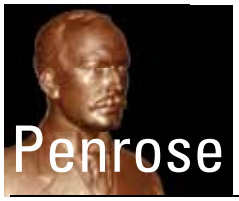

Comparative evolution of past and present accretionary orogens: Central Asia and the Circum-Pacific Urumqi, Xinjiang Uygur Autonomous Region, China

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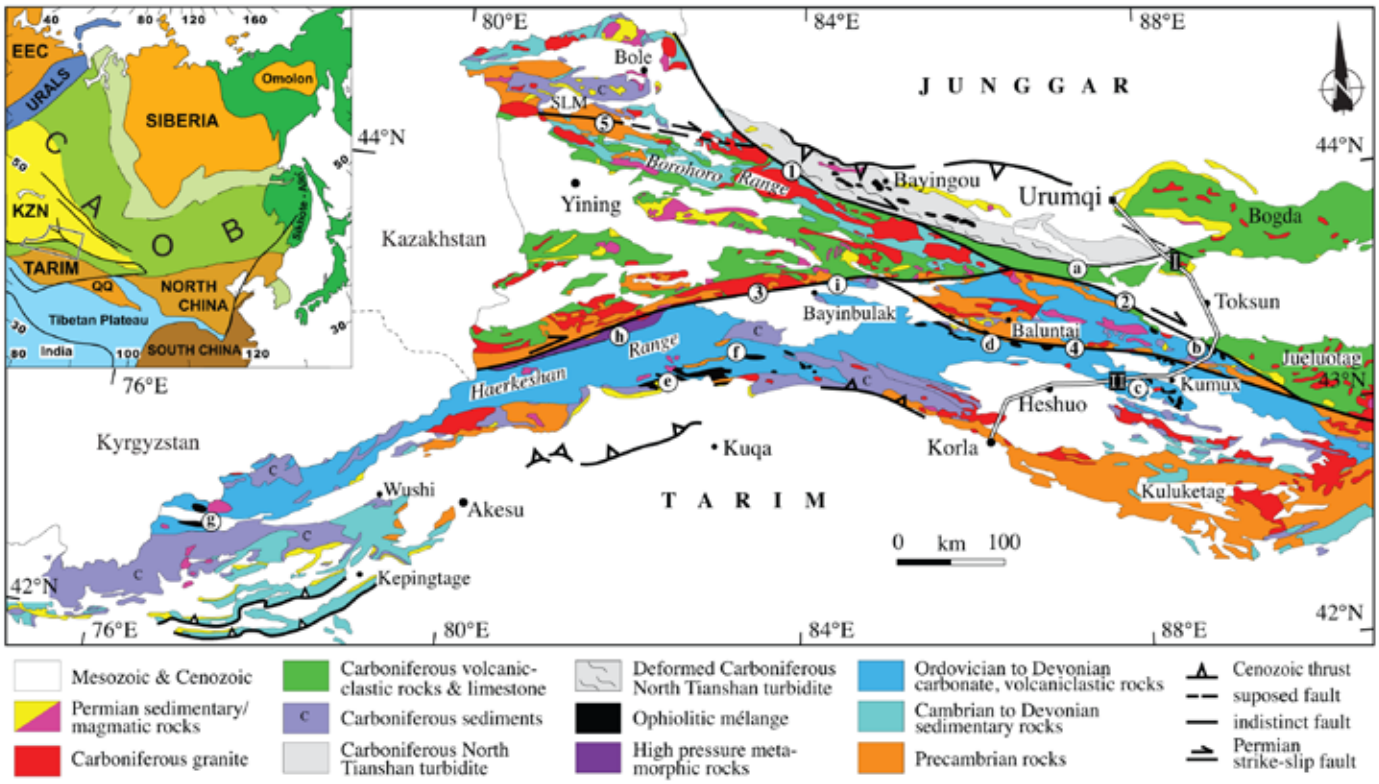
INTRODUCTION

The Central Asian Orogenic Belt (CAOB, also known as Altaids) is one of the largest accretionary orogens on Earth and evolved over some 800 million years, from the latest Mesoproterozoic to the early Triassic. It contains a record of geodynamic processes during a major episode of Neoproterozoic to Paleozoic continental growth. There has been much discussion about its evolution over the past 20 years, and models range from a single, giant arc system to accretion of multiple arc–backarc systems. The CAOB crust appears to comprise long chains of arcs and slices of older continental crust that extend for several hundreds to thousands of kilometers. Amalgamation of these linear crustal elements and their interactions with continental margins generated considerable Phanerozoic continental growth. Its large size, from the Pacific to the Urals, and its extent across six countries (China, Mongolia, Russia, Kazakhstan, Kyrgyzstan, and Uzbekistan) and many more language barriers have complicated orogen-wide comparisons, correlations, and understanding. Current tectonic models mostly see analogues with modern accretionary orogens. In view of the discovery of world-class mineral deposits, a wealth of new age and isotopic data, and much-improved possibilities for international cooperation, it was considered timely to discuss and compare the formation of the CAOB with that of modern accretionary orogens, such as the multiple arc terranes of the circum-Pacific in Indonesia, Melanesia, Taiwan, Japan, Alaska, and California. We hope that the multidisciplinary in-depth comparisons on which the conference was based will spur research and stimulate thinking about the tectono-magmatic evolution of the CAOB and lead to new concepts for accretionary orogeny in general and new strategies for finding mineral deposits. The conference brought together Asian, Russian, and Western geoscientists, and many issues about accretionary orogeny were addressed from the viewpoint of different expertise and methodologies, especially process-oriented comparisons between ongoing orogeny in the circum-Pacific region and geological observations in the CAOB. This conference provided a clearer path for future research in Central Asia and generated contacts that should lead to increased international collaboration.

This Penrose Conference was funded by the National Natural Science Foundation of China, the State Key Laboratory of Lithospheric Evolution of the Chinese Academy of Sciences (IGGCAS), National 305 Project Office Xinjiang, Uygur Autonomous Region of China, Chinese Academy of Geological Sciences, State Key Laboratory for Mineral Deposits Research, Nanjing University, Topo-Central-Asia (CC-1/4) Project of the International Lithosphere Program (ILP), the Centre for Russian and Central EurAsian Mineral Studies (CERCAMS) at the Natural History Museum, London, UK, and Gold Fields Corporation Inc. The 60 participants (including 6 students) who attended the conference came from Australia, China, France, Germany, Italy, Japan, Russia, the UK, and the United States.

VENUE

Urumqi, the capital of the Xinjiang Uygur Autonomous Region of China, was chosen as a meeting venue because it is almost in the center of the Central Asian Orogenic Belt and immediately adjacent to the well-exposed and snow-capped Tianshan (Heavenly Mountains), which were visited during the field trip preceding the discussion meeting. Participants assembled the afternoon of 4 September, and after welcome addresses by R. Zhu,



Geological map of the Chinese western Tianshan belt (after Wang et al. 2008; Lin et al., 2009). Numbers in circle refer to the main faults: 1, North Tianshan fault (NTF); 2, Main Tianshan shear zone (MTSZ); 3, Qingbulak-Nalati fault (QNF); 4, Sangshuyuanzi fault; 5, Jinghe fault. Capital letters correspond to localities cited in text: a, Houxia; b, Gangou-Mishigou; c, Yushugou; d, Guluogou-Wuwamen; e, Heiyingshan; f, Kulehu; g, Aheqi; h, Kekesu; i, Nalati. Roman letters stand for the excursion sections: I, Houxia section; II, Aiweiergou section; III, Gangou section; IV, Yushugou section; V, Cedaya section; VI, Duku road section. Inset shows location of the Tianshan Belt in Central Asia (modified from Jahn, 2004). Abbreviations: CAOB, Central Asian Orogenic Belt; EEC, Eastern European Craton; KZN, Kazakhstan; QQ, Qaidam-Qinling.

Geological map of the Chinese western Tianshan belt showing major tectonic units and excursion route for the Penrose Conference (after Wang et al., 2008, and our excursion guidebook).

director of IGGCAS, and B. Wang, Director of the National 305 Project Office, L. Shu of Nanjing University introduced the geology of the field trip with an overview talk on "Tectonic evolution of the Chinese Tianshan," which was followed by H. Hou's presentation of a seismic profile across the Tianshan titled, "Fine crustal structure beneath the junction of the western part of the southwest Tianshan Mountains and Tarim Basin, China."

FIELD TRIP AND PRESENTATIONS

The six-day Penrose Conference was divided into two parts. The first, from 5 to 7 September, was a three-day field trip across the Chinese Tianshan from Urumqi via Heshuo to Korla, which visited the well-exposed Central Tianshan Carboniferous Suture Zone, a Paleozoic ophiolitic mélange, and a northern Tianshan Permian pull-apart basin. Details of the outcrops visited as well as general models for the tectonic evolution of the Chinese Tianshan were presented in a guidebook, compiled by W. Lin of IGGCAS, and the book, along with an abstract volume of keynote lectures, is available online (ftp://penrose:penroseiggcas@159.226.119.207). During the evenings, participants discussed the geology visited and tectonic models for the Chinese and Kyrgyz Tianshan.

The second part, from 8 to 10 September, was a discussion session in the Mingyuan Newtimes Hotel in Urumqi, where all participants stayed. This meeting was held in a large hall, whose walls displayed 19 posters on geological and geophysical features of Central Asia, which were discussed during breaks. The first day was devoted to 18 overview presentations and discussions of accretionary orogens in the Circum-Pacific and the evolution of different parts of the CAOB, chaired by R. Seltmann, A. Kröner, R.J. Stern, and L. Zhang. The discussion centered on some fundamental problems, such as how to define continental (cratonic?) crust, how much really new and juvenile crust is produced in accretionary orogens, the life of an intra-oceanic arc and how to recognize it in a later orogen, and whether retreating orogens formed as a result of subduction rollback, such as the Tasmanides of eastern Australia and the ongoing evolution of the South Pacific east of Australia, are viable models for the CAOB.

The next two days were devoted to the following discussion themes, which were introduced by keynote presentations and followed by shorter topical contributions on aspects of the CAOB.

Theme 1: Ophiolites and oceanic crust; group leaders: J.W. Shervais and T. Kusky; overview talk by J.W. Shervais: "Supra-subduction zone (SSZ) ophiolites: The fore-arc connection and implications for orogenic belts." Much discussion was devoted to how to recognize upper and lower plate ophiolites, backarc versus forearc origins of ophiolites, the significance of ophiolitic mélanges, and that mafic/ultramafic rocks do not necessarily

mark sutures. T. Kusky briefly explained the differences between modern and ancient ophiolites and oceanic crust formed in different tectonic settings, and how the modern concept of ophiolites differs from the classic 1970s "Penrose" definition. This topic led to much discussion, especially about how to interpret ancient xenocrystic zircons found in some young oceanic crust and ophiolites.

Theme 2: Metamorphic rocks; group leaders: M. Brown and L. Zhang; overview talk by M. Brown: "Metamorphism in accretionary orogens." This talk generated hot debate about whether ridge subduction was the primary source of heat for high-temperature/low-pressure metamorphic belts such as those present in Japan, Alaska, and parts of the CAOB.

Theme 3: Magmatism, plumes, and ore deposits; group leaders: W. Collins and Y. Xu; overview talk by A. Wurst: "Au-Cu porphyry deposits in accretionary orogens—Comparing the Central Asian Orogenic Belt (CAOB) and modern examples." Much of the debate centered on whether a plume was responsible for widespread Permian magmatism in the CAOB or whether the magmatism was associated with other processes, such as slab breakoff following collision.

Theme 4: Structures, subduction kinematics, and geophysical data; group leaders: K. Schulmann, W. Xiao, and W. Mooney; overview talk by R. Glen: "The SW Pacific and the Tasmanides of Eastern Australia: Possible analogues of the CAOB?" This talk led to a lengthy discussion on subduction kinematics, structural criteria, and seismic observations pertaining to accretionary orogens and particularly the CAOB.

Theme 5: Paleogeography and sedimentary basins; group leaders: Q. Wang and L. Teng; overview talk by Q. Wang: "The Carboniferous Junggar Basin in northwest China exemplifying basin evolution in the CAOB." Much of the discussion centered on the nature and composition of the crust beneath the Junggar basin as well as the sedimentary records of the nearby accretionary terranes.

Theme 6: Isotopes and continental growth; group leaders: B.-M. Jahn and B.F. Windley: overview talks by Windley on "What we have learnt (and not learnt) from the Central Asian Orogenic Belt since Sengör et al. (1993)"; Jahn on "Distinct crustal development of SW and NE Japan—Sr-Nd isotopic evidence and tectonic implications"; and E. Belousova on "Hf isotopes in zircons from the CAOB: Crustal evolution history and tectonic significance." The ensuing discussion and talks on isotopic data touched many aspects of crustal evolution in Central Asia, such as the proportion of juvenile crust in Central Asia and whether the "Baikalian" event (late Neoproterozoic) in Siberia is a separate orogeny or part of CAOB evolution. Jahn's conclusion that SW Japan is not really juvenile may have important implications for considering Japan as a model for the CAOB.

The final discussion of the conference stressed that researchers working in the CAOB should place more emphasis on detailed field mapping and structural analysis and not consider any one particular accretionary orogen of the circum-Pacific as the only model for CAOB evolution. Participants emphasized that the following topics require future study: How to recognize the subduction of an ancient oceanic ridge. Are the western and southern Pacific good analogues for the evolution of the CAOB? Was subduction in the southern Tianshan southward or northward?

Most presentations from the conference are available at ftp://penrose:penroseiggcas@159.226.119.207. A themed issue of *Lithosphere* papers derived from research presented at the conference is in preparation, and R. Hall (London), B.-M. Jahn (Taipei), J. Wakabayashi (Fresno), and W. Xiao (Beijing) volunteered to be guest editors.

Participants: Dmitriy Alexeiev, Robin Armstrong, Elena Belousova, Georgiy Biske, Michael Brown, Keda Cai, Ke Chen, Dominique Clouzel, William Collins, Jun Gao, Dmitry Gladkochub, Richard (Dick) Glen, Longlong Gou, Robert Hall, Dengfa He, Hesheng Hou, Bor-ming Jahn, Ping Jian, Yingde Jiang, Alexander Kotov, Victor Kovach, Alfred Kröner, Timothy Kusky, Wei Lin, Xiaoping Long, Zeng Lü, Huadong Ma, Alekandr Mikolaichuk, Walter Mooney, Onno Oncken, Scott Paterson, Minghua Ren, Inna Safonova, Karel Schulmann, Reimar Seltmann, Inga Sevastianova, John W. Shervais, Liangshu Shu, Robert J. Stern, Yoshihiko Tabata, Louis Teng, Ying Tong, Dondov Tumurkhuu, John Wakabayashi, Koji Wakita, Bo Wan, Bo Wang, Kuo-Lung Wang, Qingchen Wang, Tao Wang, Simon Wilde, Brian F. Windley, Andrew Wurst, Wenjiao Xiao, Yigang Xu, Chao Yuan, Lifei Zhang, Shjihong Zhang, and Rixiang Zhu.

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Group photograph at end of field trip in Baiyanggou section, southern Bogda Mountains.