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Juvenile crust, mantle magmatism and metallogeny of the Central Asian Orogenic Belt: Progress Report of IGCP#592

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1. Introduction

The IGCP-Project #592 “Continental construction in the Central Asian Orogenic Belt compared to actualistic examples from the western Pacific” funded by UNESCO-IUGS was launched in 2012 and catalysed an explosion of research activities in Central Asia itself and in other countries engaged in investigations on that region. The results, some of which can be highlighted as break-through advances in our understanding of geological processes, were published in ~60 articles in SCI peer-reviewed journals and reported at six scientific conferences. This paper summarizes main topics and scientific results of the 3rd year of project activities. The meeting program included international conferences and workshops in China, Turkey and Russia and the educational program included nine lecture and field training courses and other capacity building activities in the United Kingdom, Kazakhstan, Russia, Turkey, China and Japan. In 2014, participants from more than 50 countries joined the research and meeting activities of IGCP#592, of which more than 35% were women and young scientists. The major scientific results come from the study of proportions of juvenile and recycled crust in the Central Asian Orogenic Belt (CAOB) with special focuses on the timing of granitoid and mafic magmatism, contribution of deep mantle processes, formation ages and genesis of major metal deposits, and comparison of the CAOB with the modern western Pacific.
processes to continental growth; (7) understanding the impact of CAOB’s tectonics on climate changes and the environment.

In 2014, our research activities focused on (1) geology, lithostratigraphy, structural/tectonic patterns and magmatism in different segments of the CAOB; (2) isotope geochronology and geochemistry; (3) deep-mantle processes contributing to continental growth; (4) metallogeny and mineral resources; (5) OPS and tectonic correlations between the CAOB and WP (Safonova et al., 2013, 2014).

The third year of research, educational and organizational activities in the frame of IGCP#592 included six international meetings (Anikina et al., 2014; Kruk et al., 2014; Safonova et al., 2014; Santosh et al., 2014; Zhang et al., 2014), nine lecture and field training courses, dozens of field missions and many hours, days and months of laboratory work. In total, participants from 53 countries joined IGCP#592 related meetings and field visits in 2014. Project participants come from Algeria, Australia, Austria, Bangladesh, Belgium, Botswana, Brazil, Canada, Chile, China, Cote d’Ivoire, Czech Republic, Denmark, Egypt, Ethiopia, Finland, France, Germany, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Kazakhstan, Kyrgyzstan, Madagascar, Malaysia, Mongolia, Morocco, Myanmar, Nepal, Netherlands, New Zealand, Norway, Poland, Republic of Korea, Romania, Russia, South Africa, Spain, Sri Lanka, Switzerland, Taiwan, Tajikistan, Thailand, Turkey, UK, Ukraine, USA, Uzbekistan, and Vietnam.

This paper represents a summary of major 2014 project activities and results including the scopes, achievements and outcomes of meetings and the major research results reported in about 60 scientific papers and conference materials volumes. In addition, we present a review of our 2014 educational and capacity building activities and a brief review of our meetings held in 2015. Project materials, conference proceedings, photos and related publications all are available either at https://sites.google.com/site/igcp592/ or at http://igcp592.igm.nsc.ru, or upon request to igcp592@gmail.com.

2. Continental Dynamics

The dynamics of Asian continental blocks related to continental collisions and deep mantle processes was discussed during the International Conference on Continental Dynamics (ICCD, Meeting#1), which was held on April 26-28, 2014 and organized by the Northwest University of Xi’an (China) and co-organized by IGCP#592. The aims of the ICCD (http://www.conferencenet.org/conference/iccd.htm) were to bring together geologists, petrologists, geochemists, geochronologists and geophysicists integrating diverse approaches and methodologies. The focuses of the meeting were discussion and exchange of ideas on a wide range of topics related to the formation of continents, cratons and supercontinents and their relationship to tectonics and deep mantle dynamics. The meeting brought together leading experts and young scientists from Austria, Botswana, Brazil, China, France, Germany, India, Ireland, Japan, Russia, South Korea, and USA and included ~200 participants from 19 countries with about 30% of young scientists (Fig. 2a). It was a successful forum for discussions on continental dynamics and tectonics with examples from the Qinling Orogen and surrounding cratons and orogenic belts including the CAOB. The program included 60 oral and 74 poster presentations on four sessions titled: (1) “The formation and destruction of continental crust”, (2) “Supercontinent cycles and their environmental implications”, (3) “Continental crust and mineral resources” and (4) “Geophysical and geochemical perspectives on continental crust” (Zhang et al., 2014). The participants discussed the amalgamation and breakups of supercontinents and their related orogeny and rifting and ocean opening and closure. In addition, they discussed continental collisions and related orogenies, and the contribution of deep mantle dynamics to continental growth. Overall, the major topics and conclusions formed during the ICCD are Precambrian terranes within orogenic belts, CAOB basement structure and metamorphic terranes and transformation of the CAOB crust. More specifically, the recent zircon U-Pb age and Hf isotope data have shown that the Korean Precambrian massifs are parts of the North China Craton and that the western CAOB includes several Precambrian continental blocks. The results of geological survey/mapping clearly indicate that the basement of the eastern CAOB is dominated by accretionary complexes. Geochemical and petrological studies of high-grade metamorphic terranes suggest that the recognition of their protoliths is a key point of tectonic interpretation. And a very important point is that the juvenile crust of the CAOB was eroded during the Middle Paleozoic (Zhang et al., 2014). Based on the conference outcomes, a special issue on continental dynamics of Gondwana Research journal “Tectonic Evolution of the Qinling Belt and Related Orogenic Belts” was launched with Prof. Yunpeng Dong, Dr. Inna Safonova and Dr. Tao Wang as Guest Editors.

3. Convergent Margins

The International Workshop on Convergent Margins was held on...
May 21-23, 2014 at Trabzon, Turkey, and organized by the Karadeniz Technical University (http://www.convergentmargins.com/). The major scope was the role of plate tectonics in the processes of construction and destruction of continents, cratons and supercontinents and their bearing on the evolution of life, resources and environment in our planet. The specific aims of the workshop were to share the latest scientific databases and models on convergent margins and related geological processes, to foster the active involvement of young earth scientists and to provide a common intellectual forum to discuss their research and ideas with experts, and to encourage multidisciplinary and international research collaborations. The workshop attracted about 400 participants from 14 countries (Fig. 2b). The program included 23 lectures of 16 leading geoscientists from Australia, Canada, China, Holland, Germany, Russia, Turkey and USA. The main topics included the geology of convergent margins, slab windows, ocean plate stratigraphy, CAOB geology, mantle plume magmatism and metallogeny, granitic magmas, supra-subduction ophiolites, radiogenic isotopes and geochronology, Archean tectonics, mantle melting and volatiles, hydrothermal systems, core complexes, underplating and magmatism, and the thermo-chemical heterogeneities of continental lithosphere. The participants, mostly under- and post-graduate students and early career scientists from Turkey, Germany, France, Greece, Azerbaijan, and Russia had an opportunity to directly communicate with experienced scientists from all over the world and share ideas.

Overall, the major conclusions of this meeting were: (1) Among the various plate boundaries, convergent margins play the most crucial role, with subduction zones acting as a conveyor belt for the production and destruction of continental crust; (2) oceanic subduction zones are important regions where mass exchange occurs between Earth’s exterior and interior; (3) convergent margins are sites of intense geological processes such as magmatism, metamorphism, crust mantle interaction and related tectonics; (4) the chemical characteristics of magmatic rocks, pressure-temperature conditions of metamorphic rocks and the depositional environments of sedimentary rocks in fossil convergent margins are important clues on the accretionary growth of continents; (5) the huge earthquakes on subduction megathrusts, tsunamis, landslides, intense volcanic eruptions and other geohazards in modern convergent margins also threaten human life, ecosystems, infrastructure and economy. IGCP#592 leader Inna Safonova presented two lectures on the Continental Crust of the CAOB and on the Ocean Plate Stratigraphy of the CAOB and western Pacific. The program of the workshop also included short field trips to the Eastern Pontides Orogenic Belt (Fig. 2c).

4. Formation of PGE Mineral Deposits

The 12th International Platinum Symposium (Meeting#3) held on August 9-14, 2014 in Yekaterinburg, Russia, included six field trips and a workshop for young scientists. The meeting was organized by the Institute of Geology and Geochemistry UB RAS and the Ural Federal University (http://conf.uran.ru/default.aspx?cid=12|ps) (Fig. 2d) and co-organized and co-sponsored by IGCP#592. The program of that important event included papers in eight sessions: (1) Magma dynamics, cumulates and ore genesis; (2) PGE mineralization in mafic-ultramafic intrusions of Russia: geology and petrogenesis; (3) PGE-Cu-Ni sulphide-bearing ultramafic-mafic intrusions of the Noril’sk Province: insights into ore genesis and exploration; (4) Models and exploration methods for magmatic Ni-Cu-PGE sulphide and PGE-oxide deposits from around the world; (5) Ophiolites and Ural-Alaskan-type intrusions: traditional and innovative looks on the PGM formation; (6) PGE and Au through experiments; (7) New advances in the understanding of PGE mineralogy from magmatic to supergene environments; (8) Open session (Anikina et al., 2014). In addition, the program included workshop for young scientists titled “Processes in magma chambers with implication to genesis of ore deposits” and pre- and post-symposium field trips to Russian major PGE-sulphide deposits.

About 160 researchers from 25 countries presented 79 talks and 67 posters. In addition to scientific sessions, the participants participated in six field trips titled: (1) “Ultramafic-mafic intrusions, volcanic rocks and PGE-Cu-Ni deposits of the Noril’sk Province, Polar Siberia”; (2) “PGM placer deposits and their sources in the ultramafic and alkaline rocks of the concentrically zoned Kondyor massif, Far East, Russia”; (3) “The Rai-Iz ophiolite Complex and related chromite deposits, Polar Urals”; (4) “The Uralian Platinum Belt: The Nizhny Tagil clinopyroxenite-dunite massif and the Volkovskiy gabbro massif, and related platinum and copper deposits”; (5) “The Ural Platinum Belt: The Kachkanar titanomagnetite deposit hosted by clinopyroxenite (Fig. 2d). Platinum placers and lode deposits related to the Svetly Bor clinopyroxenite-dunite Uralian-Alaskan-type intrusion”; (6) “The Iloko-Dovyny mafic-ultramafic layered intrusion in the Northern Baikal region and associated PGE-Cu-Ni deposits” (Fig. 2e). The participants agreed that magmatic ore deposits produced by mafic-ultramafic magmatism are related to igneous cumulate rocks that are generated by processes of magma differentiation, crystallization and solidification in crustal chambers. Another conclusion was that sulphide and chromite transport in the parental magmas and percolation of sulfides and volatiles through the cumulative pile are of key importance in understanding scenarios of formation of PGE mineral deposits. Finally, our understanding on the origin of ultramafic-mafic intrusions with different degrees of PGE-Cu-Ni sulphide mineralisation (i.e., economic, subeconomic and non-economic) evolves with our understanding of mineralogy, petrology, geochemistry, geochronology and structural controls.

5. Granitoid Magmatism and Earth’s Evolution

The II International Conference and Field Trip “Granites and Earth’s Evolution” (Meeting #4) was held on August 16-20, 2014 in Novosibirsk, Russia, organized by the Institute of Geology and Mineralogy SB RAS (http://www.igm.nsc.ru/granites2014/index.php). The focus of the meeting were (1) sources for magmatic granitoids of various geochemical types; (2) links between granitoid geochemistry and characteristics of host rocks; (3) granite magmatism and continental crustal growth within large lithospheric blocks; (4) mantle-crust interactions and the role of mantle material and mantle heating in the generation of granitic magma; (5) syntectonic granitoid magmatism; (6) granitoids of Large Igneous Provinces: composition, sources and mechanisms of magma generation; (7) ore mineralization in granitoids. About 110 participants and paper authors from 16 countries presented 43 oral and 8 poster presentations (Kruk et al., 2014). The meeting program included scientific sessions and field
Fig. 2. Photos from the 2014 conferences and related field trips. A, International Conference on Continental Dynamics (Xi’an), group photo. B-C, International Workshop on Convergent Margins (Trabzon): B, workshop group photo, C, field trip to the eastern Pontides orogenic belt: a late Cretaceous turbiditic sequence of the Kermutdere Formation (Gumushane area; Eyuboglu et al., 2015); D-E, XII International Platinum Symposium: D, the Silurian Kachkanar Fe-Ti Deposit of the Uralian Platinum Belt hosted by Silurian gabbro-pyroxenites and Ordovician basalts and dolerites; C, the Neoproterozoic Ioko-Dovyren PGE-Cu-Ni deposit hosted by layered dunite-troctolite-gabbro of northern Transbaikalia, southern Siberia (Anikina et al., 2014) - Prof. Kislov, Ulan-Ude, in the photo); F-G, International Conference on Granites and Earth’s Evolution (Novosibirsk): F, the Mochische mine of Permian granites of the Novosibirsk Region, G, the late Permian-early Triassic Sinyukha granite massif of the Rudny (Ore) Altai (Kruk et al., 2014).
trips. Key discussions were on “first” granites and continental crust formation, Sr-Nd-Hf isotopic characterization of granitoids in accretionary orogens of the CAOB and western Pacific (Japan and Russian Far East), and on the role of mantle plumes in the granitoid magmatism of Western Transbaikalia. Three field trips (Fig. 2f) were taken to a Devonian granite massif in the Borok quarry of Novosibirsk, Early Triassic granitoids of the Novobibeevo and Mochische quarries, and Middle Paleozoic granitoids of the North-western Russian Altai. Field observations were focused on (1) Middle Devonian-Early Triassic granitoids that occurred in different geodynamic settings (suprasubduction, transform margin, collisional, post-collisional and intra-plate); (2) interaction of mantle-derived and crustal melts during the formation of granitoids; (3) ore deposits associated with mafic and granitoid magmatism; (4) the Altai accretion-collision system of the western CAOB, which is known for the Paleozoic–Early Mesozoic juvenile crustal growth resulted in formation of numerous granitoid massifs (Kruk et al., 2014). The participants of the Altai trip observed the Altai active margin of the Siberian continent and the magmatic complexes and mineral deposits of the Rudny Altai including the Pavlovsky Complex (granites), Ust’ansky complex (granites, diorites, tonalites), Zmeinogorsky Complex (granites and gabbroids); Volchikhinsky Complex (granites), Sinyukha Complex including famous Savushski granitoid pegmatites (Fig. 2g), and the Stepnoye ore deposit.

6. Mineral deposit systems of active continental margins: subduction, accretion to collision

Session “Mineral deposit systems of active continental margins: subduction, accretion to collision” was organized in the frame of the 14th Quadrennial IAGOD Symposium “Mineral Resources: Discovery and Utilization”, which was held on August 19–22, 2014, in Kunming, China (http://onlinelibrary.wiley.com/doi/10.1111/ acgs.2014.88.issue-2/issuetoc). The main goals of the symposium were to provide opportunities to present and exchange knowledge on the research on the genesis of ore deposits, to cover all aspects of currently hot topics in economic geology that will lead to an enhanced understanding of the genesis of mineral deposits in continental settings, as well as to improve techniques for exploration, discovery, and utilization. IGCP#592 participated in the 2014 IAGOD symposium as the metallogeny and minerals resources of the CAOB is one of the major goals of the IGCP#592 Project. The key topics of the related workshops for early career scientists were mafic magmatic deposits, orogenic gold deposits, and sediment hosted base metal deposits. The IGCP#592 Session was to hold a discussion on the metallogeny and mineral resources of the CAOB with contributors on giant gold deposits, pegmatite, porphyry, hydrothermal, active margin and contrasting deposits. The session was attended by 13 scientists from Australia, Japan, Korea and New Zealand with eight invited talks on (1) mantle contribution to the formation of giant ore deposits in Uzbekistan; (2) time–space distributions of contrasting ore deposits in the Southern Altai; (3) granitoid pegmatite deposits of the Chinese Altay; (4) molybdenum deposits in the Qinling Orogen; (5) geodynamics of active continental margins and associated mineral systems; (6) polymetallic hydrothermal ore systems; (7) magmatic-hydrothermal ore systems; (8) Alaskan-type mineral deposit systems. The participants also discussed other important issues of CAOB metallogeny, e.g. porphyry-epithermal Cu-Au-Mo-Ag ore systems, geochronology and geodynamic settings of epithermal Au deposits of the Tianshan. The presentations reflected a large topical and methodical progress in modern fundamental and prospective studies of accretionary orogens in terms of their social impact as hosting important mineral deposits. The post-conference field trips showed: (1) porphyry-skarn Au-Pb-Zn, Pb-Zn, polymetallic tin, and MVT-type Pb-Zn deposit of the Yunnan Province; (2) Carlin-like gold, black-shale hosted barite, phosphorus and Mn deposits of the Guizhou Province; (3) Au deposits of the Shandong Province; (4) Cu-Au and epithermal Pb-Zn-Ag deposits of the Jiangxi Province. The cooperation with researchers working in other areas of Asia was to mutual benefits of research and created synergy.

7. Tectonic Evolution from Gondwana to Asia

The 2014 International Association for Gondwana Research (IAGR) Annual Convention and 11th International Symposium on “Gondwana to Asia” organized by the China University of Geosciences (CUGS), and co-organized and co-sponsored by which IGCP#592 (Meeting#6), was held on September 19-23, 2014, in Beijing, China (http://www.iagrhomepage.com). The meeting was aimed to provide important opportunities to meet with renowned geoscientists, for exchange of scientific ideas and for the growth of excellence in academic and scientific pursuits to address a wide range of topics related to supercontinent tectonics in general and Gondwana-Asia in particular. The oral and poster presentations were in four sessions: (1) Secular evolution of Earth: supercontinents, life and environment; (2) Gondwana to Asia: orogenic belts, correlations and connections; (3) Metallogeny; (4) Geophysical imaging of continents and cratons. About 270 participants and paper authors from 21 countries presented 35 oral and 51 poster presentations (Santosh et al., 2014). In addition to the sessions, the program included a pre-symposium workshop on establishing a Global Research Centre, Best-Poster Challenge for young scientists, the Annual Meeting of Gondwana Research (GR) and Geoscience Frontiers (GSF) Editorial Boards and International Association of Gondwana Research (IAGR) Secretariat, and a post-symposium field trip “Paleoproterozoic post-collisional magmatism – the Damiao anorthosite-gabbro-mangerite-granite suite”. The GR-IAGR meeting discussed the annual results of GR and IAGR activity. The participants of the post-conference field excursion examined the lithology, structure and metamorphic architecture of the Damiao Complex. The abstract volume includes 90 abstracts of oral and poster presentations (Santosh et al., 2014). The hottest discussions were on the correlations between the CAOB and Japan, the target of IGCP#592. This meeting helped IGCP#592 to promote the major goals of our project, i.e. (i) correlations between the CAOB and western Pacific; (ii) erosion of the CAOB juvenile crust.

8. Educational, social and capacity building activities

The geographic position of the major areas of interest (Central and East Asia) determines the high portion of project participants from developing countries, namely China, Kazakhstan, Kyrgyzstan, Mongolia, Russia, Tajikistan, Uzbekistan. Participants from developing countries outside the CAOB are also involved including
India, Egypt, Iran, Thailand, Vietnam and other countries (~65% of IGCP#592 participants). By having a female Project Leader, IGCP#592 also attracted the continued participation of female scientists in elevated numbers (42 from 8 countries). Catalysed by the training modules and field courses offered by IGCP#592 that took place in the UK (Oxford, London), China (Xi’an, Kunming, Beijing), Russia (Novosibirsk), Kazakhstan (Oskemen) a large number of young scientists (postdocs, PhD students, specifically from countries of struggling economies) became involved into IGCP#592 linked research. A Researcher Links workshop on sustainable use of nature’s wealth (co-sponsored by IGCP-592) took place in Oskemen (Kazakhstan) in March 2014 and included young Kazakh and British scientists (limited to early career researchers) aiming to develop bilateral and multinational cooperation projects. At a special session IGCP#592 was presented that promoted as a suitable program to seek seed funding for joint research projects in the future. It was agreed to enter into preparations for an IGCP Young Scientist Project (YSP) involving researchers from developing countries of Central Asia, Russia and China, with guidance from experienced researchers from Russia, China and UK. The project is planned to be submitted in 2015. Among those financially supported by IGCP#592 are about 70% female scientists and 50% young scientists. Female and/or young scientists and those from developing countries form 90% of participants supported by IGCP#592.

Best Student’s Poster challenge was organized in the frame of the International Conference on Continental Dynamics (supervisors Prof. S. Tsunogae, Dr. I. Safonova; see Section 2) and the Gondwana to Asia Symposium (supervisors: N. Rogers, S. Glorie, E. Andreeva; see Section 7) (Fig. 3a). The International Workshop on Convergent Margins (Section 3) was organized exclusively for early career scientists (see above). In addition, to the capacity building activities in the frame of IGCP#592 meetings, the educational program of IGCP#592 included six lecture and field training courses: (1) A training module on mineral deposits in the frame of the Mineral Deposit Studies Group annual meeting in Oxford (UK) and a methodology training for PhD students from Kazakhstan at the Natural History Museum in London (UK), both in January 2014 (supervisor: R. Seltmann); (2) A training course at the East Kazakhstan State Technical University (EKSTU) in Oskemen, Kazakhstan, March 2014 (supervisors: R. Seltmann, A. Dolgopolova); (3) A seminar on “Asia as a frontier of a futures supercontinent Amasia” with focuses on tectonics and petrology was held in the Institute of Geology and Mineralogy SB RAS, Novosibirsk, Russia, March 2014 (supervisor: I. Safonova) (Fig. 3b); (4) A field training course on mineral deposits for PhD students was held at EKSTU, Oskemen, Kazakhstan, June 2014 (supervisor: R. Seltmann) (Fig. 3c); (5) The pre-symposium workshop for students “Processes in magma chambers and genesis of ore deposits”, Yekaterinburg, Russia (supervisors: R. Barnes, R. Latypov) was organized in the frame of the 12th International Platinum Symposium (Section 4); (6) Short lecture courses on climate changes and environmental problems for Russian and Japanese students were organized at the Institute of Geology and Mineralogy SB RAS,
Novosibirsk, Russia, on September 27, 2014, and at the Gifu University, Gifu, Japan, on December 10, 2014 (supervisor: S. Krivonogov) (Fig. 3d).

9. Major research targets and general scientific achievements

In 2014, the research activities in the frame of IGCP#592 were performed in the fields of geology, geochemistry, geochronology, petrology and metallogeny. Geological, lithostratigraphic, structural studies of tectonic patterns and magmatism were performed in different segments of the CAOB including the Russian-Kazakh Altai and East Kazakhstan (e.g., Cai et al., 2014; Kurganskaya et al., 2014; Safonova, 2014; Yang et al., 2014); Junggar Region in NW China and SE Kazakhstan (e.g., Shen et al., 2014; Simonov et al., 2015; Zhao et al., 2014); Kyrgyz and Chinese Tianshan (Ju and Hou, 2014; Klemd et al., 2014; Konopelko et al., 2014; Mao et al., 2014); southern CAOB (e.g., Guo et al., 2014; Song et al., 2013, 2014; Tian et al., 2013; Xiao et al., 2014); eastern CAOB (e.g., Fedotova et al., 2014; Li et al., 2014; Ruppen et al., 2014). Isotope geochemical and geochemical studies were focused on the formation of continental crust and timing of granitoid magmatism (Cai et al., 2014; Guo et al., 2014; Konopelko et al., 2014; Kruk et al., 2014; Mao et al., 2014; Song et al., 2014); the evolution of convergent margins and the timing of mafic and andesitic magmatism (e.g., Mao et al., 2014; Tian et al., 2013; Yang et al., 2014; Zhao et al., 2014); juvenile vs recycled granitoid magmatism (e.g., Cai et al., 2014; Kröner et al., 2014); the provenance analysis of metasediments (e.g., Glorie et al., 2014; Ruppen et al., 2014); the timing of deformation and metamorphism (e.g., Klemd et al., 2014; Song et al., 2014). A special emphasis was made to deep-mantle processes contributing to continental growth in terms of deep-mantle dynamics and plume magmatism (Safonova and Maruyama, 2014; Safonova and Santosh, 2014; Zhang et al., 2014; Santosh et al., 2014).

A key goal of the project was the study of CAOB metallogeny and mineral resources, such as PGE deposits (Anikina et al., 2014; Santosh et al., 2014), porphyry and sulphide deposits (Kruk et al., 2014; Plotinskaya et al., 2014; Seltmann et al., 2014; Han et al., 2014); gold deposits (Kruk et al., 2014; Seltmann et al., 2014; Shatov et al., 2014; Santosh et al., 2014), and iron deposits (Han et al., 2014; Kruk et al., 2014). And finally, the main goal of the project, i.e. correlations between the CAOB and western Pacific were discussed in terms of the magmatism and tectonics of CAOB versus western Pacific convergent margins (Cai et al., 2014; Guo et al., 2014; Kurganskaya et al., 2014; Li et al., 2014; Ruppen et al., 2014; Safonova, 2014; Tian et al., 2013); collisional and post-collisional processes (Cleven et al., 2014; Fedotova et al., 2014; Safonova, 2014) and global tectonic correlations (e.g., Kröner et al., 2014; Safonova and Maruyama, 2014; Safonova and Santosh, 2014; Xiao and Santosh, 2014).

The major general achievements of the 2012-2014 IGCP#592 research activities include the geologic and lithostratigraphic comparisons of the CAOB and WP, and Pacific- and collision-type orogenic belts, which highlighted the presence of ocean plate stratigraphy (OPS) units in both Phanerozoic (CAOB, WP) and Precambrian accretionary orogens (e.g., Biske et al., 2013; Glen, 2013; Kusky et al., 2013; Safonova, 2014; Safonova et al., 2015a; Song et al., 2014; Tian et al., 2013). The comparison with the modern WP showed that the CAOB is dominated by P-type orogenic belts as it hosts numerous localities of granitoids with juvenile isotope characteristics, blueschists derived from MORB and OIB protoliths, accreted carbonate-capped OIBs and other OPS units (Fig. 4), huge granitoid batholiths and boninites (Kusky et al., 2013; Safonova, 2014; Safonova and Santosh, 2014).

The timing of granitoid and mafic magmatism shows peaks in the late Neoproterozoic (mafic), Cambrian-Ordovician, Devonian and Triassic (granitoid) periods and indicates the late Permian closure of the Paleo-Asian Ocean (PAO; Cai et al., 2014; Guo et al., 2014; Konopelko et al., 2014; Li et al., 2014; Safonova and Santosh, 2014). Combination of U-Pb zircon ages with Nd and Hf isotopes elucidated source characteristics showed the Early-Middle Paleozoic crust growth and a mixed character of CAOB crust (Fig. 5), despite dominating P-type orogens due to tectonic erosion (e.g., Huang et al., 2013; Konopelko et al., 2013; Kröner et al., 2014; Zhang et al., 2014). The identification of juvenile versus recycled crust domains in the Altai Orogen, Junggar terrane and Tienshan Orogen (western CAOB), in the Beishan Orogen and adjacent Dunghuang terrane (southern CAOB) and in Inner Mongolia (eastern CAOB) showed both juvenile and recycled domains in the Kyrgyz Tianshan and dominantly juvenile domains in Altai and Beishan (Kröner et al., 2014; Safonova, 2014; Song et al., 2014; Tian et al., 2013).

Deep mantle dynamics contributed to the continental construction in the CAOB through the Meso-Cenozoic intra-plate continental volcanism, which is manifested in the Junggar terrane of Kazakhstan and China (Fig. 6), Transbaikalia, Mongolia, and East China (Ju and Hou, 2014; Safonova and Maruyama, 2014; Simonov et al., 2015). That magmatism could be related to hydrous-carbonated plumes generated in the mantle transition zone and triggered by the oceanic subduction, tectonic erosion and arc subduction at Pacific-type convergent margins surrounding Laurasia and Eurasia (Safonova and Maruyama, 2014; Safonova et al., 2015b).

New data on the formation ages and genesis of gold, PGE,
porphyry and iron deposits contributed to the understanding of metallogenesis and evolution of the whole CAOB. In particular, it was shown that significant porphyry Cu–Au/Mo and Au–Cu deposits formed during the whole Paleozoic and early Mesozoic (Plotinskaya et al., 2014; Seltmann et al., 2014; Shatov et al., 2014). The combination of geology and petrologic modelling in studying PGE-Ni deposits allowed us to highlight the formation of porphyry deposits by a subduction-related input of juvenile material and to recognize major episodes of metallogeny in CAOB likely related to certain geodynamic settings. For example, the Ni-Co sulphide mineralization at 290 Ma related to plume-related decompression melting, ascent of melts via translithospheric faults, melt-crust interaction and, finally Cu-Ni-Co-sulphide accumulation (e.g., Dolgopolova et al., 2013; Han et al., 2013; Ma et al., 2013; Seltmann et al., 2014).

Multi-proxy studies of sedimentary cores and wells showed links between tectonic activity, humidity and sedimentation and their effects on environmental and climate changes (e.g., Krivonogov et al., 2012; Gao et al., 2013). The late Quaternary volcanism and tectonics in the

Figure 5. Juvenile versus recycled crust domains in the Central Asian Orogenic Belt (modified from Kröner et al., 2014). Domains: red – juvenile, blue – recycled, green – mixed.

Figure 6. Localities of Meso-Cenozoic intra-plate volcanism in the Tianshan-Junggar region (from Simonov et al., 2015). Basaltic fields: Jurassic (rhombs) and Late Cretaceous-Paleocene (stars).
Darkhad Basin of northern Mongolia affected topography and climate and accordingly changed the environment as recorded in the dammed lake sedimentary sequence and glaciomorphs (Krivonogov et al., 2012). The Paleogene change of the tectonic pattern in the Junggar Basin affected the transportation of hydrocarbons and changed the conditions of sedimentation and related lithologies (Gao et al., 2013).

10. IGCP#592 activities and meetings in 2015

For the final year of our project we planned to increase the number of field trip training programs for young scientists, finalized evaluation of juvenile to recycled crust proportions in major CAOB terranes, traced accretionary tectonics, OPS records and mantle temperatures back to the Precambrian and to the Cenozoic, and evaluated the timing of ocean closures to fix the beginning of the CAOB amalgamation and the timing of intra-plate magmatism and metallogeny to better constrain the end of CAOB accretionary orogeny and the initiation of whole Asia intra-continental orogeny, continental crust erosion and cratonization.

The list of meetings included five events. The VI Conference on isotope geochronology “Isotope dating of geological processes: new results, approaches and prospects” was held at the Institute of Precambrian Geology and Geochronology, St.-Petersburg, Russia, on June 2–5, 2015 (http://www.ipgg.ru/geochron2015.php). The Conference brought together geochronologists, geologists, petrologists and geochemists to integrate diverse approaches and methodologies in isotope dating. The conference consisted of four days of sessions on the following topics: dating of recent volcanism, dating of sedimentary units, duration of geological processes; problems of stable isotope dating, problems of geological and petrologic interpretation of detrital zircon patterns, isotope systems and minerals-geochronometers.

The XIX Quadrennial INQUA Congress was held on July 27 – August 2, 2015, in the Nagoya University, Nagoya, Japan (http://inqua2015.jp/). Since 1928, INQUA, the International Union for Quaternary Research, promoted communication and international collaboration in Quaternary research. The current scientific scope of INQUA is reflected by its five Commissions: Coastal and Marine Processes; Palaeoclimate; Humans and Biosphere; Stratigraphy and Chronology; Terrestrial Processes, Deposits and History. The Congress program addressed the themes of the Commissions during 6 days of oral and poster sessions, plenary presentations, and side meetings. IGCP#592 participants contributed to sessions “Tibetan Plateau and arid Central Asia” and “Recent progress in the field of active tectonics and paleoecosmology”.

The XVIII International Congress on the Carboniferous and Permian (ICCP 2015) was held on August 11-15, 2015 organized by the Kazan Federal University, Kazan, Russia (www.ICCP2015.kpfu.ru). The Carboniferous and Permian are important stages of the CAOB evolution as it is the timing of the closure of the Paleo-Asian Ocean and subsequent collision of the North China, Tarim, Kazakhstan and Siberian continental blocks. The XVIII ICCP provided opportunities for basinal studies, global and regional tectonic reconstructions, paleogeographical and biostratigraphic research, and upper Paleozoic fossil collecting, including our understanding of the paleoclimate at the end of the Paleozoic, and new insights into the causes and consequences of Carboniferous-Permian events, especially the P-T extinction. IGCP#592 participants contributed to sessions “Carboniferous and Permian plate tectonics and orogenies and IGCP#592” and “The late Paleozoic oceans: paleoceanography”.

A key event was the “First Chinese-Russian Conference on the Central Asian Orogenic Belt and IGCP#592 Workshop” held on September 24-25, 2015, which was organized by the Institute of Geology and Geophysics, CAS, Beijing, China. The First China-Russia International Meeting and IGCP#592 Workshop included 2 days of talks in sessions followed by a post-conference field trip to Inner Mongolia orogenic belts during September 26-October 1. This meeting provided a forum for discussion to compare the tectonic evolution of the CAOB in Russia, China and neighbouring countries, to present and discuss new data and evolutionary models, and to discuss future international cooperation on geological and geophysical research. The main topics were: (1) Evolution of Palaeo-Asian oceans: from accretion to collision (ophiolites, ocean plate stratigraphy, tectonics, magmatism, metamorphism and deformation styles); (2) Across-border correlations in the CAOB and nomenclature; (3) Continental crustal growth and architecture; (4) Intra-plate processes and mantle plumes; (5) Mineralization in the Central Asian; (6) Superposition of the palaeo-Pacific and Okhotsk tectonics; (7) Continental amalgamation in the CAOB, Neoproterozoic to Palaeozoic palaeogeography and palaeomagnetism.

The 2015 IAGR Annual Convention and 12th “Gondwana to Asia” International Conference and Field Trip to the Kanto area, co-organized and co-sponsored by IGCP#592 was held at the University of Tsukuba, Tsukuba, Japan on October 21–25, 2015. The 2015 IAGR conference provided important opportunities to meet with renowned geoscientists, for exchange of scientific ideas and for the growth of excellence in academic and scientific pursuit. A wide range of topics related to supercontinent tectonics in general and Gondwana-Asia in particular was addressed with a special focus to the correlations between the CAOB and western Pacific. The program included two days of scientific sessions and a post-conference field excursion to the Mineoaka ophiolitic melange and surrounding Neogene accretionary complexes of the Boso Peninsula where the participants observed various ophiolitic rocks (pillow lava, dolerite, amphibolite), and chert exposed along the coastal area of the Chiba Prefecture.

Conclusions

In 2014, the research activities of IGCP-Project #592 “Continental construction in the Central Asian Orogenic Belt compared to actualistic examples from the western Pacific” funded by UNESCO-IUGS were focused on (1) geology, lithostratigraphy, structural/tectonic patterns and magmatism in different segments of the CAOB; (2) isotope geochronology and geochemistry; (3) deep-mantle processes contributing to continental growth; (4) metallogeny and mineral resources; (5) OPS and tectonic correlations between the CAOB and WP (Section 9). The program included international meetings (Sections 2-7), lecture courses, field training courses (Section 8), and field missions in various regions of the CAOB (http://igcp592.ign. nsc.ru/field-works). We have obtained a lot of breaking through scientific results, which were published in about 60 articles in SCI peer-review journals and reported at six scientific conferences in China, Turkey and Russia. The educational program included nine training courses and other capacity building activities in the United Kingdom, Kazakhstan, Russia, Turkey, China and Japan.

The major scientific results come from the study of proportions
of juvenile and recycled crust in the CAOB, timing of granitoid and mafic magmatism, contribution of deep mantle processes, formation ages and genesis of major metal deposits, and comparison of the CAOB with the modern western Pacific. The geologic and lithostratigraphic comparisons of the CAOB and WP, and Pacific- and collision-type orogenic belts highlighted the presence of ODPs in both Phanerozoic (CAOB, WP) and Precambrian accretionary orogens. We showed that the CAOB was dominated by P-type orogenic belts as it is composed of juvenile granitoids, blueschists and accreted OIBs. The granitoid and mafic magmatism of the CAOB peaked in the late Neoproterozoic (mafic), Cambrian-Ordovician, Devonian and Triassic (granitoid) suggesting the late Permian closure of the PAO. The CAOB crust has a mixed character despite the predominance of P-type orogens suggesting tectonic erosion of juvenile rocks. Both juvenile and recycled domains were recognized in the Kyrkyz Tianshan, whereas the Altai and Beishan orogens are dominated by juvenile crust. The construction of the CAOB crust was affected and overgrown by deep mantle processes manifested by the Meso-Cenozoic intra-plate continental volcanic fields of the Tianshan-Junggar region. The CAOB is special for numerous Cu–Au/Mo and Au–Cu deposits, which formed during the whole Paleozoic and early Mesozoic. The 290 Ma peak of Ni-Co sulphide mineralization was related to mantle plume processes. The links between tectonics and environmental changes were reconstructed from Cenozoic sedimentary records.

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