ISSN 1349-1237

Abstracts of the

2nd International Symposium on

Earth History of Asia

October 31 – November 3, 2014
Niigata, Japan

新潟大學
Niigata University (Ikarashi Campus),
Niigata, Japan

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"Science Reports of Niigata University (Geology)"
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ISSN 1349-1237

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The 2nd International Symposium on Earth History of Asia

31 October – 3 November, Niigata, Japan

Message

The International Symposium on Earth History of Asia was held in October, 2009 at Niigata University, Japan. The symposium was a milestone for initiating collaboration in research and education between Niigata University and partner institutions. Since then our collaboration has been increasing continuously. The International Symposium on Earth History of Asia-II aims at having an opportunity to exchange idea for understanding the evolutionary history of geo-sphere and bio-sphere of the earth, especially in the Asian regions. Another objective of this symposium is to enhance partnerships among cooperative organizations, especially the Double Degree Program. Participating institutions include China University of Geosciences (Beijing), China University of Geosciences (Wuhan), Nanjing Institute of Geology and Palaeontology, Chinese Academy of Science, National Cheng Kung University (Taiwan), Pukyong National University (Korea), and Indian Institute of Science. During the symposium, we visit the Itoigawa Global Geopark and have an outreach session on geopark activities. We hope the symposium will provide a platform for exchange of ideas, give opportunity to students to interact with researchers across several Asian countries and pursue research in partnership institutions.

MATSUOKA Atsushi
Chairperson of the organizing committee

Date and Venue

October 31 (Friday)
Opening session, keynote lectures, and poster presentations
Niigata University Library, Ikarashi Campus, Niigata University

November 1 (Saturday)
Invited talks, oral and poster presentations
Graduate School of Science and Technology, Ikarashi Campus, Niigata University

November 2 (Sunday) – 3 (Monday)
Field Excursion and Geopark session
Geosites of Itoigawa Global Geopark and Itoigawa City Hall

Organizing Committee

Prof. Atsushi MATSUOKA, Niigata University (Chairperson)

Prof. Eiichi TAKAZAWA, Niigata University

Prof. M. SATISH-KUMAR, Niigata University

Prof. Toshiyuki KURIHARA, Niigata University

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Prof. Huai-Jen YANG, National Cheng Kung University

Prof. Tae-Seob KANG, Pukyong National University

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Prof. Heon-Tae KIM, Pukyong National University

Co-Organizing Agency

Graduate School of Science and Technology, Niigata University

Faculty of Science, Niigata University

Research Center for Earth Environment and Earth Material Science, Niigata University

Research Center of Science on Form, Niigata University

Itoigawa Geopark Council

Japanese Geoparks Network

EARTH HISTORY OF ASIA-II : PROGRAM

31st October, 2014

Opening session — University Library Hall

13 : 30 Welcome speech
Prof. KUDO Hisaaki
Dean, Graduate School of Science and Technology

13 : 40 Opening address
Prof. MATSUOKA Atsushi
Vice Dean, Graduate School of Science and Technology

14 : 10～14 : 30 Group photo

Keynote lectures — University Library Hall

14 : 30 WAN Xiaoqiao, MATSUOKA Atsushi, ZHANG Yiyi and YOSHINO Kohei
Songliao basin: the largest lacustrine oil field in East Asia —— Time, biota, climate 1

15 : 00 WANG Yongdong, HUANG Chengmin, SUN Bainian, QUAN Cheng, WU Jingyu and LIN Zhicheng
Palaeo-CO_2 variation trends and the Cretaceous greenhouse climate 3

15 : 30 KANG Tae-Seob
Seismic interferometry and ambient noise tomography in East Asia 4

16 : 00～16 : 30 Coffee break and poster viewing

16 : 30 LAI Steven Yueh Jen and CAPART Hervé
Evolution of river deltas and submarine canyons driven by hyperpycnal flows: a sandbox experiment 6

17 : 00 FUKUOKA Hiroshi
Landslides, GeoParks, and World Heritages 7

19 : 00～21 : 00 Conference Banquet at Hotel Nikko Niigata

1st November, 2014

Invited talks — Science of Matter and Industrial Science University Institute Center

9 : 00 SAJEEV K., ISHWAR-KUMAR C. RATHEESH-KUMAR and SATISH-KUMAR M.
Geological correlations between India and Madagascar in a Gondwanan perspective 9

9 : 20 YANG Huai-Jen and LIU Yung-Hsin
An evaluation on using the Nd–Hf isotopic systematic as an indicator for the protolith characteristics of eclogites 11

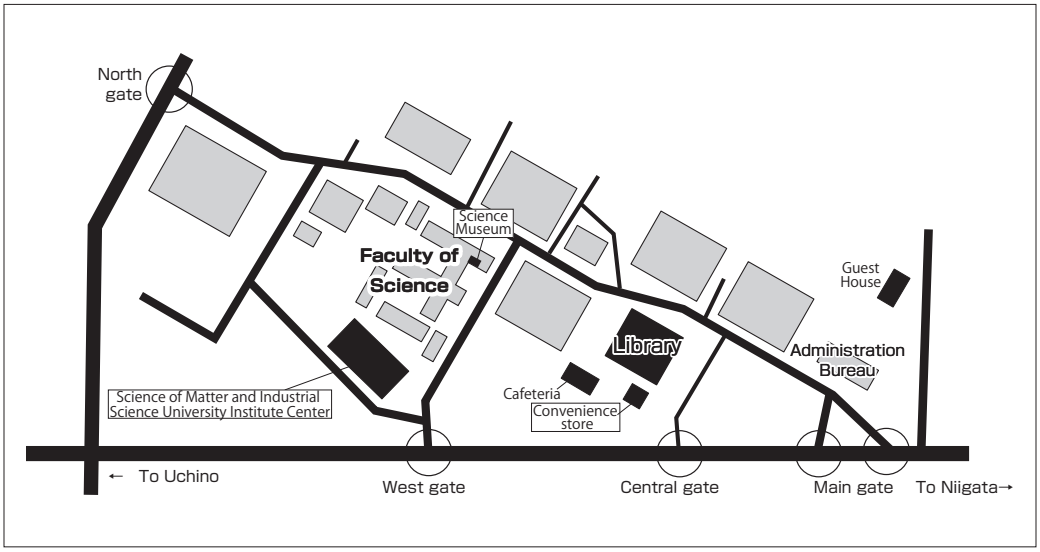
9 : 40 ZHANG Yiyi
Mid-Cretaceous Charophyta Stratigraphy from Core SK1 (South) in Songliao Basin and its Correlation with Marine Chronostratigraphy 13

Oral Presentations Science of Matter and Industrial Science University Institute Center

Poster presentations

Science of Matter and Industrial Science University Institute Center

November 2～November 3　Excursion to Itoigawa Global Geopark



Venue of Earth History of Asia - II

October 31 : Keynote lectures at University Library Hall

November 1 : Invited talks, Oral and Poster Presentations at
Science of Matter and Industrial Science University Institute Center
Conference reception at Cafeteria

For a detailed map please refer to the Niigata University web site
http://www.niigata-u.ac.jp/e/top/ikarashi_map.html

FIELD EXCURSION AND GEOPARK LECTURE/ PANEL DISCUSSION IN ITOIGAWA

November 2 (Sunday)

8 : 00	Departure from west gate of Niigata University
9 : 00	Departure from Chisun Hotel
11 : 30	Arrive at Kotakigawa Jade Gorge Geosite
12 : 00	Lunch
13 : 30	Excursion along the Kotakigawa River
16 : 30	Arrive at Hotel White Cliff
17 : 30	Arrive at Omi Junior High School Seminar House (Students)

November 3 (Monday)

8 : 30	Departure from Hotel White Cliff
8 : 30	Departure from Omi Junior High School Seminar House (Students)
9 : 00	Arrive at Fossa Magna Park (Itoigawa—Shizuoka Tectonic Line)
10 : 30	Arrive at Omi Coast Geosite
11 : 30	Lunch
12 : 30	Itoigawa City Museum of History and Folklore
13 : 30	Lecture/Panel Discussion at Itoigawa City Hall
	13 : 30 Opening address
	13 : 35 Welcome speech
	13 : 40 Charms of Itoigawa Global Geopark (Itoigawa Geopark Council)
	14 : 00 Charms of Tateyama-Kurobe Geopark (Tateyama-Kurobe Geopark Council)
	14 : 15 Group Photo
	14 : 30 Panel Discussion
	15 : 30 Closing address
15 : 40	Departure from Itoigawa City Hall
18 : 00	Arrive at Chisun Hotel
19 : 00	Arrive at west gate of Niigata University

Opening address for the 2nd International Symposium on Earth History of Asia: From collaboration in research to collaboration in education

MATSUOKA, Atsushi [1, *]

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The International Symposium on Earth History of Asia was held in October, 2009 at Niigata University, Japan. It was about 10 years after the conclusion of the agreement for cooperation with China University of Geosciences, Beijing and China University of Geosciences, Wuhan. Just before the symposium, the agreement with Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences was concluded. That symposium was a milestone for initiating collaboration in research and education between Niigata University and partner institutions. Since then agreement for cooperation and memorandum for student exchange have been established actively between Niigata University and cooperative organizations such as Chungnum National University, Islamic Azad University-North Tehran Branch, and Indian Institute of Science. In addition, scientific and educational meetings have been organized in Niigata University. They include the Niigata Graduate Research Forum in January 2013 and the 3rd International Congress on Natural Sciences in October 2013.

The Double Degree Program (DDP) is a special educational program through which participating students are matriculated at both Niigata University and the partner institution and able to obtain “the double-degree”, receiving a separate degree from each university or institution. The DDP agreements were concluded with Pukyong National University and China University of Geosciences, Wuhan in 2011. Moreover, National Cheng Kung University and Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences participated in the DDP in 2012. China University of Geosciences, Beijing joined the program in 2013. To date, three graduate students in the field of earth sciences have been sent to partner institutions in China and one has been received from Taiwan.

Besides the DDP, a wide variety of exchange programs were performed between National Cheng Kung University and Niigata University. In 2011 and 2012, students and faculty members of Niigata University visited Taiwan and participated in a field

excursion by courtesy of the sisterhood institution. On the contrary, students from National Cheng Kung University joined a field excursion offered by Niigata University in 2013 and 2014.

The International Symposium on Earth History of Asia-II aims at having an opportunity to enhance partnerships among cooperative organizations, especially Double Degree Program partners. This event includes keynote speeches, educational exchange opportunities, international academic symposium, and a visit to Itoigawa Global Geopark. Participating graduate students from each institution will also have an occasion to present their research achievements either in oral or poster presentation session and to participate in further discussion sessions and various exchange opportunities with students from Niigata University and other international partner institutions. We believe that this is a great chance to foster and expand international academic networks among faculty members and students in order to make advancements in research and education.

This is the 300th memorial event of the Earth History Seminar in the Department of Geology, Faculty of Science, Niigata University. We have added 100 seminars after the 1st International Symposium on Earth History of Asia held in October 2009.

Keynote Lectures

Songliao Basin: the Largest Lacustrine Oil Field in East Asia —— Time, Biota, Climate

WAN Xiaoqiao[1,*], MATSUOKA Atsushi[2], ZHANG Yiyi[1], YOSHINO Kohei[1, 2]

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The Songliao Basin is the largest Cretaceous oil and gas-producing lacustrine basin in China. The modern Basin is 700 km long from north to south, and 370 km wide from east to west, covering 260,000 km^2 areas of Heilongjian, Jilin, Liaoning and Inner Mongolia provinces. Its greatest aerial extent happened in the middle Cretaceous while the thickness of sedimentary strata grew up to 8000m. The first commercial oil well in the Daqing Oil Province was completed in 1959. Its available resources are 6.0*109 t with the production of more than 40*106 t/a, and the cumulative oil production is over 2 billion tons.

The geologic history of this basin is well known because of the extensive drilling for hydrocarbons. However, the background of lacustrine hydrocarbon is scientific issues, which needs to understand the links and feedbacks of the carbon cycle during times of global greenhouse. For this purpose, numerous studies have focused on the Cretaceous climate,, much of what we know about this warm period in Earth's history comes from the study of ocean sediments from both ocean drill cores and marine sediments exposed on the Earth's surface. In contrast, there are few studies of Cretaceous terrestrial sediments. The Songliao basin located in northeast China offers a unique opportunity to perceive Cretaceous paleoclimate of terrestrial settings as it contains a nearly complete record of lacustrine sediments deposited throughout the Cretaceous and an active drilling program to recover core from this paleolake.

A coring program (SK1) has to date yielded 2485.89m of continuous core (96.46% recovery) and provides significant material for Cretaceous research. The sequence of the core consists mainly of lacustrine sandstone, dark grey mudstone, shale and oil-shale. The Upper Cretaceous stratigraphic section has been subdivided into the Quantou, Qingshankou, Yaojia, Nenjiang, Sifangtai and Mingshui formations in ascending order. Late Cretaceous microfossils are diverse and abundant. A detailed biostratigraphic study has subdivided the sequence into high precision biozones: 21 ostracod assemblages, 10 phytoplankton assemblages, 7 palynological zones and 4 charophyta assemblages, respectively. In addition, marine foraminifera were first discovered from the basin. Three 206Pb/238U ages of 91.4 ± 0.5 Ma, 90.1 ± 0.4 Ma, 83.7 ± 0.5 Ma and one 40Ar/39Ar age of 88.3Ma were analyzed.

Eleven local magnetozones have been recognized in the well SK1. Based on biostratigraphy, high-resolution magnetostratigraphy and SIMS U-Pb zircon analyses, the SK1 stratigraphy is correlated with Upper Cretaceous stages. The upper part of the Quantou Formation is lower Turonian; the Qingshankou Formation is upper Turonian- lower Coniacian; the Yaojia Formation is from upper Coniacian to middle Santonian; the Nenjiang Formation is upper Santonian to middle Campanian; the Sifangtai Formation is limited to upper Campanian; and the Mingshui Formation is uppermost Campanian to Maastrichtian. It is likely that the upper part of the Mingshui Formation belongs to Paleocene, and the K/Pg boundary is within the uppermost part of the Mingshui Formation.

The Cretaceous Period is a paradigm of a greenhouse climate and provides significant records of global climate changes and driving processes. For the paleoclimate study, we present carbon, oxygen and strontium isotopic data from ostracods collected from drill core SK1. These data record robust isotopic trends with numerous carbon and oxygen isotope shifts that are not only rapid but also long-term. We tentatively interpret this record to reflect the changes in both global climate and regional basin evolution. In the Turonian and Coniacian Qingshankou Formation we observe several carbon isotope shifts that appear to be correlative to marine isotopic records based upon timing and magnitude of the isotopic changes. Thus we suggest that the carbon isotope record in the Songliao basin reflect the decrease in carbon isotope ratios following the strong positive excursion at the Cenomanian/Turonian boundary, a positive isotope excursion in the late Turonian, and the negative isotope shift that occurs at the Turonian/Coniacian boundary. Upward in the section, however, the marine and Songliao isotopic records diverge as sediment sources shift from the southwest, east and north to more northerly. Strontium isotopes record the change in source region as they increase markedly between the Coniacian/Santonian Yaojia and Santonian/Campanian Nenjiang Formations. The rich isotopic records are compared to global climate changes and basin evolution as well.

Lake water salinity changed in a freshwater–brackish water –freshwater cycle, along with a Coniacian-Santonian marine incursion. Lake-level fluctuations resulted in the development of periodic anoxic environments in the deepest parts of the basin. One of these times of deposition of organic-rich mud correlates with the mangnetochron boundary of C34N/C33R and Coniacian-Santonian planktic foraminifera. This marine flooding correlates with OAE 3 and it is possible that the global oceanic anoxic event may have influenced organic carbon burial in the Songliao Basin for this brief period. The signal from Songliao Basin shows that the terrestrial climate change is somehow similar to marine recode as under one single Earth system.

Palaeo-CO_2 variation trends and the Cretaceous greenhouse climate

WANG Yongdong [1*], HUANG Chengmin [2], SUN Bainian [3], QUAN Cheng [4], WU Jingyu [1, 3] and LIN Zhicheng [5]

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The Cretaceous was one of the most remarkable periods in the geological history, with a "greenhouse" climate and several important geological events. Reconstructions of atmospheric CO_2 using proxies are crucial for understanding the Cretaceous "greenhouse." In this paper we summarize the major approaches for reconstructing CO_2 based on palaeobotanical or geochemical data, and synthesize the CO_2 variations throughout the Cretaceous. The results show that atmospheric CO_2 levels remained relatively high throughout the Cretaceous, but were lower in the early Cretaceous, highest in the mid-Cretaceous and gradually declined during the late Cretaceous. However, this overall trend was interrupted by several rapid changes associated with ocean anoxic events (OAEs) and the end-Cretaceous event. New data on paleo-CO_2 levels from palaeobotanical and palaeosol evidence support not only the overall trends indicated by geochemical models, but provide more precise records of the short-term fluctuations related to brief episodes of climate change. Temporal resolution within the long quiet magnetic period in the middle Cretaceous is one of obstacles preventing us from a more comprehensive understanding of the CO_2 climate linkage. But new palaeo-CO_2 determinations and climatic data from stratigraphic sections of sediments intercalated with datable volcanic rocks will allow a better understanding of the relationships between fluctuations of atmospheric CO_2, climate change, and geological events.

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Seismic interferometry and ambient noise tomography in East Asia

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Seismic imaging methods based on recordings of earthquakes suffer from various limitations. Above all, their resolution tends to degrade in areas of low seismicity, far from plate boundaries or other tectonically active areas. Waveforms from remote earthquakes are poor at high frequencies, due to the attenuation and scattering of waves along paths between sources and stations. This results in a low-resolution tomography with traditional surface waves.

Nowadays most of the seismological networks produce continuous records of ground movement. Huge amounts of data are accumulated and most of them are full of so-called seismic background noise that corresponds to the seismic waves produced by natural processes or human activity. The passive imaging is based on the possibility of extracting consistent information on the seismic wavefield between two sensors from the recordings of ambient noise.

The existence of correlation between seemingly random signals recorded at distant stations was first shown with the multiply diffracted wave coda (Campillo and Paul, 2003). The correlation is considered to be the Green's function that is the response of the Earth between two points, from which we can measure the travel time. Shapiro and Campillo (2004) has successfully applied the same approach to recordings of ambient noise and has opened the way for many applications (e.g., Kang and Shin, 2006; Choi et al., 2009).

In many recent studies where the noise was used to obtain the seismic response between two points, coherent waves were extracted from the noise even though at first glance, these coherent signals are hidden deep in an incoherent noise. One of concerns among those applications is the imaging of structures at different scales. Here the noise reduces the gap between spatial resolution methods based on earthquakes and active sources. Firstly, correlation methods used in seismology allow waves between stations near higher frequency than what is possible with remote earthquakes. The crust and upper mantle are now commonly imaged, mainly with surface waves, at scales ranging from thousands of kilometers to tens of meters. In addition to prospecting, correlations

can extend the analysis to lower frequencies compared to conventional active methods. In this presentation, some studies on seismic tomography using ambient noise cross-correlation in East Asia are introduced in various scales.

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Evolution of river deltas and submarine canyons driven by hyperpycnal flows: a sandbox experiment

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Hyperpycnal flows easily appear in small mountainous rivers along active margins because of the high uplift and erosion rates (Milliman and Syvitski, 1992; Dadson et al., 2003; Mulder et al., 2003). The flows contain abundant suspended sediment and can plunge into the receiving basin (lakes or the sea) to form an underwater flow transporting terrestrial sediment to deep marine. However, only a few studies address the physical processes of how unconfined hyperpycnal flows shape the landscape and seascape. To fill this gap, we design a unique sandbox experiments to investigate and visualize how river deltas and submarine canyons evolve under the influence of unconfined hyperpycnal flows. In our experiments, terrestrial and submarine domains jointly respond to block uplift and rainfall runoff. The hyperpycnal runoff is generated by salt water in which the liquid is distinguished by the density of the applied rainfall relative to the density of the ambient water. Detailed evolving processes are recorded by time-lapse photography every 5 seconds. Bed topography of each experimental stage is reconstructed to form high resolution digital elevation models by using laser-scan imaging technique. Our preliminary results show that unconfined sediment-laden flows generate a line of prograding hyperpycnal deltas at the shoreline. At the submarine downstream end, hyperpycnal flows dissipated retrogressive breaching and generate a series of deeply incised submarine canyons. We found that the combination of differential uplift and hyperpycnal flow is necessary to provide a viable valley-canyon forming mechanism. We hope our novel and unexpansive experiments can stimulate new questions and motivate more future research.

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Landslides, GeoParks, and World Heritages

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1. Landslides in areas of high societal values

Landslides are the most typical hazardous phenomena which give fatal and societal impacts. Most recent serious disastrous landslides in Japan, took place in Hiroshima in August 2014 and in Izu-Oshima, a volcanic island of Tokyo. Hiroshima case claimed 74 casualties and Izu-Oshima claimed 39. Both disasters were induced by extreme rains, recording large return period. Both of the landslide hit areas are newly developed residential sites expanding to hillside slopes, which generally attracts people by good view and but places higher risk to residents.

2. GeoParks and World Heritages at landslide risk

UNESCO World Heritage Center has inscribed many natural and cultural sites in its World Heritages list. Most important factor of World Heritage definition is the "irreplaceable" value for mankind. UNESCO also launched GeoPark programme and creating Global GeoPark Network (UNESCO, 2014). Definition of Geopark is specific heritage sites of international and geological significance. Many of municipal or national governments which manage Geoparks are keen to promote awareness and education of geological hazards, such as landslides, earthquakes, volcanic eruption.

UNESCO-IUGS (International Union of Geological Sciences) joint programme IGCP (International Geological Correlation Programme) No. 425 on "Landslide hazard assessment and mitigation for cultural heritage sites and other locations of high societal value" was organized in 1998-2002 to promote international joint research on this topic. More than 20 joint projects were proposed and launched. This activity contributed to the establishment of the International Consortium on Landslides (ICL) which consists of about 60 organizations now and coordinates international research and education projects. It operates the International Programme on Landslides (IPL) which is supported by 5 UN agencies (UNESCO, FAO, WMO, UNISDR, and UNU).

3. Landslide risk reduction through assessment and monitoring

The author have been involved in research projects on landslide risk at Machu Picchu (Peru, World Heritage site) (Sassa, 2014, Sassa, et al., 2008), Lishan mountain

(China, national cultural heritage site) (Fukuoka et al., 2005), Unzen volcano (Japan, World GeoPark site) (Sassa, 2014), Zentoku landslide of Iya valley (Tokushima, Japan, cultural heritage site), as well as above-mentioned Izu-Oshima recent landslide disaster site (Japan, national GeoPark site). In Niigata prefecture, we have Itoigawa national GeoPark site which has a landslide disaster site which took place decades ago.

3.1 Mechanical approach

In the case of recent Izu-Oshima landslide case, author has conducted undrained and stress-controlled ring shear tests to prove that the high mobility of the event came from the generation of high excess pore pressure to reduce the effective stress, and thus the shear resistance dropped largely. The major cause of the pore pressure generation was grain crushing of the volcanic ash deposits on the hill slope surface. These phenomena are called as "Sliding surface liquefaction." (Sassa, Fukuoka, et al., 2007)

3.2 Monitoring approach

In the case of international joint research on Machu Picchu, researchers from Japan, Italy, Canada, and Czech Republic joined and contributed / installed various sensors on the slope. Japanese team installed short-span and long-span extensometers and found small displacement which corresponded to rainfall. According to geomorphic interpretation of the airphotos, this site had been subjected to large-scale ancient rock slides, and the current World Heritage site was apparently at landslide risk possibly caused by future earthquake because the site is located on crossing of two fault system. Interim report of our study gave great impact to Peruvian society and we learned that dissemination of scientific research on risks at heritage sites required careful consideration.

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Invited talks

Geological correlations between India and Madagascar in a Gondwanan perspective

K. Sajeev[1*], C. Ishwar-Kumar[1], R.T. Ratheesh-Kumar[1] and M. Satish-Kumar[2]

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The understanding of position of southern India in various supercontinent assemblies, its amalgamation and rifting with various continental fragments have significant implication in understanding the tectonic processes through geological time-scale. The southern India is a mosaic of various crustal domains, which are divided by shear/suture zones, but several controversies exist regarding the tectonic framework, shear zones and crustal blocks of southern India. The detailed structural lineament mapping of southern India along with new and compiled of geological and geochronological datasets help in delineating new shear zones and redefining the Precambrian crustal blocks of southern India. Especially, in a Madagascar-India correlation point of view, recent studies have reconstructed plate margins of India and Madagascar based on flexural isostasy along the Western Continental Margin of India (WCMI) and the Eastern Continental Margin of Madagascar (Ratheesh-Kumar et al., 2014). In this context, the newly proposed Mesoproterozoic Kumta and Mercara suture zones (1400-1000 Ma) welding Archean crustal blocks in western India offer critical insights into Precambrian continental juxtapositions and the crustal evolution of Gondwana (Ishwar Kumar et al., 2013).

The textural evidences, mineral chemistry and thermodynamic modeling of quartz-phengite schist, garnet-biotite schist from the Kumta suture suggest peak metamorphic *P-T* conditions of *c.* 18 kbar, 550°C and *c.* 11 kbar, 790°C respectively and garnet-biotite-kyanite-gedrite-cordierite gneiss from the Mercara suture suggests peak metamorphic *P-T* conditions of *c.* 12.5 kbar, 825°C. The calc-silicate granulite and mafic granulite were re-equilibrated under high-pressure conditions of 15-20 kbar at a temperature of 800-900^{o} C. The Bondla-ultramafic complex in the northwest of Kumta suture contains shale, basalt, dolerite, gabbro, chromite bearing serpentinite, chromitite and peridotite. The chromite chemistry from ultramafics suggests the evolution in a supra-subduction zone arc setting. Towards the east of the Kumta suture, the Sirsi shelf contains weakly deformed sedimentary rocks (limestone, shale, banded iron formations, greywacke, sandstone and quartzite) unconformable on high-grade *ca.* 2571 Ma gneisses of the Dharwar craton.

The Karwar block to the west of the Kumta suture is mainly composed of weakly deformed tonalite-trondhjemite-granodiorite (TTG) with enclaves of amphibolite. Whole-rock

major and trace element data suggest that the TTGs (Type I, low K_2O, high Na_2O, Sr) were derived from a volcanic arc, and that the TTGs (Type II, high K_2O, low Na_2O, Sr) have within-plate signatures. Amphibolites have a chemical composition comparable to basalts to basaltic andesites with MORB signatures. The Karwar block TTGs (Type I) are *ca.* 3200 Ma with εHf range of -0.7 to 4.4. The whole-rock εNd ranges from -2.4 to 2.1 representing juvenile crustal origin. The Coorg block, about 100 km south of Karwar block mainly consists of highly metamorphosed lower-crustal rocks yielding 3200 Ma age with positive to negative εHf spread (3.3. to -3.2) indicating their source as mixture of juvenile and recycled crustal materials. Metasedimentary rocks from the Kumta suture have ƐHf (t) values that range from -9.2 to 5.6, and T_{DM} ages that range from 2747 to 3546 Ma; comparable values in metasedimentary rocks from the Mercara suture range are from -18.9 to 4.2 and from 3214 to 3647 Ma respectively.

Synthesis of the above results suggests that the Kumta and Mercara suture zones incorporate sediments, which range in age from Paleoarchean to Mesoproterozoic, and were subjected to high-pressure metamorphism in the late Mesoproterozoic. The protolith sediments were mainly derived from juvenile crust that was mixed with products of recycled older continental crust. Integration of the new results with published data indicates the Mesoproterozoic Kumta-Mercara suture in western Peninsular India interpreted as eastern extension of the Betsimisaraka suture of Madagascar into western India.

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An evaluation on using the Nd–Hf isotopic systematic as an indicator for the protolith characteristics of eclogites

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The nature of protolith of eclogites is one of the critical elements for re-constructing regional tectonic evolutions. However, identifying protolith characteristics of eclogites has been subjected to complications from metamorphic modifications on the protolith compositions, since a large number of constituent elements of eclogitic protoliths are mobile during metamorphism at high P–T conditions. Jahn (1999) postulated that the positive and negative metamorphic initial εNd values of eclogites can be protolith indicators of oceanic and continental affinities, respectively. However, the metamorphic initial εNd values alone cannot determine whether the protoliths were generated by subduction-related or intra-plate magmatism, handicapping investigations on tectonic evolution. In contrast to the εNd(t) values that evolve with rates depending on the abundance ratios of two REE (Sm/Nd), the εHf(t) values are sensitive to REE–HFSE (Lu–Hf) fractionation, providing additional constraints on protolith characteristics. This contribution presents an evaluation on using the Nd–Hf isotopic systematic to characterize the nature of the protoliths of eclogites from the Sulu terrane at eastern China.

Based on major and trace element compositions, the analyzed Sulu ultra-high pressure (UHP) eclogites are classified as high-Fe-Ti eclogites, group I high-Al eclogites, group II high-Al eclogites, and garnetites. Despite the compositional differences, these eclogites all deviate from the terrestrial εNd–εHf array, implying metamorphic modifications on the Sm–Nd or Lu–Hf or both of these two isotope systems. All these UHP rocks define an $^{143}Nd/^{144}Nd$–$^{147}Sm/^{144}Nd$ errorchron of 232 ± 36 Ma (MSWD = 4.6), which largely overlaps with the peak metamorphism age of 220–245 Ma. The U-shaped LREE patterns of the high-Fe-Ti eclogites and group I high-Al eclogites provide additional evidence for the metamorphic modifications on the Sm–Nd isotope system of the protoliths. In contrast, the Lu/Hf ratios of these eclogites are generally within the range for basalts and do not vary systematically with the $^{176}Hf/^{177}Hf$ ratios. The range for the protolith initial $\varepsilon_{Hf}(780)$ values calculated from the Lu/Hf ratios of the samples is nearly identical to that for the ~780 Ma magmatic zircon grains from the Yangtze craton, suggesting the dominance of protolith

characteristics on the Lu–Hf isotope system. Being controlled by different processes, the Sm–Nd, and Lu–Hf isotope systems of the samples therefore are decoupled. Since the Sm/Nd ratios of the eclogites were modified by metamorphism, the protolith initial calculated from these values, $\varepsilon_{Nd}(780)_{meta}$, are not protolith indicators. The protolith initials, $\varepsilon_{Nd}(780)_{ig}$, calculated from the metamorphic initials using the Sm/Nd ratios inferred from the Sm/Nd–Lu/Hf trend of igneous rocks better characterize the protoliths. In the $\varepsilon_{Nd}(t)$–$\varepsilon_{Hf}(t)$ plot, the protolith initials and metamorphic initials of the eclogites distribute similarly with respect to the trend defined by the rocks formed at 0–1382 Ma by continental magmatism; specifically, higher ε_{Hf} values at a given ε_{Nd} and within the field for arc lavas. Metamorphosed from protoliths generated by backarc rifting is finally proposed for the eclogite samples to account for their arc signatures and the felsic–mafic bimodal compositions of the Sulu UHP rocks.

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Mid-Cretaceous Charophyta Stratigraphy from Core SK1 (South) in Songliao Basin and its Correlation with Marine Chronostratigraphy

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Cretaceous plays a significant role during the sweep of geologic history in light of some major events such as global warming and mass extinction. Recent years, with the chronostratigraphy standard established, the marine Cretaceous is supposed to be well observed, while the non-marine Cretaceous is relatively poorly studied in part because there is a lack of comprehensive fossil records.

In northeastern China, however, we found Charophyta fossils in the Songliao Basin, one of the biggest Cretaceous continental rift basins all over the world, in which the southern hole of Songke–1 (SK1(S)) is located in the centre. According to Gramast (1972), Charophyta may be an ideal instrument of dating non–marine strata, in particular those of the Cretaceous and valuable tool for intercontinental correlation.

The target interval in this study is from the upper Quantou Formation to the lower Nenjiang Formation deposited during the depression stage in the Cretaceous. The member 3 of Quantou formation yields *Atopochara restricta, Mesochara symmetriea*, *Obtuochara niaoheensis* and *Euaclistochara mundula*; Member 4 is dominated by *Amblyochara elliptica*, *Ambyochara quantouensis*, *Atopochara restricta* and others; Member 2-3 of Qingshankou Formation contains mostly *Aclistochara bransoni minor*, *Ambyochara elliptica*, *Atopochara restricta*, *Aclistochara songliaoensis*, *Maedlerisphaera ellipsoidalis*; Member 1 of Yaojia Formation yields *Aclistochara bransoni minor*, *Atopochara restricta*, *Obtusochara niaoheensis*, *Songliaochara heilongjiangensis*, *Songliaochara heilongjiangensis nonganensis*; Member 2-3 of Yaojia Formation contains *Aclistochara bransoni minor*, *Aclistochara songliaoensis*, *Obtusochara niaoheensis*. Based on the high-resolution sampling from SK1(S) and the outcrops across the basin, four charophyta assemblages are classified: *Obtusochara niaoheensis* Assemblage in member 3 to lower member 4 of Quantou Formation, *Amblyochara quantuoensis* Assemblage in middle Member 4 of Quantou Formation, *Maedlerisphaera ellipsoidalis* Assemblage in upper Quantou Formation to lower Qingshankou Formation, and *Aclistochara songliaoensis* Assemblage in upper Qingshankou Formation to yaojia Formation.

According to the previous research and the microfossils involved in SK1(S), it is suggested that the age of the upper Quantou Formation possibly is from Cenomanian to lower Turonian, the Qingshankou Formation is upper Turonian- lower Coniacian; the Yaojia Formation is referred to upper Coniacian to middle Santonian, and the lower Nenjiang Formation rests in upper Santonian.

Terrestrial paleoenvironments during the mid-Cretaceous reconstructed from the continuous lacustrine strata in Southeast Mongolia

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To elucidate the causal relationship between environments of land and ocean during the mid-Cretaceous Oceanic Anoxic Events intervals, we have investigated terrestrial paleoenvironmental records of Cretaceous lacustrine strata in the intra-continental Gobi Basin, southeast Mongolia. This study has been conducted as the Japan-Mongolia-China joint researches since 2009 (Ando et al., 2011).

The Shinekhudag Formation, its below (Tsagantsav Fm.) and above (Khuhuteg Fm.) exposed in the Shine Khudag area, Shaazangiin Gobi region are studied to cover the majority of terrestrial sequences for constructing a composite section (Jerzykiewicz, and Russell, 1991; Hasegawa et al., 2012). The lacustrine Shinekhudag Fm. is composed of alternating beds of dark greyish paper shale (oil shale), greyish calcareous shale, light greyish dolomitic marl, and yellowish to brownish dolomite. The strata are continuously exposed up to 400 m in thickness. The shale and dolomite successions are rhythmically alternated (decimeter-, meter-, tens of meter-scale), possibly controlled by orbital cycles. Paper shale contains micrometer-scale laminations, which are most likely varve origin. The estimated sedimentation rate is ca. 6-7 cm/k.y. by the varve-counting methods on thin sections. The age of the Shinekhudag Fm. is currently assigned to be Aptian or Barremian-Aptian based on the ostracodes, concostracans, floral and molluscan evidence (Jerzykiewicz and Russell, 1991; Yuan and Chen, 2005), and $^{40}Ar/^{39}Ar$ dating of basaltic rocks in the uppermost part of the underlying Tsagantsav Fm. (ca. 121-125 Ma: Graham et al., 2001).

In order to clarify the depositional environments and the controlling factors for the rhythmically alternating lithofacies changes, we conducted XRD analysis, elemental analysis (C, N, S), Rock-Eval pyrolysis, and a quantitative study of palynofacies to evaluate the organic matter (OM) composition. The mineral composition results confirmed the cyclic alternations (ca. 1.5 m cycle) of dolomite abundant layers and detritus minerals and calcite rich layers. C/N values are significantly low (< 10) in the dolomite samples, while higher (> 15) in shale samples. Rock-Eval analysis shows significantly high hydrogen index (> 650 mg/g) with relatively high T-max values (430–440˚C), and all the samples are composed of Type I–II OM. Palynofacies analysis further indicated the dominance of *Botryococcus* colonies in dolomite layers, whereas shale layers are abundant in amorphous OM, algal cysts, and terrestrial palynomorphs.

These lines of evidence indicate that the rhythmically alternating lithofacies changes in the Shinekhudag lacustrine deposits were mainly controlled by orbitally driven changes in lake level and lake productivity during the OAE1a–1b interval. Namely, the dolomite layers were formed during low lake levels by microbially mediated precipitation in highly alkaline lake waters. *Botryococcus* colonies were abundant under such oligotrophic and euryhaline conditions. On the other hand, the shale layers were deposited during high lake levels, which were characterized by higher algal productivity and increased inputs of detrital minerals.

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Middle Permian tectono-sedimentary history with biotic reaction of the Southern Kitakami Terrane, northeast Japan

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Prior to the near-complete elimination of terrestrial and marine biota at the end-Permian, marine shelly biota, mainly benthic animals such as bryozoans, brachiopods, gastropods, bivalves, trilobites and fusulines, suffered severe damage in the Guadalupian Epoch of the Middle Permian, the so-called Guadalupian extinctions (Stanley and Yang, 1994). It has been suggested that the extinction was caused by oceanic anoxia, mode of climatic oscillations, tectonically activated paleogeographical rearrangements and volcanisms, while it still remains controversy. Apart from the geological and climatic arguments, extinction is a manifestation that organisms could not adapt to a newly emerged habitat as a result of environmental changes. Thus understanding the environmental history with biotic reaction could expand our knowledge of the global event of the Middle Permian mass extinction. The aim of this presentation is to exemplify the transition of sedimentary environments and their organism-related responses in the active margin setting of the Middle Permian in the Southern Kitakami Massif (see Shiino et al., 2011).

In the Kamiyasse area, the Middle Permian sequence is subdivided into three formations; the Hoso-o, the Kamiyasse and the Kurosawa Formations in ascending order. The transition in the sedimentary environment began with an upper slope to outer shelf depositional setting that was associated with a river system and thus deposited abundant botanic remains in the Hoso-o Formation. By contrast, the sediments of the overlying Kamiyasse Formation, the base of which is roughly equivalent to the base of the Capitanian, originated from complex depositional sources in the context of fault-related tectonic basins. This is likely due to volcano-tectonic activations in this period, considering the reliable evidence for tuffaceous sand layers. Brecciated reef corals and cemented brachiopods were derived as talus deposits, suggesting a presence of shallower hard substrate environment nearby. This unique depositional setting resulted in the seemingly “mixed” fauna associated with this formation. The depositional environment of the overlying Kurosawa Formation is

similar to that of the Hoso-o Formation, but with many fewer, monotonous biotic remains. Of these, brachiopod *Spiriferella* sp. is suggestive of the cool and swift water environment (e.g., Shiino and Angiolini, 2014). Its exclusive occurrence at the basal part of the formation may lead to a hypothesis of prompting the inflow of cool water upwelling onto the onshore area as a consequence of tectonic activations. Transgression of the sea level may also facilitate the generation of cool water inflow. Such an inflow of cool water could damage benthic organisms, and we interpreted this as a likely scenario for the Guadalupian extinction. A comparatively thick sandstone layer with rhythmical laminations at the base of the Kurosawa Formation may represent such a cool and swift water inflow into the basin.

The lines of evidence presented here may imply that volcano-tectonic activations have brought a wide variety of habitats for benthic animals, resulting in the Middle Permian diversification prior to the Guadalupian extinction. In turn, a new tectonic setting with the aid of transgression caused the inflow of cool and swift water to the basin, the event that enables to wipe out the benthic animals in the Southern Kitakami Terrane.

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Late Mesozoic clam shrimp palaeobiogeography of China

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Clam shrimps are freshwater bivalved crustaceans with a chitinous carapace and have a long geological history extending back to the Devonian. Their individuals are generally between a few millimeters to two centimeters, and the largest fossil record is up to 42 mm shell length. Although there are only 17 extant genera in four families, they were much more prosperous during Late Mesozoic. They are commonly abundant and widely distributed in freshwater lacustrine deposits in China and the neighbor areas in eastern Asia of that age (Li et al., 2014). Consequently, they are useful for biostratigraphic correlation of non-marine Mesozoic deposits and palaeobiogeographic subdivision. Here the author would like to introduce the palaeobiogeography of Chinese clam shrimps during the Jurassic and Cretaceous time.

During the Early Jurassic and early Middle Jurassic, the consistent and unified clam shrimp palaeobiographic provinces have developed in northern and southern China, such as the Early Jurassic *Palaeolimnadia baitianbaensis* Province, and the Middle Jurassic *Euestheria ziliujingensis* Province. Since late Middle Jurassic, clam shrimps differentiated into a *Palaeoleptestheria* Province in the palaeo-lake system of southwestern China, and a *Sinokontikia* Province in northern China. During Late Jurassic, a *Pseudograpta* Province developed in northern China, while an *Eosestheriopsis dianzhongensis* Province occurred in the palaeo-lake system of southwestern China and a *Qinghaiestheria-Mangyalimnadia* Province occupied the Qaidam Basin (Li and Matsuoka, 2012).

Since Early Cretaceous an *Orthestheria* Province developed in the palaeo-lake system of southwestern China, an *Eosestheria-Yanjiestheria* Province occupied southeastern and northern China. During the Cenomanian a homogeneous *Nemestheria* Province was widely distributed in China. Soon after, the clam shrimps differentiated into three palaeogeographic provinces: a *Euestherites* Province in the ancient Heilongjiang River-Songhua Lake drainage system in northeastern China; two successive clam shrimp provinces (i.e. the earlier *Linhaiella* Province and the later *Tenuestheria* Province) in the Yunmeng Lake system in southeastern China; and an *Aglestheria* Province in the palaeo-lakes of southwestern China (Chen et al., 2007).

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Early evolutionary history of belemnites (Cephalopoda), revisited: Importance of East Asian fossil records

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Belemnites (order Belemnitida), a very successful group of Mesozoic cephalopods, provide an important clue for understanding Mesozoic marine ecosystems and the origin of modern coleoid cephalopods. Following current hypotheses, belemnites originated in the earliest Jurassic (Hettangian, 201.6–197 Ma) with very small forms (*Schwegleria*: ~4 mm in diameter) without prominent groove (e.g., Doyle, 1993; Doyle et al., 1994). According to this view their paleobiogeographic distribution was restricted to northern Europe until the Toarcian (183–176 Ma). The fossil record is, however, biased by the fact that all the previous studies on belemnites so far focused on Europe.

Here we report on true belemnite taxa from the Upper Triassic-lower Jurassic of East Asia. *Sichuanobelus* and *Sinobelemnite* (Sinobelemnitidae) occur in the Carnian of Southwest China, and the Hettangian, Sinemurian of Japan (Iba et al., 2012). The Sinobelemnitidae, which has enigmatic morphologial features (e.g., dorsal groove) may be included in the future in a new suborder. A large-sized taxon of the suborder Belemnitina (33 mm in diameter) also occurs from the Hettangian of Northwest Japan (Iba et al., 2012). This large diameter can be compared with that of *Megateuthis* (Middle Jurassic), the largest belemnite ever observed. In the Sinemurian, there are two belemnites from Northwest Japan; *Nipponoteuthis katana* and *Eocylindroteuthis* yokoyamai (Iba et al., 2014). These two belemnites have small to large rostra with one deep and long apical groove, a diagnostic character of the Belemnitina. Morphologically these forms are completely different from coeval European genera of Hettangian–Sinemurian age. A Sinemurian belemnite also occurs from South Tibet, which was located at Gondwana margin at that time (Iba et al., in press). The Tibetan belemnite resembles Sinobelemnitidae or *Pachybelemnopsis* (Suborder Pachybelemnopseina). The Sinemurian belemnite from Tibet represents the earliest

firm record of the Belemnitida from the Southern Hemisphere.

It is concluded that the earliest Jurassic (Hettangian-Sinemurian) Belemnitida had a much higher diversity, including extremely large taxa and wider distribution than previously thought, including extremely large taxa (Iba et al., 2012, 2014a, b). The Belemnitida did not originate in northern Europe, contrary to previous hypotheses. The Sinobelemnitidae can be considered as a possible rootstock of all belemnites; the small European belemnites of the earliest Jurassic are here seen as an endemic offshoot. It is postulated here that the belemnites did not originate in the earliest Jurassic, but in the Late Triassic (Carnian). The fossil record of the Order Belemnitida is therefore extended by ~33 m.y. before the Triassic-Jurassic boundary, where one of the five largest mass extinctions in the Phanerozoic occurred.

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Radiolarians and diatoms from the Hiraiso Formation of the Nakaminato Group (late Campanian to early Maastrichtian) in the northern Kanto Region of Japan

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The Nakaminato Group in the northern Kanto Region of Japan is composed of the Hiraiso, Isoai and Chikko formations to the upward, and has been dated to be late Campanian to early Maastrichtian due to some ammonites and inoceramid (Tanaka, 1970; Sakamoto et al., 1972; Ando, 2006). The Hiraiso Formation is composed mainly of dark gray siltstone with frequent intercalations of thin fine- to very fine-grained sandstone beds and occasional thick massive medium-grained sandstone layers with sharp erosion base. The overlying Isoai Formation is mainly sandstone-dominated, sandstone and mudstone alternations with some intercalations of conglomerate and pebbly mudstone beds. The Chikko Formation is now not exposed owing to the fishery port and town artificial cover. Here we report radiolarians and diatoms from a calcareous nodule in the Hiraiso Formation. Also, an outline of this study has been already reported preliminarily in Ando et al. (2014).

Radiolarians (22 individuals identified) are all spumellarians, and include *Orbiculiforma* spp. (16), *Actinomma* ? spp. (3), spherical morphotype (2), and ellipsoidal morphotype (1). Also there are no nassellarians in the studied sample. Radiolarian age can't be determined due to no age-assignable species.

Diatom fossils (50 specimens examined) are poorly-preserved, and mostly populated by disc form (43) with small amount of cylindrical form (7). All specimens occur as solitary forms. Although most of them show internal mold, some of disc form remain the circular valve with fine pores on some extent. The valve diameter varies from 45-124 μm. Because residue treated for microfossil analysis is from 63-425 μm in grain size, individuals less than 63 μm are only 2 specimens (45 and 55 μm in diameter of circular valve). The cylindrical form shows 35-51 μm in width and 68-226 μm in length. The diatom assemblage from the Hiraiso Formation shows low diversification

in the present study.

Radiolarian faunal composition should be noticed: spumellarian-dominated assemblage and abundant occurrence of the genus *Orbiculiforma*. The similar assemblages have been reported from the Middle and Late Jurassic shallow marine strata of the Tetori Group in central Japan. So the radiolarians from the Hiraiso Formation probably indicate the shallow marine assemblage. In Japan, Cretaceous diatom fossils have been reported from the Upper Cretaceous marine strata (Takahashi et al., 1996; Iwata et al., 1998; Shimada et al., 2013). Among them, Shimada et al. (2013) demonstrated well-diversified diatom assemblage ranging mainly from 10-40 μm in size from the Santonian – lower Campanian in Hokkaido. Thus the low diversification of diatoms from the Hiraiso Formation is probably due to examined residue size with poor preservation. Additional examination of smaller diatoms less than 63 μm will be necessary for reconstructing more precise composition of the diatom assemblage.

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The Ordovician (Middle Darriwilian-Earlist Sandbian) conodont biostratigraphy and biofacies of the Wuhai area in Inner Mongolia, North China

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The Ordovician strata of the Wuhai area are biostratigraphically important because of the richness of their macrofaunas and microfaunas. These fossiliferous Ordovician strata are totaling nearly 1000m in thick and excellently exposed around the town of Hainan in a desert-like terrain. They represent a successive deposition of the western Ordovician edge of North China platform. The Ordovician conodonts of the Wuhai area have been reported in several publications (An et al., 1983; Wang and Luo, 1984; An and Zheng, 1990; Wang et al., 2013a; 2013b), however, most of them were written in Chinese language, and some latest taxonomic views have not been represented in this area. More taxonomic and biostratigraphic considerations are necessary for such a critical area of North China.

During a recent field survey, limestone samples were collected from two well exposed sections in the Wuhai area – the Wolonggang Section and the Hatuke Creek Section. All samples, which weighed 2.5 kg on average, were treated with diluted acetic acid and heavy liquid to isolate conodonts. Forty-two species belonging to 26 genera, span the middle Darriwilian to the earliest Sandbian interval, occurred in most samples and were systematically studied.

This conodont fauna is dominated by cosmopolitan and widespread species and accompanied with several endemic taxa. Four conodont zones, the *Dzikodus tablepointensis*, *Eoplacognathus suecicus*, *Pygodus serra*, and *P. anserinus* Zones, and three subzones, the *Pygodus lunnensis*, *P. anitae*, and *Yangtzeplacognathus foliaceus* Subzones, are recognized. Because of its platform-margin habitat, the conodont fauna of Wuhai area differs from the coeval faunas on North China platform which typify a shallower and warmer water environment, but is similar to the contemporaneous faunas in Baltoscandia, South China and Tarim. Moreover, the study sections share several stratigraphically diagnostic taxa with the counterparts of North China platform and Western Newfoundland, this makes it an effective link for biostratigraphical correlations both regionally and internationally.

The vertically regular occurrences of *Spinodus spinatus*, which is regarded as a good index of deep water environment (Zhang, 1998), represent a *Spinodus* biofacies. The lithology, and the conodont association of open-sea taxa with epi- and mesopelagic lifestyle indicate a

slope environment, which coincides with the Ordovician paleo-tectonic regimes of the North China Platform.

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Oral presentations

The geologic evidence for the chaotic behavior of solar planets and its constraint on the third order eustatic sequences during the end of the LPIA

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A high-resolution (948 samples) measurement of anhysteretic remanent magnetization (ARM) was performed on ~200 m thick Early-Middle Permian Maokou Formation at Shangsi section, South China. The ARM variation within the sedimentary rocks is periodical and the wavelengths of cycles represent the ratio of 20:5:2:1 throughout the formation, corresponding long eccentricity, short eccentricity, obliquity and precession in hierarchical domain.

According to conodont biostratigraphic record (Fang et al., 2012), the Maokou Formation ranges from the late Kungurian to early Capitanian stage coeval to the end of the Late Paleozoic Ice Age. The strong obliquity (~44 and ~33 kyr) signal indicates the wining and waxing of ice sheet in the eastern Australia during the end of the Late Paleozoic Ice Age (LPIA) exert a significant effect to global climate.

The Late Paleozoic era lacks accurate Earth's orbital parameter model, but the 405 kyr eccentricity have been consistent throughout the geologic time by the virtue of stable orbit of Jupiter (Laskar et al., 2004). The periodic g_2-g_5 term is well expressed in the ARM series and used as the astronomical metronome to calibrate three conodont zones and correspondingly providing the estimated durations of Roadian, Wordian, and Capitanian stage are ~4020.5 kyr, ~2575.3 kyr and ~1170 kyr, respectively.

The ~2.2 and ~1.8 Myr cycles within Maokou Formation corresponding to g_4-g_3 are a little shorter than the ~2.4 Myr detected in Cenozoic era, which indicates the instability of the g_4-g_3 due to chaotic motion of the solar planets. The ~1.1 and ~0.9 Myr explained as s_4-s_3 also behaved as reduced periodicity. The 2:1 secular resonance

of g_4-g_3 and s_4-s_3 could be observed throughout the section suggesting the movement of the Earth and Mars kept the resonance (s_4-s_3)-2(g_4-g_3)=0 during the end of the LPIA.

The long-term obliquity appears to keep pace with the global third order depositional sequences indicating their astronomical origin. The mismatch between them would be explained by several possibilities: astronomically, the fluctuation of the s_4-s_3 term caused the variation of every orbitally induced third order eustatic cycle; climatically, g_4-g_3 and s_4-s_3 could alternatively control the glacioeustatic signal during deglaciation; tectonically, the germination of the NeoTethys disordered the glacioeustatic signal in the low latitude region. The local sea-level sequences have a barrier of performing the global correlation because of the interferential eustatic signals induced by mantle plume event of Emeishan large igneous province (LIP) nearby.

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Analysis of tsunami characteristics in accordance with fault models of the 2011 off the Pacific coast of Tohoku earthquake

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Simulating tsunamis generated by earthquakes requires precise fault modelling, and hence accurate fault models which consider the time history of the rupture process must be considered. Here, we compare results using a finite fault model and a uniform model. We select three finite fault models, USGS model (Hayes, 2011), UCSB Ⅰ and UCSBⅢ (Shao et al., 2011) for the 2011 Tohoku earthquake, and we make three uniform fault models based on the finite fault models. CLAWPACK (Conservation LAWs PACKage), developed by Randall J. LeVeque, is used for tsunami simulations. The regional setting for the simulations is longitude 125°E ~ 160°E, latitude 25°N ~ 50°N. We utilize the ETOPO1 database of 4 minutes grid for bathymetry data, and accuracy is verified by comparing synthetic results with observations from DART (Deep-ocean Assessment and Reporting of Tsunamis) buoys offered by NOAA(National Oceanic and Atmospheric Administration). We calculate RMS values from the results of finite fault models and uniform models to compare their accuracy between them. Among the finite fault models, the synthetic result using UCSBⅢ fit best. Synthetic tsunami data derived using uniform models does not compare well to observations, whereas finite fault model derived synthetic data fit the observations well.

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Organic matter distribution and preservation in the latest Permian Dalong Formation in the Northeast Sichuan Province, South China

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Sedimentary organic matter (OM), which associates "active" surface pools of organic carbon with carbon pools that cycle on geological time scales, is the major reservoir of organic carbon in the global carbon cycle (Burdige 2007, Zonneveld, Versteegh et al. 2010). It influences the content of atmospheric CO_2 and O_2 on long times scales in a highly simplified fashion OM burial in sediments (Burdige 2007), and it comprises the primary source of oil and gas that is stored in organic deposits. Only less than 0.5% of the original OM that is produced within the upper water column can be transported to the sediments-water interface and buried, after degraded by aerobic and anaerobic re-mineralization processes (Hedges and Keil 1995). The chemical, physical and biological effects on OM preservation are key topic of many scientific research disciplines. However, until now synergetic discussion has been scarce. On this basis, ascertaining the controls on OM preservation in sediments is a valuable and significant topic in geological and chemical oceanography exploration.

Organic matter is always preserved well in finely laminated, pyrite-rich sediments (Pedersen and Calvert 1990, Kennedy, Pevear et al. 2002), and the same circumstance appeared in the latest Permian Dalong Formation in Shangsi, Northeast Sichuan, South China. Our work aims to seek out controlling factors on preserved organic matter in Dalong Formation. 126 samples were collected in the fields and analysis of trace elements, major elements and TOC were proceeded. High TOC values appear in black argillaceous rocks formed in transgression period, the lower-middle part of the Dalong Formation, which indicates high primary productivity within this interval. On the basis of Ti content, the bio-relate elements, such as Cu, Zn, Ni, donated as Cu_{xs}, Zn_{xs}, Ni_{xs} show significant correlation with TOC content in this interval, as Fe and S do.

Scanning electron microscope（SEM）and Energy Dispersive Spectrometer（EDS）studies has been used to identify organic matter and observe micro-structure of samples in this study. According to morphology and elements content, we divided organic matter into 3 categories: biopolymers, adsorbed organic matter and bitumen. Biopolymers from the samples are extracellular polymers substances (EPS). As EPS is major composed of proteins which are high-molecular-weight and stable, this organic matter is selectively preserved in sediments.

Adsorbed organic matter co-exists with the mineral matrix and emerges in two forms: discrete and diffuse. Bitumen preserved in large crack of carbonate or carbonate interlayer of mudstone. Both adsorbed organic matter and bitumen suggest that clay minerals are conductive to preservation of organic matter. We found that only discrete organic matter is preserved in low TOC samples (c.a. TOC<1), both discrete and diffuse organic matter occur in moderate TOC samples (c.a. TOC~2-5) and more diffuse organic matter can be seen in higher TOC samples (c.a. TOC>10). In addition, diffuse organic matter is accompanied with Fe in the mineral matrix, which was consistent with the correlation between TOC and Fe. Conclusively, elevated primary productivity and mineral matrix with distinct metal elements co-operation promote the preservation of organic matter.

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Geochemical characteristics of the Late Devonian to Early Carboniferous cherts from Loei Fold Belt in NE Thailand: implication for geotectonic setting

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It is widely known that Southeast Asia is composed of several terranes that separated from Gondwana during the geological history. Indochina Block located in the eastern part of Thailand has been rifted from Gondwana since Early Devonian (Metcalfe, 2013). In the western margin of Indochina Block, the ocean basement was created as a result of the separation which is evidenced by the existence of both Middle Devonian deep-sea radiolarian-bearing cherts and Late Devonian to Early Carboniferous MORBs and oceanic island-arc lavas (Metcalfe, 2002;. Panjasawatwong et al., 2006）.Several previous studies have been carried on both volcanic and sedimentary rocks in Loei Fold Belt situated to the western of Indochina Block aiming at identifying the regional tectonic evolution. Recently we collected the radiolarian cherts from Loei fold belt and make the chemical analysis in order to identify the depositional regime of the chert and and gain more understandings on the tectonic evolution of this area.

Here I present the result of the detailed chemical analysis of cherts located in Loei fold belt, northeast Thailand.

Moderately-preserved Late Devonian to Early Carboniferous radiolarians were extracted from Loei, Pak Chom area, northeast Thailand. Six species were indentified from the radiolarian fauna, including *Albaillella paradoxa* Deflandre, *Astroentactinia multispinosa* (Won), *Stimosphaerostylus* sp.D Wang, *Trilonche parapalimbola* Wang, *Spongoentactinella micrococcua* Wang, *Helenifore robustum* (Boundy-Sanders et Murchey). The radiolarian-bearing cherts have high SiO_2 (>90 wt.%) contents, various Al_2O_3 (1.61-2.52 wt.%), high Al/(Al+Fe+Mn) ratio(0.82-0.95) and high Si/(Si+Al+Fe) values. The major elements of these chert indicate a biological origin and the sedimentary environment is the continental margin. However, when it comes to the REE of the cherts, a distinct conclusion is drawn. These cherts are characterized by slightly negative NASC-normalized Ce anomalies (average 0.74) and the positive Eu/Eu* (average 1.57). The REE indices show that these radiolarian cherts were influenced by hydrothermal fluids during deposition. According to the geological background, the cherts are in close relationship with the Loei Central volcanic

rocks which mainly consist of tuff, tuffaceous shale/mudstone, basalts and andesites that formed in the same period (Sashida, 1993; Panjasawatwong et al., 2006). Therefore, it is inferred that the depositional environment of the cherts is not the typical continent margin or the pelagic, but a mature bakarc basin. The contemporaneous volcanic rocks are the results of the expansion of back-arc basin.

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Zircon U-Pb geochronology, whole-rock geochemical and Lu-Hf isotopic constraint on the petrogenesis of rhyolites in Loei fold belt and their tectonic implication

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What makes SE Asia today is a number of terranes that were successively rifted off from Gondwana, drifted towards north and accreted to each other. The Indochina Block was originated from eastern Gondwana and was rifted since the Early Devonian (Metcalfe, 2013). The Loei fold belt, situated in the west of Indochina, has been intensely studied regarding the controversy over its regional tectonic evolution (Intasopa and Dunn, 1994; Panjasawatwong et al., 2006; Udchachon et al., 2011; Vivatpinyo et al., 2014). Recently, we find Silurian rhyolites in Loei fold belt. The identification of lower Paleozoic volcanic rocks is of significant importance in studying the geological tectonic evolution and reconstruction of Gondwana. We analysis the U-Pb geochronology and Hf isotope of zircon and the whole rock geochemical contents of the rhyolites.

Zircon grains from Loei rhyolites yielded concordant $^{206}Pb/^{238}U$ ages, with mean of 423.7±2.7 Ma, suggesting the timing of emplacement of Loei rhyolites was Homerian. The Loei rhyolite samples show enriched SiO_2 (75% - 77%), Al_2O_3 (12.10%-13.13%), K_2O (2.97%-3.50%) and low CaO (0.26-0.61%), Fe_2O_3T (0.98%-2.24%) and P_2O_5 (0.05%). The molecular A/CNK ratios of the samples range from 1.19 to 1.34, classified as characteristics of strongly peraluminous. The rhyolites show moderate negative Eu-anomalies (δEu=0.58-0.56). In the primitive mantle-normalised spidergram, all samples are enriched in LILE (eg:Ba, K, Pb) and LREE and depleted in HFSE (eg: Th,Nb, Ta, Zr, Ti).

Although the high A/CNK (1.20-1.34), i.e. features of strong peraluminnous of the Loei rhyolites resemble those of the S-type granites. However, we suggest Loei rhyolites belong to highly evolved I-type rhyolites because the positive εHf(t) of Loei rhyolites indicate that the protolith of Loei rhyolites were juvenile crust which is similar to the I-type granites. Beside, low P granitoids may be highly fractionated I-type granite. On the Rb/Sr vs. Rb/Ba diagram, all samples plot within clay-poor area. In the figures of $(Na_2O+K_2O)/CaO$ and FeOt/MgO vs. Zr+Nb+Ce+Y, all samples fall in Fractionated I-type Granites. The geochemical features of Loei rhyolites are significantly different from A-type granite: (1) A-type granites enrich HFSEs and deplete in Ba and Sr (Wu et al., 2003; Whalen et al., 1987), whereas the Loei

rhyolite show lower HFSEs and higher in Ba, Sr; (2) Low FeO*/MgO (3.73-5.18) are different from A-type granite (FeO*/MgO>10 (Whalen et al., 1987)); (3) In the Nb, Zr, Na_2O+K_2O, K_2O/MgO-Ga/Al diagrams (Whalen et al., 1987), all samples plot without in the field of A-types, combined with relatively low petrogenetic temperatures (Whole rocks Zr saturation temperatures: 791-800 ^oC) , excluding the possibility of A-type granitoids.

Geochemically, the concentration of LILE of the Loei rhyolite are high (such as Ba, K, Pb). They are relatively depleted in HFSE (such as Th, Nb, Ta, Zr, Ti). These are main features of magmas formed in active continental fringe related a subduction setting (Qi et al., 2014). On the La/Yb vs. Th/Yb tectonic discrimination diagram, all the Loei rhyolites plot within the area of 'continental margin-arc'. According to the regional geological outline of Indochina Block, magmatism, metamorphism and deformation were widespread in Indochina Block during Silurian, suggesting a subduction of ocean plate under Indochina. Therefore, we argue the rhyolites from the Loei fold belt were generated from partial melting of juvenile lower crust related to ocean lithosphere beneath the Indochina Block and then underwent multistage melting and differentiation.

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Felsic Intrusion in a Strike-slip Dilational Overstepping Linkage in the Upper Crust: An Example of Palgongsan Granite in SE Korea

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The Palgongsan Granite which intruded into the Cretaceous Gyengsang Basin in SE Korea is elongated in NW-SE direction (ca. 2.4 aspect ratio of long axis to short in exposure) and is generally thought as being emplaced along the WNW-ESE trending Palgongsan Fault which is the boundary between the Uiseong sub-basin (north) and Miryang sub-basin (south) within the basin.

It is widely believed that emplacement of the pluton along the sub-basin boundary removed all evidence associated with the faulting. Recent studies of gravity and aeromagnetic anomalies in the vicinity of the granite imply that the emplacement of this pluton was controlled by the geometry of WNW-ESE trending right-lateral overstepping lineaments. It gives us an opportunity to examine the controlling factors for emplacement such as the internal structural characteristics of the pluton, thermal cooling history, residual magmatic fluid overpressure, and external regional stress regime.

Within the granite, pegmatitic dykes and hydrothermal deposits related to the late stages of intrusion are frequently observed and penetrative joints and faults are also well developed. The study of orientation, distribution, relative cross-cutting relationships and kinematics based on the indicators of each structural element coupled with geochronological and geophysical data provides information of the prevailing stress regime at the time of dyke intrusions and the controlling structures, such as strike-slip overstepping and dilational linkage. The results of 3-D mohr-circle analysis for NW-SE trending dykes show they intruded under vertical σ_1 and NE-SW horizontal σ_3 in low differential stress and relatively high residual overpressure of magmatic fluid. This coincided with regional NW-SE horizontal σ_1 and NE-SW horizontal σ_3 direction based on other structural analysis.

Although these results imply the possibility that the pluton was emplaced in a dilational overstep along a WNW-ESE reactivated dextral strike-slip fault, felsic intrusions in the upper crust are not only controlled by pre-existing structures but are also controlled by other factors such as magmatic flow behavior. Therefore further studies such as magnetic anisotropy suspension and seismic exploration are required to fully understand the mode of emplacement of the Palgongsan Granite.

Preliminary report on the Graptolite Biostratigraphy from Latest Darriwilian to Early Sandbian (Ordovician) in Chengkou area, northern Chongqing, South China

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The latest Darriwilian to early Sandbian interval (Miaopo Formation) of Ordovician in Yichang, western Hubei Province is well known for its well-preserved, three – dimensionally preserved pyritic graptolites. Recently, the Miaopo Formations were studied from four sections in the Yichang-Yuan'an area, which is the despositional center of Miaopo Formation distribution. In contrast, in the transition area between the Miaopo Formation and its coeval Datianba Formation, the graptolite fauna and biostratigraphy are poorly known. Accordingly, the corresponding research is of important scientific significance. Except the scientific significance, the investigation of Miaopo Formation is economically significant for the petroleum and gas exploration, as this Formation is potentional hydrocarbon source rock.

In this study we report the graptolites collected from two new sections with well exposed Sandbian strata that were discovered recently and located on the marginal area of the Miaopo Formation - the Liaozikou section and the Dacao section in Chengkou County, Northern Chongqing. The graptolite biostratigraphy of Dacao Section is still in progress. Based on the collections from the Miaopo Formation in the Liaozikou section, one graptolite zone, the upper *Nemagraptus gracilis* Zone, is recognized and discussed in detail as below. The upper *Nemagraptus gracilis* Zone is recognized based on the occurrence of the eponymous species and a low diversity graptolite fauna in the Miaopo Formation. Slightly below the first occurence of the *Nemagraptus gracilis*, some other species, including *Archiclimacograptus modestus*, *Dicellograptus sextans*, *Orthograptus whitfieldi*, *O. apiculatus*, *Hustedograptus teretiusculus* appear. Among them, *Archiclimacograptus modestus* with the species of *Orthograptus* are abundant, while specimens of *Dicellograptus* are rare and *Dicranograptus* has not been recorded. *Oepikograptus* n. sp. first occurs in this section with *N. gracilis*. Slightly above the FAD of *N. gracilis,* graptolite species *Orthograptus calcaratus incisus*, *Corynoides*

calicularis and *Normalograptus brevis* make their first appearances.

It is worthy to note that most species of *Dicellograptus* and *Dicranograptus* species are absent in this section, which do occur commonly in the *Nemagraptus gracilis* Biozone in the Yichang-Yuan'an areas. Besides, the graptolite fauna shows a somewhat low diversity and a prominent similarity to that of upper *N. gracilis* Biozone to lower *Climacograptus bicornis* Biozone in the Yinchang area and elsewhere in the world (e.g. North America, Scandinavia). Since no *Climacograptus bicornis* has been recorded in the Miaopo Formation at the Liaozikou section, we think that the fauna probably indicates an interval corresponding to the upper part of *Nemagraptus gracilis* Biozone elsewhere. Thus the base of the Miaopo Formation at Liaozikou, Chengkou County, is slightly higher than that of the formation in the Yichang area, which suggests a diachronity for the basal boundary across its distribution area. At the Liaozikou section the diversity is somewhat lower than that in the Huanghuachang section in Yichang area and in the Dawangou section in Tarim. No graptolites diagnostic of an age younger than the *N. gracilis* Zone are recorded in the Liaozikou section, indicating that the top of the Miaopo Formation in Northern Chongqing is probably not younger than early Sandbian.

Foraminiferal biostratigraphy of the Jurassic/Cretaceous transition sequence of the Gucuo section in northern Nyalam, southern Tibet

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According to the latest International Stratigraphic Chart, the base of the Cretaceous is the last system boundary to have a GSSP. It is not an accident because it is fraught with problems and complications. Ammonite, as one of the most important index fossils, has its deficiency of faunal continuity and provincialism during the Jurassic/Cretaceous (J/K) transition. Other fossils, like calpionellids and nannofossils, and non-fossil methods, such as magnetostratigraphy, all have their dificiencies to be used to define this boundary at the moment.

Several decades studies on the biostratigraphy of the J/K boundary sequences in southern Tibet may provide some crucial links for correlating the strata of the western Tethys with that of Pacific domain (Wan et al., 2005). The Gucuo section in northern Nyalam, which has a relative simple structure and yields aboundant fossils, was thought to be one of the best sections to search for the J/K boundary in Tibet (Liu and Wang, 1987; Liu, 1988; Yao et al., 1990).

In the Gucuo sections, the Upper Jurassic Menkadun Formation (Fm) is immediately followed by the Lower Cretaceous Gucuo Fm 1, 2, 3, 4 and 5 (Liu and Wang, 1987). The Gucuo Fm 1 is composed of white, coarse-grained sandstones in the lower part, and a suite of yellow-greenish shales with abundant concretions in the upper part (Yin and Enay, 2004). The Gucuo Fm 2 is composed of greyish green and black shales, mudstone, coarse sandstone and marls. The J/K boundary was delineated either at the base of the Gucuo Fm 1 (Yue et al., 2003), or between the Gucuo Fm 1 and Gucuo Fm 2 (Liu and Wang, 1987; Liu, 1988), or within the Gucuo Fm 1 (Shi, 2000).

In order to settle this dispute we have carried out a microfossil biostratigraphic research on the J/K boundary sequence at the Gucuo village. We collected 79 microfossil samples from the Menkadun Fm, and 50 samples from the Gucuo Fm 1 and Gucuo Fm 2. In total, 50 samples were analysised in the laboratory. We have for the first time found benthic foraminifers in 14 samples, which are mainly from the Gucuo Fm 1. The abundant foraminifer fauna consists of 14 genera (including 10 identified species): *Hyperammina gaultina*, *Rhabdammina cylindrica*, *Ammobaculites agglutinans*, *Ammobaculites coprolithiformis*,

Ammobaculites areniferus, *Ammobaculites cuneatus*, *Ammobaculites* spp., *Ammodiscus* spp., *Astacolus* spp., *Marginulina* spp., *Dentalina biloculina*, *Dentalina* spp., *Nodosaria biloculina*, *Nodosaia* spp., *Lagenammina* spp., *Reophax nodulosus*, *Reophax metensis*, *Reophax* spp., *Haplophragmium* spp., *Trochammina* spp., *Haplophragmoides* spp., *Lenticulina* spp.

Although most of the above mentioned taxa have a long geological range, *Rhabdammina cylindrica* Glaessner, 1937 ranges from Berriasian to Valanginian, *Ammobaculites cuneatus* Vasilenko, 1951 and *Haplophragmoides* Cushman, 1910 occur since the Early Cretaceous. Thus, the above mentioned benthic foraminifer fauna can be of an Early Cretaceous age, which supports the Early Cretaceous age assignment for the Gucuo Fm 1.

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Late Triassic palaeoclimate and palaeoecosystem variations inferred by palynological record in the northeastern Sichuan Basin, China

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The end-Triassic mass extinction is one of the five largest extinctions in the Phanerozoic. However, the terrestrial records of Triassic-Jurassic transition are still limited in Asia. In China, the Triassic and Jurassic strata are well-developed in the Sichuan Basin, especially in the northeastern margin of the basin. In particular, the Upper Triassic Xujiahe Formation is widely distributed and well cropped-out in this region, containing rich fossil plants. This provides a significant reference for the study of the palaeoecological environment variations during the Triassic/Jurassic transition.

In this study, we focus on the Late Triassic palynological record from the Qilixia section in Xuanhan County, northeastern Sichuan Basin. In this area, the Upper Triassic Xujiahe Formation is composed of black mudstone, shale, and grayish white feldspar-quartz sandstones. This formation is divided into seven lithological members. Among them, Members I, III, V and VII are mainly dominated by mudstones, whereas the Members II, IV and VI are mainly represented by sandstones.

The palynoflora of the Xujiahe Formation in Xuanhan shows a high diversity of spores and pollen grains, including 151 species of 64 genera. A sporo-pollen assenblage, i.e. *Dictyophyllidites* - *Cyathidites* - *Pinuspollenites* - *Cycadopites* (DCPC) assemblage is recognized, characterized by a dominance of spores and abundance of pollen grains, dated as Rhaetian of Late Triassic in age. Palaeovegetation reconstruction shows a predominance of fern floras, followed by gymnosperms represented by conifers. This palynoflora indicates that a tropical-subtropical humid and warm climate generally prevailed during the Late Triassic in Xuanhan.

The Sporomorph Ecogroup Model (SEG) (Abbink et al., 2004) is applied to analyze the palaeoecosystem of the Late Triassic in Xuanhan of the Sichuan Basin. Four SEG groups have been recognized according to the habitat of the parent plants, including Lowland SEG, Highland SEG, River SEG and Pioneer SEG. The

palaeoenvironment is reconstructed with the variations of the four SEG ecogroups. It suggests that the overall humid and warm climate condition was not static and unchanging throughout the Late Triassic episode, but was punctuated by several climatic and ecosystem variations: two warm and humid climate events in the Members V and VII of the Xujiahe Formation, accompanied by a cool and dry trend in the end-Triassic episode. This is in accordance with the macroflora study (Huang, 1995) and the clay minerals and eigen elements analysis (Xu et al., 2010). The study reveals the terrestrial ecosystem variations before the Triassic/Jurassic boundary in the Sichuan Basin, and thus provides important evidence for understanding the response of terrestrial vegetation to regional and global environmental changes across the Triassic/Jurassic transition.

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Seawater incursion event in the Songliao Basin: New evidence from the calcareous nannofossils of SK-1

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The Songliao Basin is the largest non-marine oil-bearing basin in China. In the absence of sufficient evidence, the hypothesis of seawater incursion(s) into the Songliao Basin remains controversial. However, Marine fossil material can provide direct explanations to this argument. More recently, abundant calcareous nannofossils were recovered from units 1 and 2 of the Nenjiang Formation of borehole SK-1.

In these fossils, some taxa have been positively identified, namely *Calculites obscurus*, *Calculites ovalis*, *Quadrum* sp., and *Micula* sp. They were distributed in the Cretaceous marine environment. Based on comparisons of the fossil assemblage with global record of calcareous nannofossils, the stratigraphical age of units 1 of the Nenjiang Formation appears to extend from the latest Coniacian to the end of the Santonian.

The abundance and diversity of calcareous nannofossils in the Songliao Basin are lower than those from a typical marine environment, but much higher than the typical inland lake. We propose that there might be a marine transgression from the West Pacific in the Songliao Basin and resulted in mixture of sea water and fresh water. As a result, calcareous nannofossils were taken into the paleo-Songliao lake, and fossil specimens of some species subsequently underwent deformation caused by salinity decline.The distribution and paleo-ecology of the calcareous nannofossils, as well as its co-existing foraminifera in the SK-1(Xi Dangpeng et al., 2010), provide further evidence for seawater incursions that occurred in Songliao basin.

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Coral biostrome of the Shangsi Formation (middle Visean, Mississippian) in Yashui, Guizhou, South China Block

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For the first time, a middle Visean (Mississippian) coral biostrome is described from the Shangsi Formation in Yashui, Guizhou, South China. The thickness of the biostrome has a lateral variation from 2.7 m to 5.2 m. The biostrome is mainly composed of tabulate and rugose corals, and its diversity is low, consisting of five species in five separate genera. Notably, the composition of the biostrome changes both horizontally and vertically. Other common fossil taxa in thin sections are brachiopod fragments, crinoid ossicles, and foraminifers. In addition, calcareous algae, ostracods, bryozoans and gastropods also occur but are relatively sparse.

The growth and demise of the coral biostrome were controlled by the changes of hydrodynamic energy resulting from sea-level variation. The growth of the biostrome was caused by hydrodynamic energy weakened due to sea-level rise, which was evidenced from the increased occurrence of micrites or peloids and in-situ coral colonies from biostrome-base to biostrome. Packstones and grainstones overlying the biostrome indicate that hydrodynamic energy strengthened owing to sea-level fall, which led to the demise of the biostrome.

In this study, the coral biostrome shows some similarities with the middle to late Visean coral biostromes from Europe and North Africa (western Palaeotethys) in aspects of biotic composition and growth mode. The distinctly different solitary rugose coral compositions of the biostromes between western Palaeotethys and South China (eastern Palaeotethys) may be ascribed to their palaeogeographic disjuncture. Consistent with the biostromes from western Palaeotethys, the occurrence of the biostrome in South China suggests that its evolution fits with that of the western Palaeotethys and a warm climate episode did exist during the Visean.

Permian radiolarian distribution: endemism of *Pseudotormentus* De Wever et Caridroit, 1984

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The Permian (ca. 300–250 Ma) is palaeogeographically characterised by the presence of superoceans, namely the Panthalassa and the Palaeotethys. The Permian planktonic distribution is not fully elucidated, in contrast to other fossil distributions of nekton and benthos. Radiolaria is a representative planktonic microfossil in the Permian palaeocean. Some researchers have discussed Permian radiolarian distributions and palaeobiogeography. Ishiga (1986) and Wonganan and Caridroit (2006) considered *Follicucullus charveti* Caridroit et De Wever, 1984 as an endemic species. Meanwhile, Wang et al. (2006) speculated that late Palaeozoic radiolarian palaeobiogeography is characterised by a single Palaeotethys planktonic faunal realm.

This study focused on occurrences of *Pseudotormentus* De Wever et Caridroit, 1984 and *Quadriremis* Nazarov et Ormiston, 1985. We compiled literature data for the Pacific Rim and used quantitative data from samples of our previous studies (Ito et al., 2013a, b). *Pseudotormentus* and *Quadriremis* co-occurred commonly in several geological units in the Panthalassa whereas some geological units in the Palaeotethys have yielded not *Pseudotormentus* but *Quadriremis*. In quantitative results, *Pseudotormentus* occurred abundantly in the Gujingling section, whereas no *Pseudotormentus* were obtained from the Liuhuang section. Both sections yielded frequent *Quadriremis*.

The results of the literature and quantitative data indicate an uneven distribution of *Pseudotormentus*, which seems to have been controlled by the differences between the oceanic areas, the Panthalassa and the Palaeotethys. A previous palaeobiogeographical study of Permian benthic organisms described faunal differences between the Panthalassa and the Palaeotethys (e.g. Shen et al., 2009). The present study shows the presence of faunal differences in Permian planktonic microorganisms. Although the cosmopolitanism of microorganisms, i.e., the hypothesis that ‘everything is everywhere’, has been believed, several researchers have highlighted endemism in recent years (e.g. Williams, 2011). According to Bass et al.

(2007), DNA analysis results 'strongly suggest that geographic dispersal in macro-organisms and microbes is not fundamentally different: some taxa show restricted and/or patchy distributions while others are clearly cosmopolitan'. They proposed a 'moderate endemicity model' of microbial biogeography. Our results suggest that this model is applicable to planktonic microorganism in the Permian palaeocean. Permian radiolarians may have comprised some cosmopolitan and some endemic taxa.

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Poster presentations

Seismic response from microtremor of Chogye basin, Korea

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When seismic waves corresponding to the resonance frequencies reach a certain area, the ground motion can be rapidly amplified. This is especially true if the nature of the soil is composed of sedimentary layers, not the bedrock in the area, as in the Chogye basin. Ground motion amplification can be observed more easily when seismic waves propagate through a basin with slow velocity. Chogye basin, which is surrounded by country rock, has a closed-basin form (Choi et al., 2001). In such a basin, incident seismic energy can form multiply reflected waves, thus causing energy concentration to occur at this closed-basin area. Therefore, measuring resonance frequencies of closed-basins is very important to estimate the earthquake response for seismic hazard evaluation. Two field investigations were conducted for this research at the Chogye basin, which is located in Chogye-myeon and Jeokjung-myeon, Hapcheon-gun, Gyeongsangnam-do, Republic of Korea. For the first on-site inspection, we set 23 observation points, which were divided into 8 transfer routes, and recorded background noise by moving two to three times. The 2nd on-site inspection was also done in the same way as before; however, this time, we included the measurement of microtremors from the basin area to the surrounding mountains. Based on the observations of microtremors acquired from two field inspections, we calculated the Horizontal to Vertical Spectral Ratio (HVSR) using on the 3 component microtremor data. Using the HVSR ratio, we were able to derive the resonance frequencies for every observation point. Through this process, we derived the link between an observed elevation and resonance frequencies. We were able to identify the thickness of the sediments is inversely proportional to the resonance frequencies. We noticed that the thicker sedimentary layers are more likely to be very sensitive to long period waves. In contrast, shallow sedimentary layers respond well to short period waves. This implies that sediment thickness is an important parameter that can be used to predict the ground response when seismic waves arrive.

Acknowledgment: This study is based upon a project completed in the undergraduate research class by Jang, B., Jeon, H., Jo, A., Han, H., and Yang, S.

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Protolith of metamorphic sole in the Oman ophiolite inferred from whole rock trace element abundances and Sr-Nd isotope ratios

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The Oman ophiolite represents a former oceanic lithosphere obducted due to intra-oceanic thrusting at mid-ocean ridge about 95 million years ago. During the thrusting the young hot oceanic lithosphere gave contact metamorphism to the upper surface of the subducting oceanic plate forming amphibolite and greenschist (Hacker and Mosenfelder, 1996). On the other hand, highly depleted peridotite is distributed over the mantle section of the northern Oman ophiolite as a results of flux melting assisted by the fluid from a metamorphic sole (e.g., Kanke and Takazawa, 2014). When considering the fluid that reacted to the mantle section, it is important to know the geochemical character of the metamorphic sole. In this study, we analyzed whole rock trace element compositions and Sr-Nd isotopic ratios of the samples collected from the metamorphic sole distributed over the Sumayni Window (Searle and Malpas, 1982) in the northern part of the Oman ophiolite. Our study aimed at clarifying the original protolith for the metamorphic sole.

The metamorphic sole is observed along three routes of Sumaini Window. The lithology changes from Gar-Cpx amphibolite to Cpx amphibolite to Ep amphibolite to greenschist (or quartzite) to chart with increasing the distance from the boundary to the mantle section. Marble is locally taken in as a block. In the Ta-Hf-Th discrimination diagram, amphibolites are plotted within the fields of N-MORB, E-MORB and oceanic island basalt to alkali basalt. There is a tendency that amphibolite near the boundary has N-MORB affinity. In the Nb-Zr-Y discrimination diagram, amphibolites are also plotted within the fields of N-MORB, E-MORB, and within plate tholeiite and volcanic arc basalt. The REE patterns of amphibolites normalized to C1 chondrite can be classified into three patterns. The amphibolites in Ash Shiyah show either N-MORB or E-MORB-like pattern. The amphibolites near the boundary to the mantle section tend to show N-MORB-like pattern, then change to E-MORB-like pattern with increasing distance from the boundary. In Wadi Sumayni, amphibolites show N-MORB-like

pattern near the boundary, then become E-MORB like pattern with increasing distance from the boundary. Greenschists are strongly enriched in LREE similar to OIB.

The Sr-Nd isotopic compositions of amphibolite and a greenschist differ from the isotopic composition of crustal rocks in the Oman ophiolite. The ε_{Sr} in 96Ma is in a range from +10 to +30, and resembles the isotopic composition of the oceanic crust polluted by seawater. The ε_{Nd} ranges from +1 to +8 lower than the values for Oman ophioilte. The ε_{Nd} is considered to reflect the various origin (N-MORB, E-MORB, OIB) of protolith supported by a negative correlation with the La/Yb ratio.

It became clear that HFS elements and rare earth elements are resistant to and is kept considerably in spite of the contact metamorphism and dehydrating process during the formation of a metamorphic sole. Our results show the original protoliths of amphibolite and greenschist are variable with N-MORB, E-MORB, and OIB. E-MORB is dominant while N-MORB partly exists near the boundary to the mantle section. On the other hand, in Wadi Sumaini, greenschist and amphibolite in the lowermost horizon were originally OIB, and the upper horizon was E-MORB to N-MORB from the bottom to the boundary to the mantle section. Further examination is required to clarify whether such stratigraphy reflects the original profile beneath seafloor or it is an apparent stratigraphy obtained by thrusting and juxtaposition at the time of metamorphic sole formation.

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Geochemical relationships of basalts and andesites from the Kuan-Yin Mt. at NW Taiwan

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The Ryukyu arc and the North Luzon arc intersect at northern Taiwan. Although the petrogenesis of these two oceanic arcs have been investigated in broad views, detailed geochemical relationships of the constituent lavas forming each volcano have yet been established. In this contribution, 45 samples form the Kuan-Yin Mt. on the western end of the Ryukyu arc were analyzed for major and trace element compositions as well as Sr, Nd, and Hf isotope ratios for insightful petrogenesis constraints.

Based on the constituent minerals, lavas forming the Kuan-Yin Mt. have been classified into pyroxene andesites (PA), two pyroxene andesites (TPA) and hyperthene-hornblende andesites (HHA) with an order of decreasing eruption ages (0.53, 0.43, and 0.34 Ma, respectively). The youngest olivine basalts (OB; 0.2 Ma) occur at the southeast of the Kuan-Yin Mt. forming a small cinder cone. All the samples are characterized by Nb, Ta, and Ti depletions, typical of arc lavas. As a whole, the Kuan-Yin Mt. lavas have CaO contents decreasing and Al_2O_3 contents increasing with decreasing MgO contents in the sequence of OB–PA–TPA–HHA samples, consistent with clinopyroxene fractionation without plagioclase fractionation. However, the PA samples have slightly higher total iron, TiO_2 and P_2O_5 and lower SiO_2 abundances than the TPA samples at a given MgO content. In addition, the La versus Nd plot clearly shows that the four sample groups define sub-parallel positive trends with La abundance increasing from OB to PA to TPA to HHA samples at a common Nd content. Similar distribution patterns are observed in the La–MREE and La–HREE plots. Therefore, these four lava groups were not related by fractional crystallization but derived from distinct parent magmas. Although the $^{143}Nd/^{144}Nd$ and $^{176}Hf/^{177}Hf$ ratios of the four group samples largely overlapped, the $^{87}Sr/^{86}Sr$ ratios of the PA samples are lower than those of the other samples. Therefore, the trace element and isotopic variations conclude that the four lava groups forming the Kuan-Yin Mt. were evolved from different parental magmas from distinct mantle sources and cannot be related by fractional crystallization and magma mixing.

The relationship between spatial compositional distribution and field occurrence of peridotites in the southernmost part of Salahi mantle section, the Oman ophiolite

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Extensive lenticular-shaped ultramafic complex that is composed of dominant amount of high refractory dunite associated with residual harzburgite and pyroxenite cumulates occur in the basal part of the Salahi mantle section (Nomoto and Takazawa, 2013). It is considered that an infiltration of fluid from the base of the ophiolite caused flux melting of harzburgite and formed boninitic melt associated with highly refractory dunite. There are two other ultramafic complexes of the same scale located in the direction of south-southeast of the above complex and the distribution of highly refractory peridotites is expected similar to the northern part of Fizh mantle section (Kanke and Takazawa, 2014). In this study, we report spatial variability in mineral compositions in the southernmost part of the Salahi mantle section. Particularly we focus on a distinct area where occurrence of dunite, mineral compositions and lithological variation are different from the surrounding area.

It is common in the Oman mantle section that dunites occur either parallel or oblique to the foliation of the host harzburgite. Concordant dunites are common in the southern part of the study area where discordant dunite is rare. In this area, spinel Cr# of harzburgite is limited in a narrow range of 0.46-0.67. The cpxs in harzburgites and concordant dunites in this area are highly depleted in LREE relative to HREE. Abundances of REE in cpxs from dunites are in agreement with those of cpxs in the adjacent harzburgite in the same outcrop. In the southern part of the study area, plagioclase-bearing peridotites and wehrlite were found from an outcrop. The abundances of REE in cpxs from plagioclase-bearing peridotites are contained in the range of abyssal peridotites indicating a possibility that a MORB melt was trapped in a residual peridotite. Moreover, basal lherzolite has been found in the southwest corner of this area. The spinel Cr# is low (0.15-0.25) similar to Type I lherzolite of Takazawa et al. (2003).

On the other hand, discordant dunites are dominant in the northeast to eastern part of the study area. In this area spinel Cr# of dunite has a wide range from 0.43 to 0.80. Moreover, highly refractory dunite with spinel Cr# >0.7 frequently occurs in the eastern part. The cpxs in discordant dunite and those in dunites from ultramafic complex are enriched in LREE relative

to the cpxs in the adjacent harzburgite.

The origin of two distinct areas will be discussed in the poster.

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Petrological study of the Salahi mantle section in the Oman ophiolite

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This study reports the spatial distribution of the whole rock chemical composition and the changes in the degree of partial melting in the area from the central part of Salahi mantle section to the Moho. Study area is located in Salahi mantle section in the northern Oman ophiolite, which mainly consists of harzburgite and dunite with small amounts of lherzolite and pyroxene. Depending on Cr# (=Cr/ [Cr+Al] atomic ratio) of spinel, there are two types of dunite in the study area. Dunites with Cr# of spinel above 0.7 and those with Cr# of spinel below 0.7. The former is dominant in the area from the bottom to the middle part of the mantle section. In the Moho side, Cr# of spinel in dunites and harzburgites are 0.55-0.60. The dunites and harzburgites with low Cr# spinel are considered as mid-ocean ridge origin (Takazawa et al, 2012). On the other hand, the dunite with high Cr# spinel in the area from the bottom to the middle part of the Sarahi mantle section was formed by the reaction of harzburgite with fluid that was infiltrated from the basal thrust during intra-oceanic detachment. This study is to fill the data of a blank area of research area through the analysis of the whole rock and mineral compositions and the changes in the degree of partial melting, to determine the influence of the fluid in the upper part of Salahi mantle section.

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Origin of Kurouchiyama peridotite mass in the northern Kanto mountains

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The Sambagawa metamorphic belt occupying the northern part of the Kanto Mountains with 60 km length in WNW-ENE and several 10's of km width. In this metamorphic belt, crystalline schists derived from the sedimentary rocks of the Chichibu belt occupy the majority, but Mikabu green rocks made of gabbro-serpentinite and a large amount of basic volcanic rocks distribute in the southern part. In the Mikabu green rocks, peridotite masses of 100m to 1km of major axis occur sporadically. Within them, Kurouchiyama mass is the largest (1km x 2km in size). This peridotite mass, consisting mainly of wehrlite, has been proposed to be a cumulate caused by crystal fractionation from magma. However, it is not clear which type of magma is responsible for the generation of peridotite mass and how the Kurouchiyama peridotite mass was taken into the Sambagawa metamorphic belt. The origin of Kurouchiyama mass is a clue to understand the formation of the peridotites in the high-pressure metamorphic belt of Japan. In this presentation, I report the results of field survey and microscopic observation for thin sections.

The Kurouchiyama peridotite appear black and massive on outcrops. The peridotites consist of olivine, clinopyroxene, amphibole, spinel with minor amount of phlogopite and secondary serpentine. Although there are some variations in modal amount of cpx and grain size of constituent minerals, it is difficult to distinguish such differences in the outcrops. In the southwestern part, the mass contacts to green schist with a low-angle fault. The fault has a strike of NNE-SSW and is inclined to west. The peridotite mass forms the hanging wall against the green schist. Moreover, picritic basalt is observed at an outcrop on the top of the Mt Kuroutiyama.

Under the microscope wehrlite shows equigranular adcumulate texture. Olivine is euhedral to half euhedral and grain boudaries are smooth. Cleavage is commonly observed in olivine. Cpx is anhedral and show poikilitic texture to fill the grain boundaries of olivine crystals. Phlogopite and amphibole also occur associated with cpx. The modal amount of amphibole is about 5%, but phlogopite is less 1%. The modal ratio between cpx and olivine seems variable at a scale of hand specimen. Therefore, the cpx-olivine ratio is a key to identify the lithological variation within the mass. Along with microscopic study we will proceed to analyze mineral and whole rock compositions for major and trace elements using EPMA, XRF, and ICP-MS, and further dicuss the origin of the Kurouchiyama mass.

Comparative study of Upper Zone and Lower Zone of Horoman peridotite complex, Hokkaido, Japan

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The Horoman peridotite complex, Hokkaido, Japan is located at the south end of the Hidaka Metamorphic Belt. It is 8 km × 10 km in size. The Horoman peridotite complex has been considered as a residue of partial melting in mid-ocean ridge at *ca.* 1 Ga. It was uplifted from upper mantle to the lower crust and taken into the Hidaka metamorphic belt when the Northeastern Japanese arc collided with the Kuril arc at 20 Ma. Horoman peridotite complex has conspicuous layered structure. Based on the mode of lithological layering the Horoman peridotite complex can be divided into two zones: Upper Zone and Lower Zone. The Upper Zone is dominated by thin layers, few centimeters to several meters, and has abundant plagioclase lherzolite. In contrast, the Lower Zone consists of relatively thick layers, a hundred meters, and shows repetititions of plagioclase lherzolite - spinel lherzolite - harzburgite - spinel lherzolite - plagioclase lherzolite.

There are many studies of the Horoman peridotite for the last 40 years (e.g., Niida and Takazawa, 2007 and reference therein). However, detailed study of consecutive compositional variation along a section normal to the foliation plane has not been conducted in the Upper Zone yet. In addition, enrichment of incompatible element in the peridotites from Upper Zone is not well known. The purpose of my study in graduation thesis aims to clarify a more detailed characteristics of Upper Zone using abundances of trace elements and incompatible elements of peridotites. I will compare the results from the Upper Zone with those from the Lower Zone. In this poster session, I report the tentative results from my study and discuss the significances of geochemical layering in the Horoman peridotite.

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Archaean Dharwar craton in India: An ideal terrane to understand the early Earth's surface environment and origin of life

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Earth's surface environment and the evolution of life in the Hadean and Archaean times has always been an intriguing topic of debate among the scientific community because of the sparsely remaining rock record. Geochemical records including the isotopic compositions of several elements have been critically used as proxies for understanding how the Earth evolved in the early stage. For example carbon isotopes were considered as most convincing (but controversial too) evidence for distinguishing biotic and abiotic origin of carbon in the Archaean, whereas multiple sulfur isotopes played a crucial role in our understanding of changes in atmospheric oxygen content. Here I attempt to showcase the Archean schist belts in Dharwar craton, in southern India, especially the Chitradurga Schist belt, Southern India, where the rock records date back to 3.0 to 2.6Ga, A compilation of available geological and geochemical results indicate that the Chitradurga schist belt is an ideal geological entity to study the environment in the "pre-great oxidation event" period.

The Archaean strata of the Dharwar comprises of Sargur supracrustals, the peninsular gneiss complex and the Dharwar Supergroup. The Dharwar Supergroup is further subdivided into the Bababudan and Chitradurga Groups (Ramakrishnan and Vaidyanadhan, 2010). Our new field mapping and zircon U-Pb dating helped us to reconstruct a detailed lithostratigraphy. The lower unit (post-3.0 Ga) consists of basal conglomerate, stromatolitic carbonate, silici-clastics with diamictite, chert/BIF and pillowed basalt, in assending order, all of which are older than 2676 Ma magmatic zircon ages from dacite dyke intruded into the topmost pillowed basalt (Hokada et al., 2013). The upper unit unconformably overlies the pillow lava, and consists of conglomerate/sandstone with ~ 2600 Ma detrital zircons, komatiite lava, BIF and silici-clastic sequence with mafic volcanics. Stromatolites have been reported by Srinivasan et al. (1989), where they described the occurrence of columnar,

pseudocolumnar and terete-shaped stromatolites from the Vanivilas formation of the Chitradurga Group. Columnar stromatolites were collected from the same localities.

Stromatolitic carbonate rocks show large variation in carbon, oxygen and strontium isotopic composition. The $\delta^{13}C_{PDB}$, $\delta^{18}O_{SMOW}$ and $^{87}Sr/^{86}Sr$ ratios vary from -2.3~0.1‰, 14.8~22.5‰ and 0.715~0.7031, respectively, whereas $\delta^{13}C_{PDB}$ values of carbonaceous material vary between -22.1~-5.8‰. Multiple sulfur isotope studies of pyrite carbonate rocks from Bababudan Group show very large variation $\delta^{34}S$ values up to +19.4‰ with negative $\triangle^{33}S$, whereas other sedimentary rocks show $\delta^{34}S$ values near to 0‰. In general, the $\delta^{13}C_{PDB}$ values of organic matter are high, but the massive dolomites have lower $\delta^{13}C_{PDB}$ values. Combining isotopic results with microstructural observations, the possibility of rise in atmospheric oxygen contents before the GOE is discussed in this presentation. Furthermore, isotopic and microstructural proxies will enlighten us about the Archaean biological activity and surface environment and its evolution.

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Regional distribution and petrologic characteristics of the high-pressure metamorphic rocks in the Omi area, Itoigawa, Niigata Prefecture, Japan

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The Omi area, located in the west of Itoigawa city, Niigata Prefecture, forms a part of the Hida Gaien belt. The rocks exposed in this area are crystalline schists, serpentinite, limestone and Jurassic sediments (Banno, 1958). The crystalline schists in the Omi area are named Omi schists, which are exposed in three metamorphic zones biotite zone, garnet zone and chlorite zone (Banno, 1958, Matsumoto, 2011 and references therein). Omi schists are exposed within serpentinite melange and tectonic blocks of garnet-amphibolite, metagabbro, albitite and sometimes jadeite rocks are also observed (Matsumoto et al., 2011). In this area, the highest grade metamorphic rock is eclogite. Eclogite is found as a boulder in westen area in Omi district (Tsujimori, 2002). This discovery led to the demarcation of eclogite unit (EC-unit) and non eclogite unit (N-EC unit) in the Omi area and the tectonic implication of high pressure rocks were discussed (Tsujimori, 2002).

In the Omi area, thin linear belts of serpentinite layers are distributed in the NW-SE direction and this trend is mostly common with the strike of the tectonic blocks (Matsumoto 1980, Matsumoto., 2011 and references therein). In the western area where eclogite boulder was discovered (EC unit) in the Chl zone, many garnet-glaucophane schist occur as boulders (Tsujimori, 2002). However, boundary between EC unit and N-EC unit is not clear.

This study is aimed in understanding the high pressure metamorphism in the western of Omi area, where high pressure rocks are distributed. During the field surveys, a new eclogite outcrop was found, which has not been reported previously. We also investigated EC/N-EC unit boundary in the area. In this presentation we will discuss the occurrence of the high pressure metamorphic rocks and their petrographic characteristics.

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Geologic age of the central African Proterozoic metamorphic rocks in South Sudan

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This study aims to report geochemistry features and geochronology of metamorphic rocks distributed in Jebel Mountain of the Juba Area of South Sudan.

In this study we carried out major element analysis (SSD-1, SSD-2; N4.840556, E31.552778) and also performed SHRIMP U-Pb age dating of the zircons from sample SSD-2.

In the study area, mela-gniess (SSD-1) was intruded by leuco-gneiss(SSD-2). Their major element compositions plotted on QAP diagram show these samples which are SSD-1 and SSD-2 belong to quartz-monzodiorite and tonalite field, respectively. In the AMF diagram, the samples correspond to the calc alkalic rock series. And also sample SSD-1 is characterized by intermediate that has 60.84 SiO_2 (wt%) but sample SSD-2 has 77.1 SiO_2 (wt%) that featured acidic rock.

Analyses of zircon rim from SSD-2 yield a predominant 206Pb/238U age population of Neoproterozoic (ca. 580 Ma). Th/U ratio less than 0.1 indicate that this area experienced a regional metamorphism during the Neoproterozoic. In spite of 1 point, the zircon core yield 207Pb/206Pb age of Archean (ca. 2590 Ma) that represents intrusive age of lueco-othogneiss.

According to these data, sample SSD-1 and SSD-2 were originally igneous rocks corresponded to calc alkalic series. The lueco-gneiss (SSD-2) intruded mela-gneiss (SSD-1) in Archean (Ca. 2590 Ma) and then they were metamorphosed during the last stage of global scale collision forming Gondwana supercontinent at ca. 580 Ma.

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Relationship between peak metamorphic condition and geological structure in the upper sequence of Hidaka Metamorphic Belt

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The relationship between peak metamorphic condition with Raman Spectra in Carbonaceous Material (RSCM) thermometry (Beysacc et al., 2002, Rahl et al., 2005), illite crystallinity (Mukoyoshi, et al., 2007) and geological structure in upper stream of Satsunai River, where belongs to upper sequence of Hidaka Metamorphic Belt (HMB) is reported in this study. In this study area, pelitic and psammitic metasediments, soley turbidite of Nakanogawa Group, underwent greenschist to amphibolite facies metamorphism during prograde metamorphism. These metasediments are divided into four metamorphic zones on the basis of mineral assemblages and peak metamorphism (zone Ia to IIb). Very low to low-grade metasediments in zone Ia and Ib are composed of muscovite and chlorite as metamorphic minerals, and the temperature estimations using illite crystallinity and RSCM thermometry (Aoya et al., 2010) range between 200 to 400°C. With increasing metamorphic temperature, metasediments in zone IIa and IIb are mainly composed of biotite and muscovite, and with rare cordierite porphyroblast and andalusite which are mostly altered to muscovite in pelitic layer. The temperature estimations using RSCM thermometry range between 400 to 600°C.

Ms-Chl metasediments in zone Ia and Ib show only NE-SW to N-S striking bedding planes, whereas, Ms-Bt metasediments in zone IIa and IIb show not only bedding plane but also biotite schistosity with increasing meteamorphic condition, which is slightly oblique to the bedding planes. These regional biotite schistosity and bedding planes are regionally folded with nearly upright tight folds having N-S to NE-SW trending fold axis. Mylonite and cataclasite zones, which cut the regional schistosity and bedding planes partly developed in this study area.

On the basis of regional geological structure and temperature estimation, we attempted to compare the geothermal gradient and cross section of geological map. In zone IIa and IIb, estimated geothermal gradient by peak metamorphism progressively increase at 39~47°C / km (R2 = 0.8~0.9), respectively. These data show relatively higher geothermal gradient than that of previous studies (Osanai et al., 2007). In addition, low-grade metasediments in zone Ia and Ib show the discordant temperature

trend. These data suggest that low-grade metasediments modified the geological structure after peak metamorphism. Detailed relationship between peak metamorphism and tectonic evolution of upper sequence of HMB is going to discuss in poster session.

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Determination of crystal orientation of cordierite using Raman spectral patterns

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Cordierite [$(Mg, Fe)_2Al_4Si_5O_{18}$] has a channel structure comprising six-membered rings of (Al, Si) O_4 stacked along the *c*-axis, which enables it to trap volatiles such as H_2O and CO_2. The volatile content is generally constrained by IR spectroscopy and Raman spectroscopy. CO_2 is aligned linearly along the *a*-axis in the channel, and therefore the peak intensity of CO_2 at 1383cm^{-1} obtained using Raman spectroscopy varies considerably depending on the crystal orientation of cordierite (Wood and Nassau, 1967; Kolesov and Geiger, 2000). Kaindl et al. (2006) has shown that the Raman spectral intensity of CO_2 band in crystallographically oriented cordierite grains represent the contents of CO_2 inside the channel. Therefore, it is necessary to apply a correction on the effect of crystal orientation for the determination of true contents of CO_2 in a randomly oriented cordierite.

Natural cordierite occurs as orthorhombic symmetry (*Cccm*), and as hexagonal polymorph indialite (*P6/mcc*). Both minerals have six-membered rings of (Al, Si) O_4, and tetrahedral and octahedral framework bond the rings. There are three tetrahedral sites occupied Al and Si in framework of cordierite and indialite; two Al and one Si occupy in three tetrahedral of cordierite, three Si occupy in its of indialite. Especially, in the case of cordierite, crystal orientation varies depending on position of two sites occupied by Al (Meagher and Gibbs, 1977).

Electron Back Scattered Diffraction (EBSD) is useful tool for determination of crystal orientation. However, cordierite has very complex structure as described above. Therefore, it is not easy to determine crystal orientation of cordierite using EBSD. On other hand, Raman spectroscopy has characteristic that Raman peak intensity varies depending on the crystal orientation. However, the incident laser of Raman spectroscopy is usually polarized, polarized laser will affect the peak intensity (Ishibashi et al., 2008). Therefore, we analyzed euhedral crystals of cordierite and revealed the relationship between Raman spectral patterns and crystal orientation using Raman peak intensities in relation with the crystal orientation and laser polarization.

In this study, euhedral cordierite crystals (X_{Mg} = 0.74 ± 0.14) collected from the

volcanic ash deposit in the Takiga swamp, Gunma Prefecture, Japan were examined in detail using micro-Raman spectroscopy and EBSD. We also checked crystal orientations of cordierite grains using a universal stage. The micro-Raman spectroscopy was carried out using a 360° rotating stage for each analytical point to check the effect of incident laser polarization and crystal orientation. Raman spectral patterns obtained for (001), (100) and (010) planes change systematically, when the sample was rotated. The spectral pattern of cordierite are characterized by 6 main peaks, the splitting peak of 554cm^{-1} and 575cm^{-1}, 970cm^{-1}, 1010cm^{-1} and 1180cm^{-1} . The peak at 1010cm^{-1} is characteristic peak of (100) plane and (010) plane, but was not observed for (001) plane. The intensity of all peaks except for the peak 670cm^{-1} changed systematically to reach maximum at every 180° of rotation. We named these six peaks (1: 554 cm^{-1}, 2: 575 cm^{-1}, 3: 670 cm^{-1}, 4: 970 cm^{-1}, 5: 1010 cm^{-1}, 6: 1180 cm^{-1}), and compared the relative intensity of each peak. The intensity of peak 3 did not change and so we used it as a normalizing peak for instrumental intensity variations. Intensity ratio of peak 5 to peak 3, I_5/ I_3, and peak 6 to peak 3, I_6/ I_3, show a periodic change to arrange from 0˚ to 360˚. I_5/ I_3 are shown a difference in (001) plane, and I_6/ I_3 are shown a difference in (010) plane. Combining the above results, the relationship between the crystallographic orientation of cordierite and Raman spectral intensities can be expressed graphically and a possible relation of crystal orientation of cordierite is derived.

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Rare earth element and Nd isotope geochemistry of Archaean banded iron formations in the Chitradurga Schist Belt, Dharwar Craton, Southern India

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Banded Iron Formations (BIFs) are chemically precipitated marine sedimentary rocks. They are formed mostly in the Archaean and early Paleoproterozoic and preserve the record about ancient seawater. BIF is composed of alternate SiO2 and iron-rich layers which consists mainly of hematite, magnetite, and siderite. It is believed that the source for iron and silica are hydrothermal vents (Bekker et al., 2010) or continental weathering (Hamade et al., 2003). The origin of BIF and oxidation-reduction state of the seawater can be constrained from the characteristics of trace element, rare earth element and isotope geochemistry. We have studied the geochemical characteristics of BIFs in the Archaean Chitradurga schist belt, Dharwar craton, Southern India.

The stratigraphic succession of the Chitradurga Schist Belt comprises of a volcano-sendimentary sequence of Dharwar Supergroup that overlies the basement Peninsular Gneiss (~3.0 Ga) which contain enclaves of the Surgur group (3.3~3.1 Ga). The Dharwar Supergroup is subdivided into two groups, the Bababudan Group and the Chitradurga group. Hokada et al., (2013) suggests that the oldest depositional age of Bababudan Group and lower unit of Chitradurga group is around 3.14 Ga and 3.22–2.92 Ga and the depositional youngest age of upper unit of Chitradurga group is between 2.68 Ga and 2.63 Ga. Three map scale BIF layers exist in the Dharwar Supergroup and we compare them using their geochemistry.

The Chitradurga BIFs are mostly composed of quartz, magnetite and hematite and rarely contain siderite, pyrite, and carbonate minerals. They contain very low content of Al2O3 (<1wt.%) indicating less detrital components. The PAAS-normalized REY (REE+Y) patterns of the majority Chitradurga BIFs show low REE contents, LREE (light rare earth element)＜HREE (heavy rare earth element) and positive Eu anomaly. These characteristic are similar to Archaean BIFs from South Africa, America and

Greenland except lack of positive La and Y anomaly. The large positive Eu anomalies in BIFs attribute to high temperature hydrothermal fluid fluxes (>250℃) (Bau and Moller, 1993). In addition, some BIFs negative Ce anomaly that reflects oxidizing condition. Therefore the environment of BIFs was at times strongly oxygenated and related to hydrothermal flux. Initial Sr isotopic ratios of BIFs have variations, which suggest post depositional alterations, whereas Nd isotope compositions have less variations than Sr and Nd is immobile element so Nd show probably primary values. It is typical that the positive εNd(t) is related to the depleted mantle, whereas the negative εNd(t) is caused by continental crustal sources. Most of the BIFs show ε Nd(2.8Ga) in the range between -2 to +2 and TDM model age are 3.0Ga to 3.3Ga which is not equivalent to inferred sedimentation age. The $\varepsilon Nd_{(2.8Ga)}$ of depleted mantle is about +4, and metabasalts of around BIFs in the range between -4 to +4. Our isotopic data is inconsistent to each other because in spite of BIFs being sampled from same stratigraphic section their $\varepsilon Nd_{(2.8Ga)}$ shows both positive and negative signatures.

The geochemical data of BIFs suggest that they were not affected by continental source and REY pattern probably show effect of high-T hydrothermal fluid fluxes. Moreover Nd isotopic data show the possibility of depleted mantle source.

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Campanian-Maastrichtian (Late Cretaceous) Paleoenvironment in the East Asia: Palynological insights

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Knowledge of the Cretaceous climatic changes has been derived principally from oceanic scientific drilling. Global cooling would have occurred before and after the Campanian/Maastrichtian (C/M) boundary (Late Cretaceous), judging from the marine sediment records (e.g. Miller et al., 2005). This cooling event may have affected terrestrial organisms. Especially, plants are sensitive to climate change, and flora would have been affected by the global cooling.

The Songliao Basin is the largest Cretaceous oil-gas producing lacustrine basin in Northeast China. The Songliao paleo-lake was at its greatest extent in the Late Cretaceous with continuous sediment deposition (Wan et al., 2013). In recent years, the Continental Scientific Drilling Project was carried out under the framework of the International Continental Scientific Drilling Program (ICDP) to recover a nearly complete Cretaceous terrestrial sedimentary record in this basin. These core samples are named the Songke Core-1 (North) (SK1 (N)) and the Songke Core-1 (South) (SK1 (S)). The SK1 expected to provide hints of the influence of the cooling event in land. We examined spore and pollen obtained from the SK1 (N) to obtain hints of the influence of the global cooling in terrestrial region in East Asia.

In the Songliao Basin, the C/M boundary is considered to exist in the section from the uppermost Nenjiang to lower Mingshui Formations (e.g. Wan et al., 2013). However, its stratigraphic position has been controversial still. We re-examined the stratigraphic position in the SK1 based on the newest Geological Time Scale. The C/M boundary is in normal polarity of C32 (Gradstein et al., 2012). Deng et al. (2013) revealed the magnetostratigraphy in the SK1, and suggested that N2, which is normal polarity from the upper Sifangtai to the lower Mingshui Formations, could be readily correlated with C32n. Therefore, this boundary could have existed in this normal polarity.

We corrected 47 rock samples between the uppermost Nenjiang Formation and lower Mingshui Formation, and found 70 genera and 136 species from 13 horizons. Most of occurrence horizons yielded *Abietineaepollenites* spp., *Cedripites* spp., and

Psophosphaera spp. Gao et al. (1999) carried out palynorogical analysis in the Songliao Basin, and explained parents of each genus, temperature zone, and humidity of their habitat. We applied our result to the conclusion of Gao et al. (1999) for examining paleaoenvironmental change.

Abiespollenites spp., *Balmeisporites* spp., *Inaperturopollenites* spp., and *Ephedripites* spp. prefer temperate temperature, and increased in N2. The C/M boundary may have existed in this normal polarity. This fact could be one of the influences of the global cooling. In other wards, parents of these genera could have increased in vegetation by the global cooling of the C/M boundary.

We proposed a range of stratigraphic position of the C/M boundary in the Songliao Basin (SK1). In the standard chronostratigraphy, however, the C/M boundary has been defined in marine sediments (Gradstein et al., 2012). Lacustrine deposits of the Songliao Basin need to correlate with marine deposits. The Izumi Group is one of the Upper Cretaceous marine deposits in southwest Japan. This group yields spore and pollen, and has a potential to produce a biostratigraphic framework for the Campanian-Maastrichtian. We found spore and pollen from 17 localities above and below the C/M boundary in the Izumi Group. We will attempt to correlate palynofloral assemblages of the Songliao Basin with those of the Izumi Group.

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Early Cretaceous plant fossil assemblages from the Tetori Group in the Itoshirogawa area, Hakusan Region, central Japan

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The Tetori Group is a Middle Jurassic - Lower Cretaceous sequence distributed in the Inner Zone of Southwest Japan. The Tetori Group consists of three subgroups: the Kuzuryu, Itoshiro and Akaiwa subgroups in ascending order (Maeda, 1961). The Kuzuryu Subgroup consists mainly of marine sediments, and the Itoshiro and Akaiwa subgroups consist mainly of non-marine sediments.

Kimura (1987) recognized two distinct floras in Late Jurassic and Early Cretaceous sediments in Japan, the Tetori-type and Ryoseki-type floras together with the Mixed-type Flora. Plant fossil assemblages from the Tetori Group include various ferns and ginkgoaleans classified as Tetori-type floral elements, which flourished under a humid warm-temperate climate (Kimura, 1987). The Ryoseki-type floral elements were recently discovered from the Lower Cretaceous Tetori Group (Yabe et al., 2003). The Ryoseki-type Flora is considered to be indicative of a subtropical condition with dry season (Kimura, 1987). We report the occurrence of the Ryoseki-type floral elements from the Akaiwa Subgroup of the Tetori Group in the Itoshirogawa area, Hakusan Region, central Japan.

In the northern part of the Itoshirogawa area, the Itsuki Formation of the Itoshiro Subgroup and the Nochino Formation of the Akaiwa Subgroup are exposed. The Itsuki Formation is composed mainly of alternating beds of mudstone and sandstone. The formation has yielded plants and brackish-water and freshwater mollusk fossils. The formation is tentatively regarded as Barremian in age based on zircon U–Pb dating which the youngest zircon grain from the sandstone of the formation has a concordant age of 127.2 ± 2.5 Ma (Kawagoe et al., 2012). The Nochino Formation is composed mainly of coarse-grained sandstone, orthoquartzite-bearing conglomerate and alternating beds of mudstone and sandstone. Plant fossils occur commonly in the alternating beds.

Plant assemblages from the Itsuki Formation of the Itoshiro Subgroup include 25 species of 20 genera (*Thallites yabei*, *Equisetites ushimarensis*, *Adiantopteris sewardi*, *Cladophlebis* ex gr. *denticulate*, *Coniopteris burejensis*, *Eboracia* sp., *Onychiopsis*

elongate, *Osmundopsis distans*, *Sphenopteris* sp., *Sagenopteris* sp., *Nilssonia kotoi*, *N. nipponensis*, *Dictyozamites kawasakii*, *Neozamites elongates*, *Otozamites* sp., *Ginkgoidium nathorsti*, *Ginkgoites digitata*, *Czekanowskia* sp., *Pityophyllum* sp., *Podozamites reinii*, *P. lanceolatus*, *Taeniopteris emarginata*, *T. vittata* etc…). Plant assemblages from the Nochino Formation of the Akaiwa Subgroup include 23 species of 18 genera (*Equisetites ushimarensis*, *Adiantopteris* sp., *Cladophlebis* ex gr. *denticulate*, *C. hukuiensis*, *Gleichenites nipponensis*, *G. porsildi*, *G. yamazakii*, *Onychiopsis elongate*, *Sphenopteris* sp., *Sagenopteris* sp., *Pterophyllum* sp., *Zamiophyllum* (?) sp., *Ginkgoidium nathorsti*, *Ginkgoites digitata*, *Czekanowskia* sp., *Brachyphyllum* (?) sp., *Elatocladus* spp., *Pagiophyllum* sp., *Podozamites reinii*, *P. lanceolatus*, *Taeniopteris emarginata* etc…). The assemblage from the Nochino Formation is the Mixed-type Flora because the occurrence of the Ryoseki-type floral elements (*Zamiophyllum* and *Brachyphyllum*) and the Tetori-type species are mixed.

The recognition of the Mixed-type Flora is important to understand climatic change in East Asia during Early Cretaceous. The floristic compositional change from the Tetori-type to the Mixed-type occurs around the lithostratigraphic boundary between the Itoshiro and Akaiwa subgroups. The mixed-type flora in the Tetori Group appeared probably in Berremian time. The change could be resulted from a warming and drying climatic trend under which the lower Cretaceous Tetori Group was deposited.

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Micro-organisms in amber from the Aptian (Cretaceous) of Yezo Group, northern Japan.

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Micro- and soft-bodied organisms such as insects and fungi play an important role in terrestrial ecosystems during the Earth's history. Especially, they have promoted evolution of plants that are essential elements of terrestrial environment. Angiosperms, which arose in the Early Cretaceous and now accounts for 98% of living terrestrial plants species, have also co-evolved with insects and fungi by their pollination, decomposition and nutrient supply.

Fossil records of micro- and soft-bodied organisms are mostly restricted to amber because amber protects them from pressure, decomposition or oxidization (Martínez-Delclòs et al., 2004; Perrichot and Girard, 2009). In amber, we can observe three-dimensionally preserved organisms. The Mid-Cretaceous represents the most important period for understanding the initial co-evolution between insects, fungi and angiosperms. Though Mid-Cretaceous amber localities are rare, we recovered new amber containing deposits in northern Japan.

Geological Settings and Methods

The Yezo Group is exposed in a belt roughly 1200 km long from Sakhalin Island to southern Hokkaido and consists of a thick Aptian to Paleocene fore-arc siliciclastic sequence. Amber-concentrated strata are intercalated in the lowest part of the Yezo Group in Nakagawa area, northern Hokkaido, Japan. To clarify depositional environments and processes of ambers, sedimentary and ichnofacies analyses have been done. The geological age was determined by age diagnostic ammonites and SHRIMP U-Pb dating of zircon in the intercalated tuff. Bio-inclusions of amber are observed under a digital zoom microscope for systematic determinations.

Results and Discussion

Amber is highly abundant in proximal turbidites, which overlies the deep-sea mudstone of the uppermost part of the Sorachi Group. This observation implies the existence of an enigmatic sedimentary event at the boundary between the Sorachi and the Yezo Group, which

transported numerous resins into the deep sea by turbidity currents. The depositional age of amber-turbidites is about 118 Ma (late Early Aptian). Numerous terrestrial bio-inclusions occur in the amber, such as arthropods (e.g., Diptera, Chacidoidea and mite), fungi (unidentified mycelium, spore-like objects, and septum), pollens (*Classopollis*? and Cyatheaceae?) and plant fragments (tracheids and a stellate hair). These occurrences are the first reports of bio-inclusions in the Aptian amber from the eastern Eurasia. Tricolpate pollen, the pollen type of predominant angiosperm groups at present (Eudicots), has recently been reported from uppermost part of Sorachi Group in the same area (Barremian?-Aptian) (Tanaka and Hirano, 2009). This represents the oldest record of Eudicots in Asia at all. Further studies of the Aptian amber bio-inclusions will provide critical information about earliest co-evolutionary history of angiosperm and micro-biota.

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Late Jurassic to Early Cretaceous and Late Paleocene Radiolarian from the Yarlung-Tsangpo suture zone, near Zhongba county, Southern Tibet

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The Yarlung-Tsangpo suture zone stands for the tectonic boundary between Eurasia and India plates. Remnants of the Neo-Tethys crop out along the Yarlung-Tsangpo suture zone. Although many hypotheses have been proposed, the precise history is still controversial among researchers (e.g., Beck et al., 1995; Yin and Harrison, 2000).

From north to south, there are 4 tectonic units: the Gangdese Batholith, Gangdese forearc basin, Yarlung-Tsangpo suture zone and Indian passive continental margin. The Cangdese Batholith is composed mainly of a calc-alkaline intrusive suit related to the northward subduction of Neo-Tethyan oceanic lithosphere under the southern margin of the Lhasa block. The Gangdese forearc basin is made up of sedimentary rocks. The Yarlung-Tsangpo suture zone consists of ophiolitic mélange and sedimentary mélange. The Indian passive continental margin sediments are distributed along the southern side of the Yarlung-Tsangpo suture zone. They are composed mainly of rhythmic cherts and siliceous shales. The four tectonic units are in fault contact with each other. The tectonic units which yield radiolarian fossils in our research area are ophiolitic mélange, sedimentary mélange and the north Tethys Himalaya from north to south.

The previous 1:250,000 geological-mapping investigations defined the strata belong to the Yarlung-Tsangpo suture zone and north Tethys Himalaya as the Sangdanlin Formation, Zheba Formation and Dengang Formation, and gave a Paleocene to Eocene age for the formations. Precise investigations on the radiolarian biostratigraphy near our research area are scarce. Late Jurassic radiolarians from the Zhongba mélange were reported (Li et al., 2013) near Zhongba County.

Based on the radiolarian assemblages, we can know that the ophilitic mélanges are Kimmeridgian to Hautervian. The sedimentary mélanges are Tithonian to Aptian. The deep water sediments in the north Tethys Himalaya are from Oxfordian to Kimmeridgian and Valangian to Hauterivian. In addition we found radiolarians

indicating of the *Buryella tetradica* (RP5) Zone and *Bekoma campechensis* (RP6) Zone, Late Paleocene in the siltstone from north Tethys Himalaya. Judging from the fossil evidence, the strata were deposited in a deep ocean from Late Jurassic to Early Cretaceous. The ocean was retreated at least after Late Paleocene.

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Redivision of the Kamiaso unit and the Nabi unit in the Mino terrane of the Mino-Hichiso area, Gifu Prefecture, central Japan

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The Mino terrane, one of the disrupted terranes in central Japan, is divided into several tectonostratigraphic units on the basis of composition, fabric and age. However, there is a problem that these data are biased, because detailed studies have been conducted only in limited areas. The Mino-Hichiso area of the central part in Gifu Prefecture is one of such areas. According to Wakita (1988), this area is occupied by the Kamiaso unit characterized by repeating coherent chert-clastic sequences and the Nabi unit characterized by broken formation composed of sandstone/mudstone and melange. Here, we will discuss redivision between the Kamiaso unit and the Nabi unit in the Mino terrane.

The Kamiaso unit is distributed in the northeastern-central part of the study area. The unit is characterized by a tectonic pile composed of chert-clastic sequences that retain the oceanic plate stratigraphy and consist of siliceous claystone, chert, siliceous mudstone, conglomerate, sandstone, mudstone, limestone and basalt. There are two types of conglomerates in the Kamiaso unit, the Kamiaso conglomerate (Adachi, 1971) and the Wadano conglomerate (Kanuma, 1956). The Kamiaso conglomerate is characterized by containing granitic rocks of pre-Cambrian age (e.g. Shibata et al., 1971). On the other hand, the Wadano conglomerate is characterized by breccias and blocks of chert, siliceous claystone, limestone and basaltic rocks of oceanic plate origin.

The Nabi unit is distributed in the southwestern part of the study area. The unit is characterized by tectonic melange and consist of siliceous claystone, chert, siliceous mudstone, sandstone, mudstone and alternating beds of chert and siliceous micrite. Melanges are categorized into three types: (1) mudstone-rich melange, (2) siliceous mudstone-rich melange, (3) siliceous claystone-rich melange. Alternating beds of chert and siliceous micrite commonly found along the Nagara River. The block including chart-limestone alternating beds continues about 10 km laterally.

As a result of extracting radiolarian fossils from rock samples, chert yield Middle Triassic to Early Jurassic radiolarians, while siliceous mudstone and mudstone samples

yield Middle Jurassic radiolarians. A chert sample in alternating beds of chert and siliceous micrite yields Late Triassic radiolarians. According to Sano et al. (2010), the Upper Triassic alternating beds of chert and siliceous micrite differs in containing siliceous micrite from the coeval bedded chert of the oceanic plate stratigraphy of the Mino terrane.

The chert-clastic sequences have been recognized as an important element in unit division. However, the chert slab distributed in Mount Takajare, which has been considered to be tectonostratigraphically the uppermost part of the Kamiaso unit, includes alternating beds of chert and siliceous micrite. The slab is different in the lithofacies from chert of the Kamiaso unit. Futhermore, sedimentary sequences distributed structurally higher than the chert slab are dominated by melange. Therefore, the unit boundary between the Kamiaso and Nabi units can be determined at the base of the chert slab. The presence or absence of alternating beds of chert and siliceous micrite is one of important criteria for distinguishing the Nabi unit from the Kamiaso unit.

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Facies and the Platform Type Limestones of the Ichinotani Formation in Fukuji Area, Takayama City, Gifu Prefecture

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This subject is targeted for consideration of the formation environment of the limestone in the Ichinotani Formation. Devonian, Carboniferous and Permian limestones are distributed over the Hida Gaien belt. There is the Fukuji Formation, the Ichinotani Formation and the Mizuyagatani Formation from a lower level in the Fukuji area. This limestone is platform type for that reason a lamina develops in them. A lot of fossils such as a coral and Fusulina produce it from there and biostratigraphy was divided.

The Ichinotani Formation is distributed over Ichinotani valley and Mizuboradani valley, and consists mostly of gray limestone. Apart from that, a black limestone, black shale, red limestone and red shale occur in this formation. A green-colored Tuff is observed under a black limestone. A mudstone and a limestone are alternately stacked near the red limestone. There is a conglomerate in red limestone. Furthermore, from a classification of Flugel (2010), these limestones understand a thing consisting of limemudstone, wackstone, packstone and calciludite. About the Ichiontani Formation, the author collects a rock sample from the range of layer thickness 300m, make a thin sample from them and observe it. This formation is divided into six of Zone of Eostaffella, Zone of Profusulinella, Lower Zone of Fusulinella-Fusulina, Zone of Beedeina, Upper Zone of Fusulinella-Fusulina and Zone of Triticites by a fusulina (Niikawa, 1980). The author divided each zone into four groups from a characteristic such as facies and biofacies. For example, There is a special facies such as a black limestone and a red limestone, poor in a large fossil such as a coral, An alga excels very much. The author considers the environment with the model whom Flugel (2010) gathered up from those group characteristics. It was assumed that the model that Machel & Hunter advocated was most suitable in the results.

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Geology and mollusks of the Early Cretaceous Koyamada Formation, Somanakamura Group, Fukushima Prefecture, Northeast Japan

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The Somanakamura Group is distributed in the hilly areas of Minamisoma City and Soma City, Pacific Ocean coast north of Fukushima Prefecture. The group belongs to the Southern Kitakami Terrane, and is characterized by alternating occurrence of river sediments and shallow-water sediments (Mori, 1963). This group is known as a fossiliferous geologic unit that produces Middle Jurassic to earliest Cretaceous plants (Takimoto et al., 2008) and mollusks (Sato et al., 2008). In recent years, new cephalopod specimens have been found (Sato et al., 2011). However, detailed studies on the bivalve from the Koyamada Formation have not been done yet.

The Somanakamura Group crops out in a narrow zone along the Futaba Fault, forming a north-south trending anticlinorium. The Koyamada Formation occupies the uppermost part of this group, distributed in both limbs of the anticlinal structure. Fossils from the Koyamada Formation have been found only in the east limb of the anticline, but have not been found in the west limb.

This study is aimed at bivalve fossils from the Koyamada Formation. Several hundreds of bivalve fossils were found during road construction at Miyamae, located in the east limb of the anticline. These specimens are kept in the Minamisoma City Museum. During our field research, some mollusks fossils were newly found from the Koyamada Formation in the west limb of the anticline. We will discuss the paleoenvironment of the Early Cretaceous on the basis of these fossils.

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Stratigraphy and molluscan fossils of the Tetori Group in the Izumi region, Ono City, Fukui Prefecture, Central Japan

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The Middle Jurassic to Lower Cretaceous Tetori Group is distributed in Niigata, Toyama, Ishikawa, Nagano, Gifu, and Fukui Prefectures, Central Japan. The Tetori Group is divided into the Kuzuryu, Itoshiro, and Akaiwa Subgroups in ascending order (Maeda, 1961a). It is well known that the Tetori Group contains various kinds of fossils including bivalve, gastropod, ammonite, plant, and dinosaur (e.g. Maeda, 1961b; Fujita et al., 1998). In the Izumi region, Ono City, Fukui Prefecture, Central Japan, the Tetori Group is widely distributed and subdivided into five areas; Mana, Ono, Itoshiro, Nagano, and Kamihambara areas. The Izumi region is the type locality of the Jurassic part of the Tetori Group. In this study, we will report the stratigraphy and molluscan fossils in the Itoshiro and Nagano areas.

Many researchers have studied the stratigraphy of the Tetori Group in the Izumi region. Maeda (1961a), Yamada et al. (1989), and Fujita (2002) suggested different opinions on the stratigraphy of the Tetori Group. In the Itoshiro area, the Kuzuryu and Itoshiro Subgroups are divided into the Shimoyama, Oidani, Tochimochiyama, Kaizara, Yambarazaka, Yambara, Ashidani, Obuchi, and Itsuki Formations in ascending order (Maeda, 1957). In the Nagano area, Kuzuryu and Itoshiro Subgroups are also divided into the Nagano, Yambarazaka, Yambara, and Ashidani Formations. Handa et al. (2014 in press) shows ammonite biostratigraphic zones with illustrations of molluscan fossils in the Kaizara Formation.

We made a geological map and found some fossils during our field survey in the Itoshiro and Nagano areas. In the Itoshiro area, we found some molluscan fossils from the Kaizara Formation. A radiolarian fauna was newly discovered from one of molluscan localities. In the Nagano area, we found bivalve and ammonite fossils from a new locality of the Nagano Formation. Bivalve fossils in marine deposits of the Kuzuryu Subgroup have not been studied sufficiently. We will pay attention to bivalve fossils and compare them between the Itoshiro and Nagano areas.

In this study, we recognized that the stratigraphy in the Itoshiro area is almost the

same as that of the previous researches. However, our data on the stratigraphy in the Nagano area show a result from the previous ones. A correlation of the stratigraphy of the Kuzuryu Subgroup between the Itoshiro and Nagano areas will be revised in this work.

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Geology and radiolarian fossils of the Misogawa Complex of the eastern Mino Terrane in the Kaida area, Nagano Prefecture, central Japan

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The Jurassic subduction complex of the eastern part of the Mino Terrane, central Japan is divided into six complexes on the basis of lithology, age and structure. The Misogawa Complex has the youngest age and is widely exposed in the eastern Mino Terrane. Many reports of radiolarian fossils have been published in the Misogawa Complex (e.g., Okumura and Otsuka, 1996; Shuto and Otsuka, 2003). Otsuka (1988) carried out an important study from a structural point of view. However, research on geology and radiolarian dating is scarce in the northern part of the Misogawa Complex comparing in the southern part.

In this study, we are making a geological map of the Kaida area located in the northern part of the Misogawa Complex. The Misogawa Complex in the study area is subdivided into Unit A, B and C on the basis of lithology. Unit A is composed of chert. Unit B is charactenized by the dominance of sandstone. Unit C consists of mudstone and mélange composed of sandstone blocks and sheared mudstone matrix.

In addition, we are trying to determine the radiolarian ages of constituent rocks of the Misogawa Complex. We have collected about 90 samples of chert from Unit A. Of these, 10 samples were treated with HF and radiolarian fossils were found from three samples.

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Geologic field trip to Central Mountain Range in Taiwan

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We participated in the geologic field trip in Taiwan organized by Department of Earth Sciences, College of Sciences, National Cheng Kung University from 4th to 9th September 2014. This geologic field trip was aimed to observe low grade metamorphic rocks in the Central Mountain Range of Taiwan and structures related to fault movement and earthquake associated with them. We first visited a small hill near Puli city in the Central Taiwan. From this point the overview of Puli basin was clearly achieved. We discussed there how this basin was formed. Some researcher has proposed it formed as pull-apart basin associated with fault movement. Then, we went up to the Central Mountains where we observed a series of metamorphic rocks such as marble, green schist, mica schist, phyllite, slate and metasandstone. We also observed deformation styles of metamorphic rocks and quartz vein system. They originally formed as continental and ocean substances deposited on the Chinese passive margin. The orogenic wedge of Taiwan was collided with the Luzon volcanic arc in the late Miocene. We discussed the diastrophism during collision and how Central mountain ridge was built up associated with a series of metamorphic rocks. Then, we moved to the Lusan hot spring. We observed the source of hot spring in the upper stream of the Tarowan river. There is a set of faults along and across the river. Using the structure of quartz veins we estimated the deformation during fault movement. Final place visited in this trip was the Chelungpu Fault Preservation Park where we observed the trench wall cut across the fault. The Chelungpu Fault caused the 921 earthquake on 21 September 1999. We learned significances of fault activity and earthquake in Taiwan.

These experiences made our understanding of metamorphism, deformation and mountain building process more deeply. As a result we recognized the geologic differences between the collision zone of Taiwan and the subduction zone of Japan, the shape of the mountain range and the metamorphic degree of the rocks. In our poster, we summarize our geologic field trip in Taiwan and show the field occurrences of metamorphic rocks and some characteristic structures.

Late Cretaceous (Turonian-Coniacian) radiolarians from the Zabyat Formation in the Wadi Jizzi area, Oman Ophiolite

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The Oman Ophiolite consists of mantle peridotites, gabbros, a sheeted dyke complex, and extrusive lavas overlain by pelagic sediments. The basaltic extrusive rocks have been subdivided into three volcanic units (the V1, V2, and V3 lavas) (Ernewein et al., 1988). The overlying pelagic sediments, named the Suhaylah Formation, consist of metalliferous and fine-grained calcareous sediments of Cenomanian-Santonian? age (Fleet and Robertson, 1980; Tippit et al., 1981). The Zabyat Formation, which covers conformably the Suhaylah Formation, is composed of conglomerate derived mainly from a collapsed oceanic crust during the thrusting stage (Woodcock and Robertson, 1982; Robertson and Woodcock, 1983). Although Robertson and Woodcock (1983) investigated the sedimentation process of this formation, they did not study the biostratigraphic age of fine-grained sediments intercalated with conglomerate at Lasail section in the Wadi Jizzi area.

At Lasail section, the stratigraphy of the Zabyat Formation consists of the lower conglomerate interbedded with micritic limestone and red mudstone and the upper red mudstone and siliceous mudstone. The micritic limestone of the lower part contains *Alievium superbum* (Squinabol), *Rhopalosyringium scissum* O'Dogherty, *Hemicryptocapsa polyhedra* Dumitrica, *Dictyomitra formosa* Squinabol, indicating Turonian in age (O'Dogtherty, 1994). From the red mudstone of the upper part, we obtained *Pseudoaulophacus lenticulartus* (White), *Pseudoaulophacus praeflorensis* Pessagno, *Theocampe salillum* Foreman, *Anikaella omanensis* De Wever et al. The occurrence of these species assigns the upper part of the Zabyat Formation to Coniacian (Pessagno, 1976; Bandini et al., 2008). Our biostratigraphic result of the Zabyat Formation, taken together with that of the Suhaylah Formation, shows that the change of the tectonic setting from mid-ocean ridge through subduction zone to oceanic thrusting occurred in a short period (c.a. 4 m.y.) of latest Cenomanian to Coniacian time.

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Radiolarian biostratigraphy of the Upper Cretaceous Suhaylah Formation in the Wadi Jizzi area of the Oman ophiolite

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The Oman ophiolite, a member of the Tethyan ophiolites, crops out over 600 km long and up to 150 km wide in the Oman Mountains. The ophiolite suite consists of mantle peridotites, gabbros, a sheeted dyke complex, and extrusive lavas overlain by pelagic sediments. The extrusive lavas have been subdivided into three volcanic units: the V1 lava with the N-MORB signature (Geotimes Unit), the V2 lava formed by intra-oceanic volcanism (Alley unit), and the V3 lava (Salahi unit) generated by intra-plate seamount magmatism (Ernewein et al., 1998). Pelagic sediments with metalliferous sediments commonly occur at the boundaries between these volcanic units. The pelagic sediments, called the Suhaylah Formation, have been studied by Fleet and Robertson (1980) in terms of depositional environments. Tippit et al. (1981) conducted radiolarian biostratigraphic study for the Suhaylah Formation intercalated in the V2 lava and in and overlying the V1 lava. They concluded that radiolarians range in age from early Cenomanian to Santonian; however detailed stratigraphic distributions of radiolarians were not shown in their study. In order to understand the pelagic sedimentation and history of volcanic activity, I have reinvestigated the lithology and radiolarian biostratigraphy of pelagic sediments.

Radiolarian study has been conducted in "Suhaylah" section, about 40 km west of Sohar. This section consists of the V1 lava and overlying metalliferous and pelagic sediments of which the maximum thickness reaches 18 m. The sediments of this study are subdivided into three lithologies: metalliferous sediments inter-bedded with thin chert layers (8 m), red mud with chert intercalations (4 m), and micritic limestone (6 m). The metalliferous sediments is dark purple to dark red in color, weakly stratified, and very fine grained with metallic luster. The thin lamination within the bed is frequently observable. The red mud is very fine grained. In the upper part of the mud sequence, several chert layers are intercalated with the mud. The micritic limestone is red in color in the lower part and greenish gray in the upper part.

Based on the species composition, I recognized two assemblages, Assemblages A

and B. Assemblage A, recognized in the chert within metalliferous sediments and red mudstone, contains *Thanarla pulchra* (Squinabol) and *Guttacapsa biacuta* (Squinabol). According to O'Dogherty (1994), the last occurrences of *T. pulchra* and *G. biacuta* are near the top of Cenomanian. Thus, Assemblage A is assignable to late Cenomanian. Assemblage B, characterized by the abundant occurrence of *Rhopalosyringium scissum* O'Dogherty and *Dictyomitra multicostata* Zittel, is recovered from red mudstone and micritic limestone. The first occurrences of *R. scissum* and *D. multicostata* are recognized near the base of Turonian (O'Dogherty, 1994). This indicates that Assemblage B is assignable to Turonian. Based on the occurrences of these radiolarians, the boundary between Cenomanian and Turonian is thought to be present in the red mudstone just above the V1 lava.

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Faunal transition of Early Devonian radiolarians in the tuffaceous strata of the Konomori and Yokokurayama areas, Kurosegawa belt, Southwest Japan

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Silurian to Devonian felsic tuffaceous rocks (Yokokurayama Group) are distributed in the Konomori and Yokokurayama areas of the Kurosegawa belt in central Shikoku, Southwest Japan. Well-preserved radiolarians have been reported from felsic tuff in these areas (e.g., Furutani, 1983; Wakamatsu et al., 1990; Aitchison et al., 1996; Umeda, 1997). Aitchison et al. (1996) also analyzed SHRIMP dating using zircons from felsic tuff at Konomori and provided a U/Pb age of 408.9±7.6 Ma. Umeda (1998) proposed uppermost Silurian to Middle Devonian radiolarian zones for the strata in the Konomori and Yokokurayama areas. From a viewpoint of the evolution of Radiolaria, a significant faunal change from the inaniguttid-dominated fauna to the palaeoscenidiid-dominated fauna occurred in Early Devonian (Kurihara, 2007). Here I focus on biostratigraphic results in the Konomori and Yokokurayama areas and report the faunal transition of Early Devonian radiolarians.

Total 27 felsic tuff samples were collected from the Konomori area and six samples were analyzed in terms of faunal composition. As a result, I recognized three assemblages (Group-A to C), in stratigraphic ascending order. Group-A is characterized by the occurrence of *Pseudospongoprunum*, indicating latest Silurian in age. Group-B contains large spherical radiolarians of the family Inaniguttidae such as *Zadrappolus* and *Futobari*. Group-C is characterized by the occurrence of the family Palaeoscenidiidae including *Deflantrica* and *Pactarentinia*. The co-occurrence of inaniguttids and *Deflantrica* was not recognized in the samples. The age of Group-B and C can be estimated to Early Devonian, based on the correlation of the current radiolarian zonation (Kurihara, 2004; Manchuk et al., 2013) and the U/Pb age of zircons (408.9±7.6 Ma) from Konomori (Aitchison et al., 1996).

I analyzed the radiolarian faunal composition of 5 samples collected from the Yokokurayama area. Based on the comparison to the radiolarian assemblages of the Konomori area, the stratigraphic interval of these samples can be correlated with strata

containing Group-B and C at Konomori mentioned above. However, the co-occurrence of *Zadrappolus* and *Defrantrica* was found in the sample of the Yokokurayama area. This implies that the inaniguttid-dominated fauna changed gradually to the palaeoscenidiid-dominated fauna. In addition, it is observable that the shell diameter of spherical radiolarians of unknown genus becomes smaller towards the upper horizons.

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Radiolarians from a Permian accretionary complex in the Kitagawa area of the Kurosegawa Belt, Southwest Japan

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The Kurosegawa belt in the Kitagawa area, Tokushima Prefecture, consists mainly of Early Paleozoic granitic rocks, high-grade metamorphic rocks, serpentinites, and Permian-Jurassic shallow marine sediments. These diverse rock suites are highly disrupted, forming lenticular bodies within the Permian-Early Jurassic accretionary complex (Hara et al., 201). The Permian accretionary complex is composed mostly of mélange-type rocks and sheared sandstone and shale. The mélange-type rocks include basalt, limestone, chert, siliceous shale, and sandstone, all within an argillaceous matrix. In the present study, I focus on the lithostratigraphy of the Permian accretionary complex and its biostratigraphic age based on radiolarians.

The Permian accretionary complex is distributed mainly in Higashi-semidani, Nakatani, and Shiraishi. Based on the lithology, rocks in this area are subdivided into three units: H1 to H3. The H1 unit is composed mainly of sheared shale and alternating sandstone and shale with a minor amount of siliceous shale. The H2 unit consists of a mélange including basalt, limestone, chert, and sandstone. The H3 unit is composed of a mélange containing chert and sandstone. These units are bounded by faults. Chert samples (2014071605 and P1 of the H2 unit) contain *F. scholasticus* and *F. ventricosus*, indicating a Middle Permian age. From siliceous shale (2012080803 of the H1 unit), *A. cavitata* was recovered. In addition, *A. protolevis* and *A. levis* were obtained from shale (2012080901 of the H2 unit). Based on the occurrences of these *Albaillella* species, the siliceous shale and shale were assigned to an early Late Permian age that can be approximated to the age of accretion.

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Stratigraphy and radiolarian age of Late Cretaceous pelagic sediments in the Wadi Hilti area of the Oman Ophiolite

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The Oman Ophiolite consists of mantle peridotites, gabbros, a sheeted dyke complex, and basaltic lavas overlain by pelagic sediments. The extrusive rocks have been subdivided into three volcanic units; the V1 lava was formed on a spreading ridge, the V2 lava was formed by juvenile arc magmatism, and the V3 lava generated by intraplate volcanism (Ernewein et al., 1988; Kusano et al., 2014; Umino, 2013). The V2 and V3 lavas are widely distributed in the Wadi Hilti area, about 25 km south west of Sohar, northern Oman. Pelagic sediments are about 50 m thick at a maximum, overlie the V2 lava and are covered by the V3 lava. The sediments also occur on and within the V3 lava. However, their stratigraphy in the Wadi Hilti area has not been studied in detail. On the other hand, litho- and biostratigraphic studies have been conducted in the Wadi Jizzi area, about 25 km north of Wadi Hilti area. Thick pelagic sediments on the V1 lava in the Wadi Jizzi area are subdivided into the Suhaylah and Zabyat formations; the former is composed of metalliferous and fine-grained pelagic sediments of Cenomanian – Santonian(?) age, and the latter consists of conglomerate derived mainly from a collapsed oceanic crust during the thrusting stage (Fleet and Robertson, 1980; Tippit et al., 1981; Woodcock and Robertson, 1982; Robertson and Woodcock, 1983). Recently, the radiolarian biostratigraphy of the Suhaylah Formation has been reexamined by Hara and Kurihara (2013). They reported Cenomanian - Turonian radiolarians from fine-grained pelagic sediments.

Based on our field examination for several sections in the Wadi Hilti area, the stratigraphy of the pelagic sediments on the V2 lava consists of metalliferous sediments, V2 lava (boninite), fine-grained pelagic sediments, conglomerate, V3 lava, and siliceous mudstone, in ascending order. We first found conglomerate containing gravels of lavas and pelagic cherts from this area. From fine-grained pelagic sediments on the V2 and V3 lavas, we obtained *Rhopalosyringium scissum* O'Dogherty and *Hemicryptocapsa polyhedra* Dumitrica that can be assigned to a Turonian age (O'Dogtherty, 1994). In addition, *Rhopalosyringium petilum* (Foreman) and *Guttacapsa biacta* (Squinabol) were recovered from a block of siliceous mudstone

probably within the conglomerate. According to O'Dogtherty (1994), the co-occurrence of these species is restricted to be middle to late Cenomanian.

Based on these age assignments, the fine-grained pelagic sediments on the V2 lava (metalliferous sediments, micritic limestone, and red mudstone) in the Wadi Hilti area can be correlated with the Turonian part of the Suhaylah Formation in the Wadi Jizzi area. This reveals that the activity of the V2 lava was terminated in Turonian. The conglomerate and the siliceous mudstone on the V3 lava are correlated with the Zabyat Formation, indicating that the eruption of the V3 lava occurred in Turonian. These age constraints for basaltic extrusive rocks imply that the tectonic setting from subduction to oceanic-thrusting changed rapidly in a short period of Turonian time.

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Tectono-stratigraphy and geologic age of Jurassic accretionary complexes (Otchizawa and Nogurizawa formations) of the Southern Chichibu belt in Ueno Village, Gunma Prefecture, northwest Kanto Mountains, central Japan

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The Chichibu Belt extends over 1,000 km from Okinawa Islands to the Kanto Mountains, central Japan, comprising Jurassic to Early Cretaceous accretionary complexes (Northern Chichibu and Southern Chichibu belts) and allochthonous fragments of an island arc/around-arc basin system of Ordovician to Cretaceous age (Kurosegawa belt). Based on the lithology and geological structure, Matsuoka et al. (1998) subdivided the Southern Chichibu belt into three units: the Ohirayama, Togano, and Sambosan units. Among them, the Ohirayama unit was first defined as chaotic rocks distributed between the Kurosegawa belt and the Togano unit in the Sakawa area, Kochi Prefecture, Shikoku; however a complicated geologic structure around in the type locality has hampered understanding of the nature and formation process of the unit. In contrast, this unit occurs widely in the western part of the Kanto Mountains (Nakatsugawa Group) (Hisada et al., 1992) and a recent study shows that the rocks in this area remain important geologic structures at deeper levels of the accretionary complex such as duplexing (Ueno et al., 2011). Here I present the results of detailed tectono-stratigraphic and radiolarian biostratigraphic investigations of the Otchizawa and Nogurizawa formations of the Nakatsugawa Group (Ueno et al., 2011) in Ueno Village, Gunma Prefecture, northwest Kanto Mountains.

The Otchizawa and Nogurizawa formations of the study area can be subdivided into six units (Units A to F) bounded by faults, in structural ascending order. Rocks of these units strike N60° to 80°W and dip 55° to 80° to the north. Unit A corresponds to the Otchizawa Formation, and Units B to F correspond to the Nogurizawa Formation in the previous studies. Unit A is composed of Permian limestone and basaltic rocks within a muddy matrix. Units B, D, and F consist of sheared mudstone beds with blocks of sandstone, chert, and basaltic rocks. Unit C is characterized by fault-bounded slices of chert and sandstone associated with lesser siliceous shale and sheared alternating sandstone and shale. Unit E is composed of large chert bodies and basaltic

rocks.

I collected 186 samples of chert and muddy rocks from which I attempted to extract radiolarians using a standard HF acid etching technique. As a result, I obtained Early Jurassic radiolarians (*Bagotum* sp., *Droltus* sp., and *Katroma* sp.) from siliceous shale of Unit C. I also recovered *Eucytidiellum* sp. and *Parahsuum* sp. from mudstone sample of Unit C.

The present tectono-stratigraphic and biostratigraphic results show that Unit C characterized by repeated tectonic slices of chert and sandstone is a key geologic unit to reconstruct of an ocean plate stratigraphy of the accretionary complex in this area. More information on ages of chert of Units C and D is also needed to better understand accretionary process.

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Molluscan shell assemblages in neritic sediments in the Japan Sea off Nou, Itoigawa City, Niigata Prefecture, Japan

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Molluscan shell assemblages in neritic sediments off Nou (Itoigawa City, Niigata Prefecture, Japan) in the Japan Sea were analyzed for elucidating the taphonomic processes of molluscan shells. Molluscan shells were collected from 5 m to 150 m depth of seabed off Nou in the Japan Sea in 1999 by a dredge (ORI type) of R/V Kubiki (19t) belonging to the Niigata Prefectural Marine Senior High School. Dredging was performed for 5 minutes at each site and a total of 60 samples were collected. The samples were fixed by 10% formalin at once and then were reserved in 70% 2-propanol dilutions. Molluscan shells were sorted out from the samples and were dried at room temperature in Laboratory. The species list of each sampling station was made, and then species composition of each sampling station was compared.

The species composition of molluscan shell assemblages exhibits a gradual change according to the latitude in the Japan Sea (Nishimura 1968). The zoogeographical position of Nou is under a warm temperature area of the Japan Sea. The bottom of the sea off Nou is classified by molluscan species composition into two or three groups. These groups have some relations to environment factors; water depth, character of bottom sediment, seasonal variations of sea water temperature and water current orientations of the warm Tsushima Current. The comparisons in distribution between living molluscan species and their dead shells indicate that the shells are transferred from their habitat to different sites.

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Belemnites originated in the Triassic—A new look at an old group

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This study sheds new light on the debated existence of Triassic belemnites. Distribution and diversity patterns of belemnites in Middle Jurassic to Cretaceous times have been well recognized. Their evolutionary history in the Early Jurassic is, however, not fully understood. Current hypotheses of the early evolution of belemnites are summarized as follows. *Schwegleria* (Belemnitina), which is characterized by small and short rostra, occur in the Hettangian of northern Europe. This genus is the oldest belemnites so far known, and was considered as a possible stock-group of all belemnites. It has been concluded that the belemnites evolved in Europe in the Hettangian; their distribution was restricted to the European shelf seas until the Pliensbachian (e.g., Doyle, 1994).

Findings of pre-Jurassic "belemnites" (e.g., *Jeletzkya* from the Carboniferous of North America, Palaeobelemnopsidae from the Permian of China, Sinobelemnitidae from the Triassic of China) challenged this view, but were reclassified later mostly as aulacocerid or phragmoteuthid coleoids (e.g., Doyle et al., 1994). The only exceptions are the Sinobelemnitidae, described by Zhu and Bian (1984) from the lower part of Ma'atang Formation in the Longmen Mountains region, China. We have re-studied the type specimens of these sinobelemnitids, which are stored at the Chengdu University of Technology, Chengdu, China. The Chinese sinobelemnitids have well preserved internal structures such as protoconch and siphuncle. They co-occur with ammonites indicating a Carnian age such as *Protrachyceras*, *Discotropites*, *Tropites*, and *Paratropites* (Gou, 1993). The Sinobelemnitidae can be clearly distinguished from the Aulacocerida by the following diagnostic features of the Belemnitida: (1) a high apical angle of phragmocone (>12°), (2) short distance of each septa, and (3) ventrally inclined protoconch. Previous studies (e.g., Doyle, 1993, 1994; Doyle et al., 1994) also considered the Chinese Sinobelemnitidae as belemnites s.s. (order Belemnitida). At the same time, the Triassic age assignment of these forms has been questioned (Doyle, 1993, 1994; Weis and Delsate, 2006) because the typical belemnite morphology (long rostra with a well-developed alveolar groove), superficially exposed by the Sinobelemnitidae, had not been recorded from pre–Middle Jurassic strata in Europe

(Doyle, 1993, 1994; Doyle et al., 1994). The Sinobelemnitidae have a long belemnite rostrum with, however, one well-developed deep groove on the dorsal side. This dorsal groove, which is only present in the Japanese Hettangian and Sinemurian belemnites (Iba et al., 2012), is a morphological feature that has been overlooked in previous European studies. The presence of Sinobelemnitids from the Triassic of China and earliest Jurassic of Japan therefore (1) extend the origin of the belemnites back by ~33 m.y. into the Triassic, (2) suggest that this group did not necessarily originate in northern Europe, and (3) imply that belemnites survived the Triassic–Jurassic extinction, one of the five big mass extinctions in the Phanerozoic.

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SCIENCE REPORTS OF NIIGATA UNIVERSITY (GEOLOGY)

No.29
(Supplement)
31 October 2014

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