstone-rich strata dipping steeply to the south. Folds with wavelength of ~ 200 m were developed in mudstone-rich turbidites behind the bifurcating fault zone. The uniaxial compressional strength and degree of fabric development increase, and the porosity decreases southward toward the splay fault. The cementation strengthened the frontal part of the splay fault, which in turn, acted as an indenter for the inner part of the accretionary wedge, and as a backstop for the outer wedge. Sediments behind and in front of the hardened ridge were thickened as trench-slope break developed in such manner. The model accounts for the over all strain distribution, porosity increasing and strength decreasing northward behind the ridge front.

41-6 11:30 Yamamoto, Yuzuru

ONLAND ACCRETIONARY WEDGE IN THE MIURA AND BOSO PENINSULAS, CENTRAL JAPAN: ONE OF THE BEST ANALOGS OF MODERN SUBDUCTION-ACCRETION SYSTEM

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Since there are major missing links between studies of modern accretionary complex (most examples are composed of late Miocene and younger sediments which are recovered from 1-2 km depths) and ancient accretionary complex (most examples are older than Eocene, experienced max. burial depth deeper than 5 km), the progressive variation of deformation, physical/chemical properties, and diagenetic/metamorphic processes along the subduction mega-thrust has not been successively traced. The Miura and Boso area, central Japan is a unique example representing a young and shallowly buried ancient accretionary wedge that gives us great opportunity to study the missing links and to perform complementary studies of modern accretionary wedges with its spatial and time variations.

The Miura and Boso are composed of two accretionary complexes: the early to middle Miocene Hota accretionary complex buried only 2-4 km, and the late Miocene to early Pliocene Miura-Boso accretionary complex buried less than 1 km with overlying several trench-slope basin sediments. They uplifted rapidly due to the Izu-Bonin island arc collision and therefore have never experienced deeper burial, thermal, and physical overprinting. These accretionary complexes preserve successive variation of deformation and related physical/chemical properties from soon after sedimentation to just prior to seismogenic realm.

In this presentation, we will show the geologic framework of accretionary wedge in the Miura and Boso areas, corresponding characteristics on physical properties and deformation/fabrics, and comparison with modern-plate convergent margins such as Nankai (SW Japan) and Kanto (central Japan) regions.

41-7 11:50 Meneghini, Francesca

THE SEISMIC CHARACTER OF MELANGE ZONES: RECORD OF MEGA-EARTHQUAKES IN THE KODIAK ACCRETIONARY COMPLEX, PASAGSHAK POINT, KODIAK IS., ALASKA

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The earth's largest earthquakes and tsunamis occur in the seismogenic zone of subduction margins, i.e. the seismically active part of the subduction channel that occupies a limited depth range (ca 4-45 km) along the plate interface: nearly all of the large earthquakes (Mw>8) occur along this interface at shallow depths, between 10 and 15 km. The plate interface of subduction margins, referred to as décollement zone, is a complex thrust zone involving fluid-rich unconsolidated sediments and hard rocks, through an ever-increasing pressure-temperature-strain regime from the surface down to a depth of ca. 80 km. Mélanges have been classically described as a typical subduction product, representing ancient strands of paleo-décollement zones formed in consequence of high shear strain and dewatering of a sediment pile undergoing progressive underthrusting.

Pseudotachylytes are so far the only unambiguously recognized ancient evidence of fault slip at seismic rates. While pseudotachylytes are commonly described in crystalline rocks, mélanges are typically dominated by "weak" pelitic lithotypes and are extensively infused by carbonate and quartz veins, thus suggesting a possible aseismic creeping mode of deformation.

Why are pseudotachylytes so rare along subduction mega-thrusts? Is the paucity of pseudotachylytes in the subduction setting due to our failing to recognize them in lithotypes so different from those typically described in continental settings? The present contribution constitutes a first attempt to answer these questions, focusing on a study conducted on a décollement-system thrust fault preserved in an accreted mélange unit of the Kodiak accretionary complex (Alaska). The accretionary complex of Kodiak Island is an ancient analogue of the active Alaskan subduction, a similar setting to the locus of the 1964 Mw9.2 Alaskan earthquake.

On Kodiak Island, decimeter-thick black fault rocks (BFR) are at the core of 10's meters-thick foliated cataclasites. The cataclasites belong to mélange zones interpreted as a paleo-décollement active at 12-14 km depth and 230-260^{o}C. Each black layer is mappable for tens of meters along strike.

The BFR have complex layering made at microscale by alternation of granular and crystalline microtextures, both composed of micron-scale sub-rounded quartz and plagioclase in an ultrafine, phyllosilicate-rich matrix. In the crystalline microlayers, tabular zoned microlites of plagioclase make much of the matrix. No such feldspars have been found in the cataclasite. We interpret these crystalline microlayers as pseudotachylytes. The granular microlayers show higher grain size variability, crushed microlites and textures typical of fluidization and granular flow deformation. Crosscutting relationships between granular and crystalline microlayers include flow and intrusion structures and mutual brittle truncation. This suggests that each 10's centimeter-thick composite BFR record multiple pulses of seismic slip. In each pulse, ultracomminuted fluidized material and friction melt formed and deformed together in a ductile fashion. Brittle truncation by another pulse occurred after solidification of the friction melt and the fluidized rock.

XRPD and XRF analyses show that BFR have similar mineral composition and chemical content as the cataclasites. The observed systematic chemical differences cannot be explained by bulk or preferential melting of any of the cataclasite components. The presence of an open, fluid-infiltrated system with BFR later alteration is suggested. The geochemical results indicate that these subduction-related pseudotachylytes, differ from those typically described in crystalline rocks and other tectonic settings.

41-8 12:10 Tortorici, Luigi

THE OPHIOLITIC MELANGE OF CENTRAL CRETE (GREECE): REMNANTS OF ALPINE ACCRETIONARY WEDGE

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The ophiolite-bearing terranes of the central Crete form the uppermost tectonic nappe of the orogenic belt and are represented by broken formation and tectonic mélange associated with remnants of a well-developed accretionary wedge emplaced on top of the cretan continental margin. These units consist of a Cretaceous-Upper Eocene matrix, which includes blocks of continental-type rocks and ophiolites with remnants of their original Upper Jurassic-Cretaceous (?) pelagic cover. The innermost portion of the accretionary wedge is represented by a polymetamorphosed and polydeformed tectonic unit made up of prevalent micaschists and calcschists with levels of marbles and quartzites, with associated blocks of oceanic and continental type rocks. The ophiolitic rocks are mainly represented by peridotites, metabasalts and metagabbros that show HP/LT mineral assemblages (glaucophane, chlorite, actinolite, titanite, epidote, albite and quartz). The intermediate structural subunit consists of a sequence of shales, schists, calcschists containing beds of quartzites, metarenites and meta-calcarenites. The associated ophiolites occur extensively as metre to kilometre-sized lens-shaped blocks. They are mainly represented by serpentinized peridotites and metagabbros with associated rare metabasalts. In places, metabasalts show remnants of their original sedimentary cover made up of varicoloured siliciferous shales, metaradiolarites and marbles. Metabasalts consist of fine-grained massive or banded rocks showing a green-schist facies assemblage represented by albite, chlorite, actinolite, epidote, titanite, opaques and rare biotite. In some samples the occurrence of assemblages with riebeckite/crossite suggests an evolution towards the HP sector of the green-schist facies. The lowermost subunit, which represents the frontal portion of the accretionary wedge, is composed of a chaotic turbiditic sequence of green to brown shale and marls, calcarenites and lithoarenites and volcanic-derived arenites. This sequence contains lens-shaped blocks of serpentinites, gabbros, basalts and Upper Jurassic oceanic sedimentary cover. Stratigraphic data deriving from micropaleontological analyses carried out on several samples collected on the matrix of the intermediate and the lowermost structural horizons show nannofossil associations indicating ages ranging from the Cretaceous to the Late Eocene. Representative samples of metabasalts, metagabbroes, serpentinized peridotite and serpentinized peridotite breccias are deeply altered suggesting a ocean floor metamorphism. Continental type rocks are represented by paragneisses and orthogneisses, amphibolites and silicate-bearing marbles intruded by Upper Cretaceous granitoids. These rocks are included within both the uppermost and the intermediate subunits and form lens-shaped blocks that ranging in length from metres to kilometres are at times separated by lenses of serpentinized peridotite. The structural analysis revealed the occurrence of four groups of structures that developed at different structural levels during continent collision suggest a south-easterly emplacement of the entire wedge on the cretan continental margin.

SESSION NO. 42, 09:30

Friday, 8 October 2010

Ophiolites, blueschists, and suture zones. Part 3 (*Ofiyolitler, mavisistler ve kenet kusaklari*)

METU Convention and Cultural Centre, Salon B

42-1 09:30 Dilek, Yildirim

GEOCHEMICAL AND TECTONIC FINGERPRINTING OF OPHIOLITES

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Ophiolites represent fragments of ancient oceanic lithosphere that were incorporated into continental margins during collisions, ridge-trench interactions, and/or subduction-accretionary events. They are generally found along suture zones in both collisional- and accretionary-type orogenic belts that mark major tectonic boundaries between collided plates or accreted terranes. The geological record of the Wilson cycle evolution of ancient ocean basins from rift-drift and seafloor spreading stages to subduction initiation and closure phases is commonly well preserved in most orogenic belts. Magmatism associated with each of these phases produces genetically-related, mafic-ultramafic to highly evolved rock assemblages, which occur in tectonic sheets. These units with varying internal structures, geochemical affinities and age spans become nested in collision zones, following the closure of ocean basins. Originally formed in different tectonic settings, tectonic slivers of oceanic remnants form discrete ophiolite complexes with significant diversity in their structural architecture, geochemical fingerprints, and emplacement mechanisms. These differences and regional tectonic constraints suggest that ophiolites form in a variety of geodynamic environments. We define here different ophiolite types based on their structural architecture, geochemical fingerprints, and tectonic evolutionary paths. Continental margin ophiolites form in small rift basins or embryonic oceans, have Hess-type oceanic crust pseudostratigraphy, and show N-MORB affinities; they may include exhumed subcontinental lithospheric mantle. Suprasubduction zone ophiolites (Mirdita, Oman, Troodos) form in extended arc-forearc to backarc settings, have Penrose-type architecture, and show MORB-IAT-boninitic geochemical progression of their magmas. These ophiolites signify oceanic crust generation during the closing stages of ocean basins and mark major subduction initiation events. Plume-type ophiolites form in plume-proximal ridges and oceanic plateaus, have thick plutonic and volcanic sequences, and show komatiitic, depleted (D-MORB), to enriched basalt (E-MORB) patterns. Mid-ocean ridge ophiolites form at plume-distal mid-ocean ridges or trench-distal backarc ridges, may have Penrose-type architecture, and show N-MORB, E-MORB, and/or C-MORB affinities. C-MORB ophiolites are crustally contaminated and may represent the products of ridge subduction or Andean-type backarc spreading in a continental-ensialic setting. Volcanic arc or Sierran-type ophiolites form in ensimatic arc settings, have polygenetic crustal architecture with multiply deformed, older oceanic basement and volcaniclastic cover (locally subaerial), and display calcalkaline affinities. This new classification of ophiolites helps to delineate the petrological lineage of mafic-ultramafic rock assemblages in Phanerozoic orogenic belts and Precambrian greenstone belts more effectively than the 1972 Penrose definition of an ophiolite. Fingerprinting ophiolites using their different lithological assemblages, chemical and isotopic compositions, internal structures, and regional geological characteristics is most useful to identify specific tectonic settings of ophiolite generation and to better document the processes through which these ancient oceanic rocks were incorporated into the continental margins.

42-2 09:50 Smith, Alan G.

TETHYAN OPHIOLITES, EMPLACEMENT MODELS AND ATLANTIC SPREADING

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The relative motions between Africa and stable Europe during Mesozoic and Cenozoic time are defined by the plate circuit Africa-North America-(Greenland)-Europe based on Atlantic ocean-floor spreading . Recent changes to the geological time-scale do not significantly alter the calculated motions.

The relative motion of Africa to stable Europe is remarkably simple and at the same time rather puzzling. In the first phase, from about 175 Ma (~Bajocian) to about 140 Ma (earliest Valanginian) Afro-Arabia slides approximately SSE past western Europe. The rate obviously varies from place to place, but in the Mediterranean region it is about 40-50 mm yr^{-1}. In phase two from ~140 Ma to ~125 Ma, from earliest Valanginian to the Barremian/Albian boundary, the motion slows to less than 5 mm yr^{-1}. It then speeds up again in phase three to about 20 mm yr^{-1}, ending in the Campanian at ~75 Ma. Phase four is another slow interval of about 4 mm yr^{-1}, from ~75 Ma to ~55 Ma, or Campanian to earliest Eocene. The final phase is at about 15 mm yr^{-1}, slowing to less than 10 mm yr^{-1} in the last 20 m.y. The motion changes direction abruptly by more than 60º from phase two to phase three, and by more than 40º from phase three to phase five.

The emplacement phase of the mid-Jurassic ophiolites of Greece and former Yugoslavia onto adjacent passive continental margins ended in latest Jurassic to early Cretaceous time. It coincided with the slow-down of phase two in the relative motion between Africa and Eurasia. The similar slow-down of phase four coincided broadly with the end of the emplacement of the late Cretaceous ophiolites in Cyprus, Syria, Turkey and Oman. There are no other major changes in the relative motions between Africa and Europe in the interval 180-0 Ma. Both sets of ophiolites have a trace element signature that indicates formation above a subduction zone, i.e. they are supra-subduction zone (SSZ) ophiolites.

The slow phases of relative motion and the timing of ophiolite emplacement can be understood in terms of the simple "roll-back" model, modified here, developed by the Open University to account for the emplacement of the Oman ophiolite and its SSZ chemistry. Ophiolite emplacement onto an adjacent continent can be regarded as the attempted subduction of a continental margin at a plate boundary, which must eventually cease. Given that the plate boundary concerned is probably the major plate boundary between Africa and Europe, it follows that the motions between Africa and Europe will, as inferred, slow down and eventually stop until a new margin is created elsewhere. The time taken for subduction that has been terminated at one location to start up at another location is estimated at about 15-20 m.y. Once a new margin between Africa and Europe has been established the rates of relative motion return to higher values. Thus the emplacement of the SSZ ophiolites seems to have influenced the spreading pattern in the Atlantic Ocean.

42-3 10:10 Gregory, Robert T.

OMAN BEFORE THE POST-MIOCENE OMAN MOUNTAINS: OPHIOLITE OBDUCTION RESULTING FROM PLATE BOUNDARY REORGANIZATION

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Structural windows into the Oman Mountains constrain the Late Cretaceous destruction of the passive Arabian margin culminating with the emplacement of the Samail Ophiolite Complex over the telescoped Arabian continental shelf, continental slope and abyssal plain of the Hawasina Ocean. The Hawasina window provided the first evidence of the involvement of the stable platform with fold nappe development, e.g. Sumeini Group (parautothochtonous shelf carbonates) The Saih Hatat window exposes a large (100 km scale) recumbent nappe that is pinned to the undeformed, stable Arabian platform. Strain in the nappe increases into a rolling hinge zone that becomes the highly-strained, generally overturned, carpholite-bearing lower limb that is truncated by a Campanian shear zone that dips towards the craton. The shear zone separates Arabian platform rocks from a lower plate consisting of three subdomains which include the lawsonite-bearing Ruwi schist, the blueschist to greenschist of Hul'w window, and the As Sifah window containing glaucophane-bearing eclogite in a section of quartz-phengite schist, mafic schist with metatuff (early Permian), calcschist and marble. An Albian, east-trending lineation in the As Sifah subplate (that roughly parallels the spreading direction of the younger Samail ophiolite lower pillow lavas) marks this early Cretaceous peak of metamorphism and predates both the Cenomanian igneous age of the Samail Ophiolite and its allochthony (age of the metamorphic sole). The lower-plate exhumation lineation (Turonian) parallels the inferred emplacement direction of the Samail ophiolite and is roughly parallel to the spreading direction of feeder dykes of the Cenomanian upper pillow lavas of the Samail ophiolite (suprasubduction or intraoceanic overthrust phase). The proto-Oman Mountains record a major plate boundary reorganization event that occurred on the northeastern edge of the Arabian plate; the event predates both the early Tertiary initiation of northward subduction now represented by the Makran of Iran and the post-Miocene uplift of the Oman Mountains.

42-4 10:50 Ishiwatari, Akira

GEOTECTONIC IMPORTANCE OF VERY FERTILE LHERZOLITE AMONG THE CIRCUM-PACIFIC OPHIOLITES WITH SPECIAL REFERENCE TO THE L-TYPE UST'-BELAYA OPHIOLITE IN NE RUSSIA

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Recent geological-geochemical works of Dilek and Furnes (2009; Lithos, 113, 1-20) and Pearce and Robinson (2010; Gondwana Res., 18, 60-) convincingly demonstrate that the harzburgite(H)-type Tethyan ophiolites (Troodos, Oman, etc.) formed through subduction initiation and slab roll-back stages in the supra-subduction zone spreading settings analogous to those of the current Western Pacific marginal basins. Nearly forty years after the Troodos debate provoked by Miyashiro (1973; EPSL, 19, 218-), the marginal-basin origin of typical Tethyan ophiolites is likely to become a new consensus.

However, another distinct type of ophiolite is present in the West Mediterranean area; the lherzolite(L)-type Alpine-Ligurian ophiolite (Ishiwatari, 1985; EPSL, 76, 93-), which represents fragments of narrow oceanic lithosphere formed between the rifted continents. Its mantle section bears some very fertile lherzolite of subcontinental origin.

The Western Pacific marginal basins have long been thought as an analogue of the Mesozoic terrane accretion (including ophiolites) of North American Cordillera (e.g. Silver & Smith, 1983; Geology, 11, 198-), and analogous view may be applicable to other circum-Pacific areas such as Northeast Russia and Japan. Indeed, most circum-Pacific ophiolites are H-type of supra-subduction zone origin, but there are a few exceptions such as the Southwest Oregon peridotite, USA (Medaris, 1972; GSA Bull., 83, 41-) and Isabela ophiolite, Philippines (Andal et al. 2005; Isl. Arc, 14, 272-), that bear extremely fertile lherzolite containing Cpx with >1.5 wt.% Na_2O and highly aluminous spinel, resembling those of subcontinental lherzolite.

Our Japanese-Russian joint research has revealed that the Ust'-Belaya ophiolite (Devonian or older) in NE Russia with a huge lherzolitic mantle section (Sokolov et al. 2003; GSL Spec. Publ., 218, 619-) with troctolitic cumulate is associated with extremely fertile lherzolite. Although the ophiolite resides on an accretionary complex of oceanic origin, the presence of the Pekulney garnet metagabbro-ultramafic complex 50 km to the east (Ishiwatari et al. 2007; Isl. Arc, 16, 1-) proves the presence of thick crust. Pervasive occurrence of low-grade metamorphic minerals in the lherzolite and occasional occurrence of glaucophane schist in the ophiolite suggest later hydration and metamorphism above a subduction zone, but the occurrence of extremely fertile lherzolite suggests continental rift-zone affinity of this ophiolite.

We stress the importance of the L-type ophiolites with extremely fertile lherzolite as they suggest that the circum-Pacific ophiolites formed not only through subduction initiation of the pre-existing oceanic lithosphere but also through continental (margin) rifting as in the case of the West Mediterranean ophiolites. Early Miocene opening of the Japan Sea basin provides an example of continental margin rifting in the Western Pacific area. The continental fragments rifted in the Paleozoic and Mesozoic time may have mostly been lost by transcurrent movement or subduction.

42-5 11:10 Anma, Ryo

RECOGNITION CRITERIA OF OPHIOLITES FORMED DUE TO RIDGE COLLISION/ SUBDUCTION

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A mid-oceanic ridge system subducts underneath South American plate at latitude 46°S off Chilean coast, forming a ridge-trench-trench type triple junction. At ~ 6 Ma, a short segment of the Chile ridge system subducted in south of the present triple junction. This ridge subduction event resulted in emplacement of a young ophiolite (5. 6 to 5. 2 Ma) and contemporaneous granite intrusions (5.7 to 4.9 Ma) and rapid crustal uplift (partly emerged after 4.9 Ma). This ophiolite, namely the Taitao ophiolite, provides criteria for the recognition of ridge collision/ subduction-related ophiolites.

A ridge collision/subduction-related ophiolite has a short-life. In case of the Taitao ophiolite, two dating methods, U-Pb (date of mineral crystallization) and FT (cooling age at 200 °C) methods on zircons yielded the same age. High-temperature deformation structures were developed in plutonic section during the emplacement and superimposed on the structures related to the ridge processes. Such superimposed high-T deformations may result in complicated magnetic structures and demagnetization paths. A ridge collision/subduction-related ophiolite may exhibit a polarity of magmatism (change in age or geochemical signature toward one direction) reflecting obliquity between the subducting ridge and trench axis. In case of the Taitao ophiolite, centre of magmatism migrated from south to north with compositional changes from N-MORB to E-MORB. The width of the ophiolite is likely narrow, because deformations must be concentrated along hot, weak region near the ridge centre. The ridge collision/subduction related ophiolite may lack in the metamorphic sole.

A ridge subduction may accompany contemporaneous granite intrusions with various compositions. Our data indicates that the granitic melts started forming near the conjunction of the subducting ridge and transform fault. Generation of granitic melts continued as the spreading center of the same segment subducted, due to partial melting of the oceanic crust and subducted sediments. Eduction of fluids and melts from the subducting slab at shallow depth may result in the lack of the volcanic activities along the volcanic front, as exemplified as the volcanic gap in Chile.

42-6 11:30 Robinson, Paul T.

UHP MINERALS AND CRUST-MANTLE RECYCLING: EVIDENCE FROM OPHIOLITES

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Podiform chromitites and peridotites of numerous ophiolites, including the Luobusa and Donqiao bodies in Tibet, the Semail ophiolite of Oman and the Ray-iz ophiolite of Russia, contain various combinations of UHP and other deep mantle minerals, such as diamond, coesite, moissanite, base-metal and PGE alloys and native elements. These are associated with a range of crustal minerals, including zircon, quartz, corundum, kyanite, sillimanite, feldspar, almandine garnet and rutile. Diamonds have been recovered from all ophiolites except Semail and they mostly consist of euhedral grains about 200 µm in size with several different morphologies. Coesite from the Luobusa ophiolite is intergrown with kyanite on the rim of an Fe-Ti alloy grain, and moissanite occurs as euhedral, hexagonal crystals or broken fragments of such crystals in all four ophiolites. The moissanite is characterized by having exceedingly low C isotopic values (mean $\delta^{13}C$ = -28). Most of the crustal minerals occur as subrounded to subangular grains, about 50-300 microns across, but some are blocky to subangular. The zircons typically have very complex internal structures although a few euhedral to subhedral grains have concentric zoning, suggesting an igneous origin. $^{206}Pb/^{208}U$ SIMS dates for the Luobusa zircons range from 549±19 to 1657±48 Ma, those from Donqiao from 484±49 to 2515± Ma, all much older than the ophiolites. Most zircons from Oman have similar ages to those from Tibet but 4 grains are essentially the same age as the ophiolite. The association of deep mantle and crustal minerals suggests subduction of crustal material to depths of 150-400 km where it was mixed with mantle material and subsequently incorporated into podiform chromitites and mantle peridotites. Based on the occurrence of these minerals in widely separated ophiolites of variable age, we suggest that diamonds and associated minerals are widely preserved in the upper mantle.

42-7 11:50 Green, Harry W.

RECORD OF DEEP UPWELLING IN OPHIOLITES: HIGHLY REDUCED ENVIRONMENT CONTAINING VERY HIGH PRESSURE PHASES AND NITRIDES FROM AT LEAST 300 KM DEPTH

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It is well known that ophiolites are rocks recording fossil oceanic spreading centers; the specific oceanic environment may be a point of controversy but since the birth of plate tectonics, they have been recognized as the locus of formation of oceanic lithosphere. My colleagues and I have recently established that at least some ophiolites contain vestiges of a highly-reduced deep mantle environment characterized by the presence of native metals, diamonds, silicon carbide and very high-pressure minerals. This environment is not associated with subduction of the ophiolite but is a primary feature of the ophiolite mantle. Specifically, the environment is encased in massive chromite where it has been protected from the low-pressure, oxidized, upper mantle environment. Here, I will discuss in some detail this environment from the Luobusa ophiolite from the Inda/Asia suture in Tibet.

The Luobusa sample described here, although small, establishes beyond a doubt that this environment exists at depths of more than 300 km, perhaps much more (Yang et al., *Geology*, 2007; Dobrzhinetskaya et al., *PNAS*, 2009). The rock consists almost completely of coesite, kyanite, and an unknown amorphous phase, with interstitial and included TiN and the cubic form of BN. The coesite is pseudomorphic after stishovite, the high-pressure polymorph of SiO_2 that is not stable at pressures less then 10 GPa at mantle temperatures (~1300¢ªC). TiN, osbornite, has only one previously described terrestrial occurrence but is abundant in meteorites, especially iron meteorites; this is the first recorded natural occurrence of boron nitride. The material also contains many native metals, including native Fe, and also SiC and the high-pressure polymorph of TiO_2 that has been described twice previously from UHPM rocks but does not yet have a mineralogical name. The presence of this phase confirms a minimum pressure of ~10 GPa at 1300¢ªC implied by stishovite pseudomorphs.

Despite the abundant evidence of highly-reducing conditions, the massive chromites show high ratios of Fe^{3+}/Fe_{total}. (Ruskov et al., *J. Met. Geol*., 2010). Thus, these rocks appear to be the first natural example of pressure-induced disproportion of Fe^{2+} into Fe^{3+} plus Fe^0 observed in very-high-pressure experiments. The origin of this material is problematic. The high concentration of SiO_2 and Al_2O_3 suggests that this material is perhaps recycled crustal material from the surface. However, nitrogen isotopes are incompatible with such an origin. At minimum, these observations require that the massive chromites carrying the high-pressure signal have their origin at very high pressure, perhaps in the lower mantle. In addition, they require that the surrounding harzburgites must have been solid during upwelling in order to transport the much more dense chromites. Thus, the interpretation of the mantle section of ophiolites needs to be revisited. These rocks are much more than the partial-melting residue of the overlying oceanic crust. It is also critical to realize that the Luobusa chromites are not unique. My colleague, J. Yang, has determined that another ophiolite, from the polar Urals, also contains diamonds, native metals, and SiC. Thus, rather than being a unique curiosity, this mineral assemblage characterizes a subset of ophiolites, the extent of which is not yet known. Thus, this rock and others yet to be describe provide a new window into the deep mantle; only future work will be able to discern how deep; what we see requires a minimum of 300 km but there is not hard upper bound on the depth.

42-8 12:10 Spalla, Maria Iole

LAWSONITE-BEARING ASSEMBLAGES IN CONTINENTAL CRUST: WHICH TECTONIC MECHANISM MAY PRODUCE SUCH A COLD CONTINENTAL SUBDUCTION?

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Structural and metamorphic settings of the lithosphere along active margins can be reorganized by subduction to generate a crust-mantle mixing that may be preserved in the axial part of orogenic belts after continental collision. This mega-mélange of nappes and tectono-metamorphic units (TMUs), proper of suture zones, is allowed by tectonic erosion and ablative subduction, which prior to collision may drag continental crustal materials to great depths, where HP-LT or UHP-LT metamorphic transformations are accomplished. Where the tectonic system implies ocean subduction underneath a continental plate, the wedge dynamics drives the exhumation of buried continental units, successively involved in continental collision (e.g.: Cloos, 1982; 1984; 1985; Platt, 1986; Polino et al., 1990; Ernst, 2001; Gerya & Stoeckhert, 2006; Roda et al., 2010). In the Western Alps, HP-LT metamorphism widely affects not only units derived from the Tethyan ocean, but also large volumes of pre-Alpine continental crust, as is the case of the Sesia-Lanzo Zone (SLZ). This portion of Adriatic crust is the largest continental slice with the early-Alpine eclogite-facies imprint and is also one of the rare examples of continental lawsonite-assemblages. Structural and metamorphic evolution of Lws-rocks of SLZ nappe is investigated to unravel coupling and decoupling mechanisms active during continental crust subduction in such a depressed thermal regime by defining number, size and shape of tectono-metamorphic units (TMUs). Three Lws-occurrences are studied: two are located in the southern part of the SLZ (Mt Soglio and Mt Croass), in different formerly defined complexes (the Eclogitic Micaschists C. (EMC) and the Rocca Canavese Thrust Sheet (RCTS)); the third is central to SLZ (Ivozio) and belongs to the EMC. The Ivozio complex consists of metabasics where, during the last stages of the prograde tectono-metamorphic evolution, Lws overgrew the prograde foliation (S1) marked by SPO of Amp, Zo, Grt and Omp. It was in turn, replaced by Ky and Zo and successively by Pg-aggregates. The first replacement occurred at the Lws HP break-down, at the end of the prograde path; the second developed at lower P, during the retrograde path, accomplished at slightly higher T. The inferred P-T-d-t path shows that the prograde Lws assemblage developed at P ≥ 1.8 GPa and T ≤ 600°C (Zucali et alii, 2004; Zucali & Spalla, subm.). In Mt Soglio EMC eclogitic boudins preserve a pervasive foliation marked by eclogite facies minerals SPO (Omp, Ep, Rt, Qz ± Grt). A blueschist facies foliation (S2) wraps the boudins and is marked by SPO of Gl, Czo, Qz, ± Grt, Ttn, ± Wm, ± Lws in metabasics and by SPO of Wm, Gl, ± Cld, Qz, Grt, Ttn ± Lws in micaschists. Lws is replaced by a fine-grained aggregate of Ep, ± Ab, Chl, ± Pg. The Lws-assemblages developed during the exhumation path at P ≤ 1.6 GPa and T ≤ 450°C (Pognante 1989; Spalla & Zulbati, 2003). At Mt Croass a complex of metasediments, characterized by a pre-Alpine dominant metamorphic imprint under granulite facies conditions, comprises silicate marbles that are characterized by the occurrence of Lws + Pmp marking the earlier Alpine fabric. The early Alpine foliation is marked by Cld, Gl, ± Ky and Wm in the metasediments, indicating blueschist facies peak conditions. In metabasic layers the Alpine foliation is marked by colorless Amp, Czo, Wm and Ttn. This TMU is bounded by ten meter-thick discontinuous mylonitic horizons, in which the mylonitic foliation is marked by colorless Amp, Chl, Ep, Qz and Ttn. These mylonites separate Mt Croass TMU from the surrounding gneisses and micaschists of the SLZ that recorded the earlier Alpine eclogitic imprint. The parageneses associated with this structural evolution are similar to those described in the RCTS (Pognante 1989; Spalla and Zulbati, 2003), where the metamorphic climax occurred at P ≥ 1.0 GPa and T = 300-400°C and followed by a P-decrease at constant T (Pognante 1989); therefore the same PT evolution is proposed for Mt Croass.

In summary Lws may be prograde or retrograde, or mark peak-conditions in SLZ, indicating that contrasted tectonic trajectories can characterize not only different volumes of a single Alpine nappe (SLZ) but also portions of the same metamorphic complex (EMC). These results indicate that the multiscale structural analysis supported by petrologic investigations is the tool to individuate corresponding TMUs within different formerly defined metamorphic complexes (Spalla et alii, 2010).

The inferred PT burial and exhumation trajectories of these different TMUs in the SLZ, even if contrasted, are all accomplished under a depressed thermal regime. To verify if such high P/T ratios, recorded in the continental lithosphere, result from tectonic erosion, ablative subduction and exhumation supported by the recycling in the mantle wedge, the oceanic subduction beneath a continent has been simulated by a 2D numerical model, considering hydration in the mantle wedge. Comparison between model predictions and natural data show that the simulated geodynamic scenario generates a thermal regime coherent with that affecting the SLZ, which may have been long time stable during Alpine subduction, allowing rocks to accomplish their burial and exhumation path under an active subduction regime.

Please see corrected version of Session 43 on page 4.

SESSION NO. 43, 09:30

Friday, 8 October 2010

Sedimentary basin evolution and oil fields in the Middle & Near East (Sponsored by the Turkish Association of Petroleum Geologists) (*Orta ve Yakin Dogu'da sedimanter havza gelismeleri ve petrol olanaklari*)

METU Convention and Cultural Centre, Salon C

43-1 09:30 Rock, Greg

EXPLORING UNDER THE OPHIOLITE

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The oil province of the SE Turkey Basin is widely viewed as a mature area for exploration activities, with many of the more significant discoveries (e.g. Beykan, Kurkan, Raman, Garzan) being made more than 30 years ago. Since acquiring Shell's assets in 1996, Perenco have managed to maintain a steady production of ca. 12,000bopd in the area whilst devising an exploration strategy to replace and replenish these fields once decline sets in. In 2006 a regional play fairway analysis was conducted incorporating all available well, seismic and published data which resulted in the identification of four themes deemed as having the potential to deliver moderate to company impact exploration opportunities. One of these themes detailed the possible northerly extension of the Cretaceous, Devonian and Ordovician plays away from the WSW – ENE trending proven oil field area (Beykan – Katin) into the more internal parts of the Taurus fold and thrust belt that developed due to the closure and over-thrusting on the southern Tethyan margin. Offset wells on trend to the south west and east of this area of interest suggest the potential for a thick pre-Tertiary sequence, sampling the Cretaceous Mardin Group, and in specific areas the unconformably underlying Devonian Hazro and Ordovician Bedinan Formations. Oil and gas shows are common throughout the sequence. The world-class Silurian Dadas Shale source rock is thought to be present and oil seepages in the area indicate the presence of a working petroleum system. In 2008 Perenco were awarded the 'Dicle' (4474) license 100% and have subsequently been awarded (June 2010) the 'Dicle East' licenses in a partnership with TPAO. Exploration studies to date have included geological fieldwork, structural, sedimentological and geochemical modelling, along with reconnaissance 2D seismic acquisition. The focus of this paper will be the exploration potential of the Dicle License area. In Dicle, surface geological outcrops are dominated by broadly east-west trending 4-way dip closed surface anticlines. These features are well defined by outcropping Eocene-aged Midyat limestones and dolomites, which where buried under an appropriate thickness of overburden, can form excellent reservoirs (e.g. Selmo field). Further north and to the south-west (e.g. Abdulazziz Anticline) erosion into these features reveals the presence of a thick ophiolitic group comprising the Hezan (Jurassic-Triassic aged carbonates) and Karadut (indeterminate aged melange of mudstones and fine-grained clastics) Formations. From close offset well data these ophiolitic units are seen to be part of an allochthonous nappe encompassed by the Maastrichtian-aged Kastel Formation (mudstones, siltstones and marls), which conformably overlie the Campanian Sayindere and Karabogaz Formations underneath which the Mardin Group is found. By projecting 40km northwards from the well explored oil field area we expect the Silurian Dadas shale and the Devonian Hazro sandstones and carbonates to subcrop the base Cretaceous unconformity from west to east. A series of structural cross sections honouring both field geological measurements and the recently acquired 2D seismic are presented which suggest sub-surface traps bearing carbonate and clastic reservoirs from the Cretaceous, Devonian and Ordovician. Burial history and 1D geochemical modelling also presented here indicates that the primary source rock interval, the Silurian Dadas Shale has potentially generated significant quantities of both oil and gas in the area. In 2011 Perenco intend to drill exploration wells in both Dicle and Dicle East to test the source, reservoir and seal play elements below the ophiolitic allochthonous nappe.

43-2 09:50 Perinçek, Dogan

SEDIMENTATION ON THE ARABIAN SHELF HAS BEEN UNDER THE CONTROL OF TECTONIC ACTIVITIES ALONG THE ZAGROS–TAURIDE THRUST BELT FROM THE CRETACEOUS TO THE PRESENT

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Turkey is located on seismically active Alpine-Himalayan Orogenic Belt. The recent tectonics of Anatolia is resulted from the plate-wise developed tectonic deformation. The Bitlis-Zagros thrust belt formed as the southern branch of the Neotethyan Ocean closed as a result of the N-S and NE-SW convergence and collision between the Arabian-African and Eurasian plates. Structures of the neotectonic period in the region are the products of intra-plate tectonic processes that occurred after this collision. Throughout Anatolia a peneplain morphology became dominant with the beginning of this neotectonic era related to the crustal shortening developed under the compressional tectonic regime. The Southeast Anatolian Thrust, which is located along the southern front of the Bitlis Suture Zone, is one of the mega-tectonic structures that has shaped the neotectonic structure of Anatolia together with the North and East Anatolian Faults.

Tectonic events: Southeast Anatolia which forms the northern margin of the Arabian plate has experienced three significant compressional phases during the paleotectonic period between the Early Cretaceous and Middle Miocene. These compressional regimes prevailed during: 1st Late Cretaceous, 2nd-Early Eocene, probably Late Paleocene, and 3rd Post-Middle Eocene, probably during the Late Eocene. On the other hand, the neotectonic period, mainly a contractional regime, which marks the 4th event, began during the Middle Miocene and continues in Present time.

The first paleotectonic period was experienced during the Late Cretaceous and was resulted in thrusting of the allochthonous units including the oceanic material of the northerly-located Tethyan Ocean. The allochthonous units emplaced onto the Arabian plate in this period filled the Campanian basin located along the northern margin of the continent. After filling of the Campanian basin with allochthonous units, transgression from south to north begins on the Arabian plate during the Maastrichtian and a significant part of the outcrop area of the allochthonous units was covered by continental (pebblestone-sandstone-mudstone) and marine (limestone-marl-sandstone) units as part of the transgressive series.

By the end of the Paleocene, a new tectonic period, which affected the northeastern margin of the Arabian continent, caused folding, uplifting and erosion in the north and east of Southeast Anatolia. After this folding and erosion stage, with an early Eocene transgression, a significant part of Southeast Anatolia fell under the marine environment conditions again.

During the early-middle Eocene, transgression reached to its maximum boundaries in Southeast Anatolia and the region was totally inundated. In this period, in the northerly-located fault controlled basin whose basement consisted of the Bitlis Metamorphic units and the Guleman Group the Maden Complex was formed. By the end of the Eocene, the northern margin of the Arabian continent was strongly affected by N-S compression, the Maden Basin was closed, and the Maden Complex together with the underlying metamorphic and ophiolitic rocks in large nappe systems were thrust towards to the south. These tectonic events have shown their effects on the Arabian Continent and during the late Eocene, a regional regression began on the Southeast Anatolian platform. On the late Eocene-Oligocene facies maps of southeast Anatolia signs of this tectonic event and the consequent regression can be seen clearly.

The late Miocene is the period in which tectonism was the most effective in Southeast Anatolia. In this period, the amplitude of the thrust faults formed in the region was larger than those formed previously. The N-S stress regime in the Miocene resulted in E-W striking structural axes in the region.

The compressional forces affecting Southeast Anatolia in the late Miocene caused first the formation of low-angle thrusts and then strike slip faults. Except for the East Anatolian Fault, which extends sub-parallel to the suture zone, other faults affected directly the autochthonous platform of the Arabian Continent. These faults are related to intra-plate deformation and differ from the East Anatolian Fault Zone. Each tectonic event created its own structural style and petroleum trap system.

43-3 10:10 Bozdogan, Nihat

PALEOZOIC SEDIMENTARY BASIN EVOLUTION AND OIL FIELDS, SE ANATOLIA, TURKEY

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The aim of this presentation is to understand the paleogeographic evolution of Paleozoic sedimentary successions of the Southeastern Anatolian region in Turkey. In order to understand the development of the sedimentary basin of the region, well data, field observations and sedimentary features of the neighboring countries were evaluated. The SE Anatolian region is a geological continuation of the Arabian plate to the north. We have examined the development of the Mardin-Kahta uplift and time-environmental relations of Cretaceous and older sedimentary depositions in this region. We have used detailed biostratigraphical data, obtained from the wells and stratigraphic sections, of the Cambrian and Ordovician age depositions to constrain the age of the Mardin-Kahta uplift. We also have investigated various geologic sections in the stratigraphic–time tables and distribution maps to detect the possible effects of the Mardin uplift on the platform.

Deposition in the Southeastern Anatolian region was continuous and uniform throughout the Cambrian, but there were paleogeographical differences and stratigraphical gaps from the beginning of these deposits. According to the relation of the Ordovician and Cambrian deposits in the region, the Mardin uplift was active from the early Ordovician onwards. The distribution of the Ordovician deposits in the region indicates the geometry of the uplift. This NW-SE-directed uplift divided the Southeastern Anatolian Platform into Diyarbakýr and Akçakale basins, and controlled all the deposition on the platform until Cretaceous time. The Mardin-Kahta uplift was covered by a late Ordovician Sea in the Mardin region and maintained its continental condition until the Cretaceous in the Kahta region, and Cretaceous sediments were deposited directly on the Precambrian units. The Akçakale basin, which is located in the west-southwest of the Mardin-Kahta uplift, contains Cambrian, Ordovician, Devonian and Triassic-Jurassic sedimentary sequences. Open marine conditions persisted in this basin throughout the early Ordovician-Cretaceous.

From the Devonian to the late Permian there was another active uplift near the Siirt area (Siirt-Nusaybin Line), which separated the Hakkari basin from the Diyarbakýr basin to the north. The Hakkari sub-basin is represented by the Cambrian, Ordovician, Late Devonian-LowerCarboniferous,cPermian and Triassic-Jurassic depositional successions. The Diyarbakýr basin, which is in the west-northwest part of the Mardin-Kahta uplift, was active from the early Ordovician to the Cretaceous and consisted of Cambrian, Ordovician, Silurian-Devonian, Permian and Triassic-Jurassic sedimentary successions. Sediments in the Diyarbakýr basin were the source-rock for Ordovician, Silurian and Upper Devonian-Lower Carboniferous deposits and reservoir-rock for the Ordovician and Devonian deposits.

All these tectonic units described from the Southeastern Anatolian Platform are the extension of the main tectonic features of the Paleozoic Widyan and Tabuk Basins in the Arabian Plate.

43-4 10:50 Erten, Tayfun

EVOLUTION OF MESOZOIC AND CENOZOIC SEDIMENTARY BASINS IN SE TURKEY

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Paleozoic sedimentary basins in southeastern Turkey are closely related to the geology of the coeval basins in the Arabian plate and can be considered as their extention to the north. By the Carboniferous, this contiunity was interrupted and several tectonic highs were developed separating the sedimentary basins in the northern part of the plate. Paleozoic and Mesozoic sedimentary sequences are also continuous in SE Turkey and in the northern part of the Arabian Plate. This continuity can be explained by the lack of any major tectonic event during the sedimentation of the late Permian-early Trassic successions. The Permian and Triassic sedimentary basin strata here are characteristic of typical foreland sequences on the passive margin of the Arabian Plate.

Triassic-Jurassic deposition occurred in similar foreland basins, which were undergoing contractional deformation, whereas the Cretacous sedimentary basins started their evolution by the Albian-Aptian in the upper plate of a north-dipping subduction zone as the oceanic crust of the Arabian plate was consumed beneath Anatolia. Widespread carbonate rocks were deposited in these extentional basins in SE Turkey, which were then overthurst to the south on the late Campanian-early Maastrichtien allohthonous units. Time gaps and disconformities within the carbonate sequences show that the entire area was still tectonically active during their deposition.

In the early Eocene, a new basin was formed following a continent-continent collision event in the region. A peripheral-type basin was active during rifting of the Red Sea in the early-mid Miocene. Final suturing of the Arabian plate to Eurasia (Anatolia) took place in the middle-late Miocene, as marked by the overthurst systems of the same age.

43-5 11:10 As-Saruri, Mustafa

PETROLEUM BASINS OF YEMEN: THEIR TECTONIC DEVELOPMENT AND LITHOSTRATIGRAPHY

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Located in the southwestern corner of the Arabian Peninsula, Yemen was the last country in the Middle East where oil was discovered (in 1984 by Hunt Oil). Following the unification of North Yemen and South Yemen in 1990, the country became an active scene for oil exploration and production. This paper describes the updated stratigraphy, structural framework and evolution, and hydrocarbon prospectivity of the Paleozoic, Mesozoic and Cenozoic basins of Yemen. The Paleozoic basins include (1) the Rub' Al-Khali basin (southern flanks), bounded to the south by the Hadramawt arch (oriented approximately W-E) towards which the Paleozoic and Mesozoic sediments pinch out; (2) the San'a basin, encompassing Paleozoic through Upper Jurassic sediments; and (3) the southern offshore Suqatra (island) basin filled with Permo-Triassic sediments correlatable with that of Karoo rift in Africa. The Mesozoic rift basins formed during the breakup of the Gondwana supercontinent and the separation of India/Madagascar from Africa-Arabia during the Late Jurassic/Early Cretaceous. The five Mesozoic sedimentary rift basins reflect in their orientation an inheritance from deep-seated, reactivated NW-SE trending Infracambrian Najd fault system. These basins formed sequentially from west to east and to southeast, sub-parallel with rift orientations. The Sab'atayn and Say'un-Masilah basins provide the only producing oil and gas fields so far. Petroleum reservoirs in both the basins have been charged from the Upper Jurassic Madbi shale. The main reservoirs in the Sab'atayn basin include sandstone units within the Sab'atayn Formation (Tithonian), turbiditic sandstones of the Lam Member (Tithonian), and the Proterozoic fractured basement (upthrown fault blocks), while the main reservoir in the Say'un-Masilah basin is the sandstone of the Qishn Clastics Member (Lower Cretaceous). The Cenozoic rift basins are related to the separation of Arabia from Africa by the opening of the Red Sea to the west and the Gulf of Aden to the south of Yemen during the Oligocene-Recent. These basins are filled with sedimentary successions up to 3 km, showing both lateral and vertical facies changes. The Cenozoic rift basins along the Gulf of Aden include the Mukalla-Sayhut, the Hawrah-Ahwar, and the Aden-Abyan basins (all trending ENE-WSW) and have both offshore and onshore sectors as extensional faulting and regional subsidence affected the southern margin of Yemen episodically. Sea-floor spreading in the Gulf of Aden dates back to the Late Miocene. Many of the offshore wells drilled in the Mukalla-Sayhut basin have encountered oil shows in the Cretaceous through Neogene layers. Sub-commercial discovery was identified in Sharmah-1 well in the fractured Middle Eocene limestone of the Habshiyah Formation. The Tihamah basin along the NNW-SSE trending Red Sea commenced in Late Oligocene, with oceanic crust formation in the Pliocene. The Late Miocene stratigraphy of the Red Sea offshore Yemen is dominated by salt deformation. Oil and gas seeps are found in the Tihamah basin including the As-Salif peninsula and the onshore Tihamah plain; and oil and gas shows encountered in several onshore and offshore wells indicate presence of proven source rocks in this basin.

43-6 11:30 Miroshnichenko, Inna

UNCONVENTIONAL OIL AND GAS TRAPS OF FERGANA VALLEY (UZBEKISTAN)

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The Fergana Valley is located in West – Central Asia near the western Chinese border, at the western end of the Southern Tian-Shan orogenic system. A central graben is bounded by high-angle reverse faults and the entire post-Paleozoic sedimentary section from the Jurassic through the Neogene is productive. It is generally believed that the Fergana basin's main source rocks are of Jurassic and Paleogene (Paleocene- Eocene-Oligocene) age. The basin's subsurface reservoir seals typically consist of shales. An overpressure condition appears to begin at depths of about 3 658 meters. Wells drilled below such depths are primarily in the central basin graben, which is filled with a thick molasse of Neogene and Quaternary clastic sediments. The valley floor slopes from an elevation of about 1 000 meters on the east to 320 meters on the west, where it is drained by the Syr-Dar'ya River. The valley is about 300 kilometers long and 175 kilometers wide; its area is about 38 000 square kilometers.

The Fergana intermontane basin formed during the Alpine orogeny as a result of horizontal compression and thrust Paleozoic formations at the Meso-Cenozoic rocks. In the on-board parts of the basin formed by powerful structure such as overthrust, which may be potential traps for petroleum accumulations.

The geological process involved three stratigraphic complexes. Lower represented strongly pressed Paleozoic formations. The second includes the Mesozoic-Paleogene sediments, which with the erosion and an angular unconformity lies on Paleozoic formations. The third complex consists of thick layer of Cenozoic molasses and the overlying Quaternary sediments.

It made a significant amount of geophysical work, such as refraction, seismic, gravimetric, magnetic, electrical and etc. We have reinterpreted seismic materials.

The results of reinterpretation were presented in a structural map of the reflecting boundary (P2) of Paleogene sediments.

Structural map of the surface of the Paleozoic basement is based on reinterpreting seismic materials conducted over the past 20 years.

Almost on all seismic profiles, crossing the zone of the North-Fergana deep fault, clearly indicates a tectonic failure zone with an amplitude of 1,0-1,5 km. In this zone northern blocks are thrusted to the southern and the magnitude of the horizontal displacement reaches 4-5 km.

The search area by the nature of tectonic structures and the depth of their occurrence are separated from north to south by three major tectonic blocks: I – the upper thrust block is bounded on the south by the North-Fergana fault, characterized by weak development of anticlinal structures (North Hanabad and North Chadak); II – subthrust block is located in the zone of the North-Fergana fault, the width of the block of 4-5 km. Here, the subthrust structures as Sarvak, Khanabad, Chadak, East Chadak and Yangi Charkesar, closed upper thrust block; III – near subthrust block includes a front Chustpap anticlinal and rear synclinal zone. Within this block are clearly distinguished anticlinal Chustpap and North Chustpap local structures.

Such a discordant structure of III block indicates that during post platform orogenesis (N2-Q), i.e. during the formation of modern structures, on the studied area passed a process of horizontal pressure from the Kuramin ridge. These tectonic movements such as drawing resulted in a crumpled layers in the system of folds, whose axes are shifted horizontally. Thus, in the formation of modern nappe-folded structures of the northern edge of the Fergana Basin took a part as collision, so postcollision processes.

Selected structural features of this zone of the northern edge of the Fergana depression can evaluate it as a prospective area for oil and gas production operations. On the basis of geodynamic model can expect the presence of the following types of oil and gas traps: anticlinal, hemianticlinal tectonically screened traps within the first block; zones of fracturing, or "pockets" of the Meso-Cenozoic productive horizons, covered with igneous formations of the Paleozoic, subthrust anticlinal structures, shielded folds, etc. – in the second tectonic block; in the third southern block most likely the presence of productive folds, whose axes are shifted horizontally. Located discordantly on top of each other, they form oil and gas traps, as in the Cretaceous-Paleogene, so in the Neogene sediments.

43-7 11:50 Zaigham, Nayyer Alam

DELINEATION OF NEW HORIZON FOR DISCOVERY OF HYDROCARBON POTENTIAL IN PAKISTAN

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During the last four decades, several tectonic models have been proposed by various researchers to explain the geologic setup and association of different minerals and hydrocarbon potential in the southwestern part of Pakistan comprising of Chagai Volcanic Arc, Kharan-Mashkhel-Panjgure Trough and the Makran Flysch Basin. In 1960's, several exploratory wells were drilled for the hydrocarbon exploration following the oil & gas discoveries in the neighboring country (Iran). The exploration activities were focus particularly in offshore areas along the coastal areas of Makran region. The exploratory wells encountered technical problems due to very high pressures within the upper strata and as such the exploration efforts were abandoned. Simultaneously, most of the researchers proposed an active subduction of the Arabian oceanic plate beneath the Afghanistan Craton (block of continental landmass) bounded on eastward by the left lateral north-south striking Chaman-Ornach-Nal transcurrent fault system originating from Hirat in Afghanistan to the Arabian Sea. Both the conditions, i.e., the failure of hydrocarbon exploratory drilling and the proposed models of subduction for the region, have diverted the attention from further hydrocarbon exploratory activities in the region till present decade. The results of present study reveal the conducive environments by delineating the new horizon, first time, for discoveries of new hydrocarbon potentials in the region. Based on present integrated geophysical analyses, it is identified that the exposed or near-surface geologic trends are camouflaging the deep-seated geologic trends those are entirely different in their tectonic style and other geologic characteristics. Considerably larger sedimentary basins have been identified in Kharan-Mashkhel-Panjgur region based on the satellite gravity anomalies. Moreover, the results of the fault-plane solutions indicate the rifting nature of these basins. It is inferred that these basins may be the excellent targets for the hydrocarbon discoveries in Pakistan. Present paper is extracted from the Ph.D. theses of principal author and one of co-authors.

43-8 12:10 Tong, Hengmao

A NEW MODEL FOR THE ORIGIN AND EVOLUTION OF THE RIFT BASIN FAULT-SYSTEMS IN THE EAST AND SOUTH CHINA –A CASE STUDY FROM BEIBUWAN BASIN

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Rift basins are rich in oil and gas resources (Tian, 1996; Wu, 1997). Especially in China, about two-thirds of total oil reserves and production came from the rift basins in the east and south China (Jin et al., 1998). There are dozens of Cenozoic rift basins, such as Bohai Bay basin, Southern Yellow Sea basin, East Sea Continental Shelf basin, Beibuwan basin, Qiongdongnan basin and so on, along the coast of south-east Asian continent (onshore and/or offshore). The existing models of fault-system origin and tectonic evolution, which mainly based on Anderson's faulting model and usually leaded to complicated tectonic evolution history, can not explain the phenomena of complicated fault system very well and were controversy with each other. On the basis of 3D seismic data interpretation, balanced evolution section reconstruction and sandbox modeling on Beibuwan basin, meanwhile, considering the basement pre-existing fabrics and applying the Activation Criterion of pre-existing fabric (Tong et al, 2010), a new model of two phases extension superposition (SE-NW direction extension before 40Ma and N-S direction extension after 40Ma) is proposed for the fault-system origin and evolution in Beibuwan basin in the paper. The model shows that the pre-existing fabrics, the superposition of two phases extension and progressive extension leaded to the complicated fault system in Beibuwan basin. Using this model, the complicated fault system in Beibuwan basin can be reasonably understood and interpreted. It played an important role in oil exploration afterwards. The model can also be used to reasonably explain the origin and evolution of basin fault-system in the east and south China. This model may provide a new insight into the tectonic evolution history in the east Asia.

SESSION NO. 44, 09:30

Friday, 8 October 2010

Subduction, collision and orogeny. Part 3 (*Yitim zonu jeodinamigi, çarpisma tektonigi ve orojenez*)

METU Convention and Cultural Centre, Salon A

44-1 09:30 Doglioni, Carlo

ASYMMETRIC SUBDUCTIONS IN AN ASYMMETRIC EARTH

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The subduction rate is $V_S=V_H-V_L$, where V_H and V_L are the velocities of the subduction hinge and the lower plate respectively with respect to the upper plate. The velocity between the upper and the lower plates (i.e., the convergence rate) is partitioned into the subduction rate and the shortening in the accretionary prism or orogen. In general, the convergence/shortening ratio along subduction zones is >1 along E- or NE-directed subduction zones, whereas it tends to be <1 along the W-directed subduction zones (Doglioni et al., 2007, ESR, 83, 125). Along E- or NE-directed subduction zones, the convergnce/shortening ration is higher during oceanic subduction (1.7-1.9), whereas it decreases during continental subduction (1.3-1.5). The difference between the W-directed and E- or NE-directed subduction zones fits with the net rotation of the lithosphere, i.e., the so-called W-ward drift. This rotation has the pole of rotation at about -56° Latitude and 137° Longitude, with an estimated angular velocity ω of 1.2°/Ma (Crespi et al., 2007, GJI, 168, 491). The "westerly" directed decoupling of the lithosphere relative to the underlying mantle can account for the asymmetry in the kinematic behavior and geometries between the opposite subduction zones and the first order tectonic differences among the related prisms. The main signatures are in order low structural and morphological elevation, shallow decollement (top lithosphere) and single verging prism, backarc basin, steep slab, and subduction rate faster than the convergence rate along the W-directed subduction zones. Along the opposite E- or NE-directed subduction zones, there rather are higher structural and morphologic elevation, shallower slab, deep decollements (whole crust and LID) and double verging orogen, and the subduction rate is slower than the convergence rate. Along the W-directed subduction zones the prism is mostly composed by lower plate rocks, whereas the orogen is dominantly composed by shortening of the upper plate during oceanic subduction, eventually involving thick sections of the lower plate during continental subduction (i.e., collision). A geographically sensitive asymmetric pattern has been suggested also for oceanic basins (Panza et al., 2010, Geology, 38, 59). All these asymmetries point for a global tuning of plate tectonics, i.e., a "westerly" directed force acting on the whole lithosphere generated by the tidal despinning of the Earth (Riguzzi et al., 2010, Tectonophysics, 484, 60).

44-2 09:50 Wang, Chi-yuen

EARTHQUAKES AND HEAT FLOW

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Heat flow is an important physical parameter for interpreting tectonic processes such as the frictional resistance to the relative motion between the lithospheric plates. However, large earthquakes can release a great amount of groundwater that may affect heat flow; thus it is important to understand how earthquake-released groundwater may affect heat flow in order to effectively use the latter to interpret plate-boundary processes. In this study we use temperature data from deep monitory wells in Taiwan before and after the 1999 M_w7.5 Chi-Chi earthquake to show that large earthquakes may significantly affect heat flow, not only shortly after the earthquakes but also throughout most of the inter-seismic period.

Following the Chi-Chi earthquake, most deep monitory wells in the alluvial fan beyond the thrust front showed an increase in groundwater temperature and geothermal gradient. On the other hand, most wells in the elevated terrains near the thrust front showed a decrease in groundwater temperature and geothermal gradient. Interpretation of these changes requires an understanding of the mechanism by which earthquake releases groundwater because the mechanism is closely related to the flow paths of the released groundwater and thus its effect on heat flow. Several hypotheses were proposed, including expulsion of deep crustal fluids due to the static elastic strain, consolidation or liquefaction of near-surface deposits, and changes in near-surface permeability, but none satisfied all the existing evidences. Wang et al. (2004) showed that large earthquakes may change the state of anisotropy of permeability of the hydraulic system near the epicenter of an earthquake and that this may explain all the relevant observations.

Taiwan is a mountain belt formed by the collision between the Philippine Sea plate and the Eurasian plate. The fold-and-thrust foothills are underlain by alternating sandstone and shale formations, with an effective layer-parallel permeability several orders of magnitude greater than that normal to the layers. Following the Chi-Chi earthquake, numerous subvertical tensile cracks appeared in the foothills, which breached the impervious beds in the sedimentary sequence and greatly enhanced the vertical permeability of the hydrological system, allowing downward draining of groundwater. Well data show that after the Chi-Chi earthquake the vertical hydraulic diffusivity increased to at least 3 m^2/s at depths exceeding 250 m. Many wells in the foothills above the thrust fault dropped in water level, and a tunnel beneath the foothills experienced sudden downpour right after the earthquake. The predicted time-dependent change in the earthquake-induced streamflow based on this model also agrees closely with observation. Finally, most monitory wells on the alluvial fan beyond the thrust front showed a rise in the groundwater level after the earthquake, indicating influxes of groundwater. Lowering of the groundwater level in mountainous terrain and increased streamflow were also reported after the 1989 Loma Prieta earthquake in California and the 1995 Kobe earthquake in Japan near the respective epicenters; thus the model of earthquake-enhanced vertical permeability may apply to different plate boundaries.

Observation shows that the post-seismic vertical permeability returns to the pre-seismic value within about 2 years. Thus the timescale for the post-seismic recovery of permeability is much shorter than the recurrence interval of large earthquakes. Between large earthquakes, the mountain slopes will again be recharged with groundwater, only to be released during the next large earthquake. The repeated downward draining of groundwater from the mountains during large earthquakes is effective in flushing the geothermal heat in the foothills and discharging it to the nearby lowlands – explaining the temperature data from deep wells in Taiwan after the Chi-Chi earthquake.

The post-seismic heat flow may slowly recover after the earthquake. The time required for this recovery depends on the thermal conductivity of rocks and the depth where a significant portion of the geothermal heat is flushed away. Using the well data in Taiwan for the vertical permeability and the depth of groundwater penetration after the Chi-Chi earthquake, we show that a significant portion of the geothermal heat in the Taiwan foothills may have been flushed down to a minimum depth of 100 m. Given a reasonable range of thermal diffusivity from 10^{-6} to 10^{-7} m^2/s for rocks and sediments, the characteristic time for the heat flow to recover to the pre-seismic level is from 300 to 3000 yr. Recalling that this characteristic time is comparable to, or longer than, the recurrent interval of large earthquakes, we conclude that large earthquakes in Taiwan may significantly alter the regional heat flow, not only shortly following the earthquakes but also throughout much of the inter-seismic interval. The latter conclusion is consistent with the existing heat flow data in Taiwan.

In other parts of the world, where large earthquakes are frequent, similar earthquake-induced changes of heat flow may occur. Thus it is important to account for the earthquake effect before using heat-flow data to interpret tectonic processes.

44-3 10:10 Beltrando, Marco

THE BACKBONE OF OROGENS: WHY A REALISTIC PALAEOGEOGRAPHY MATTERS

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The type of lithosphere reaching subduction zones has profound implications for the evolution of orogenic belts and for mass balance calculations in subduction zones. Numerical and conceptual models of subduction generally distinguish between only two types of lithosphere: (1) oceanic and (2) continental, with the latter consisting of subcontinental mantle and a 20-30 km thick crust, overlain by pre-, syn- and post- rift sediments. However, recent studies of present day rifted margins provided compelling evidence of the existence of a third type of transitional lithosphere between typical 'oceanic' and 'continental' lithosphere. Such domains, which can be up to 200 km wide, have been labeled Ocean-Continent Transition Zones (OCTZ). They are characterized by the presence of windows of exhumed mantle between slivers of hyper-extended and hydrated continental crust resting upon serpentinized mantle. Pre-rift sediments are present only rarely as extensional allochthons and syn- and post- rift sediments seal the extension-related lithostratigraphy.

Lithological associations compatible with distal continental margins as described above are frequently found in the high-pressure parts of Alpine orogens. However, the pervasive deformation that affected these heterogeneous units during plate convergence leads them to be often discarded as tectonic mélanges, where the juxtaposition of seemingly unrelated rocks is ascribed exclusively to the orogenic event. Our study indicates that several high pressure units of the Western Alps derive from OCTZ's, which were located along the margins of the Jurassic Tethys. These results have profound implications for understanding the dynamics of orogens and the processes of burial and exhumation of (U)HP rocks.

Here we present two examples from the Zermatt-Saas Zone, which is part of the Eclogitic Piemonte Units, and from the Sesia Zone. The Zermatt-Saas Zone consists of abundant serpentinized mantle, intruded by Jurassic gabbros and locally overlain by slivers of continental basement rocks and by syn- to post- rift sediments. Our study on zircons from Permian plutonic rocks of the Etirol-Levaz continental basement slice shows that a distinctive phase of zircon growth occurred at ca. 170-160 Ma. High U/Th ratios and zoning patterns suggest that zircons grew as a result of melt infiltration related to the intrusion of mafic magmas, also dated at ca. 170-160 Ma, in the underlying serpentinites. Therefore, the continental basement slices and the oceanic basement rocks were already juxtaposed in the Jurassic and they were probably part of an Ocean-Continent Transition Zone (OCTZ). Alpine tectonics resulted only in minor reworking of the Jurassic contacts, generally preserving the original geometry.

Differently from the Eclogitic Piemonte Units, the Sesia Zone (SZ), which underwent Alpine metamorphism in blueschist to eclogite facies conditions in the Cretaceous, consists largely of Palaeozoic continental basement and Jurassic/Cretaceous metasediments, while Jurassic serpentinites are rare. Evidence of pre-Alpine cataclasis along the serpentinite-continental basement contact is locally preserved. Palaeozoic basement and exhumed serpentinites are locally overlain by Mesozoic sediments, consisting of syn-rift meta-arkose, and post-rift Jurassic metachert and calcschist. Therefore, the different units of the Sesia Zone preserve a relationship between continental basement, exhumed peridotites and sedimentary cover typical of the distal part of extended continental margins and of OCTZ's.

The partial preservation on a regional scale of the rift-related relationships between rock units that underwent subduction to (U)HP conditions indicates that (1) the association of serpentinites and continental basement does not necessarily derive from chaotic counter-flow in a subduction channel, but may also be an inherited feature from the rifting history and (2) the process of tectonic burial and exhumation is not necessarily chaotic but large coherent blocks can behave relatively rigidly, while well-defined movement zones accommodate most of the deformation.

Furthermore, this study indicates that large gneissic terranes found in metamorphic belts may sample extensional allochthons derived from hyper-extended continental crust. Therefore, in those circumstances, gneissic terranes do not represent small slivers scraped off larger microplates of continental lithosphere that have gone into subduction. These results have important implications for the geochemical and geodynamic evolution of convergent plate margins, implying that large masses of continental crust are not necessarily recycled in the mantle during orogenesis.

44-4 10:50 Oh, Chang Whan

SYSTEMATIC CHANGES IN METAMORPHIC STYLES ALONG THE DABIE–HONGSEONG AND HIMALAYAN COLLISION BELTS, AND THEIR TECTONIC IMPLICATIONS

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The Gyeonggi massif located in the middle part of Korean Peninsula is one of the important basements in Korea. From the Hongseong area in the southwest Gyeonggi Massif, Triassic (ca. 230 Ma) eclogites were found indicating that the Dabie-Sulu collision belt between the Sino-Korean block (North China block) and South China block is extended into the Hongseong area in Korea. The eclogites formed at 16.5–20.0kb and 775–850°C and was overprinted by granulite facies metamorphism (at 11.0–15.6kb and 760–825°C). Late Permian (ca. 257 Ma) mangerites that intruded the Odesan area in the eastern part of the Gyeonggi Massif show geochemical characteristics of post-collision tectonic settings, implying that the Hongseong collision belt extends to the Odesan area. In the Odesan area, gneisses near mangerite intrusion underwent UHT metamorphism (9.0~10.6kb, 914-1157°C) at around 245 Ma. The Hongseong-Odesan collision belt in Korea may continue into the Paleozoic subduction complexes in the southwest Japan and further to the Yanji belt, a Carboniferous and Permian subduction complex along the northeastern boundary of the Sino-Korean block. These data indicate that Phanerozoic subduction along the margin of the Sino-Korean block and the collision between the Sino-Korean and South China blocks contributed to formation of the Dabie-Sulu-Hongseong-Odesan-Southwest Japan-Yanji belt (Dabie-Hongseong collision belt). The metamorphic ages of peak metamorphism along the belt decrease from east (late Permian in the Odesan area) to west (Triassic-early Jurassic in the Sulu and Dabie areas) suggesting that collision had started from Korea in late Permian and propagated towards east until early Jurassic due to the clockwise rotation of the South China block. P-T estimations along the Dabie-Hongseong collision belt reveal that geothermal gradient and first-stage retrograde metamorphic grade decrease from the collision starting area to the east, resulting UHT metamorphism in the Odesan area (collision starting area), HP metamorphism overprinted by granulite facies in the Hongseong area and UHP metamorphism overprinted by amphibolite facies (~8kb and 500–650°C) in the Dabie areas. In the Himalayan collision belt, opposite trend was recognized; the collision started from west (~ 55 Ma) and propagated towards east (~ 35 Ma) and the geothermal gradient and the retrograde metamorphic grade increase from the collision starting area to the west resulting UHP eclogite (22~24kb and 610–700°C) overprinted by amphibolite facies metamorphism (10~13kb and 610–580-600°C) in the western Himalaya and HP eclogite overprinted by granulite facies metamorphism (7~10kb and 750–790°C) in the eastern Himalaya. These differences are related to the distance between two blocks before collision and the time of delamination of oceanic slab. In the Dabie-Hongseong collision belt, the collision started from east where the distance between Sino-Korean and South China blocks was narrow and the amount of subducted oceanic slab was not enough to pull down continental crust to the UHP condition depth. The distance between the Sino-Korean and South China blocks before collision increased toward west, which increased the amount of subducted oceanic slab towards west. As a result, the largest amount of oceanic slab subducted in the Dabie and Sulu areas, causing enough pulling force which subducted the South China block to UHP condition depths. The main delamination of oceanic slab along the Dabie and Hongseong belt started after reaching of the continental crust in the Dabie area to UHP condition depth. The buoyancy force of subducted continental crust after delamination increases as the subduction depth increases, and stronger buoyancy causes faster uplift. As a result, the uplifting time span increased to the east causing longer thermal relaxation and higher geothermal gradients during the retrograde metamorphic stage towards east. While in the Himalayan collision belt, there was a wide ocean between the Asian and Indian blocks before collision and the amount of subducted oceanic slab was enough to pull down continental crust to the UHP condition in the west Himalaya where collision started. The process of oceanic slab break-off most likely occurred from ~ 44-48 Ma, Oceanic slab break-off likely coincided with exhumation of UHP terranes in the western Himalaya and led to the initiation of low angle subduction and S-type granite generation along the belt, particularly in the east. As a result, the UHP eclogite occurred only in the west and HP eclogite occurred in the east. Due to the difference of buoyancy, the UHP eclogite uplifted fast and HP eclogite uplifted relatively slow, which caused more thermal relaxation and higher geothermal gradient towards east. As a result, UHP eclogite in the western Himalaya was overprinted by amphibolite facies metamorphism and the eastern Himalaya eclogite by granulite facies metamorphism. The results of this study indicate that the systematic change of metamorphic conditions along collision belt can be used to interpret the tectonic process during collision.

44-5 11:10 Wang, Lu

STRUCTURAL GEOMETRY OF AN EXHUMED UHP TERRANE IN YANGKOU BAY, THE EASTERN SULU OROGEN, CHINA: IMPLICATIONS FOR CONTINENTAL COLLISIONAL PROCESSES

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High-precision 1:200-1:1,000 mapping of Yangkou Bay, eastern Sulu orogen, defines the structural geometry and history of one of the world's most significant UHP (ultrahigh-pressure) belts. At least four stages of folds are recognized in UHP eclogites and associated quartzo-feldspathic gneiss. UHP-eclogite facies rootless F_1 and isoclinal F_2 folds are preserved locally in coesite-eclogite. Mylonitic to ultramylonitic quartzo-feldpsthic and coesite-eclogite shear zones separate small-scale 5-10-meter-thick nappes of ultramafic-mafic UHP rocks from banded quartzo-feldspathic gneiss. These shear zones are folded, and progressively overprinted by amphibolite-greenschist facies shear zones. The prograde to retrograde D_1-D_5 deformation sequence is explained by deep subduction of offscraped thrust slices of lower continental or oceanic crust from the down-going plate, caught between the colliding North and South China cratons in the Mesozoic. After these slices were structurally isolated along the plate interface, they were rolled in the subduction channel during exhumation and structural juxtaposition with quartzo-feldspathic gneisses, forming several generations of folds, sequentially lower-grade foliations and lineations, and intruded by in situ and exotically derived melts. Shear zones formed during different deformation generations are wider with lower grades, suggesting that deep-crustal/upper mantle deformation operates more efficiently, perhaps with more active crystallographic slip systems, than deformation at mid-upper crustal levels.

44-6 11:30 Moazzen, Mohssen

SHANDERMAN ECLOGITES FROM NORTHERN IRAN, P-T PATH AND PALEOTETHYS GEODYNAMICS FROM SUBDUCTION TO EXHUMATION

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Shanderman eclogites and related metamorphosed ophiolitic rocks mark the site of closure of Paleotethys ocean in northern Iran. Eclogitic mafic rocks have experienced different stages of metamorphism during subduction and subsequent exhumation. Mineral formed during prograde stages are preserved as inclusions in peak metamorphic garnet and clinopyroxene. The rocks have experienced blueschist facies metamorphism on their prograde path. They are metamorphosed in the eclogite facies at the peak of metamorphism. The eclogites has simple paragenesis of omphacite, garnet (pyrope-rich), paragonite, zoisite, glaucophane and rutile. Based on textural relations, post peak stages can be divided into amphibolite and greenschist facies. Pressure and temperature estimations on eclogite facies minerals (peak of the metamorphism) revealed pressures of 15-20 (kbar) at a temperature of ~600 °C. Pre-peak blueschist facies yield pressures lower than 11 kbar and temperatures of 400-460°C. Average pressure and temperature of post-peak amphibolite and greenschist stages were 5-6 kbar, ~ 470 °C and 2-3 kbar and 273-320 °C, respectively. The estimated pressures and temperatures indicate a clockwise P-T path for the rocks. The peak pressure indicates that the eclogites formed by Paleotethys oceanic crust subduction to a depth lower than 75 km in northern Iran. The PT path indicates subduction of the Paleotethys oceanic crust, subsequent collision between the Central Iranian and the Turan blocks and eventually exhumation of the high-pressure rocks.

44-7 11:50 Toraman, Erkan

CHARACTERIZATION OF DEFORMATION MICROSTRUCTURES IN SUBDUCTION ZONE COMPLEXES AND IMPLICATIONS FOR EXHUMATION MECHANISMS

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Understanding the rheological behavior of subducted crust at depth is essential to elucidate the geochemical, geophysical and geodynamic evolution of convergent margins. To accomplish this, quantitative analysis of petrofabrics of high-pressure rocks can define deformation mechanisms of high-pressure textures and fabrics that were developed during subduction, exhumation and collision. The Sivrihisar Massif, west-central Turkey, exposes very well preserved blueschist and eclogite facies metasedimentary and metabasaltic rocks that represent exhumed remnants of a passive continental margin sequence of the Neo-Tethyan Ocean. In the NW part of the massif, coherent layers of marble are interlayered with quartzite, calc-schist, and blueschist containing centimeter to meter scale pods of lawsonite eclogite that record metamorphic conditions up to 24 kbar and ~550 ˚C.

In the southeast part of the Sivrihisar Massif, high-pressure low temperature (HP-LT) rocks were partially to completely overprinted by regional metamorphism at lower pressures and a range of temperature, from greenschist to amphibolite facies (sillimanite zone). In a N-S traverse across this part of the massif, blueschist facies assemblages are preserved at the northern end, but are progressively overprinted to the south. Lawsonite has been pseudomorphed by white mica and epidote, garnet in eclogite pods is partially to completely replaced by chlorite, and phengite is rimmed by muscovite. H*P* marble is characterized by rod-shape calcite crystals (aragonite pseudomorphs) with a very pronounced crystallographic orientation; the strength of the fabric diminishes towards the Barrovian sequence. Quartzite contains relict H*P* mineral compositions up to the staurolite-in isograd, but evidence for earlier H*P* conditions in marble is obliterated in the greenschist facies. Some kyanite and chloritoid in the Barrovian sequence may be inherited from the H*P* metamorphism, as indicated by the presence of kyanite before staurolite and the occurrence of chloritoid in HP quartzite that have not been overprinted.

Quartzite microstructure shows the preservation of a H*P* texture that was overprinted by Barrovian deformation and recrystallization. The H*P* texture consists of thoroughly recrystallized grains of quartz and phengite. Argon ages for phengite in quartzite and marble are 88-81 Ma. The Barrovian overprint took place under relatively high flow stress that produced fine recrystallized grain size (50 micron), with evidence of grain boundary migration recrystallization. Micas are recrystallized into very fine grains as well as layers in which bundles of grains display conjugate shear bands; argon ages vary but are typically 62-58 Ma for muscovite at the southern end of the terrain. EBSD pole figures from Barrovian quartzite across this traverse show pronounced constrictional strain girdles in the c-axis (wide-angle small circles about lineation) and a-axis (low angle small circles about lineation).

Relations at the regional to microstructural scales indicate that the Barrovian domain developed in transtension. 3D strain modeling shows that the metamorphic sequence was thinned, resulting in the collapse of isograds. Given the orientation of foliation and lineation, the shape of the finite strain ellipsoid determined from qualitative aspect ratio of tectonites, and the patterns of quartz microfabrics, the Barrovian terrain deformed in an E-W dextral with N-S extension transtension zone, likely during Early Cenozoic time.

44-8 12:10 Casale, Gabriele

EXHUMATION OF THE BOSNIAN SCHIST: IMPLICATIONS FOR DINARIC AND PANNONIAN TECTONICS

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Syn or post collisional extension is expressed in several Mediterranean orogens as mid-crustal rocks exhumed along low angle normal faults and has variously been attributed to slab rollback or break-off. The Dinarides are a late Cretaceous-presently active fold-and-thrust belt driven by the collision between the Adria microplate and Eurasia. The Mid-Bosnian Schist Mountains (MBSM) are a fault bounded body of lower greenschist facies metamorphic rocks in the hinterland of the active Dinaric fold-and-thrust belt. Existing geologic maps and cross sections indicate that the faults bounding the MBSM are thrust faults and interpret the emplacement of these mid-crustal rocks as a compressional event. However, field observations along the fault bounding the east side of the MBSM support a normal shear sense suggesting an extensional tectonic exhumation. New low temperature thermochronolgic dates along with published Ar/Ar dates reveal an Eocene-Oligocene episode of relatively rapid cooling synchronous with foreland shortening. We propose that the MBSM represent the tectonic inversion from shortening to extension in an active fold-and-thrust belt. The relatively short duration and geographically restricted extent of exhumation supports a slab break-off event rather than an ongoing and migrating process (roll-back) as the exhumational driving force.

Several important considerations remain regarding the implications of tectonic inversion in the Dinaric setting. First, exhumation occurred along the paleogeographic margin of a thick carbonate platform. Second, tomographic images across the Dinarides reveal an intact shallowly dipping slab, the entirety of which may have been subducted following break-off of a pre-existing slab. The questions arise: What is the role of upper crustal lithology on microplate interaction, and what drives subduction in the absence of a negatively buoyant slab?

SESSION NO. 45, 08:30

Friday, 8 October 2010

Modern accretionary wedges and ancient analogues. Posters (*Güncel ve fosil yigisma-prizmasi kamalarinin iç yapilari ve tektonik evrimleri*)

METU Convention and Cultural Centre, Exhibition Hall

45-1 BTH 1 Yamamoto, Yuzuru

FORMATION OF CHAOTIC ROCK-UNITS DURING PRIMARY ACCRETION PROCESSES: LIQUEFACTION AND MASS TRANSPORT DEPOSITS IN THE MIURA BOSO ACCRETIONARY PRISM, CENTRAL JAPAN

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Chaotic rock-units are characteristic components in accretionary complex and trench-slope basins in subduction zone. They preserve detailed tectonic information related to the periods before, during, and immediately after accretion. The Miura and Boso area, central Japan is composed of two accretionary complexes: the early to middle Miocene Hota accretionary complex and the upper Miocene Miura–Boso accretionary prism, and several trench-slope basins. They uplifted rapidly due to the Izu-Bonin island arc collision, therefore have never been experienced deeper burial, thermal and physical overprinting, and give us great opportunity to study primary accretion processes and mélange-formation process in shallow portion of subduction zone.

We identified 5 types of chaotic rock-units formed during primary accretion processes, on the basis of the grain sizes and characteristics of blocks and surrounding matrices and cross cutting relations. The chaotic rock-units composed of silt matrices and sandy to pebbly blocks (Type 3) formed by gravity-driven slumping upon the seafloor. The slumping occurred contemporaneously with deposition. Vertical variations in the direction of slump vergence represent successive changes from an initially flat seabed to tilting to the NW and finally to the SE. Slumping with a NW vergence indicates landward tilting of the seafloor immediately prior to accretion, whereas vergence to the SE reflects oceanward tectonic tilting that occurred once the sediments had crossed the deformation front. These slumps and sedimentary sequence were cut by subsequent thrust systems during off-scraping accretion at the toe of the prism. These accretion-related thrusts concentrate in the lower part of the accretionary prism while rare in the upper part. Chaotic rock-units that have matrices abundant in sand and pebble (Type 1, 2) formed as a result of subsurface liquefaction and injection associated with large earthquakes that occurred during and after accretion of the sediments. When liquefaction occurred on the tilted seafloor, typically at trench-slope basin, liquefied sand and sedimentary unit deposited above were easy to slide on the slope, and make another type of chaotic unit (Type 4: rotated blocks in sand/pebble matrices). Imbricate thrust and/or plate-boundary décollement zone in relatively deeper part (2-4 km) made tectonic mélange representing block-in-matrix with intense S-C structure (Type 5: another talk in this session). These chaotic rock-units are useful in examining surface/subsurface changes such as tectonic tilting of the sea floor, earthquake events, and subduction-related deformations during the initial accretion process.

45-2 BTH 2 Meneghini, Francesca

THE PROCESSES OF UNDERTHRUSTING AND UNDERPLATING IN THE GEOLOGIC RECORD: STRUCTURAL DIVERSITY BETWEEN THE FRANCISCAN COMPLEX (CALIFORNIA), THE KODIAK COMPLEX (ALASKA) AND THE INTERNAL LIGURIAN UNITS (ITALY)

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Existing studies on active subduction margins have documented the wide diversity in structural style between accretionary prisms, both in space and time. Together with physical boundary conditions of the margins, the thickness of sedimentary successions carried by the lower plate seems to play a key role in controlling the deformation and fluid flow during accretion. We have tested the influence of the subducting sedimentary section by comparing the structural style and fluid-related structures of four units from three fossil accretionary complexes characterized by similar physical conditions but different subducting sediment thicknesses: (1) the Franciscan Complex of California, (2) the Internal Ligurian Units of Italy and (3) the Kodiak Complex, Alaska. Similar comparisons have been commonly reported in literature but essentially for modern margins.

Subducting plates bearing a thick sedimentary cover generally result in coherent accretion through polyphase deformation represented by folding and thin thrusting events, while underplating of sediment-starved oceanic sections results in diffuse deformation and mélange formation. These two structural styles can alternate through time in a single complex with a long record of accretion such as Kodiak.

The parallel analysis of the selected analogues show that although the volume of sediments carried by the lower plate determines different structural styles, deformation is strongly controlled by injection of overpressured fluids during underthrusting and accretion. Transient hydrofracturing occurs through development of a system of dilatant fractures grossly parallel to the décollement zone.

SESSION NO. 46, 08:30

Friday, 8 October 2010

Ophiolites, blueschists, and suture zones. Posters Part 2 (*Ofiyolitler, mavisistler ve kenet kusaklari*)

METU Convention and Cultural Centre, Exhibition Hall

46-1 BTH 3 Kilic, Ayse Didem

DUNITE BLOCKS IN MAFIC-ULTRAMAFIC SEQUENCE: EVIDENCE FOR MAGMA CHAMBER

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The study area is located Eastern Taurus Belt. The ophiolitic units is one of remnant of oceanic lithosphere in Neotethyan ocean.

Mafic-Ultramafic section in the Guleman ophiolite are consist of dunite containing disseminated chromites, wehrlite, gabbros (layered gabbro and layered gabbro) and clinopyroxenite. Dunite blocks above the harzburgite massif are very interesting. These blocks have irregular contacts with the enclosing peridotites. Dunite blocks are generally around a few of meters. Dunite blocks consists of gabbro and pyroxenite patches.

The origin of dunite blocks which are belong to the transition zone of harzburgitic ophiolites is located at the base of the mafic layered section. Their are entirely or largely magmatic formed by olivine and chromite ponds at the base of the crustal magma chamber.

Magmatic origin of these dunite blocks is supported by geochemical evidence. One of this evidence Ni value are 3131 ppm in harzburgites and 2027-2036 ppm in dunites and others evidence forsterite (Fo) value of olivine in dunites is coommonly equal to harzburgites. This results are shown in values that dunites represents from harzburgite not produced by interaction with a melt otherwise dunite represents a higher fo contents harzburgites.

These geological, geochemical and petrological characteristic suggest that these dunite block are considered to be the the product of melt-peridotite interaction and is produced blocks fault above small magma chamber.

^{40}Ar-^{39}Ar isotope age in plagioclase within gabbros of the Guleman ophiolite are determined as a 72.4 million age. This is equal to Santonien.

46-2 BTH 4 Azimzadeh, Zohreh

REMNANTS OF THE PALEOTETHYAN SUTURE ZONE IN NW IRAN (MISHO MOUNTAINS) AND REGIONAL CORRELATIONS

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The closure of the Paleotethyan Ocean was marked by a collisional event between the Turan and Central Iran plates along an E-W suture zone (PTSZ), which is well displayed in the Misho Mountains in NW Iran. The Misho Mountains are bounded both in the north and the south by two dextral, oblique-slip Cenozoic fault systems along which they have been uplifted as a major positive flower structure. Basement rocks in the Misho Mountains are composed mainly of the Precambrian Kahar formation, which consists of pelitic micaceous shale and fine-grained sandstone and tuff that are locally intercalated with limestone. These rocks are locally contact-metamorphosed to hornfels along the periphery of a series of mafic to ultramafic plutons. Mafic plutonic rocks consist of gabbro, dunite, norite, pyroxenite, troctolite, anorthosite, and are locally covered by basaltic extrusive rocks. These basaltic rocks contain mainly plagioclase, orthopyroxene, clinopyroxene and olivine, and show tholeiitic to calc-alkaline compositions. Micro-sond analyses (ARL-EMX computer) show that pyroxenes of the massif are made of enstatite to hypersthene, plagioclases are labradorite to bytownite and olivines are hyalosiderite. The FeO content is high in the mafic plutons and their LREE/HREE >1 is related to their mantle origin. Positive correlation between CaO and Al_2O_3 and HREE suggests an origin of partial melting of the upper mantle. All mafic rock types are likely to have been derived from the same parental magmas since their spider diagrams and multi-element patterns are similar. Diabasic dykes intrusive into mafic and ultramafic plutons and are crosscut by S-type and A-type granitoids. S-type granitoid plutons are syn-collisional whereas the A-type granitoid plutons are post-collisional in origin. Permian dark-gray limestone and massive dolomitic limestone units (Routeh Formation) unconformably cover all these plutonic rocks and provide an upper age limit for the collision-related magmatism in the region.

Regional correlations suggest that the mafic-ultramafic plutons along the PTSZ in the Misho Mountains continue to NE Iran and into Afghanistan, where an early Carboniferous-early Permian subduction occurred NW of the Hindookosh basin forming the Carboniferous granitoids (Bulin 1973). The Hercynian orogenic phase in Turan-Russia (NE Iran), northern Pamir and Tianshan also produced mafic and ultramafic rocks in this orogenic system. The Carboniferous sedimentary rocks, meta-ophiolites and meta-flycsh deposits representing Paleotethyan remnants in south of Mashhad (Binalood zone) are intruded by Triassic to Cretaceous syn-collisional, S type-granitoids. The ophiolites here have been dated at 281-277 Ma (Karimpour et al. 2002) to 268 Ma (Ghazi et al. 2003) by ^{40}Ar-^{39}Ar methods, and the S type-granitoids at 256 Ma (Madjidi 1978) through K-Ar dating. The Hercynian phase in the Agh Darband area is represented by lower Permotriassic sedimentary rocks and Hercynian folded rocks (folded belt). To the south and southwest of the Caspian Sea, mafic and ultramafic complex in the Talesh mountains (Gasht-Masooleh ophiolites) consists of gabbro, pyroxenite and wherlite with ages around 297 Ma (Ghazi et al. 2003) and the Lahijan metamorphic rocks consist of slate, phyllite, schist and gneiss with ages of 390-375 Ma (Crawford 1972), all part of the PTSZ. Syenitic and granitic plutons in the Moro and Misho Mountains (Moro is separated from Misho via the Tabriz fault) and metamorphic rocks in NW Orumieh are part of the PTSZ. The PTSZ continues into the Greater Caucasus, where it includes the 330 Ma metamorphic rocks of Arax (Berberian & King 1981). Remnants of the Paleotethyan Ocean are likely to continue under the eastern part of the Black Sea.

46-3 BTH 5 Elitok, Ömer

GEOLOGICAL AND GEOCHEMICAL CONSTRAINTS ON THE NORTHWARD PROPAGATED OCEAN BASIN EVOLUTION AND SUPRA-SUBDUCTION ZONE TYPE OPHIOLITE IN THE ISPARTA ANGLE AREA, SW TURKEY

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Allochthonous assemblage in the northern part of the Antalya Complex in SW Turkey is mainly characterized by slope basin deposits associated with late Triassic alkaline volcanic units. These volcanic rocks range in composition from alkali basalt with high-Ti (TiO_2>2) to fractionated trachyandesite with low-Ti (TiO_2<2), late Jurassic-early Cretaceous tholeiitic volcanic rocks varying in the composition from basaltic to rhyolitic, and Cretaceous tholeiitic MORB-type volcanics. The MORB-type volcanic units are spatially associated with serpentinites, deep basin deposits and arc-type mantle peridotites (Egridir Kizildag peridotites) which are intruded by thloeiitic isolated diabasic dykes. Mantle peridotites represented by harzburgitic mantle

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tectonites with minor dunite have high MgO varying between 42.15-45.61 wt%, Mg# values (90.52-91.45) and low to very low contents of Al_2O_3 (0.32-0.97 wt%), CaO (0.47-1.31 wt%). The isolated dykes intruding the Kizildag peridotite show flat REE patterns with relatively low (La/Yb)n ratios (0.57<(La/Yb)n<0.68), consistent with N-MORB composition. Depletion in LREE indicates that the melt that formed isolated diabasic dykes was generated from a mantle source depleted by previous melt extraction. The geochemical data from the mantle peridotites and the isolated diabasic dykes indicate that the Late Cretaceous ophiolites in the northern part of the Antalya Complex (in the south of Egridir Lake) developed in a suprasubduction zone setting. The change from alkaline to transitional and tholeiitic MORB-type composition reflects evolution of continental rift into an oceanic rift, as in the present-day Red-Sea example. Late Triassic alkaline volcanics in the north of Antalya Complex are associated with rift-related deposits, whereas the Triassic alkaline volcanics in the south and in the west of Antalya Bay (Kara Dere-Sayrun unit) are associated with serpentinites. Also, the Triassic alkaline lavas in the west of Antalya Bay are interlayered with thin, pelagic limestone layers. To the further south, in the Mamonia Complex (SW of present Cyprus Island), late Triassic volcanics which represents the remnants of intra-oceanic island volcanoes are in places overlain by late Triassic reef limestones and pelagic deposits, suggesting deepening and widening of Antalya ocean towards the Cyprus ocean in the south. These geological and geochemical data suggest a continental rifting and opening of wedge-shaped ocean basin propagated northward in the Isparta Angle area in SW Turkey.

46-4 BTH 6 Kolndreu, Dede

OUTLINE ABOUT GEOSTRUCTURES IN OPHIOLITES OF THE NORTH CENTRAL MIRDITA IN ALBANIA, BASED ON THE INTEPRETATION BY METHODS OF GEOMECHANICS

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Based on the interpretation of Geostructures by Method of Geomechanics (Kolndreu, 1987, 1988, 1991, 1995, 1996) the Mirdita Ophiolite Complex is a part of the West Reflection Arc of the e- Epsilon type structure of the Balkan Peninsula (J.S. Lee, 1973, 1984) formed during the compression of Euro-Asian against Africa (Mesozoic time).

At the beginning stage (rifting) was formed the MOR-western ophiolites, then the MOR-western ophilolite type evolved into the IAT-boninite-Eastern-type ophiolite (subduction) (Melo, Beccaluva, Shallo, Aliaj, Robertson, Dilek , Bortelotti et al.).

During J_3 - Cr_1 geological time, after the Ophiolitic-complex forming, it was formed the Structure Ksi Type of Ophiolite Mirdita Zone (folds and faults) with the compressive-shear planes (including the Riedel-type displacement structures, the Structure Lambda Type, S-Type, Vortex and Wrench Structures as well (Spaç, Bulshar, Reps etc.). This interpretation also is conform to the Geochemically Experiments Data about Evolution of the Subduction which explain clearly the milieu where successively occur in subduction zone where oceanic plates sink into the mantel. “Raw materials entering the subduction factory are processed into magmas, which erupt as characteristic arc volcanism and construct continental crust…. This mixing process can create the andesitic crust, the composition of the total crust is still basaltic, nor andesitic (Tatsumi, 2005)”.

The anticlines and synclines are the structures of first order, the fractures are the second order in the Succession of the Generation of the Structural Feature that compound the Ksi Type Structure of Ophiolite Mirdita Zone in Albania.

46-5 BTH 7 Banerjee, Neil R.

PETROGRAPHY AND GEOCHEMISTRY OF EPIDOSITES FROM THE MIRDITA OPHIOLITE, ALBANIA

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Hydrothermally altered rocks from the sheeted dike and overlying volcanic sequence of the Mirdita ophiolite record evidence of subseafloor seawater-rock interaction. Samples are variably altered to greenschist facies and lower mineral assemblages including chlorite, epidote, actinolite, and smectite. Epidote and quartz are commonly developed in greenschist facies metabasalts and plagiogranites (tonalite, trondhjemite, and quartz diorite). In extreme cases, pervasive alteration has produced rocks consisting almost entirely of epidote and quartz called epidosites. Epidosites are characterized by the complete replacement of primary igneous textures by granoblastic assemblages of epidote + quartz ± chlorite ± actinolite ± ilmenite ± magnetite ± sulfides. Epidosites metasomatically replace basalt and plagiogranite protoliths and represent extremely pervasive alteration resulting from high-temperature fluid-rock interaction at high water-rock ratios. Epidosites are well documented in other ophiolites including the Troodos ophiolite in Cyprus and Semail ophiolite in Oman. Within sheeted dike complexes, epidosites commonly form as either patches in single dikes or dike outcrops or compose large zones as much as tens of meters wide, parallel to the axis of spreading. Plagiogranite-hosted epidosites more commonly occur as irregular patches, centimeters to meters wide. Preliminary temperatures calculated from oxygen isotope analyses of quartz-epidote mineral pairs from the Mirdita ophiolite indicate the epidosites formed at temperatures between approximately 200º to 400º C, which is consistent with studies from other ophiolites. Field and petrological data suggest that epidosites form at the base of ore-forming hydrothermal systems and may be useful in exploration for massive sulfide deposits.

46-6 BTH 8 Meshi, Avni

MIRDITA OPHIOLITE (ALBANIA) AS A REMANT OF AN EARLY JURASSIC BACKARC SPREADING CENTER–EXTENSIONAL TRANSFORM ZONE INTERSECTION

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The Mirdita ophiolite occurs in the western branch of the Dinaride–Albanide–Hellenide ophiolite belt, which escaped much of the Alpine deformation events possibly due to a thick, in-situ ophiolitic basement. It covers an area of 250 x 40 km^2 extending to the south by the Pindos and Othrys ophiolites of the Helenide belt and to the north by the Rahovec ophiolite (Kosove) of the Dinaride belt. The Mirdita nappe displays an eastward increasing thickness, and exposes, in a synform structure, mantle rocks along two peripheral eastern and western zones; a discontinuous amphibolitic sole delimits both peridotite zones. The central part of the nappe exposes a crustal section composed of gabbroic plutons and a poorly organized sheteted dyke complex. Previous studies have distinguished western “lherzolitic” massifs that are juxtaposed against the eastern “harzburgitic” massifs in the Mirdita ophiolite. However, our detailed mapping in the last decade has revealed that the mantle section in a structurally deeper level across the entire Mirdita ophiolite is largely harzburgitic and that the major differences in ophiolitic units are restricted to the uppermost mantle and the lower crustal section. In the western massifs, the plagioclase-lherzolite is spatially associated with higly deformed, mylonitic peridotites. Clinopyroxene and plagioclase in them were introduced by tectonic dispersion of gabbroic dykes and melt impregnation patches. Gabbroic rocks underwent strong plastic deformation during tectonic extension. The upper mantle peridotites in the western massifs are locally directly overlain by doleritic dikes and volcanic rocks of the upper crust. The sheeted dyke complex seems to have been variously developed and locally reduced in thickness in the western massifs. The eastern massifs are composed of harzburgite with locally thick dunitic and chromite–rich Moho transition zones. The best exposed transition zone occurs in the northen part of the Kukes massif, which displays a typical lower crust composed of layered olivine–gabbro and norite plutons. The layered gabrro grades upsection into foliated and isotropic, hydrothermally altered amphibole gabbro and a sheeted dyke complex, which consists of basalt, rhyodacite and plagiogranite dikes. The extrusive unit is well developed, consisting of basalt to basalt–andesite lavas and pillow lavas, overlain by rhyodacitic and boninitic extrusives.

This contrast in crustal architecture and rock units in the Mirdita ophiolite is an artifact of the two linked spreading segments of the Mirdita backarc basin formed in the early Jurassic: the NW-SE–trending extensional transform zone in the north and the NE-SW– trending Mirdita spreading center in the south. We infer that the oceanic lithosphere of the Mirdita backarc basin originated from a right–lateral pivoting motion between the Korab–Pelagonian and Apulian microcontinents. The Mirdita spreading center formed a wedge varying in width from 60 km at its northwestern end to zero at its southeastern tip.

46-7 BTH 9 Plissart, Gaëlle

OCCURRENCE OF A MYLONITIC ZONE DEVELOPED ON OCEANIC AND SEDIMENTARY ROCKS (ALMAJ MOUNTAINS, ROMANIA): RECORD OF THE OBDUCTION OF THE DANUBIAN OPHIOLITE?

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Regional context

The Alpine Upper Danubian Nappe crops out in the Southern Carpathians in Romania and in the North of the Balkans in Serbia and Bulgaria. The pre-alpine basement of this Nappe displays an important tectonic marker in the form of the Danubian Ophiolite. This Ophiolite consists of four dismembered ophiolitic massifs: Tisovita Iuti in Romania, Deli Jovan and Zaglavak in Serbia and Tcherni Vrah in Bulgaria. Together, these massifs (~ 500 km^2) display all the components of a classical ophiolitic assemblage, from serpentinized harzburgites to pillow lavas. They probably represent the relics of a unique oceanic domain presently dismembered along 160 km by Oligocene Alpine tectonics. Although the Danubian Ophiolite has been considered as Late Proterozoic during the last decades (Haydoutov 1989), the Deli Jovan massif has been recently dated to the Lower Devonian (U-Pb zircon age of 405 ± 2.6 Ma; Zakariadze et al. 2006).

Petrology of the mylonitic zone

Our study concerns a mylonitic zone developed in the Eastern part of the ophiolitic massifs on oceanic- and sedimentary- derived rocks. This zone is well exposed in Romania where it has been investigated in details. In this region, it consists of a narrow N-S band (< 5km in width) cropping out at the East of the Tisovita Iuti ophiolitic massif and extending Northwards along the Carboniferous Cherbelezu granite. It includes three units of different natures: (1) oceanic-derived rocks, (2) metasedimentary rocks and (3) high-grade metamorphic rocks.

Oceanic-derived rocks consist mainly of deformed listvenitic gabbros. The listvenitization process in this area has already been described by Plissart et al. (2009) as the metasomatic transformation of amphibolitic gabbros by CO_2-rich seawater-derived fluids at temperatures around 280°C. At the final stage, this process generates the unusual assemblage of zoisite + calcite + (Cr)-clinochlore + (Cr)-muscovite. Interestingly, this mineralogical transformation is in most cases associated with a strong deformation producing a gneissic or a schistose texture.

Directly at the East of the listvenitic gabbros are found the metasedimentary rocks of the Corbu Unit and the high-grade metamorphic rocks. Nowadays, these two units appear tectonically imbricated but their origin is interpreted differently. The Corbu rocks consist of deformed and slightly metamorphosed margin and volcano- sediments, as various as pelites, greywackes, limestones, sandstones, dacitic tuffs and andesitic tuffs. In a different way, high-grade metamorphic rocks are believed to come from Mn-rich oceanic sediments and commonly display an assemblage of garnet + staurolite ± andalousite + muscovite + biotite + chlorite + plagioclase + quartz.

Structural analysis

Structural observations and measurements performed on these three groups of rocks indicate that the entire mylonitic zone has undergone a similar deformation which is partitioned between highly deformed mylonites and slightly-deformed juxtaposed rocks. These rocks display high-dip North-Southwards foliation planes, associated with a strong subhorizontal stretching mineral lineation and isoclinal folds parallel to this lineation. These fabric elements appear to develop during the same event, giving evidence for components of both simple and pure shear and suggesting a deformation which probably occurred in a transpressive context.

Geochronology

New ^{40}Ar-^{39}Ar ages performed on two Cr-muscovites from slightly and highly listvenitized gabbros give plateau ages of 372.6 ± 1.3 Ma and 360.6 ± 1.2 Ma respectively. These ages correspond to the intense metasomatic event affecting amphibolitic gabbros and generating listvenites in localized zones. As the deformation observed in these rocks seems contemporaneous to their metasomatism, it is likely that an important thrusting occurred during Late Devonian times, when the oceanic lithosphere was still in contact with seawater necessary to promote such large chemical remobilisations.

Interpretations & conclusions

Listvenitization of gabbroic rocks is a very uncommon process which certainly requires a specific geodynamic context. According to the transformation/deformation intercorrelations observed in these rocks and to the age obtained for this event, we propose that the listvenitic rocks were formed in the first stages of the obduction of the Danubian ophiolite during a Variscan oblique collision.

As the deformation type encountered in the metasedimentary rocks of the Corbu Unit is similar to the one observed in the listvenitic gabbros, the scenario envisaged is the continuation of the transpressive obduction-related thrusting onto the margin sediments, whereas high-grade metamorphic rocks could correspond to the metamorphic sole developed previously on oceanic sediments and subsequently incorporated as slices in this mélange during the oblique collision.

These results imply the occurrence of a Variscan oceanic suture in the Eastern part of the Variscan Belt, classically ending in the Sudetes Area (Poland). Moreover, the Late Devonian closure of the Danubian oceanic domain is very similar to data observed for the evolution of the Rheic Ocean and its associated basins (Nance et al. 2010).

46-8 BTH 10 Huber, Kathryn G.

PETROLOGICAL EVOLUTION OF OPHIOLITE ASSEMBLAGES EXPOSED NEAR THE NORTH ANATOLIAN FAULT IN THE TOKAT MASSIF, NORTHEASTERN TURKEY

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The North Anatolian Fault (NAF) is a significant and active dextral strike-slip fault that extends ~1600 km E-W throughout northern Turkey from the Karliova triple junction in the east to the North Aegean Trough in the west. The NAF may have formed in the late Miocene or Pliocene. Located in the Sakarya Zone of the eastern Pontides, the Tokat Massif is cut by the NAF and is described as Permian-Triassic metamorphic, volcanic, and sedimentary group of rocks that is located either between the towns of Amasya and Susehri or ~100 km further east between Corum and Susehri. In this area, the NAF is located near the Izmir-Ankara-Erzincan suture, but the role of this paleosuture in facilitating more recent movement has been unexplored. An additional unknown is the petrological evolution of ophiolite assemblages exposed along the suture in the Tokat Massif. Deciphering the assembly of the Tokat Massif is important for understanding the evolution of the NAF as the structure cuts through the region and facilitates the development of basins and locally developed thrust faults. Structures that facilitated ophiolite exposure may have reactivated during the development of the NAF.

The stratigraphy of the Tokat Massif is debated. According to one interpretation, the Tokat Massif is split into three tectonic units that make up a subduction-accretion complex: the Tokat, Yesilirmak, and Akdagmadeni groups (Yilmaz and Yilmaz 2004). The Yesilirmak group is made up of an ophiolitic mélange and fore-arc sequences. The ophiolitic mélange is part of the North Anatolian Ophiolite Belt that begins in Izmir and continues eastward 1000 km to the Lesser Caucasus. The Akdagmadeni group consists of gneiss, amphibolite, schist, quartzite and marble. These rocks have initially undergone amphibolite facies metamorphism, then cataclastic metamorphism during the Late Cretaceous. The Tokat Group, which comprises most of the Tokat Massif, is comprised of a pre-Jurassic metamorphic group called the Turhal metamorphics and a Silurian to Triassic heterogeneous unit called the Devecidag Mélange. Others characterize the central Pontides as various imbricated piles of Pre-Tethyside and Tethyside tectonic units that have been fragmented by the NAF. During the formation of the Tokat Massif, each orogenic phase was overprinted onto a previous one, creating a complicated assemblage. Rojay (1995) classifies the tectonostratigraphic units of the Amasya region into 7 units based on age, lithostratigraphic evolution, internal organization and location: the Tokat Group, the Devecidag Complex, the Amasya Group, the North Anatolian Ophiolitic Mélange, and 3 metasedimentary units.

The debated stratigraphy of the Tokat Massif is likely due to the region's complex tectonic history. Providing geochronologic and geochemical information from metamorphic and igneous assemblages within the massif is essential to understanding its role and relationship within the Pontides. To address this, ophiolite samples were collected from the Tokat Massif and analyzed for their major and trace elements. Although the samples display alteration features, their incompatible element concentrations can be used to speculate about their volcanic history due to their immobility during metamorphism. Major element concentrations of our samples are similar to tholeiitic island-arc basalts exhibited by the subalkaline nature of Na_2O+K_2O vs. SiO_2 as well as FeO/MgO vs. SiO_2 ratios. Y vs. Cr and V vs. TiO_2 data for all our samples also suggest island arc tholeiitic sources. Chondrite-normalized REE diagrams for ophiolites display negative slopes with slight LREE enrichment and flat patterns for HREE. Overall REE abundances are between 15-20X chondritic. This is typical for transitional MORB types and suggests chemical contributions from an enriched mantle source.

Age data for rocks displaced by the NAF in the Tokat Massif is lacking, yet this information is key for deciphering the region's past tectonic history and role in facilitating more recent deformation. We recently found micron-sized zircon grains in clusters in our ophiolite samples from the Tokat Massif. These grains have the potential to be dated using an ion microprobe, which will be used to constrain the timing of crystallization and the relationship of the rocks to ophiolites elsewhere in the Pontides. The age data and kinematic studies of structures in the region will be used to compare the relationship of units in the Tokat Massif across the Pontides.

Rojay (1995) *Geologica Romana* **31**, 329-350. Yilmaz and Yilmaz (2004) *Turkish Journal of Earth Sciences* **13**, 231-246.

46-9 BTH 11 Köksal, Serhat

RE-EVALUATION OF THE PETROLOGICAL FEATURES OF THE EKECIKDAG OCEANIC PLAGIOGRANITES IN CENTRAL ANATOLIA / TURKEY

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Remnants of the Izmir-Ankara-Erzincan branch of the Alpine Neotethys are represented by dismembered ophiolitic units in the Ekecikdag area (central Anatolia/Turkey). In the Ekecikdag and nearby areas, the ophiolitic rocks thrust over the central Anatolian metamorphic basement and intruded by the Late Cretaceous granitoids. Among these ophiolitic rocks plagiogranites are significant for the petrological evaluation of the oceanic history. The available data and interpretations on the Ekecikdag plagiogranites (Göncüoğlu and Türeli, 1993) are re-assessed by using the new geochemical data. The Ekecikdag plagiogranites are composed of quartz, plagioclase, hornblende, biotite ± clinopyroxene, with accessory amount of zircon, titanite and apatite minerals. They are tonalite in composition on the normative Ab–An–Or plot, but display extremely low Or %. The plagiogranites in the Ekecikdag area show high SiO_2 (69.9–75.7 wt. %), but exceptionally low K_2O contents (less than 0.6 wt. %), which correspond to the oceanic plagiogranite description of Coleman and Peterman (1975). Furthermore they contain Na_2O contents ranging from 2.7 to 5.3 wt. %, Al_2O_3 contents ranging from 12.8 to 14.3 wt. %, and CaO contents ranging from 3.0 to 5.4 wt %. They are subalkaline, calcic, and have transitional characters from metaluminous to peraluminous, and from magnesian to ferroan. Furthermore, depletions in Th, Nb, La, Ce, P, Zr and Ti are noticeable on the primitive normalized spider diagrams. Chondrite-normalized REE diagram of plagiogranite samples shows LREE contents, increasing from La to Sm, and flat MREE and HREE profiles. Overall REE pattern reveals higher HREE with respect to LREE ($[La/Yb]_N$ = 0.33–0.46] and negative Eu anomalies ($[Eu/Eu^*]_N$ = 0.67–0.97) suggesting plagioclase fractionation. Additionally, the plagiogranite samples plot into the VAG field within the Nb vs. Y diagram of Pearce et al. (1984), but still in the fields of plagiogranites from the Troodos and Oman ophiolites. The Ekecikdag plagiogranites likely to be derived from partial melting of the depleted mantle sources in a supra-subduction zone setting, and are comparable with other plagiogranites in the Tethyan realm.

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Pearce, J.A., Harris, N.B.W. and Tindle, A.G.W., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology 25:956–983.

46-10 BTH 12 Foudazi, Mohammad

PETROGRAPHY AND MINERALOGY STUDY OF PYROXENITE AND WHERLITIC DIKES IN NAIN OPHIOLITE,CENTRAL IRAN

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Various petrological facies of the northern Nain Ophiolite include serpentinized peridotite, mantle peridotites type harzburgite, dunite pods, peridotites type cumulate (plagioclase bearing harzburgitic dikes), wherlite and pyroxenite dikes, isotrophic gabbros, pegmatite gabbro dikes, diabasic sheeted dike complex, isolated diabasic dikes swarm dikes, pillow basalts and sheet flows. The relationship of these rocks is related to Tertiary tectonic sedimentary units which are directed on Akhoreh Formation flysch sediments aged Eocene as well as conglomerate sediments, marn and Miocene sandstone in the North East part of Nain. Red cherts which are located in an allogenic manner on the serpentinized peridotite as well as on microgabbroic dikes and sometimes between pillow basalts have also radiolarian facies and belong to the late cretaceous. Schistose limestones of the late cretaceous are also located in an allogenic manner on the ophiolite units.

Peridotite dikes (wherlite)and pyroxenite dikes with webstrite to olivine webstrite compound have sometimes cut off the isotrophic gabbros and sometimes sheeted dikes of northern Nain ophiolite. wherlitic dikes are often changed into serpentinite with cross-linked texture. Olivine webstrite texture is granular and there is clinopyroxene, orthopyrxenite and a little chloritized and serpentinized olivine in their mineralogy compound. webstrite have also a granular texture and their mineralogy compound constitutes clinopyroxene and orthopyroxene. In these rocks first orthopyroxene has been formed and then subhedral clinopyroxene crystals were formed in the remaining space. Orthopyroxenes have sometimes changed into talc and chlorite, and sometimes to amphibole and talc in the directions of the fractures.

The average chemical compound of clinopyroxene type augite in the pyroxenites cutting isotrophic gabbros is $En_{50.617}$ $Fs_{7.26}$ $Wo_{42.123}$, and in pyroxenites cutting sheeted dikes is $En_{52.271}$ $Fs_{6.24}$ $Wo_{41.489}$.

The average chemical compound of orthopyroxene type enstatite in the pyroxenites cutting isotrophic gabbros is En86.388 $Fs_{10.661}$ $Wo_{2.951}$, and in pyroxenites cutting the sheeted dikes is $En_{89.052}$ $Fs_{7.989}$ $Wo_{2.96}$.

46-11 BTH 13 Toksoy-Köksal, Fatma

IS A SINGLE MODEL ADEQUATE TO EXPLAIN ORIGIN OF THE GABBROS FROM CENTRAL ANATOLIA, TURKEY?

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Genesis of the Late Cretaceous gabbroic rocks playing a significant role in the geodynamic evolution of central Anatolia is debate. Contrasting models have been discussed so far by various researchers. Are they (a) member of ophiolitic units deriving from closure of Izmir-Ankara-Erzincan branch of Neotethys Ocean in Turkey, (b) mafic unit of intrusive bodies originating in a collisional setting, or (c) formed in a continental arc setting? To shed light on origin of these rocks, gabbroic rocks from two igneous associations, namely Agaçören and Ekecikdag, on the west of the Central Anatolian Crystalline Complex are investigated. Basement units in the study area are metamorphic rocks that are thrusted by ophiolitic units from north to south. Gabbros, having either layered or isotropic character, also tectonically overly the metamorphic rocks. Medium-coarse sized gabbros are cut by diabase dykes. Granitic rocks intrude both basement metamorphics and gabbros.

Gabbros are heteregeneous in composition and texture. Petrographical and mineral chemical data show that magnesio-hornblende ($Mg/(Fe^{2+}+Mg)$=0.68-0.94) and high Ca plagioclase (An=69-98) are essential phases of the rocks while olivine (Fo=74-76), augitic diopside ($Wo_{46-47}En_{37-38}Fs_{14-15}$), and biotite are rarely present. Based on the presence of biotite, gabbroic rocks are named as biotite-gabbro or biotite-free gabbro.

The biotite-free gabbros together with the diabase dykes are tholeiitic in character whereas the biotite gabbros are calc-alkaline. The biotite-free gabbros and the diabase dykes display comparable geochemical features, i.e. similar ranges of major oxides. However, the biotite gabbros differ by their higher K_2O, Na_2O an TiO_2 and lower MgO and CaO contents. They have also higher large ion lithophile, high field strength and light rare earth elements compared to the biotite-free rocks. All the rocks show negative anomalies of Nb and Zr where the biotite gabbros have higher concentrations. The biotite-free gabbros and the diabase dykes are depleted in light rare earth elements (LREE) compared to heavy rare earth elements (HREE) while the biotite gabbros are enriched in LREE compared to HREE.

Low Ti/Y and Zr/Y, and high V/Ti ratios of the gabbroic rocks in the area infer plate margin. Lower K_2O and P_2O_5 contents compared to TiO_2 of the biotite-free rocks suggest oceanic setting while biotite gabbros with higher K_2O were likely to be derived in a continental setting. Mineral data from the biotite-free rocks are comparable with those of gabbros from island arc settings. Additionally, whole-rock geochemical characters of these rocks strongly indicate island arc – backarc setting in an intra-oceanic subduction zone. Although the biotite-free gabbros display ophiolitic origin, the biotite gabbros reveal similar geochemical characteristics to the Late Cretaceous syn- to post collisional granitoids in the area. Consequently, a single model is not sufficient to explain the origin of the gabbroic rocks in central Anatolia, since gabbros with different origins are present, as the ophiolitic gabbros and collision related intrusive gabbros.

46-12 BTH 14 Faridazad, Morovvat

PETROLOGY AND PETROGENESIS OF ULTRAMAFIC ROCKS OF THE KHOY OPHIOLITIC COMPLEX-NW IRAN

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Ultramafic rocks have extensive outcrops in the metamorphic complex of north of Khoy. Petrographically these rocks are: harzburgites, dunites and pyroxenites and are of both cumulate and tectonite types. Geochemically these rocks are two types. First type has U-shape REE pattern and with modeling of PUM batch melting, indicates rate of melt of 30-90% and with modeling of PUM Rayleigh melting, indicates 10-30% of partial melting of the upper mantle as source for these rocks. Second type has flat REE pattern and negative slope, probably indicating a metasomatized mantle. Modeling of PUM batch melting indicates rate of melt of 30-50% and with modeling of PUM Rayleigh melting indicates 10-20% for partial melting of the upper mantle.

SESSION NO. 47, 08:30

Friday, 8 October 2010

Sedimentary basin evolution and oil fields in the Middle & Near East. Posters (Sponsored by the Turkish Association of Petroleum Geologists) (*Orta ve Yakin Dogu'da sedimanter havza gelismeleri ve petrol olanaklari*)

METU Convention and Cultural Centre, Exhibition Hall

47-1 **BTH 15** Omrani, Mehdi

BIOSTRATIGRAPHY OF THE ILAM FORMATION IN HALEGAN WELL, SOUTHERN IRAN

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Halegan oil well is selected in order to study the biostratigraphy of Cenomanian to lower Companian sediments in the southern Zagros mountain, southern Iran. The sediments are consisted of limestone sequences of upper parts of the Sarvak and lower parts of the Ghorpi Formations, that overlay disconformably top of the Sarvak Formation and paraconformably underlay the Ghorpi Formation. Based on microscopic studies, six planktonic genus and eleven planktonic species along with eight benthonic genus and seven benthonic species and eight samples of non-foraminifera were distinguished. Based on studies by Martinez (2009), among distinguished benthic foraminifers, four genus and five species of rotallid like-form are reported for the first time from the Halegan well in this study. Based on distinguished benthic foraminifers, middle to upper Cenomanian age for the Sarvak Formation, Cantonian age for Ilam Formation with interfingering of the Ghorpi Formation marls and early Companian age for lower part of the Ghorpi Formation are prposed. Based on foraminifers stratigraphic distribution and comparison with biozones of Martinez (2009), four biozones are introduced for Cenomanian and Cantonian sediments. Based on distinguished zones, Cantonian sediments are divided into lower, middle and upper parts for the first time in this study. The introduced foraminifers show that there are no Tronian and Coniacian sediments in the studied area.

Boix, C., Villalonga, R., Caus, E., and Hottinger, L., 2009. Late Cretaceous rotaliids (Foraminiferida) from the Western Tethys. *Neues Jahrbuch für Geologie und Paläontologie* **253**, 197-227.

47-2 **BTH 16** Bülent, Coskun

STRUCTURAL EVOLUTION-OIL POTENTIAL RELATIONSHIPS IN THE MARMARA SEA, NW TURKEY

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In spite of gas production in the K. Marmara gasfield , many non explored zones, which could contain important prospects, could still exist in the Marmara Sea.Evaluations of seismic lines,well and field data indicate that Osmancik sandstones , eroded and transported from the northern Istranca Massif's metamorphics, constitute prospective sandstone channels and incised valleys in the Kumburgaz area, while prospective reefoidal Sogucak limestones and likely Hamitabat sandstones are localized in the northern and middle part of the Marmara Sea. Occurrence of prospective structures started their evolution since Late Cretaceous with emplacement of ophiolites which provided paleohigh and basement for overlying younger Eocene and Oligocene reservoir units. During the Miocene time, appearence of the North Anatolian Fault (NAF) generated multiple splays which compartmented existing formations and ameliorated also reservoir characteristics wity formation of fractures and small scale faults. Evaluations of data inticate that some regions in the Marmara Sea remain still unexplored to date. Future oil and gas discoveries in these zones will contribute a lot to the Turkish economy.

47-3 **BTH 17** Sadaoui, M.

STRUCTURAL EVOLUTION OF THE ILLIZI BASIN AND ITS IMPACT ON THE GENERATION OF HYDROCARBONS. THE SAHARAN PLATFORM

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Our present work is to examine the structural evolution of the Illizi basin and its impact on the generation of hydrocarbons.

Illizi basin is located in the South - West of the Algerian Sahara with an area of 108.424 Km2. This basin is subject of a huge exploration effort which began in 1956 with the discovery of the Edjeleh field. The Illizi basin is an intracratonic, consisted of different structural elements.

Basically, the sedimentary cover consists essentially of detritic deposits of a thickness varying from 2500 to 3000 m, between the Cambrian and the Paleogene times.

It was the a subject of a succession of tectonic phases which are the source of the current structural frame: of phase N040 (Viséan age), phase N120 of (hercynian- end Carboniferous age), phase N090 (Austrian- ante-Cretaceous medium) and phase N050-060 (Oligocene age).

During the lower Paleozoic movements, It existed a distention episode (rifting Cambro-Ordovician), with a continue implementation of sedimentary series, and the subsidence in the lower Devonian. Since the Devonian, the Tihemboka uplift become active regarding the rest of the basin.

On the basis of a structural analysis, two phases have been highlighted during the upper Paleozoic movements. It concerns the Hercynian movements that are assigned to early phase (N040) and Hercynian phase (N120) in a strict sense. Because of their compressive character, they were responsible for large number of strains and they had a very important role in the structuration of the Eastern Sahara. The majority of stand accidents have been reactivated and depreciated in carboniferous land, except the major trends crossing all series of Paleozoic and Mesozoic series. The influence of this reactivation is transmitted on sedimentation by the facial changes and the large variations of thickness.

The different phases of the Meso-Cenozoic have their importance in the current structuration basin. Although the influences by Hercynian and especially Pan-African heritage, they had well printed all the important structures.

The Illizi basin is the most studied oil province and one of the most productive of the Saharian platform. It contains mostly all favorable conditions to the Genesis, migration, and trapping of hydrocarbons.

The history of burring sources rocks shows a quick subsidence during the Paleozoic. The generation periods of hydrocarbon began in the Carboniferous and the expulsion of the oil began later.

47-4 **BTH 18** Yousefzadeh, Elham

MICROBIOSTRATIGRAPHY, MICROFACIES AND SEDIMENTARY ENVIRONMENT STUDIES OF TARBOUR FORMATION (SOUTHWEST OF IRAN)

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During Campanian – Maestrichtian an association of Rudist-rich sediments was found along the south east of neothetys margins, this rock unit is called Tarbour Formation in the Zagros Mountains in Iran.

Tarbour is a Formation that developed extensively in Zagros Mountains. On the other hand, equal formations of Tarbour in other countries such as Iraq are famous oil resources. According to these reasons and following the previous studies and completion of previous studies, we needed some more comprehensive and newer studies in other areas in Zagros Mountains.

In order to study of Micropaleontology , Stratigraphy and Sedimentary of the upper cretaceous deposits in the Zagros Mountains, Kherameh section, located on south east of Shiraz (south west of Iran) was selected. More than 100 samples collected and studied by thin sections. Tarbur Formation deposits in this area with the 228 meters thickness is lied on the Gurpi Formation(a marl limestone and marl) and Sachun Formation is in the upper of Tarbour Formation . It is dominantly formed from carbonate rocks ,thick bedded to massive limestone.

The Micropaleontological study of above deposits led to recognition some genera and species of benthic foraminifera, such as *Orbitoides concavatus, Lepidorbitoides minor, Orbitoides media, Minouxia lobata, Omphalocyclus macroporous, Nezzazatinella sp., Rotalia skourensis* and etc.

According to foraminifers' assemblage, the age of studied section was Maestrichtian. This section is comparable with omphalocyclus – loftusia assemblage zone of wynd(1965) that is used in Zagros Mountains by Iranian oil companies.

Based on field and sedimentology study, seven carbonate facies related to "Lagoon ", " Bar " and "Open marine" environment have been identified in Tarbour Formation.

SESSION NO. 48, 13:30

Friday, 8 October 2010

Keynote Talk 8

METU Convention and Cultural Centre, Kemal Kurdas Salon

48-1 13:30 Dick, Henry J.B.

MODES OF ACCRETION AT SLOWER SPREADING OCEAN RIDGES

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Seafloor mapping and drilling at oceanic core complexes exposing the sub-volcanic basement at slow and ultraslow spreading ocean ridges has documented an enormous diversity of ocean crust structure. Locally, large regions of 'crust' are generated much as originally envisaged by Harry Hess, with altered mantle rock pulled directly to the seafloor with only scattered volcanism, elsewhere thick gabbro massifs in excess of 1.5 km are generated with an overlying volcanic carapace centered on magmatic ridge segments, and a diversity of crustal architectures form between these extremes with local magmatic centers formed within mantle rock. This diversity goes a long way to explaining that seen in ophiolite complexes.

While a full understanding of the diversity of the ocean crust, its composition, and the mass flux it represents from the Earth's interior to the lithosphere, oceans and atmosphere will require substantial future mapping and sampling, it would appear that we can identify the principle processes involved in its construction. These include pooling of melts in the mantle at the base of the crust, where melt-rock reaction with the mantle forms dunite, troctolite and gabbro, and direct intrusion of small bodies of melt to higher levels up to the base of the sheeted dikes. Mode two occurs by vertical melt infiltration due to compaction of partially molten rock, resulting in a significant mass addition to higher levels of the lower crust, with accompanying excess enrichments in trace elements. Finally, mode three occurs by upward rafting of olivine-rich troctolite and gabbro from the crust-mantle transition zone, and local intrusions in the overlying section to higher levels. This process essentially represents an extension of corner flow, normally associated with the mantle beneath the crust to the base of the sheeted dikes. Evidence for this process is seen in mantle-derived olivine-rich troctolites drilled within the 1.4 km gabbro section at the Atlantis Massif on the MAR (Drouin et al, 2007, Geoph. Res. Abs., 2009, Chem Geol.; Suhr et al., 2008, G3), intercalation of sheeted dikes with amphibolitized and ductily deformed gabbros, (Dick et al., 2008, G3), and the very formation of oceanic core complexes. One major implication of these modes of accretion is that MORB evolves quite differently in the lower crust than previously supposed, no longer representing simple fractional crystallization of a primary melt.

SESSION NO. 49, 14:30

Friday, 8 October 2010

Mélanges and mélange–forming processes. Part 3 (*Melanjlar ve melanj olusturan mekanizmalar*)

METU Convention and Cultural Centre, Salon A

49-1 14:30 Harris, Ron

LINKING MÉLANGE TYPES AND OCCURRENCES WITH ACTIVE MÉLANGE-FORMING PROCESS IN TIMOR AND TAIWAN

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Active arc-continent collisions provide a unique environment to investigate mélange development processes because mélange exposures can be traced along orogenic strike to active mélange forming settings. Tectonic, sedimentary and diapiric processes are commonly all found in these settings. However, the fundamental association of mélanges with plate boundary segment development indicates that they are primarily of tectonic origin, and connected in some way to a subduction channel. For example, in the active arc-continent collisions of Timor and Taiwan different types of mélange are found that connect directly to evolving plate boundary segments in the front, back, and slicing through the orogenic wedge that are ultimately tapping a subduction channel.

In the Timor region of the active Banda arc-continent collision mélange is found primarily along the base of the Banda Terrane, which is a large crystalline nappe of forearc basement emplaced over a duplex of mud-rich Australian continental margin rocks. The Banda Terrane formed the roof of the initial subduction channel. A well-known mélange comparison is the Oman mélange at the base of the Oman ophiolite. The Banda mélange is stratified with more subduction-related (serpentinitic and pelagic) compositions near the top and collision-related materials (dismembered thrust sheets of continental margin material) at its base. The high degree of mixing, of blocks of a wide variety of types, its structural setting and connection with active mélange forming processes documents its primary origin as part of the original subduction channel.

Two other settings of mélange development are notable in the Banda arc-continent collision. On Savu Island and along the north coast of Timor mélange associated with retrowedge development is well exposed and includes young volcanic arc material not found in mélange at the base of the Banda Terrane. Also, mélange extruded by a line of large mud diapirs marks the boundary of a major wrench fault slicing through the orogenic wedge west of Timor and is exhumed on the islands of Rote and Semau. Both of these settings have smaller blocks, but display similar high degrees of block dispersion and mixing indicating that ultimately these conduits for mélange mobility are connected to the subduction/collision channel.

Taiwan provides two similar contrasting examples in the Kenting and Lichi mélanges, which differ in their structural setting, but are fundamentally similar in composition and structure. The Kenting Mélange developed within the frontal accretionary prism of the Hengchun Peninsula and separates two different accretionary packages along a major shear zone that was one time part of the subduction channel before it was clogged by shelf facies continental margin material. It contains matrix and blocks of mostly chaotically-sheared late Miocene continent-derived clastic successions, seamount volcanics and oceanic crust-mantle materials. Like the Banda mélange, the Kenting mélange was generated by decollement propagation as part of a clogged subduction channel, but materials derived from the South China Sea floor differ from typical Tethyan-type mélanges like the Banda mélange.

In comparison, the Lichi Mélange represents chaotically-sheared forearc material associated with development of the retrowedge of the Taiwan collision. Like the mélange associated with the Savu Thrust system in the Banda Arc, it consists of chaotic forearc sediments and some accreted continental margin units with a variety blocks including andesite and tuff from the Luzon arc, sepentinite blocks, gabbro and glassy basalt of SSZ origin. The Lichi Mélange records a two-stage development: an initial arc-continent collision stage (~3 Ma) where the Lichi Mélange developed within 3.5-3.7 Ma forearc strata that were back-thrust as part of the retrowedge; and a second stage of mélange development that occurred during advanced arc accretion (last 1.5 Ma) as the forearc ridge and basin is thrust westward over the Lichi Mélange along a low-angle decollement.

Ultramafic rocks and gabbro are found in each of these mélanges and are most likely derived from the upper plate deep in the subduction channel and made their way to the surface through return flow (Poiseuille flow) via various shear zone conduits. It is highly unlikely that the harzburgite blocks and SSZ volcanics are derived from the mantle or MORB-type crust of the lower plate. Poiseuille flow in the subduction channel would systematically sample and incorporate material from the upper part of the lower plate (seamount volcanics, pillow basalt and overlying sedimentary cover of MORB and OIB composition) and the lower part of the upper plate (serpentine, gabbro, and ultramafic rocks). These types of relations are characteristic of most mélanges.

49-2 14:50 Huang, Chi-Yue

MECHANISM AND CONSEQUENCE OF FOREARC BACK-THRUSTING IN FORMATION OF LICHI MÉLANGE IN COASTAL RANGE, EASTERN TAIWAN

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The Coastal Range orogen in eastern Taiwan was resulted from the collision between the Luzon Arc of the Philippine Sea Plate and the Asian continental margin since latest Miocene. The collision is still active today off SE Taiwan where provides the modern analog in understanding the tectonic evolution of the Coastal Range and the mechanism responsible for formation of the Lichi Mélange. Multiple evidence, including geochemistry, sedimentology, stratigraphy study, indicate that two volcanic islands of the Luzon Arc and four remnant forearc basins of the North Luzon Trough were accreted as the Coastal Range in the last 1.5 Ma. The intensively sheared Lichi Mélange represents the lower forearc turbidite sequences (3.5-3.7 Ma) that have experienced two stages of thrusting during the arc-continent collision. During the initial arc-continent collision (~3.5 Ma), the northwest-moving Luzon Arc as a backstop on the upper plate collided the underthrusting Asian continental margin to result in an arcward (eastward) back-thrusting in the western part of the North Luzon Trough forearc basin to form the deformed Lichi Ridge (analog to the modern Huatung Ridge in modern active collision zone off SE Taiwan) along the rear accretionary prism. The Lichi Ridge was especially elevated in areas between volcanic islands to progressively deform the North Luzon Trough into a sausage-like configuration of two pairs of a large, deep remnant forearc basin in the north followed by a small, elevated remnant basin in the south. The large, deep (Shuilien and Taiyuan) remnant basins are characterized by filling of 1.5 km thick Pliocene classic turbidite sequences and ~2 km thick Pleistocene fluxoturbidites, while only 1.5 km thick Pliocene classic turbidites were deposited in the small, elevated (Loho and Taitung) remnant basins in which the Lichi Mélange is also exposed in the basin center. During the advanced arc-continent collision (~1.5 Ma in the north and <0.9 Ma in the south), the deformed Pliocene Lichi Ridge was thrust westward incorporating with some arc crust/mantle blocks of the upper plate materials to become the Lichi Mélange. Finally, the volcanic islands and remnant forearc strata were further thrust westward over the Lichi Mélange along a low-angle decollement to form the Present Coastal Range in eastern Taiwan. The Lichi Mélange beneath the decollement was able be exposed as window structures either by river erosions along the collision suture (the Longitudinal Valley) and in the Loho remnant forearc basin center, or by wave erosion along the coast of the Taitung remnant forearc basin.

49-3 15:10 Zhai, Qingguo

PALEOZOIC OPHIOLITIC MELANGE IN CENTRAL QIANGTANG, NORTHERN TIBET: GEOCHEMISTRY AND SHRIMP U-PB DATING

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E-W trending mafic-ultramafic rocks occur widely in the middle part of the Qiangtang Block in northern Tibet. Due to the very limited accessibility, these rocks have only been discovered recently. They were interpreted by some workers as an ophiolite sequence, but such interpretation has not been universally accepted. In order to resolve this controversy, we undertook a detailed zircon geochronology and geochemical-isotopic study of these rocks. Our results confirm the ophiolite interpretation.

In the central Qiangtang block, two ophiolitic mélange suites have been identified: an Early Paleozoic (467-345 Ma) and a Late Paleozoic (Permian). The Early Paleozoic ophiolitic mélange occurs in the Gangma Co and Guoganjianian area, and it is composed of cumulate gabbro, basalt, hornblendite and plagiogranite. All the rock types have been metamorphosed to the greenschist facies. Geochemical data indicate that these rocks show typical N-MORB characteristics, with depleted or flat REE patterns, and positive $e_{Nd}(T)$ values (4.9-8.8). SHRIMP Zircon U-Pb dating on the cumulate gabbros yielded three weighted mean ages of 467 ± 4 Ma, 438 ± 11 Ma and 345 ± 5 Ma. $e_{Hf}(T)$ values of zircons range from 4.5 to 5.9 for cumulate gabbro from the Gangma Co area, and 5.1 to 13.1 for those from the Guoganjianian area. We conclude that this suite of rocks represent a Paleozoic ophiolitic mélange.

The Late Paleozoic or Permian ophiolitic mélange lies in the Jiaomuri area, and consists of ultramafic rocks (harzburgite), mafic dyke rocks (gabbro and diabase), pillow lavas and minor amount of chert. Geochemical analyses indicate that the basaltic rocks belong to two distinct groups, namely, alkaline and tholeiitic. The alkaline basalt samples are similar to OIB, whereas the tholeiitic basalt samples exhibit E-MORB characteristics. So far, no zircon ages have been determined for this ophiolitic mélange suite, but its age can be inferred as Permian from the index fossils (fusulinid) in the intercalated or overlying limestone. In addition, Permian oceanic island basalt with interbedded limestone and chert of the Lugu Formation are widespread in central Qiangtang.

The newly discovered ophiolitic mélange suites suggest that a Paleozoic Ocean basin (Paleo-Tethys) existed in central Qiangtang block during Middle Ordovician to Permian. The ocean was closed in the Middle to Late Triassic as inferred from the metamorphic ages of eclogite and blueschist that occur nearby and seem to have formed from the protolith of the Permian ophiolitic melange. The ophiolitic mélange in central Qiangtang block could be the western extension of the Sanjiang Paleo-Tethys ophiolite. A tectonic framework of the Qiangtang block and its implications will be presented.

49-4 15:50 Sarifakioglu, Ender

THE IZMIR-ANKARA-ERZINCAN SUTURE ZONE AS A PACIFIC-TYPE SUBDUCTION-ACCRETION COMPLEX IN THE TETHYAN REALM

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We present new structural field observations and geochemical, biostratigraphic and geochronological data from the *Izmir-Ankara-Erzincan Suture Zone* (IAESZ) in northern Turkey, and introduce a regional tectonic model for its geological evolution as one of the major subduction-accretion complexes in the Tethyan realm of the eastern Mediterranean region. The IAESZ runs across the entire length of northern Anatolia and connects with the Vardar suture zone in the Hellenides to the west and the Sevan-Akera suture zone in the Lesser Caucasus to the east. It separates the Sakarya microcontinent of the Rhodope-Pontide tectonic belt in the north from the Tauride ribbon continent and the Central Anatolian Crystalline Complex (CACC) to the south. Locally well-preserved ophiolite sequences along the IAESZ include depleted harzburgite, ultramafic cumulates, layered to isotropic gabbros, doleritic to plagiogranitic dikes and lava flows, and occur in km-size blocks within a sheared serpentinite or shaly matrix as part of ophiolitic mélanges (i.e. the Ankara mélange). Both these ophiolitic blocks and the matrix rocks commonly display structural fabrics indicating south-directed shearing. Ophiolitic units range in age from Mississippian (Refahiye ophiolite) to Plienbsbachian-Toarcian (Edige-Eldivanli) and Cenomanian (Çorum), suggesting that fragments of oceanic lithosphere with the late Paleozoic, early Jurassic and early Cretaceous ages were integrated as tectonic sheets into the IAESZ during its evolution as a south-facing and southward growing accretionary prism complex. These ophiolitic fragments have MORB and IAT (island arc tholeiite) geochemical affinities, which indicate their origin as mid-ocean ridge and SSZ-generated oceanic lithosphere. Large blocks (locally >10-km-long) of tholeiitic-picritic lava flows intercalated with pelagic limestone also occur within the IAES as fragments of a large oceanic plateau (LIP), which was accreted into the subduction-accretion system in the late Cretaceous. Late Cretaceous volcanic and volcaniclastic rocks with basaltic-, basaltic-andesitic, andesitic and trachyandesitic compositions overlie the mélange units, and represent calc-alkaline to shoshonitic, island arc products. Campanian-Maastrichtian to Paleocene epiclastic and flysch-type sandstone-shale, marl-reefal limestone sequences locally overlie the mélange and island arc volcanic units, and represent forearc sediments that were deposited in local basins developed directly on the accretionary prism complex. The IAESZ, Sakarya, Tauride and CACC units are all overlain by post-collisional Ypresian-Lutetian volcanic and volcaniclastic rocks, constraining the timing of the final suturing event along the IAESZ as the latest Paleocene-early Eocene. Much of the tectonic evolution of the IAESZ involved subduction-accretion processes in intra-oceanic conditions (far from an adjacent continental margin) that are reminiscent of the subduction-accretion systems in the SW Pacific.

49-5 16:10 Rojay, Bora

TECTONIC EVOLUTION OF THE CRETACEOUS OPHIOLITIC MÉLANGE (THE “ANKARA MÉLANGE BELT”) DURING LATE CRETACEOUS-PRE- MIOCENE PERIOD

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The so called “Ankara Mélange Belt” being a continuous deformational belt is situated on tremendous Alpine-Himalayan mountain chain between the Mesozoic-Paleogene Black Sea Magmatic Arc in north and Anatolide-Tauride Belt in south in northern Turkey, that links the Vardar Zone (Balkans) to Sevan-Akera Zone (Lesser Caucasus).

The belt is differentiated into three imbricate tectonic subbelts as i) Paleozoic metamorphics that are unconformably overlain by Triassic clastics, ii) Triassic Karakaya Complex (Mélange a blocchi calcarei) that is unconformably overlain by Liassic clastics, and iii) Cretaceous Ophiolitic Mélange (Mélange a blocchi ofiolitici).

The Cretaceous ophiolitic mélange is composed of Cretaceous ultramafics, Valanginian to Barremian pillow basalts of seamounts, Late Barremian - Early Aptian biodetrital carbonates of atolls, Oxfordinian-Turonian radiolarites and associated Cenomanian-Turonian hemi-pelagic basinal sequences, and Callovian to Aptian-Cenomanian platform carbonate blocks which all set in a highly sheared-brecciated, place to place detrital matrix. An important issue is the missing of Dogger age carbonate blocks or sequences in the Cretaceous ophiolitic mélanges. As being a dynamic mass, the age is of the ophiolitic mélanges based on the age of constituents of the mélanges and bracketed by closely related Cretaceous basins situated structurally above. These relationships reveal an age interval of post-Albian-Aptian to Maastrichtian in northern Central Anatolia.

Collectively, the sea-floor spreading in northern Anatolia should have started prior to the evolution of the seamount (dated as Late Valanginian - Barremian) and younger than the Liassic rifting. The triggering of the carbonate platform can be the voices of initiation of subduction of the northern Neo-Tethys which is the period of Valanginian to Aptian times. The accreted dynamic mass overthrusted onto the Maastrichtian-Paleogene basinal sequences and thrusted onto Upper Miocene mudrocks with southward vergence in Ankara-Amasya region (northern central Anatolia) and back thrusted onto post-Middle Eocene – pre-Miocene sequences with northward vergence in Amasya region (east of central Anatolia) to eastern Pontides.

49-6 16:30 El Bahariya, Gaafar A.

ON THE CLASSIFICATION AND ORIGIN OF THE NEOPROTEROZOIC OPHIOLITIC MELANGE OF THE CENTRAL EASTERN DESERT, EGYPT: GEOLOGICAL AND GEOCHEMICAL STUDIES

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The Eastern Desert of Egypt is a part of the Neoproterozoic Arabian–Nubian Shield (ANS). Neoproterozoic ophiolites and ophioitic mélange are common in the Arabian–Nubian Shield (ANS). Field geology, petrography, whole rock chemistry and mineral chemistry have been used to investigate the petrology and origin of the ophiolitic rocks and their significance in the classification and origin of the ophiolitic mélange of the central Eastern Desert of Egypt.

Different occurrences of ophiolitic melange in the Central eastern Desert of Egypt have subjected to investigation. The melange is composed of exotic and native blocks and fragments of variable sizes and types set in a fine sheared volcaniclastic matrix. The predominant exotic blocks in the mélange are mainly ophiolitic and include serpentinites and metamorphosed ultramafics, metagabbros, massive and pillowed metabasalts and pelagic sediments. These ophiolites commonly occur as dismembered blocks and fragments, together with native fragments of metavolcanics and their metapyroclastic counterparts. Ophiolitic blocks and fragments of the ophiolitic melange occur as mountain-size sheets and blocks, tectonic slices, blocks-in-matrix, and fragments up to boulder size. Based on the mode of occurrences of these exotic ophiolitic components, the ophiolitic mélange of the Central Eastern Desert is classified and mapped into tectonic mélange, olistostrome and olistostromal mélange.

The chemical analyses of primary chrome spinels in metamorphosed ultramafic rocks have been used for petrogenetic and petrotectonic indications. Compositional variation of the investigated chrome spinel clearly indicates three distinct groups based on their cr#: group I has low Cr# (0.3-0.42), group II has moderate Cr# (0.45-0.68), whereas group III has high Cr# (0.78-0.88). Two types of ultramafic rocks in the ophiolitic mélange have been recognized, which display mid-ocean ridge (MOR) and suprasubduction zone (SSZ) tectonic setting. The MOR-type rocks include lherzolite and Cpx-bearing harzburgite with low-Cr# (<0.6), whereas the SSZ-type rocks include the Cpx-free harzburgite and dunite with high-Cr#. Ophiolitic metabasalts mostly define a subalkaline suite characterized by low K and moderate to high Ti contents, that has tholeiitic affinities.

The metamorphosed ultramafic represent fragments of oceanic lithosphere that formed and/or modified in an arc/back-arc environment and are comparable to those of ophiolitic harzburgite and Alpine ophiolites. The ophiolitic metabasalts within the mélange show similarity to MORB and marginal basin tectonic setting. The whole rock associations of the ophiolitic melange have been subjected to different events of deformation and metamorphism. Ophiolitic components have incorporated into the mélange through sedimentary and/or tectonic processes. Back-arc or inter-arc basin is favored to be the possible site for the formation of the ‘ophiolitic mélange’.

SESSION NO. 50, 14:30

Friday, 8 October 2010

Ophiolites, blueschists, and suture zones. Part 4 (*Ofiyolitler, mavisistler ve kenet kusaklari*)

METU Convention and Cultural Centre, Salon B

50-1 14:30 Furnes, Harald

GEOCHEMICAL AND TECTONIC EVOLUTION OF A TRENCH-DISTAL BACKARC OPHIOLITE, SOLUND-STAVFJORD COMPLEX (443 MA), IN THE WESTERN NORWEGIAN CALEDONIDES

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The late Ordovician (443 Ma) Solund–Stavfjord ophiolite complex (SSOC) and associated rocks exposed in the southwest Norwegian Caledonides display characteristic features of an oceanic crust developed in a trench-distal backarc basin adjacent to a continental margin, analogous to the modern Andaman Sea. The structural architecture of the SSOC complex, particularly the orientation of its sheeted dike complex, suggests two different stages of ocean-floor spreading during its evolution. The oceanic crust in the younger domain contains pillow lavas, massive sheet flows and hyaloclastites, NE-trending sheeted dikes, and high-level isotropic gabbros. The proportions of pillow lava to massive sheet flows, the thick (~1.2 km) sheeted dike complex, and the hydrothermal alteration patterns as defined by $\delta^{18}O$ data are reminiscent of the modern intermediate-spreading oceanic crust (e.g. the 5.9 Ma Costa Rica Rift). The metabasaltic rocks in this domain are predominantly Fe-Ti basalts of N-MORB composition and show a large range in their incompatible (e.g. Zr) and compatible (e.g. Cr) element contents as a result of magma mixing and fractional crystallization. Insignificant variations in the Nd-isotopic character of these rocks suggest derivation of their magmas from an isotopically homogenous melt source. Abrupt changes in their chemostratigraphy within short distances along-strike of the ophiolite indicate, however, magma delivery from small, separate melt lenses that evolved independently of each other beneath the spreading axis. The oceanic crust in this domain developed along a rift system that propagated northeastward (in the present coordinate system) in a late Ordovician backarc basin, similar to the tectonics of the modern Lau Basin. The pre-existing oceanic crust in this basin is represented by the older domain, consisting of NW-trending sheeted dikes and massive to layered gabbros.

The extrusive sequence in the SSOC locally contains phyllite intercalations, and is conformably overlain by continentally derived quartz-rich meta-sandstone that contains N-MORB basaltic lavas and shallow-level intrusions. These late-stage igneous rocks in the sedimentary cover show weak subduction geochemical signatures, indicating their formation in a basin that was in close-proximity to continental crust on-land. The occurrence of calc-alkaline lavas and sedimentary, serpentinite-bearing mélanges and olistrostromes, tectonostratigraphically beneath the SSOC attests to the presence of an island arc and associated accretionary prism complex at the time of the evolution of the backarc basin. During the emplacement of the SSOC onto the Baltica continental margin in the middle Silurian, a different mélange unit that contains mafic-ultramafic components from different structural levels of the ophiolite, developed beneath the advancing ophiolite nappe. The evolutionary history of the SSOC thus involves oceanic crust formation in a short-lived (< 20 m.y.), trench-distal, continent-proximal backarc basin during the late closing stage of the Iapetus Ocean.

50-2 14:50 Machi, Sumiaki

SERPENTINIZATION AND METASOMATISM IN THE MANTLE WEDGE; A CASE STUDY IN THE UST'-BELAYA OPHIOLITE

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The Ust'-Belaya ophiolite is exposed in the 80 km x 40 km area on the south of Ust'-Belaya (N65 30', E173 17'), Far East Russia (Sokolov et al., 2003, Geol. Soc. London, Spec. Publ., 218, 619-). The associated limestone suggests Devonian or older age of this ophiolite. It is an important character of this ophiolite that glaucophane-bearing rocks occur. Here we report the petrographical features and mineral chemistry of the peridotite from the Ust'-Belaya ophiolite and discuss about their metamorphism and metasomatism.

Mantle section of the Ust'-Belaya ophiolite is composed of fertile lherzolite to moderately depleted harzburgite. Those peridotites are characterized by significant hydration and low grade metamorphism, which causes formation of secondary olivine, secondary cpx, amphibole, chlorite, antigorite, and opaque minerals. They are divided into three major types on the basis of the mineral assemblage; (1) olivine + amphibole + chlorite +/- talc, with or without relict minerals, (2) olivine + antigorite + amphibole + chlorite and (3) olivine + antigorite + chlorite +/- secondary clinopyroxene. In some of antigorite-bearing peridotites, olivine shows an apparent “cleavage”. Basically secondary olivine occurs along with antigorite replacing primary olivine or amphibole replacing primary pyroxene. Such petrographical features resemble those of the antigorite-bearing serpentinite from Mariana forearc (Ohara & Ishii, 1998, Island Arc, 7, 541-; Murata et al., 2009, Geosphere, 5, 90-).

Amphiboles show different compositional trend corresponding to the mineral assemblage. Amphiboles in mineral assemblage (1) are calcic amphiboles, showing a pargasite/edenite-tremolite trend. On the other hand, amphiboles in mineral assemblage (2) show a richterite-tremolite trend with some pargasites.

Pargasite/edenite in the mineral assemblage (1) and richterite in the mineral assemblage (2) may be formed at relatively high temperature and low temperature, respectively. Several amphiboles in the mineral assemblage (2) shows zoning composed of pargasitic core, tremolitic mantle and rihiteritic rim. This zoning indicates a multiple-stage addition of Na_2O by fluid.

Relict minerals of the Ust'-Belaya peridotite do not resemble those of common forearc peridotite (Parkinson & Pearce, 1998, J. Petrol., 1577-) in terms of their degree of partial melting, suggested from Cr# (0.1-0.6) in spinel. On the other hand, they are similar to forearc peridotite in terms of their low equilibrium temperature suggested from Mg# in spinel and pervasive low-grade metamorphism as described above.

Glaucophane-bearing rocks, low equilibrium temperature of peridotites and the evidence of fluid-peridotite interaction are suggesting the Ust'-Belaya peridotite may represent a fragment of the Early Paleozoic forearc mantle wedge, which has been effectively cooled and metasomatized by H_2O-rich fluids released from the subducting slab. Absence of highly depleted peridotite suggests that expected subduction zone had been “cold subduction zone”

50-3 15:10 Morishita, Tomoaki

PETROLOGICAL AND GEOCHEMICAL EVOLUTION OF THE MOHO IN A JURASSIC SUPRASUBDUCTION ZONE OCEANIC LITHOSPHERE: EASTERN MIRDITA OPHIOLITE, ALBANIA

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We examined the peridotite massifs, mafic-ultramafic cumulate sections, and late melanocratic intrusions in the Eastern Mirdita Ophiolite (EMO, Albania), which includes ~700 meters of volcanic rocks in the upper extrusive sequence showing island arc affinities. Clinopyroxene porphyroclast-bearing harzburgites (Cpx-harzburgite hereafter) occur structurally in the lower parts of the peridotite massifs, whereas harzburgitic and dunitic peridotites with chromitite bands and layers are more abundant in the structurally upper levels. Orthopyroxenite occurs as dikes and/or vein networks in all structural levels within the peridotites, although more abundantly in the uppermost sections. Orthopyroxenite commonly crosscuts the foliation planes in the peridotites and lithological boundaries between the chromitite-bearing dunites and harzburgites, suggesting its late stage formation. Major and trace element compositions of minerals in the Cpx-harzburgites indicate that these peridotites were formed as residue after partial melting. Harzburgites have more depleted signatures in major element compositions in comparison to the Cpx-harzburgites. Light rare earth element (LREE)-enrichment in clinopyroxene coupled with silicate mineral inclusions in spinels indicate that their host harzburgites were produced as a result of enhanced partial melting of depleted peridotites that was facilitated by infiltration of LREE-enriched, slab-derived fluid flux. Dunites and chromitites were produced by melt-mantle interactions, whereas orthopyroxenites by the reaction of pre-existing olivine with hydrous, orthopyroxene-saturated melts that were produced by assimilation of dissolved pyroxene during formation of dunites. The ultramafic-mafic cumulate sequence just above the peridotite massifs mainly consists of dunite, wehrlite and gabbro-norite, indicating early crystallization of olivine and clinopyroxene before plagioclase. This crystallization sequence can be explained by magma crystallization at crustal pressures under hydrous conditions (i.e. island-arc setting). Melanocratic, massive intrusive rocks occur in gabbroic rocks and are characterized by large, poikilitic orthopyroxene crystals containing numerous, rounded olivine grains. Chemical compositions of spinels in the melanocratic intrusive rocks are relatively high in the Cr#(=Cr/Cr+Al) atomic ratio) (Cr#＞0.53) and low in TiO_2 contents, and are similar to those in arc-related rocks. The crystallization sequence combined with high Cr# spinel suggests that the melanocratic intrusive rocks were formed from melts which were produced with high degrees of partial melting of peridotites. We infer that orthopyroxenites and late melanocratic intrusions are genetically associated with the late stage boninitic dikes and lavas in the uppermost crustal section of the EMO. The lower crustal and upper mantle sections of the EMO appear to have formed first in a seafloor spreading setting and then to have undergone metasomatism and repeated melting due to the infiltration of slab-derived fluids in an island arc setting.

50-4 15:50 Tremblay, Alain

THE VARDAR ZONE AS A SUTURE FOR THE MIRDITA OPHIOLITE : CONSTRAINTS FROM THE STRUCTURAL ANALYSIS OF THE KORABI ZONE, NE ALBANIA

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The Dinaro-Hellenic foldbelt is the result of Mesozoic–Tertiary convergence and continental collision between the Eurasian and Adriatic plates after the closure of the Tethys ocean. In

Albania, it consists of (1) a Western zone of Early Oligocene–Middle Miocene fold-and-thrust nappes derived from proximal sedimentary facies of Adria; (2) a Central belt made up of an ophiolitic nappe, the Mirdita ophiolite, and underlying thrust slices of continental and oceanic origin; and (3) an Eastern zone, the Korabi zone, of Hercynian basement unconformably overlain by Permian–Lower Triassic rift deposits and Middle Triassic–Upper Jurassic platform carbonates. The Korabi zone and correlative rocks of former Yugoslavia are interpreted either as a micro-continent originally located between two separate oceanic basins, the Mirdita–Pindos oceanic basin to the west and the Vardar Zone oceanic basin to the east, or as a tectonic window below a single ophiolitic thrust sheet in which the most distal paleogeographic domains of Adria are exposed. The age of the Mirdita ophiolite is known from U/Pb zircon ages clustering between 160 and 165 Ma in plagiogranite and quartz-diorite intrusions (Dilek et al., 2007). The ophiolite has been thrusted over a metamorphic assemblage derived from both continental and oceanic domains, including a metamorphic sole that yield $^{40}Ar/^{39}Ar$ ages varying from 171 to ca. 162 Ma, and which record the age of obduction. The root zone of the Mirdita ophiolite and correlative terranes of the Dinarides has been, and still is, a source of debate; some argue that it is a far-travelled thrust sheet that roots eastward into the Vardar zone (Schmid et al., 2008) whereas others believe that Albanian and Greek ophiolites are doubly-verging (West- and East-directed) terranes forming the remnants of a small Jurassic oceanic basin formed between a Pelagonian block to the East (the Korabi zone) and the Apulian (Adria) passive margin to the west (Dilek et al., 2007). The metamorphic sole of the Mirdita ophiolite yields ambiguous shear-sense indicators and precludes precise and unambiguous characterization of the obduction kinematics.

A 20-km long structural transect along the Luma River of NE Albania has been performed in order to put kinematic constraints on regional deformation in the Korabi zone. The metamorphic grade in both the Hercynian basement and overlying Permian-Triassic (P-T) cover sequence is at greenschist facies. The P-T cover sequence shows two phases of regional deformation, D_1 and D_2. D_1 is associated with a NE-trending, SE-dipping regional schistosity that is axial-planar to NW-verging F_1 folds and associated with SE-dipping thrust/reverse faults, which locally over-thrust the Hercynian basement onto the P-T cover rocks. D_2 is characterized by a heterogeneously-developed, NNE-trending sub-vertical crenulation cleavage related to upright F_2 folds. There are currently no isotopic age constraints for deformation and metamorphism in the Korabi zone of Albania. Zircon fission-tracks ages yielding 150-125 Ma (Muceku et al., 2008) suggest, however, that both the P-T sequence and the Hercynian basement were at temperatures below ca. 240ºC at that time, and that the greenschist-grade metamorphism has to be Early Cretaceous or older. K-Ar muscovite and biotite ages from adjacent countries, where the eastern edge of the Korabi zone and/or the leading edge of West-Vardar terranes are exposed, vary between 148 and 130 Ma (Most, 2003). This suggests that D_1 is Late Jurassic or older, which is slightly younger than but consistent with Middle Jurassic ages preserved in the metamorphic sole of the Mirdita ophiolite. Therefore, an East-dipping subduction zone and a continent-ocean suture located East of the Mirdita ophiolite, in the Vardar Zone, can have accounted for the top-to-West structural polarity of regional deformation in the Korabi zone, in agreement with the inferred east-dipping subduction and west-directed obduction (the «Eohellenic orogeny»). Such an interpretation is moreover consistent with (1) the occurrence of a major, Mio-Pliocene west-dipping normal fault system at the western boundary of the Korabi zone (Muceku et al. 2008); the Mirdita ophiolite lies in the immediate hanging wall of these normal faults, suggesting that it was located higher in the crust and structurally above the Korabi zone in pre-Miocene times, and (2) the fact that the Mirdita ophiolite forms a tectonic sheet that bevels towards the west and thickens eastward, as expected for the emplacement of a West-verging nappe developed over east-dipping subduction.

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50-5 16:10 Aldanmaz, Ercan

MULTI-STAGE EVOLUTION OF THE NEO-TETHYAN OCEANIC UPPER MANTLE: EVIDENCE FROM OS ISOTOPE AND HSE SYSTEMATICS OF SPINEL-PERIDOTITES FROM SW TURKEY

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Ophiolites exposed across the western Tauride belt in SW Turkey represent fragments of oceanic lithosphere emplaced following the closure of the Neotethys Ocean during the Late Cretaceous. The mantle sections of the ophiolites contain peridotites with diverse suites of geochemical signatures indicative of residual origin by melt depletion in both mid-ocean ridge (MOR) and supra-subduction zone (SSZ) settings. We examined Re and Platinum Group Element (PGE) abundances and $^{187}Os/^{188}Os$ systematics of peridotites in order to identify the nature of the mantle source and the processes effective during variable stage of melt extraction in these discrete tectonic settings. The MOR peridotites are marked by chondritic Os/Ir and Pt/Ir ratios and slightly supra-chondritic Pd/Ir and Rh/Ir ratios, indicating a mantle region compositionally similar to estimates for the Primitive Mantle (PM). Moderate enrichment in PPGE/IPGE ratios with respect to the PM composition in some of the samples, however, reflects compositional modification by sulfide addition in some parts of the mantle during post-melting processes. The $^{187}Os/^{188}Os$ isotopic compositions of the MOR peridotites range from 0.12227 to 0.12544. The sub-chondritic $^{187}Os/^{188}Os$ isotope ratios (γOs = -3.4]) in the most depleted and chemically undisturbed samples are accompanied by depletion in Re/Os ratios, suggesting long-term differentiation of oceanic upper mantle by continuous melt extraction. The observed positive covariance between $^{187}Re/^{188}Os$ and γOs and higher PPGE and Re abundances than expected for low-degree melting (< 9%) residues can most likely be explained by interaction of solid residues with MORB melts most probably produced by melting of relatively more radiogenic components in the mantle source. The SSZ peridotites, on the other hand, display larger variations in relative PGE and Re abundances, reflecting a more complex evolutionary history. Significantly wide range of Os isotopic ratios (0.12086 to 0.13182; γOs = -4.8 to +3.8) in these high-degree melting (> 13%) residues seems to be consistent with multi-stage evolution of oceanic upper mantle and suggests that parts of the lithospheric mantle contain material that have experienced ancient melt extraction processes (~1Ga) which created time-integrated depletion in Re/Os ratios, while some other parts display evidence indicative of interaction with melts from a mantle reservoir carrying a radiogenic component, most probably created by addition of radiogenic ^{187}Os during fluid assisted re-melting of previously depleted mantle in a SSZ setting.

50-6 16:30 Shafaii Moghadam, Hadi

A TRIP TO THE ZOO: ZAGROS OPHIOLITE OVERVIEW

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The Zagros Fold-and-Thrust belt of SW Iran is among the youngest continental convergence zones on Earth, continuing to accommodate ~20mm/yr of convergence between Arabia and Eurasia. This belt extends NW-SE from eastern Turkey, through northern Iraq and the length of Iran to the Strait of Hormuz and into northern Oman. The Zagros Fold-and-Thrust belt reflects the shortening and off-scraping of thick sediments from the northern margin of the Arabia platform, essentially behaving as the accretionary prism for the Iranian convergent margin. Distribution of ophiolites in the Zagros orogenic belt defines the northern limit of the evolving suture between Arabia and Eurasia and comprises two parallel belts: 1- Outer Zagros Ophiolitic Belt (OB) and 2- Inner Zagros Ophiolitic Belt (IB). These ophiolite belts contain abundant, complete (if disrupted) ophiolites. Mantle sequences include tectonized mantle harzburgites and rare ultramafic-mafic cumulates as well as isotropic gabbros as lenses and isolated dikes within mantle peridotite. Crustal sequences include gabbros, sheeted dike complexes, pillowed lavas, and felsic extrusives. All the inner and outer Zagros ophiolites are overlain by late Cretaceous pelagic limestone. Limited radiometric dating indicates that OB and IB formed at the same time during the late Cretaceous. All components of outer and inner Zagros ophiolites show strong supra-subduction zone affinity from mantle harzburgites to overlying crustal lavas. This supra-subduction zone affinity is distinguished by spinel and orthopyroxene compositions of mantle harzburgites as well as by REE and trace elements characteristics of overlying lavas. These similarities compel the conclusion that IB and OB once defined a single tract of forearc lithosphere that has since been disrupted by exhumation of metamorphic ricks of the Sanandaj-Sirjan zone. Our data for the OB and IB along with better-studied ophiolites in Cyprus and Oman compel the conclusion that a broad and continuous tract of fore-arc lithosphere was created during the late Cretaceous as the magmatic expression of a newly-formed subduction zone developed along the SW margin of Eurasia. This subduction zone has persisted for 85 Ma, forming the Urumieh-Dokhtar arc of Iran. The development of this subduction zone has played a key role in the evolution of the region.

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