Workshop 3: Continental Amalgamation and Stabilization of Northeast Asia: Stories before the Stone Age

Thursday, February 21, 2019 | 10:40–17:30

Organizer: Tatsuki Tsujimori (Tohoku University)

Program

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10:40-11:20	Keynote speech: **Shigenori Maruyama** (Tokyo Institute of Technology) "Global climate in the past and near future: A geological perspective" .... page 2
11:20–12:00	Keynote speech: **Hugh Beach** (Uppsala University) "Sustaining Arctic Livelihoods and Sustaining Anthropology in the Anthropocene" .... page 3
12:00–13:30	Lunch Break
13:30-14:00	**Daniel Pastor-Galán** (University of Salamanca) "The supercontinent cycle and the growth of East Asia" .... page 5
14:00-14:30	**Moonsup Cho** (Chungbuk National University) "A new tectono-stratigraphic scheme of the Korean Peninsula" .... page 6
14:30-15:00	**Yukio Isozaki** (University of Tokyo) "Nipponides vs. Altaids" .... page 8
15:00-15:30	**Sun-Lin Chung** (Academia Sinica / National Taiwan University) "Tibet and beyond: A geochemical perspective on Asian orogeny" ..page 9
15:30-16:00	Coffe Break
Session 2	
16:00-16:30	**Shigenori Maruyama** (Tokyo Institute of Technology) "Concept of the second continent — Why important?" .... page 10
16:30-17:00	**Dapeng Zhao** (Tohoku University) "Seismic Imaging of the Second Continent" .... page 11
17:00-17:30	**William F. McDonough** (University of Maryland / Tohoku University) "Testing a proposed "second continent" beneath eastern China using geoneutrino measurements" .... page 13
18:00-20:00	Banquet

Friday, February 22, 2019 | 09:30-15:30
Organizers: Tatsuki Tsujimori (Tohoku University)

Session 3

09:30-10:00 **Guanghai Shi** (China University of Geosciences)
"The Myanmar jadeite jade (Feicui) and introduction of the Chinese jadeite culture" ······ page 14

10:00-10:30 **Yoshiyuki Iizuka** (Academia Sinica)
"Geochemical sourcing study of nephrite jade in East- and Southeast Asian prehistory" ······ page 15

10:30-11:00 **Ilona Bausch** (Kokugakuin University Museum / SISJAC)
"Not merely an accessory: the role of jades in Jômon society" ······ page 16

11:00-11:30 **Gina L. Barnes** (University of London)
"Green tuff, sanukite and obsidian: Archaeological stones and their geological sources" ······ page 18

11:30-12:00 **Sergey Krivonogov** (Novosibirsk State University)
"The history of the Aral Sea: Implications from multi-disciplinary study" ······ page 19

Session 4

13:30-14:00 **Bold Uyanga** (Mongolian University of Science and Technology)
"Precambrian to early Paleozoic Geology of the Central Asian Orogenic Belt" ······ page 21

14:00-14:30 **Kuo-Lung Wang** (Academia Sinica)
"Ancient continents among the Central Asia Orogenic Belt: evidence from lithospheric mantle xenoliths" ······ page 22

14:30-15:00 **Inna Safonova** (Novosibirsk State University)
"Tectonic erosion at subduction zones: Examples from East and Central Asia" ······ page 24

15:00-15:30 Discussion with coffee

Global climate in the past and near future: A geological perspective

Shigenori Maruyama

Tokyo Institute of Technology

IPCC (4th) had predicted global temperature would increase drastically up to 2–6K in the coming century. However, such an increase has not been observed during 2000–2018. Another prediction (IPCC 5th) was published in 2013, which modified the previous prediction by a much slower curve starting at 2015 and sharper increase after 2050.

The prediction through the super-computer depends on the past climate change model during the past 1000 years and evaluated the increase in atmospheric CO_2. Our group has examined the radiative forcing by the level of atmospheric CO_2 from zero to 800ppm by the simple model, and the result showed it increased the temperature up to only 0.6K even in the case of 800ppm.

Also, I predicted the climate change of the 21st century based on the relationship among galactic cosmic rays (GCRs) ($\Delta^{14}C$), sunspot number, and global temperature ($\delta^{14}C$ and sea-level change) during past 2,000 years. The result indicated the temperature would decrease gradually since 2000.

Application of the super-computer simulation to the Neoproterozoic Snowball Earth (total solar irradiation (TSI) was 94% of present-day; atmospheric CO_2 was 20–50 times) and Paleoproterozoic Snowball Earth (TSI was 85%, and the level of CO_2 was 100-1000 times) has been done by USA, France, and Germany, however, all failed to reconstruct the Snowball state. One possible scenario to reproduce Snowball Earth is to include GCRs-induced cloud in the super-computer simulation which was ca. 10 times more than the present-day Earth. Strong positive feedback of X_{CO2} through the simulation, possibly reaching to ten times than sole radiative forcing, might be overestimated.

Sustaining Arctic Livelihoods and Sustaining Anthropology in the Anthropocene

Hugh Beach

Uppsala University

For this address, I wish to broaden our definition of "domestication" to refer to the subordination of any object, ethnicity or species to the epistemological and legal purposes of another. I propose that our deep-rooted intuitive justification for the confirmation of rights for indigenous peoples does not derive merely from the fact that they were supposed "here first." It has been questioned and shown in numerous cases that their "firstness" is disproven or that the ethnic identity of the group in question loses validity in the pre-historic context. It is also the reason why there are conflicting concepts used for defining "indigeneity," and not always only firstness which holds prominence. In Russia, for example, there are criteria of living in specified areas and of practicing a traditional lifestyle. I argue that foundational to all such criteria is the notion that undomesticated or least-domesticated peoples should nonetheless be in possession of certain rights. In the Swedish case of the Saami, these rights are confirmed, not constructed, by the governing powers. This distinction of confirmation vs. construction of rights bares the basic vulnerability of the indigenous, for the rights recognized, be they confirmed or constructed, necessarily become de facto forms of domestication. The indigenous become dependent on the governing majority for their special "privileges" and face imposed legal contests about who is to be considered indigenous with access to these privileges.

The situation bears a strong resemblance to the Swedish wolf debate. When the wolf was wild, it was also shot to protect livestock. When environmental consciousness gained force, and the wolf became a protected species, this imposed a shield of domestication on the species. Its ravages amongst livestock is no longer a natural, but instead a legislated disaster. As I have argued, one can now speak of "wolf herding." Wolf categorizations have also been gerrymandered to justify being termed endangered. Similarly, I have argued that the creation of National Parks, World Heritage Sites and the like are modes of domestication of landscapes. In effect, Armstrong's first step for Mankind on the moon was also the first step toward human domestication of the moon. In time, should our species have the time and technology, I do not doubt that we will be putting the moon to some human use.

The vulnerability I spoke of earlier follows naturally when the deep-rooted moral protective shield for "the wild" be it a species, a landscape, or a people come to clash with their perceived domestication. The wolf becomes in effect a zoo animal, the wilderness a managed Park, the indigenous "wild" nothing different from anyone else. As indigenous Saami reindeer herders are seen to herd by helicopter, snowmobiles and GPS senders on their animals, the majority population (especially those living for generations in the North) question the justification of their special rights. This is a prime reason many local people express their failing support of indigenous rights; the indigenous have simply become "too well-off." They gain support to the extent they are perceived as impoverished and needy, not when business tycoons running gambling casinos.

One obvious result of the realization of the Anthropocene era is that science projects can hardly obtain funding today if not linked somehow or other to studies dedicated to the challenges of RCC. Most applications tailor themselves regularly to this reality of project funding success. Here, I wish to draw attention to what I consider an even more sinister result of Anthropocene recognition.

Now that RCC has become the paramount focus of science across both natural and social disciplines, human survival trumps that of individual ethnicities; indigenous resources and "privilege" (as opposed to rights) become increasingly subjected to the drive to maximize efficiency for the common good, hence to become more domesticated. These sentiments are not without justification. We must all share the burden of environmental stress if we are to sustain our planet and humanity.

However, selfish intentions often purposely camouflage themselves as ecologically noble, and even good intentions are perverted by biases resulting in forms of what I have come to term "ecolonialism" or "eco-colonialism." What results is a spiraling runaway loop whereby increased environmental fears promote increased indigenous "domestication," leading to increased public sentiment that indigenous peoples, now increasingly like the ambient majority, do not deserve any special privileges and thereby further domestication, and so forth.

The main determinant of the impact of climate change is how we think about it. In this address, I wish to explore 1) the human bias in our science, 2) our species bias, 3) our eco-colonial bias and 4) our epistemological bias when attempting to forge sustainability. Can we find a pattern in our flawed thinking?

The supercontinent cycle and the growth of East Asia

Daniel Pastor-Galán

Universidad de Salamanca

Plate tectonics describes the lithosphere, Earth's solid outer shell, as rigid plates that interact along discrete divergent (where they separate), transform (sliding against each other), or convergent (crushing areas) boundaries. Although elegant at a global scale, plates are not perfectly rigid, and instead undergo major shortening, growth, break-up and even destruction. In addition to the plate tectonic concept, there is an emerging consensus that plates have amalgamated into supercontinents in a quasi-periodic cycle, forming rigid super-plates with limited lithosphere-mantle interactions in their cores. The supercontinent cycle has been linked to other episodic changes such as crustal growth and loss, development of large igneous provinces, long-term variations in the geomagnetic field. Besides some authors described coincidences with other crucial secular changes in sea-level, biogeochemical cycles, global climate change and mass extinctions. If these hypotheses are correct, long-term mantle dynamics and much of the geological record, including the distribution of natural resources, may be largely controlled by these cycles. Despite their potential importance, however, many of these proposed links are, to date, permissive rather than proven[1].

Asia, and very particularly most pieces of east Asia have witnessed part of these supercontinent cycles and very particularly have been in the external edge of the later one, the amalgamation of Pangea, and it is the most reliable source of information we have to uncover the supercontinent's significant other: super-oceans. East Asia preserves the majority of the relics of the Panthalassa super-ocean and its interactions with Pangea becoming the most prominent area to study the supercontinent cycle as a geodynamic feature.

A new tectono-stratigraphic scheme of the Korean Peninsula

Moonsup Cho

Chungbuk National University

In this presentation, I introduce a new tectonostratigraphic scheme of the Korean Peninsula, and discuss its implication for tectonic evolution of the Qinling–Gyeonggi microcontinent which could be linked to the proto-Japan arc (Fig. 1). The Korean Peninsula consists of three Precambrian massifs (Nangrim, Gyeonggi, and Yeongnam) which are affected by the ~1.88–1.85 Ga orogenesis prevalent in the 'Paleoproterozoic Korean arc'. The Gyeonggi Massif underwent composite clockwise P–T evolution, whereas the Yeongnam Massif has remained at upper-middle crustal depths since late Paleoproterozoic. The Yeongnam Massif is unconformably overlain by Cambrian–Ordovician platform sequences of the Taebaeksan Basin which contain trilobites diagnostic of the North China Craton (NCC). The SHRIMP U-Pb dating of detrital zircons from these strata reveals the presence of youngest populations whose ages gradually decrease up-section from ~510 Ma to ~485 Ma. Thus, we envisage that syn-sedimentary volcanic materials, possibly derived from an arc complex along the NCC periphery, were fed into the Taebaeksan Basin.

In contast to the Taebaeksan Basin, a Permian–Triassic fold-and-thrust belt or the Gyeonggi Marginal Belt (GMB) underwent deep burial to yield medium- to high-pressure metamorphic rocks. This belt comprises the Imjingang Belt, Taean–Hongseong Complex, and Ogcheon Metamorphic Belt; each of these sub-belts contains two diagnostic metasedimentary units**:** (1) early Neoproterozoic Sangwon Supergroup; and (2) Devonian turbiditic sequence. The former unconformably overlies the Nangrim Massif gneisses of the NCC (Fig. 1), whereas the latter yields detrital zircon age patterns characterized by two major populations at ~1000–950 Ma and 450–430 Ma typical for the northern Qinling Belt. This age pattern and turbiditic lithology are two major reasons for correlating the GMB with the Qinling Belt.

Taken together, the Qinling–Gyeonggi microcontinent model accounts for a new tectono-stratigraphic scheme where some SCC-like units of the GMB were juxtaposed with the Gyeonggi Massif (or NCC) at middle-late Permian, and then thrust under the overriding Taebaeksan Basin during the Triassic Songrim orogeny. Such a scenario is linked to the evolution of proto-Japan arc, and further studies on this linkage are in urgent need.

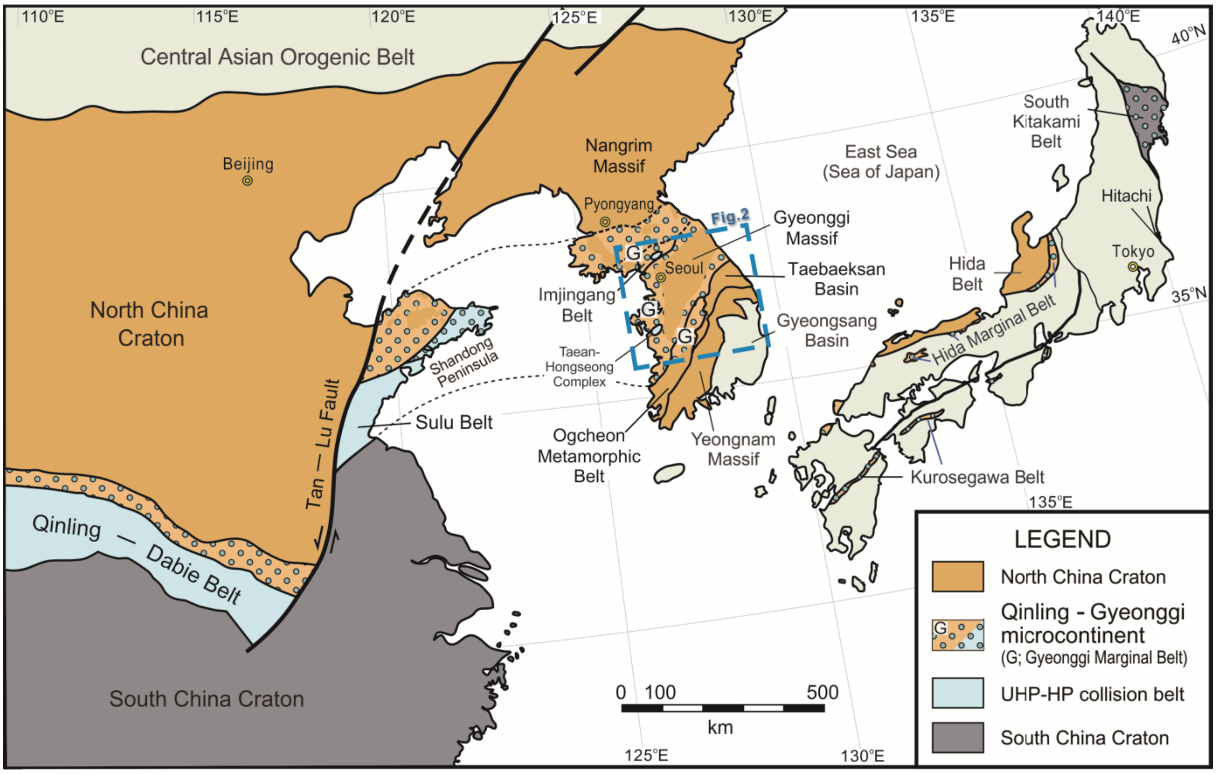

Fig. 1. Schematic map showing various tectonic provinces in East Asia, including the Gyeonggi Marginal Belt (Cho et al., 2018). For further details, please refer to Cho, M., Min, K., and Kim, H., 2018, Geology of the 2018 Winter Olympic site, Pyeongchang, Korea: International Geology Review, 60(3), 267–287. doi.org/10.1080/00206814.2017.1340196

Nipponides vs. Altaids

Yukio Isozaki

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The Pacific margin of Greater South China (GSC) is fringed by the Phanerozoic subduction-related Pacific-rim orogenic belt that features various arc granitoids, accretionary complexes, blueschists, and ophiolites, for nearly 3000 km, all the way from the Philippines to Primorye via the Ryukyus, and SW/NE Japan. This Phanerozoic orogenic belt generated by oceanic subduction from the Pacific (Paleo-Pacific or Panthalassan) side was called the *Nipponides* by Sengör & Natal'in (1996) with respect to the *Altaids* (named by Suess, 1901 nearly a century before) that corresponds precisely to Central Asian orogenic belt (CAOB). It is noteworthy that the general trend of the *Nipponides*, nearly in a N-S direction, is totally oblique or even perpendicular to that of the *Altaids*. The former represents a typical collision-free pacific-type orogen, whereas the latter a typical collision-type. The structural characteristics of the "T-junction" between these two are particularly interesting in revealing a process of continental growth through merging multiple orogens. In addition, mutual relationship between the *Nippoonides* and the North/South China blocks during the pre-Cenozoic time has been a key issue in understanding geotectonics in Japan. In the late Permian, the North China block was already incorporated into the convergent tectonics along the southern margin of the CAOB along the Solonker suture. Namely, North China was stabilized in part with the CAOB and also with the Siberian craton by the early Mesozoic in relatively higher latitudes. On the contrary, South China *sensu stricto* on the mainland remained in a low-latitude setting during the late Paleozoic, and it collided and merged with the south-neighboring Indochina block sometime by the mid-Triassic. Given that the GSC extended up to Far East Russia/NE China to form GSC, its size during the Paleozoic was much greater, probably twice as large as South China s.s., and probably much larger than North China. This may require the termination of the Qinling-Dabie-Sulu suture at the eastern end of the North China block, thus the eastern segments of GSC in Japan and Primorye, being free from the Triassic collision episode, may have been positioned in much higher latitude than North China. This configuration of relevant continental blocks around Japan provides new constraints on regional tectonics and faunal provincialism in late Paleozoic western Panthalassa.

Tibet and beyond: A geochemical perspective on Asian orogeny

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Asia that comprises numerous ancient cratonic blocks and young mobile belts is the largest composite continent on Earth. It was enlarged by assembly of dispersed terranes that, in association with opening and closure of the Paleo-Asian and Tethys oceans, led to significant continental growth. The Central Asian orogenic belt (CAOB), for instance, is celebrated for its accretionary tectonics and production of massive juvenile crust in the Phanerozoic or, predominantly, in the Paleozoic. The Tethyan domain consisted of two major oceans, i.e., Paleo-Tethys in north and Neo-Tethys in south, separated by a strip of continents/terrains called the Cimmerian Continent, most of which had begun splitting from the northern margin of Gondwanaland during Triassic time. Elimination of the Tethys oceans by collisions of the Cimmerian continental fragments and subsequent Gondwana-derived terrains with Eurasia resulted in a double, largely over-printed orogenic system, the Alpine-Himalayan or Tethyan orogenic belt.

Here I present a synthesis of geochemical data of collision zone magmatism from Asia, particularly from Tibet and "CIA" (Caucasus/Iran/Anatolia) in the eastern Tethyan orogenic belt (ETOB) that has traditionally been regarded as a typical collisional system. The dataset suggests that, before the terminal collisions, the entire region evolved through time from an accretionary into a collisional system. In contrast to generating massive juvenile crust in the earlier, accretionary stages, crustal recycling plays a more substantial role in the subsequent, collisional stages. The latter involves addition of older continental crust materials into the upper mantle, which in turn melted and caused compositional transformation of the juvenile crust formed in the accretionary stages. Similar features are observed in young volcanic rocks from eastern Taiwan, i.e., the northern Luzon island arc and part of the complex tectonic system in South East Asia, where active orogenic processes are operating and thus would one day evolve to resemble CAOB or ETOB by the final collision with the northward advancing Australian continent. A brief introduction about our ongoing project in South East Asia will be given in hope to attract more interactions and future collaborations.

Concept of the second continent — Why important?

Shigenori Maruyama

Tokyo Institute of Technology

Second continents exist on the bottom of upper mantle. Their total volume is ca. 10 times bigger than the surface continent. They are formed through tectonic erosion of TTG crust and direct arc subduction. We geologists have long believed that trench moves oceanwards always because of continuous formation of accretionary complex at the trench through time. But it was wrong. Tectonic erosion has been more common which destroys hanging wall of continental plate and arc subduction as well, both of which develop the second continents to generate hydrous plumes under Asia, resulting in the formation of microplates by self-heating process, ca. 100K/1 million years.

As demonstrated by the presence of intra-continental blueschists and eclogites in Asia, upper mantle of underneath Asia must have been hydrated and cooled during the Phanerozoic time. Volatiles-enriched material and presence of second continents on the bottom of upper mantle causes the sporadic occurrence of strongly alkaline basalt of intracontinental volcanoes in Eurasia.

So-called marginal basins characteristic of short life (< 20 Myr), small size and developed on the backside of arc with minor exceptional examples which occurs on subducting plates such as S. China basin and Caroline plate. This may be related by double-layered mantle convection underneath and role of second continents right above 660 km depth in east Asia.

Asia is a nuclei of future supercontinent Amasia. The formation of Amasia began around the end of Permian by the birth of super-cold downwelling in central Asia through the amalgamation of composite continents Asia. The double-sided subduction zones swallow continents from the east and the south, in addition to water, and tectonically eroded TTG materials. Both of those will play a critical role of breakup Amasia in future.

Seismic Imaging of the Second Continent

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In this presentation I make a review of recent findings on seismic imaging of the Asian orogens and subduction zones, in particular, the structure in and around the mantle transition zone (MTZ, 410–670 km depths). High-resolution images of seismic tomography and receiver functions of the Asian region are obtained, revealing significant lateral heterogeneities in the crust and upper mantle, which are caused by active plate subductions and continental orogeny (*Zhao et al*., 2017a). A significant advance in seismic imaging is tomographic inversions for 3-D distribution of seismic anisotropy in the crust and mantle, which provides important new information on the lithospheric deformation and mantle convection associated with the continental orogeny and plate subductions. The intraplate volcanism in NE Asia is caused by hot and wet upwelling flow in the big mantle wedge (BMW) above the stagnant Pacific slab in the MTZ. The age distribution of the subducting Pacific slab beneath East Asia is estimated, shedding new light on the evolution of the Pacific slab, as well as the East Asian tectonics during the Late Mesozoic to the Cenozoic. Significant low-velocity anomalies are revealed in and around the MTZ under East Asia, which reflect the second continent caused by tectonic erosions associated with plate subductions (*Maruyama et al*., 2007; *Kawai et al*., 2013).

The nucleation of great earthquakes, such as the 2008 Wenchuan earthquake (M 8.0) and the 2011 Tohoku-oki earthquake (M 9.0), is controlled by structural heterogeneities in and around the seismogenic fault zones. It is considered that fluids are involved in the nucleation and rupture processes of all types of earthquakes (*Zhao et al*., 2017a, 2018a). The cause of deep earthquakes is still not very clear, though transformational faulting triggered by metastable olivine transforming to spinel in the cold, stressed core of the subducting slab is a viable mechanism, and a metastable olivine wedge is revealed within the western Pacific subducting slab at the MTZ depths. The 2015 Bonin deep earthquake (M 7.9, ~670 km depth) occurred at the MTZ bottom within the vertical Pacific slab which is penetrating into the lower mantle. This very unusual deep event was caused by joint effects of several factors, including the slab's fast deep subduction, slab tearing and thermal variation, stress changes and phase transformations in the slab, and complex interactions between the slab and the ambient mantle (*Zhao et al*., 2017b).

Seismic tomography also reveals significant lateral heterogeneities in the lunar interior (*Zhao et al*., 2008, 2012). A correlation is found between S-wave velocity (Vs) tomography and distribution of thorium. The area with a high thorium content exhibits a distinct low Vs, which extends to a depth of ~300 km below the Procellarum KREEP Terrane (PKT), perhaps reflecting a thermal and compositional anomaly beneath the PKT. The distribution of deep moonquakes shows a correlation with tomography in the deep lunar mantle, which is similar to earthquakes affected by structural heterogeneities in the terrestrial crust and upper mantle. The occurrence of deep moonquakes and seismic-velocity heterogeneities implies that the lunar interior may contain fluids; therefore, it is still thermally and dynamically active at present. Because there is no plate tectonics in the Moon, the lunar surface and interior structure formed at an early stage of the Moon's history have been preserved until today. Consequently, the results of lunar tomography provide useful information for our understanding of the Hadean Earth (*Zhao et al*., 2018b).

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Testing a proposed "second continent" beneath eastern China using geoneutrino measurements

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Plate tectonics provides the framework for understanding the modern evolution of the crust and mantle system, with subduction zones linking these two major domains of the silicate Earth. Sediment recycling into the mantle at subduction zones is well established, although unknowns (e.g., past and present-day rates, amounts, depth of recycling, etc) remain significant. The present day subduction zone settings include ocean-ocean, ocean-continent, and continent-continent collisions and each of these likely have differing degrees of efficiencies of sediment recycling, as evidence by distinct differences in the remnants of meta-sediments exposed in fossil forearc regions of different collision zones. The retrieved metamorphic record of ocean-ocean and ocean-continent collision zones documents meta-sediments experiencing high-grade (granulite to eclogite facies) metamorphism versus continent-continent collisions return meta-sediments having experienced ultra-high-grade (up to diamond facies) metamorphism. What is not known is the effectiveness of deep sediment recycling, past the magmatic zone, in each of these three different convergent margins. Models that envisage successful subduction channel transport of upper crustal materials below 300 km depth, past a critical phase transition in buoyant crustal lithologies, are capable of accumulating and assembling these materials into so-called "second continents" that are gravitationally stabilized at the base of the Transition Zone, at some 600 to 700 km depth. Global scale, Pacific-type subduction (ocean-ocean and ocean-continent convergence), which lead to super continent assembly, were hypothesized to produce second continents that scale to about the size of Australia, with up to continental upper crustal concentration levels of radiogenic power. Seismological techniques are incapable of imaging these second continents because of their negligible difference in seismic wave velocities with the surrounding mantle. We can image the geoneutrino flux linked to the radioactive decays in such hypothesized second continents with land and/or ocean-based detectors. We present predictions of the geoneutrino flux for second continents, assuming different scaled models and show that the combination of the KamLAND-JUNO-Jinping neutrino experiments are strategically positioned to discover or constrain a predicted second continent beneath eastern China. The power emissions from second continents were proposed to be drivers of super continental cycles. Thus, testing models for the existence of second continents will place constraints on mantle and plate dynamics when using land and ocean-based geoneutrino detectors deployed at strategic locations.

The Myanmar jadeite jade (Feicui) and Introduction of the Chinese jadeite culture

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The jadeitites worldwide have two types according to its original country/host rock: marble-hosted and serpentinite-hosted ones. The latter was classified further into R-type and P-type. The Myanmar jadeitite is a serpentinite-hosted one, and has both D-and P-types.

Its mineral components consist of about forty species, including jadeite, albite, analcime, natrolite, omphacite, kosmochlor, Cr-bearing jadeite-omphacite, nyböite, eckermannite, magnesiokatophorite, glaucophane, richterite, winchite, natrolite, thomsonite-Ca, thomsonite-Sr, banalsite, thomsonite, pectolite, vesuvianite, titanite, grossular, uvarovite, allanite, phlogopite, hyalophane, cymrite, celsian, zircon, graphite, quartz, diaspore, kaolinite, pyrite, galena, chromite, antigorite, ilmenite, iron cosmic spherule , etc. The mineralogical characteristics of Myanmar jadeitites are closely associated with their formation process.

The textures of the white Myanmar jadeitite include two major parts: (i) primary texture: jadeitites of coarse-grained with mosaic, granitoid or radial textures; (ii) deformed and recrystallized texture: jadeitites of finer grain size and compactness generally formed by metamorphism of the coarse-grained jadeitites, with microstructures showing variable preferred orientation of crystals, mechanical twinning, shear zones, subgrains, serrated high-angle sutured grain boundaries, or a ‘foam’ pattern. Geologically, the textures of Myanmar jadeitites provide evidence of metamorphism processes over the primary jadeite. It is inferred that the processes are linked to the major Sagaing strike-slip faults. Gemologically, the studies of jadeite textures can be applicated both in identifying and grading rough material as well as in the design, fashioning and grading of manufactured articles.

The Myanmar jadeitite can be used both as jade materials and as gem materials. The part of jade-gem quality are named *Feicui* by Chineses. Feicui vary greatly in transparency, color, compactness and toughness due to their diverse mineral components, textures and microstructures, which led to a series of trade names. The most precious *Feocui* are called “*Laokeng*” (trade name, which described as ‘icy’ or ‘glassy’ in texture, as well as the pure, bright, rich and even green. The “glassy” is relating to the best quality of their transparency. Jadeite jade has certain good intentions and excellent qualities people vested to Yu (nephrite jade), and may bear the best gem quality, which are only shown of the rare precious colored gemstone.

By contrasting the Yu (nephrite jade) utility history (more than 8000 years), the jadeite jade has a short history of less than 300 years in China. It didn’t appear in China mainland until the early Qing Dynasty according to the ancient documents and archaeological studies. The earliest recorded was in 1781. There is a Chinese sayings that goes, "Gold has a value, while jade is invaluable". It doesn’t mean the jade material only, it means the carving art on it as well. The jade culture is an important part of ancient Chinese culture. The Chinese term for jade, "*yu*" is often used in family names, as well as in terms to describe beautiful and warm moral of people.

Geochemical sourcing study of nephrite jade in East- and Southeast Asian prehistory

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Geological sourcing of stone artifact is an applied geology and recently has more strong linkage to the archaeometric (archaeological Science) study. Nephritic jade artifacts are commonly found in Neolithic and the Metal age archaeological sites in East and Southeast Asia. Since nephrite deposits only occur rarely in nature, it is widely accepted that chemical analysis is required if nephritic artifacts are to be sourced to specific quarries. Several types of analysis have been applied to the study of nephritic artifacts. Both handheld (portable) type X-ray fluorescence spectrometer (pXRF) and low vacuum (LV) type scanning electron microscopy (SEM) with an energy dispersive X-ray spectrometer (EDS) are powerful and completely non-destructive (or non-invasive) techniques. It requires no conventional sample preparation, apart from surface cleaning of the sample. The p-XRF is handy and good to material identification and technique of LVSEM with EDS can be used not only for sample surface observation, but also for quantitative chemical analysis for the study of precious ancient materials. Recently these techniques combined with EPMA (electron microprobe) results from natural rocks has been applied to many of archaic jade (nephrite) study in Taiwan and Southeast Asia including Philippines, Malaysia, Vietnam, Thailand and Myanmar. By now it is discovered that Taiwan (Fengtian) nephrites have been exported to some islands of the Philippines in prehistorically period since approximately 3,500 years ago with probably first migration stage of the Austronesian language speaking people from Taiwan. The results also indicate that Taiwan nephrites were still exported for Borneo, southern Vietnam and the Peninsula Thailand thought the Philippines in their metal age.

Not merely an accessory: the role of jades in Jômon society

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Prehistoric jade objects all around the world have been recognised by archaeologists as "valuables" (*kichôhin* 貴重品). It is generally accepted that due to a unique combination of characteristics of the material (rarity, beauty and hardness), jade objects were regarded as having special, magical properties by past societies. In other words, jade had an intrinsic special value and role in society. This is also true within the context of the hunter-gatherer society of the Jômon, where jade was used between ca. 6,000–2,500 Before Present. The majority of jade objects from the Jômon period are made of jadeitite sourced to the Itoigawa source; they were dispersed widely through Japan through long-distance exchange networks.

Characteristically, Jômon jade objects have a drilled hole. Their function is universally interpreted as bodily adornment; this is reflected even in their official archaeological terminology: *sôshingu* 装身具. Jades from the earlier phase (late Early Jômon to start Late Jômon, but especially common during the Middle Jômon period) are known as "large pendants" (*taishu* 大珠). During the later phase (Late and Final Jômon), jade use shifts to much smaller "round beads" or "curved beads" (*marudama* 丸玉 or *magatama* 勾玉). In publications or museum exhibitions aimed at the general public, Jomon jades are included under the wider category "accessories" アクセサリー; an inadequate term because of its strong suggestion that the primary function of such objects is to temporally and superficially enhance an individual's appearance and prestige. Moreover, although jades are known to have been used by both men and women, archaeological interpretations of the meaning and function of jade objects tend to be somewhat gendered. There seems to be a stronger assumption that the jade designated a "community leadership" role, if worn by a man (c.f. Kurishima 2015's translated title: "the man who wear large bead").

However, this presentation proposes that jades may have been connected to group and personal identity, history and memory in a more permanent, yet less straightforward, way.

In addition to the drilled hole, the interpretation as personal bodily adornment may also be related to the perception that Jomon jades are always found inside burials.

However, especially in the case of the earlier *taishu,* the deposition/find context strongly varies according to the region and the phase. For example, in the Central Japanese Alps they are often found buried, but in the Kanto Plains and coastal area, jade objects are frequently found in houses, or scattered around the settlement, or located inside a kaizuka shell midden layer; and at Sannai-Maruyama they are placed at a specially designated ceremonial area. Such diversity reflects differences in local customs regarding function and social value.

Nevertheless, the social role and value of Jomon jade objects also changes through time. Indeed, later Jômon small beads are often found in large quantities (strung together as a beaded necklace) in a few graves; these may have been connected more strongly to individual personhood than earlier Jômon jades.

Finally, this presentation aims to examine the general assumption of *taishu* as "large pendants", to be exclusively worn with a string around the neck. As many archaeologists have recognised, such "large pendants" are often too heavy for constant. Moreover, due to the placement of the drilled hole and the shaping of the object, the way a *taishu* hangs on the body may not have the striking visual effect that we modern people would expect. Other variable characteristics, such as quality of the jade material or the smoothness of the surface, and the specific shape of the objects, also will be discussed in order to propose a potentially broader range of uses within Jômon society than our modern idea of “personal adornment”.

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Green tuff, sanukite and obsidian: Archaeological stones and their geological sources

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The sub-discipline of geoarchaeology grew out of studies of archaeological site formation processes instigated by Michael B. Schiffer in the early 1980s, coming to fruition in the publication of *Geoarchaeology: an international journal* (beginning in January 1986), and Schiffer (1987) then Rapp & Hill (1998) with the inclusion of rock types and provenience sourcing. For the latter, petrography has been an important analytical area in archaeology, but even today, it is difficult to obtain petrographical information on artefacts due to three reasons: 1) not all archaeological units have the expertise or equipment to do rock identifications, 2) it is expensive to send out artefacts for analysis, and 3) the most important artefacts, for which such identifications would be most useful, often cannot be sampled with destructive methods. These disadvantages have been somewhat compensated for via the development of portable X-ray Floresence machines, which can do non-destructive analyses; but again, these are not widespread nor widely used.

In this presentation, I take a different approach and examine the most popular stone resources in Japanese prehistory through the lens of what I call Tectonic Archaeology, based in plate tectonics. While geoarchaeology deals with Earth surface phenomena – sites and artefacts, tectonic archaeology delves deep into the Earth to understand the actual formation of these important stone resources. Three stone types are particularly important for Japanese archaeology, and they happen to all be volcanic products but of very different time periods and formative processes: green tuff relates to the opening of the Japan Sea in the late Miocene from ca. 24 mya; sanukite is the product of the beginning of subduction under the new Japanese Islands, at 14 mya after that opening; and obsidian is mainly formed during Quaternary volcanic activity since 700 kya. The geological processes determine the location and chemical composition of the stone resources, both of which are necessary to understanding artefact production and exchange patterns in the different periods.

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The history of the Aral Sea: Implications from multi-disciplinary study

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The Aral Sea (an intracontinental saline lake in western Central Asia) is of great interest because of its rapid shrinkage during the last 50 years, which caused catastrophic environmental and socio-economic consequences for the region and its population. Geoscientists established the existence of similar multiple fast and deep lake level fluctuations in the past; however, a comprehensive picture of these changes has been lacking. In our study, we used multiple lines of evidence to reconstruct the patterns of geological history of the Aral Sea as a model of possible future natural and human-induced ecological disasters in Central Asia and other arid regions on Earth. For this purpose, we combined data from geological (including geomorphological, sedimentological, paleontological, and radiocarbon methods), archaeological, and historical sources. This lecture describes current status of the lake, summarizes all available data about the Aral Sea lake level changes during the last two millennia, the interval studied in detail, and throws a glance into its older history (Krivonogov et al., 2014).

The Aral Sea is quite changeable water body experienced a number of the climate and, in recent times, human induced desiccations. The data allow us to recognize the following Aral Sea lake level changes during the last two millennia. There were two deep regressions followed by the modern artificial regression since ca. 0.05 ka cal BP, and two intermediate transgressions. The regressions occurred at ca. 2.1-1.3 and 1.1-0.35 ka cal BP according to the sedimentary and faunal data, and 2.1-1.45 and 1.0 (0.85)-0.45 ka cal BP according to the other data. All these regressions were very deep. The Aral Sea level dropped to ca. 29 m a.s.l. in late Middle Ages similar to present conditions, and levels may have reached 10 m a.s.l. from late Antiquity to the early Middle Ages. Intermediate transgressions are established with an inferred Aral Sea lake level of ca. 52 m a.s.l. for the middle Middle Ages, and an elevation of ca. 53 m for the sixteenth – twentieth centuries. The highest level of the last transgression could be as high as 54 m a.s.l., as the flooded ruins of the Puljai settlement indicate. According to currently available data, the duration of regressions is unclear. They could be longer than the transgressions or of equal duration. Reasons for past Aral Sea lake level changes proposed by previous investigators include both natural and human-related causes, as the region features more than 2000 years of agricultural activity. In any case, it is evident that during the last 2000 years the Aral Sea experienced several desiccations and related ecosystem impacts, and it subsequently recovered naturally through time.

Reconstructions of the older history of the Aral are less detailed. Totally 10 boreholes opened the lake sediment sequence from top to bottom show a variety of layers formed in deep-water and shallow-water environments. Numerous AMS radiocarbon dates obtained from the cores depict an interruptive pattern of sedimentation: a number of hiatuses represent long-lasting regressions, while transgressive phases were limited. Medium and low levels were more typical states of the lake than high levels. Three thousand years long regression is recorded in the early Holocene between about 10 and 7 ka cal BP. Considerable change of the sedimentation conditions occurred at the late Pleistocene/Holocene boundary, when the environment of the last glacial period changed to the interglacial one. This change is well-seem in the sedimentation patterns and biota. The oldest Aral Sea sediments were dated to ca. 18 ka cal BP and the subbase non-lacustrine sediments have date of 24 ka cal BP. This allows us to conclude that the Aral Sea is a product of deglaciation to which the last glacial maximum (LGM) turned at about 20 ka cal BP (Burr et al., 2019).

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Precambrian to early Paleozoic Geology of the Central Asian Orogenic Belt

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Comprehensive understanding/interpretation of the Precambrian to early Paleozoic history of the Central Asian Orogenic Belt (CAOB) provides a stable basis in constructing the latter (Paleozoic) tectonic evolution scenarios responsible for building the largest region of continental crustal growth on Earth. The entire belt is composed of numerous pre-existing continental crustal fragments that are now stitched together by unique geologic entities such as ophiolite, blueschists, accretionary complex, and arc volcanics. To fully describe the birth history, better integration of the geologic context of each of these fragments is essential. Here we consider the importance of existing (1) paleomagnetic constraints, (2) oldest radiometric ages, and (3) contrasting tectonic evolution models with a goal to characterize the best-fitting Precambrian to early Paleozoic geologic evolution model for the CAOB. U-Pb detrital age spectra from Proterozoic siliciclastic rocks provide evidence for basement sources, magmatic and metamorphic ages for regional tectonism and metamorphism, and stratigraphy of the cover sequences for regional integration of each of the regions. Although the radiometric age constraints vary between these regions, the important ages are ~2 Ga, ~1 Ga, ~800 Ma, and ~500 Ma. We suggest that most of these ancient crustal fragments were exotic to Siberia and have potentially formed ribbon continents in its geologic history. Regional oroclinal bending may have been an effective mechanism to trap supracrustal material between them to aid the net continental crustal growth.

Ancient continents among the Central Asia Orogenic Belt: evidence from lithospheric mantle xenoliths

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Processes for deriving juvenile material from the mantle and accreting vertically are expected to have affected the SCLM beneath the CAOB. Cenozoic alkali basalts occur throughout Central and East Asia encompassing southern Siberia, central and southern Mongolia, NE China and the Russian Far East. Some basalts carry fragments of mantle rocks that provide direct evidence on the nature and composition of the deep lithosphere and contain a record of mantle processes. In this study, we summarize in-situ Os model ages on sulfides in peridotitic xenoliths from off-cratonic settings (Tariat, Mongolia; Vitim, Khamar Daban range (KDR) and Sviyaginsky volcano, Russia) of the CAOB to examine SCLM formation.

Both T_{MA} from the least-disturbed sulfides ($^{187}Re/^{188}Os<0.07$) and T_{RD} from higher Re/Os sulfides without later introduction/loss of Os, yield model ages ranging from 0.5 to 3.0 Ga, with peaks around 1.7-1.5, 1.2 and 0.7-0.5 Ga. These ages suggest that the sub-continental lithospheric mantle (SCLM) beneath the Tariat region formed at least by the Proterozoic time, and that some domains are Archean (Wang et al., 2013). The oldest age reported on the Precambrian Tarvagatay Terrane, where is underlain by Tariat volcanic field, is ca 3.05 Ga by Pb-Pb zircon dating in anorthosite (Mitrofanov et al., 1985). Other zircon U-Pb ages from nearby anorthosites are 1.78 and 1.7 Ga (I. Kozakov unpubl. data). The sulfide Os ages are consistent with these formation events recorded in the overlying crust. Younger sulfide Os ages (1.2 and 0.7~0.5 Ga) may mark the commencement of the Central Asia Orogeny since the Neoproterozoic and involvement of the mantle as suggested by Jahn (2004).

For KDR peridotites, both T_{MA} from the least-disturbed sulfides and T_{RD} from higher Re/Os sulfides yield model ages ranging from 0.7 to 3.0 Ga, with peaks around 2.0 and 1.2-1.0 Ga. These ages suggest that the SCLM beneath the KDR region formed at least by the Proterozoic time, and that some domains are Archean. For Vitim peridotites, although their sulfides have younger model ages, which range from 0.6 to 1.8 Ga with peak ages at 1.2-1.0 and 0.5 Ga, these ages still indicate parts of the SCLM beneath Vitim region have resided at least since Mesoproterozoic. The sulfide Os ages are consistent with these formation events recorded in the overlying crust. Younger sulfide Os ages (1.2-1.0 and 0.5 Ga) may mark the commencement of the Central Asia Orogeny since the Neoproterozoic and involvement of the mantle as suggested by Jahn (2004). This could be the first result showing ancient root beneath the HDR region, consistent with dating results of detrital zircons from near-by regions up to 2.9 Ga (Kovach et al., 2013). However, compiling with Mesoproterozoic Os model ages (up to 2.0 Ga) from the Vitim region, ancient lithospheric mantle domains are prevailing in the Central Asia Orogenic Belt, which might diminish extents of juvenile crustal growth in the Orogeny as expected before.

The Os isotope compositions of sulfides in mantle xenoliths hosted by late Miocene alkali basalts from the Sviyaginsky volcano, Russian Far East, reveal the presence of Archean-Proterozoic subcontinental lithospheric mantle (SCLM) beneath the Khanka massif. Both their

T_{MA} and T_{RD} model ages reveal similar peaks at 1.1 and 0.8 Ga suggesting later thermotectonic events in the SCLM, whereas T_{RD} model ages give the oldest age of 2.8 ± 0.5 (2□) Ga. The events recognized in the SCLM are consistent with those recorded in crust of the Khanka massif. The sulfide Os-isotope data show that the SCLM beneath the Khanka massif had formed at least by the Mesoproterozoic, and was subsequently metasomatised by juvenile crustal-growth events related to the evolution of the Altaids The Khanka massif is further proposed to have tectonic affinity to the Siberia Craton and should originate from it accordingly (Wang et al., 2015).

Recent studies have shown that volumes of ancient depleted material can survive in the convecting asthenospheric mantle for long periods of time so that the use of Os model ages of mantle xenoliths to constrain the age of lithospheric mantle events should be approached with caution. However, it would be a remarkable coincidence if sulfides derived from randomly selected fragments of refractory material in the convecting asthenospheric mantle would combine to give such a systematic correlation as shown in the above sections. Moreover, some of the ancient Os model ages are from apparently residual sulfide phases with subchondritic $^{187}Re/^{188}Os$ and $^{187}Os/^{188}Os$ ratios. To interpret these sulfides as being derived from depleted material residing within the asthenospheric mantle, it would be necessary to quantitatively melt the older sulfides, transport them into the SCLM and deposit them again without modifying their isotopic systematics. This seems to be an unlikely scenario. We therefore prefer the simplest interpretation of these data, namely the sulfide Os model ages in the Tariat, Vitim Khamar Daban Range and Sviyaginsky peridotites record major events (i.e., melt extraction) that affected the underlying SCLM. Comparing the lithospheric mantle domains from the above regions as revealed by Os model ages, with ancient microcontinents at least Mesoproterozoic in age and predating formation of the CAOB significantly diminishes the volume of new juvenile crust generated during the orogeny. Although significant mantle involvement during evolution of the CAOB has been summarized in previous chapters, the extent of ancient continental material may be larger than previously estimated.

Tectonic erosion at subduction zones: Examples from East and Central Asia

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Subduction zones form and exist at Pacific-type convergent margins (PCM). PCM's are very important geological entities because on one hand they are major sites of juvenile crust formation on the Earth, but on the other hand they are places of strong crust destruction through tectonic erosion (e.g., Maruyama et al., 2007; Stern, Scholl, 2010; Safonova et al., 2015; Vanucchi et al., 2016). The mechanism of tectonic erosion includes destruction of oceanic slab, island arcs, accretionary prism and fore-arc by thrusting, oceanic floor relief (horst/graben), and (hydro)fracturing. Accordingly, two contrast types of Pacific-type convergent margins – accreting or growing and eroding or narrowing - have been recognized so far (Scholl, von Huene, 2007). The accreting margins form accretionary complexes and grow oceanward. The eroding margins are characterized by shortening distance between arc and trench, which accompanies the tectonic and subduction erosion of accretionary wedge, fore-arc prism and volcanic arc. Dozens of scientists have been studying PCM and 90% of thematic papers discuss the formation of crust. Hundreds or even thousands of papers have been published on crustal growth through supra-subduction magmatism and accretion, but much less on tectonic erosion (Clift and Vanucchi, 2004; Scholl and von Huene, 2007; Stern and Scholl, 2010; Vanucchi et al., 2016).

The first evidence for the tectonic erosion at Pacific-type convergent margins was obtained from seismic reflection profiles made across the Tonga and Nankai trenches. The modern Pacific is surrounded by 75% of eroding convergent margins and 25% of accreting margins (Scholl and von Huene, 2007). The subduction of the Pacific plate provides high-rate tectonic erosion of the hanging walls of the western Pacific margins. Evidence for this comes from the Cretaceous Shimanto accretionary complex of Shikoku Island in Japan, where accretionary units are spatially adjacent to the coeval granitoids of the Ryoke belt, suggesting that older accretionary complexes have been eroded (Safonova et al., 2015).

As the present Western Pacific is a most probable analogue of the Central Asian Orogenic Belt (CAOB), processes of tectonic erosion could have been also active at the convergent margins of the Paleo-Asian Ocean, which evolution and closure were responsible for formation of the CAOB. Evidence for this comes from the Chatkal-Atbashi arc in the middle Kyrgyz Tienshan, from the Itmurundy accretionary complex in central Kazakhstan and from the Zharma and Char zones in eastern Kazakhstan. The Chatkal-Atbashi complex includes coeval and spatially adjacent Early Devonian arc granitoids, ophiolites and accretionary units. The Itmurundy and Zharma-Char zones host thick greywacke units of andesitic composition but very limited outcrops of arc rocks; detrital zircons from those greywackes show unimodal U-Pb age curves and positive epsilon Hf suggesting intra-oceanic arcs once existed in the Paleo-Asian Ocean, but later disappeared. At those fossil convergent margins, a big amount of materials of island-arc and accretionary terranes were probably eroded and submerged to the deep mantle (Yamamoto et al., 2009).

Recently the zones of subduction have received another focus as to deliver tectonically eroded surface materials of both oceanic and continental crust to the deep mantle, mantle transition zone, MTZ (Ishikawa et al., 2013; Safonova et al., 2015). Supply of large amounts of continental and oceanic crust material down to the MTZ may significantly affect the temperature of melting and the composition of the mantle (Litasov et al., 2013). During the last years, the fate of subducted materials and the possibility and mechanisms of their accumulation in the MTZ have been studied and discussed by several research groups worldwide (e.g., Ishikawa et al., 2013; Kawai et al., 2013; Litasov et al., 2013; Safonova et al., 2015), however we are still far from getting solid petrological, geochemical and geophysical data on that and integrating them into a well-proved holistic model.

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