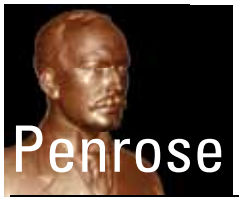

Penrose Conference Report

Deformation, Fluid Flow, and Mass Transfer in the Forearc of Convergent Margins

Il Ciocco, Castelvecchio Pascoli, Lucca, Italy
25–31 March 2012.

CONVENERS

Donald Fisher, *Dept. of Geosciences, Penn State University, University Park, Pennsylvania, USA, dmf6@psu.edu*

César Ranero, *Barcelona Center for Subsurface Imaging, Barcelona, Spain, cranero@cmima.csic.es*

Paola Vannucchi, *Dipto. di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italia, paola.vannucchi@unifi.it*

ORGANIZING COMMITTEE

Eli Silver, Univ. of California at Santa Cruz; Demian Saffer, Penn State Univ.; Greg Moore, Univ. of Hawaii; Kelin Wang, Univ. of Victoria; Onno Onken, GFZ Potsdam; Timothy Dixon, Univ. of Miami; Carlo Doglioni, Univ. di Roma "La Sapienza"; Claudio Faccenna, Univ. di Roma 3; Jean-Yves Collot, Geoazur Nice; Francesca Remitti, Univ. di Modena e Reggio Emilia; Giancarlo Molli, Univ. di Pisa; Roland von Huene, Univ. of California at Davis; Serge Lallemand, Geosciences Montpellier; Sean Willett, ETH Zurich.

INTRODUCTION

This conference was held 25–31 March at Il Ciocco, a venue in the hills overlooking the town of Barga, Italy, at the foot of the Apuane Alps. The meeting location was ideally suited for field trips, including a two-day pre-meeting field trip that focused on the sub-Ligurian thrusts and associated underthrust sediment section, and a one-day post-meeting trip in the Apuane Alps that related to the exhumed metamorphic rocks of the underthrust continental margin. The conference brought together 64 scientists from 15 different countries.

The purpose of this Penrose Conference was to explore recent developments related to deformation, fluid flow, and mass transfer in the forearc of convergent plate boundaries and their potential relationships to earthquake phenomena and seismogenesis. The meeting included onshore studies, marine observations, and insights from geodynamic modeling. A number of time scales were considered, from the short-term secular variations of the seismic cycle to the long-term evolution of structure and topography. Talks and posters were grouped into four themes: (1) Short and Long Time Scales of Deformation, (2) Structure of Margins and Relationship to Seismicity, (3) Deformation Processes and Seismicity in the Forearc, and (4) Fluids and Forearc Properties.

Short and Long Time Scales of Observation

This session addressed deformation and deformation rates in forearcs at a range of time scales. It began with a keynote presentation by K. Wang that explored the variations in stress and deformation that accompany the earthquake cycle, with systematic variations in the nature of upper plate seismicity and the GPS velocity field (relative to the upper plate) over the duration of the interseismic period. Other related issues that generated discussion were the significance of normal faults in forearcs and the potential for dynamic weakening at high velocities where rate-state friction behavior may not apply. Talks in this session addressed the evolution of splay faults and the conditions for splay fault reactivation, the interpretation of the regional velocity field in Central America, and the rupture characteristics of tsunamigenic earthquakes that lead to rapid slip in the shallow updip region of the forearc. Overall, this session emphasized that the shallow segment of plate boundary faults has complex behavior and can both store elastic strain and slip coseismically during large earthquakes.

Structure of Margins and Relationship to Seismicity

This session highlighted examples from convergent margins around the world, including the Sumatra, Nankai, Middle America, Makran, Aleutian, Mediterranean, Colombia, Ecuador, Hispaniola, and Apennine margins. The keynote talk by J.-Y. Collot focused on structures within the underthrust sediment sequence observed in a high-resolution seismic reflection profile of the Ecuador margin. Extensional structures are observed at shallow depths that give way to shortening features further down dip. It was noted that extensional structures are typical of the early history of underthrust rocks. Such structures were also observed, for example, on the pre-meeting field trip in blocks contained within the strata that were incorporated in the plate boundary shear zone beneath the Ligurian units.

Discussion followed about when the term "subduction channel" is appropriate when referring to the material that is underthrust beneath the forearc. Introduced into the literature by Shreve and Cloos in 1988, the term originally referred to a deforming channel along the plate boundary where combinations of shear flow and pressure-driven flow could lead to a variety of behaviors, including two-way flow regimes where material is exhumed by return flow beneath the forearc wedge. This led to a debate—that ended inconclusively—about how narrowly the term "subduction channel" should be defined and whether it is a useful term when referring to the subducting sediments at relatively shallow depths where much of the slip may be restricted to a narrow shear zone. The discussion made apparent the need for higher geophysical resolution at depth to resolve these issues.

Participants. See page 28 for a list of names.

F. Tilmann presented a second keynote talk that emphasized the segmentation of the subduction interface both along-strike and downdip as illustrated by seismicity along many convergent margins. He also showed the difficulty of using past performance as an indicator of future behavior. There were numerous examples of the impact that lateral variations in the incoming plate have on the deformation and fluid flow in the upper plate. New studies of the Mediterranean basin described the feedbacks between sedimentation, accretion, backarc basin formation, slab rollback, and the seismic hazard potential of the segmented arcs that make up this plate boundary. N. Bangs presented preliminary results of a recent 3-D seismic survey of the forearc wedge offshore Costa Rica that showed depth-related variations in structural style with extension at shallow levels and contraction at deeper levels.

Deformation Processes and Seismicity in the Forearc (and Deeper)

This session began with a keynote presentation by S. Lallemand on how the deformation of the downgoing oceanic plate, the state of stress of the upper plate as an indicator of elastic strain accumulation, and/or the "subduction channel" play(s) a role in the seismogenesis of subduction zones, with a global assessment of the upper and lower bounds of the seismogenic zone in terms of slab dip plate velocity and age of plate at the trench. The role of seamounts in seismogenesis and deformation of the upper plate was emphasized by several speakers and poster presenters because seamounts appear to show a complex behavior as nucleation points to earthquakes or barriers to rupture propagation. One topic of discussion that generated great interest was the relationship between permanent deformation, such as normal or thrust faults with a long, complicated slip history, and the stress variations associated with the earthquake cycle. S. Willett presented a keynote talk in which he used thermomechanical numerical models of forearc basin evolution to show that strata infill geometry could be used to evaluate the competition between sedimentation, which stabilizes the forearc, and the deformation that occurs outboard of the stable region. There was some consideration of the impact of tectonic erosion and accretion on seismicity in subduction zones, as well as new estimates of erosion rates based on forearc subsidence from the recent CRISP-IODP drilling offshore Costa Rica that are significantly faster than previous estimates. This session included contributions on deformation processes from Nankai, Tohoku, Costa Rica, and New Zealand.

Fluids and Forearc Properties

One of the highlights of this session was new high-resolution bathymetry data from the Costa Rica Margin (E. Silver, J. Kluesner) that was used to identify scarps and seeps that indicate focused fluid flow. Posters presented results of consolidation experiments on fluid flow parameters, coupled models of fluid flow and transport, analysis of velocity porosity relationships in different parts of the forearc system, and field studies of fluid alteration.

Pre-Meeting Field Trip in the Ligurides

The two-day pre-conference field trip, led by F. Remitti and P. Vannucchi, focused on the east side of the Appenine chain, which corresponds to the shallowest part of the complex built by west-directed subduction. In this region, the Late Cretaceous–middle Eocene intraoceanic accretionary prism, built at the front of the European plate and represented by the External Ligurian Units, sits on top of Oligo-Miocene foredeep turbidites of the subducting Adria plate. Sandwiched between the two are more-or-less chaotic units of early Cretaceous–middle Miocene rocks forming the Sestola-Vidiciatico Tectonic Unit interpreted as the early-middle Miocene interplate shear zone—the object of the trip. During the first day, the field trip was organized around providing examples of the offscraped and frontally accreted oceanic and trench sediments forming the Ligurian prism, as well as the slope sediments unconformably deposited on top. On the second day, the field trip examined the units forming the plate boundary shear zone underthrust beneath the Ligurian units and overthrust above the Adriatic foredeep turbidites. Participants concentrated on the deformation of these units as well as on the evidence for incorporation of blocks from the upper plate dissected by faults that record layer parallel extension.

Post-Meeting Field Trip in the Apuane Alps

The post-meeting field trip, led by G. Molli, provided the opportunity to examine structures and strain indicators from Apuane metamorphic rocks of the continental margin that were

deforming at the same time as the Sestola-Vidiciatico Tectonic Unit. These units were underthrust and underplated in the early-middle Miocene and finally exhumed during the development of extensional structures starting from the late Miocene. Special emphasis was given to the deformed breccias from spectacular quarries of the Carrara marble. The role of fluids and fluid-rock interaction during underplating and exhumation was discussed in the context of extensional deformation.

ACKNOWLEDGMENTS

We would like to thank the Tectonics Program of the National Science Foundation for support of graduate students and early career faculty. We would also like to thank the European Geosciences Union (EGU) for the support to P. Vannucchi and R. von Huene as EGU ambassadors. This meeting was cosponsored by the European Geosciences Union, the Italian Geological Society, the Spanish Ministry of Science and Innovation, and the U.S. National Science Foundation.

Participants: Tiago M. Alves, Nathan L. Bangs, Anne Bécel, Rocio Bernal-Olaya, Mirko Carlini, Wu-Cheng Chi, Irina Chursina, Mark Cloos, Jean-Yves Collot, Darrel S. Cowan, Stuart Crampin, Carlos Doglioni, Ake Fagereng, Donald M. Fisher, Marina Frederick, Thomas W. Gardner, Dibakar Ghosal, Sean S. Gulick, Kellen L. Gunderson, Peter J. Haeussler, Shuoshuo Han, Pierre Henry, Justin W. Herbert, Gaku Kimura, Joe D. Kington, IV, Jared Kluesner, Peter C. LaFemina, Serge Lallemand, Rachel Laver, Maureen A. LeVoir, Pilar Llanes, Yossi Mart, Kylara M. Martin, Lisa C. McNeill, Kathryn Metcalf, Raphaele Moeremans, Gregory F. Moore, Kristin Morell, Jason Phipps Morgan, Julia K. Morgan, Andrew Newman, Devon Anne Orme, Alina Polonia, César R. Ranero, Robert Reece, Francesca Remitti, Holly Rotman, Valenti Sallares, Julia Schneider, David W. Scholl, Eli A. Silver, Satish Singh, Gemma Smith, Telemaco Tesei, Frederik Tilmann, Harold J. Tobin, Joanne Tudge, Michael B. Underwood, Paola Vannucchi, Roland von Huene, Kelin Wang, Susanna I. Webb, Sean D. Willett, Lindsay Lowe Worthington, Asuka Yamaguchi, and Yuzuro Yamamoto.

United Nations Educational, Scientific and Cultural Organization

Two New UNESCO World Heritage Sites Selected for Globally Outstanding Geologic Values

During the 24 June–6 July 2012 United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Committee meeting in Saint Petersburg, Russia, two new UNESCO World Heritage Sites were selected for their globally outstanding geologic values: **Chengjiang Fossil Site, China,** and **Lena Pillars, Russian Federation.** The two sites were "inscribed" World Heritage under the World Heritage Convention criterion (viii): outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features. Twenty-six new sites total were added to the World Heritage List during the 2012 meeting in Saint Petersburg.

GSA plays a role in this process through its International Program. GSA International Liaison, Wesley Hill, assists UNESCO, the International Union of Geological Sciences (IUGS), and the International Union for Conservation of Nature (IUCN) by finding global geologic desk-top evaluators to write a review of the sites during the selection review process. Hill is currently working with the 2013 nominated sites and the review reporting process. Four sites have been nominated under criterion viii for the 2013 World Heritage selection process: Mount Etna, Italy; El Pinacate and Gran Desierto de Altar Biosphere Reserve, Mexico; Namib Sand Sea, Namibia; and Tajik National Park (Mountains of the Pamirs), Tajikistan. The 2013 World Heritage Site selections will be announced in June.

For more information on the newly inscribed 2012 UNESCO World Heritage Sites go to **http://whc.unesco.org/en/newproperties/.**