Sandstone petrography and areal comparison of the Lower Siwalik Group(Miocene), west-central Nepal

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Metamorphism and exhumation of high-grade metamorphic rocks that consists of the Higher Himalaya took place during Miocene time (Sakai, 2005). The Himalayan orogen is a result of ongoing collision between Indian and Asian continents. A number of studies carried out about this example of continental collision progressed from Paleogene to present time (Honda and Sakai, 1988; Najman, 2006). Metamorphism and uplift process is related to formation of the Himalayan orogeny. In this study, sandstone petrography is studied in the Lower Siwalik Group in four areas; Karnali River, Dang Valley, Surai Khola and Tinau Khola in west-central Nepal. The comparison with each petrographical result reveals the timing of exhumation of the high-grade metamorphic rocks in central Himalaya.

Siwalik Group is interpreted as a foreland basin deposit of Himalayan orogen from Miocene to Pliocene time, especially the deposition of the Lower Siwalik Group is contemporaneous to the exhumation of Higher Himalaya. Thus this study aims to clarify the historical change of the hinterland constitution using modal composition of sandstones, heavy mineral assemblage and chemistry of detrital garnet grains by EDS. Paleomagnetic stratigraphy is used to determine the depositional age in each area (Gautam and Fujiwara, 2000; Rosler et al., 1997; Gautam et al., 2012). Result of modal analysis of sandstone in each area shows the recycled orogenenic provenance, which indicates the Himalayan origin. Furthermore most quartz grains are classified into middle and upper rank metamorphic field in triangular diagram proposed by Basu et al. (1975), which is suggestive of middle and upper rank metamorphic rock source. Some sandstones, which were deposited in 13-8Ma, contain high-temperature minerals, such as kyanite, sillimanite, and staurolite. These minerals imply the exhumation of high-grade metamorphic rocks in hinterland, though definite timing of unroofing in these crystalline rocks is obscure due to scarcity of the minerals. Then the chemical composition of detrital garnet grains, which are included in all of sandstone samples, is used to chase the transition of hinterland. As a result, the chemical composition of detrital garnet grains had been changed in the Lower Siwalik deposited during 13~8Ma. Because this duration is likely to be close to an appearance of kyanite and staurolite, the compositional change of detrital garnets suggests the exhumation of Higher Himalaya in Late Miocene time. Timing of exhumation in each area are estimated as follows; 13.2~12Ma in Karnali River area, 13~10.9Ma in Dang Valley area and 10.9~9.5Ma in Srai Khola area. It is suggested that the unroofing in western area is probably prior to that in eastern area. This tendency indicates the unroofing of Higher Himalaya propagated from the west to the east. Previous works in Pakistan and north-western India showed that the unroofing of high-grade metamorphic rock progressed from the west toward the east in north-western margin of Indian sub-continent (Najman et al., 2003a,b; White et al., 2002).

Keywords: Himalayan orogen Siwalik Group

Origin and tectonic evolution of the accretionary complex in central and north-central Mongolia

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Introduction We aim to clarify the origin and tectonic evolution of accretionary complexes (ACs) in central and north-central Mongolia. **Geologic setting** **North-central Mongolia (NCM)** consists of the following three terranes: the **Haraa** and **Bayangol terranes** consisting of an AC and minor volcaniclastic cover rocks of Early Paleozoic times, and the **Khentei terrane** consisting of an AC and shallow-marine cover of Middle Paleozoic to Early Mesozoic times. The Khentei AC strikes NE and dips to N. The pelagic chert of the AC yields Late Silurian and Early-Late Devonian microfossils (Kurihara et al., 2009). The overlying Lower Carboniferous mudstone yields brachiopods, and the Middle-Upper Permian Urmegtei formation is a periglacial formation. **Central Mongolia (CM)** consists of the following two terranes: the **Zag terrane** consisting mainly of Early Paleozoic crystalline schists, and the **Khangai terrane** consisting of an AC and terrestrial cover. The terranes of CM and NCM are separated by a sinistral shear zone, whereas the boundary between the Zag and Khangai terranes trends NWN and dips N. A NWN-trending syncline runs in the middle of the Khangai terrane, where plant-bearing Carboniferous sediments with horizontal conglomerate occur with andesite pebbles. The Carboniferous sediments are thus terrestrial sediments. The Zag terrane collided with the terranes on the south in Permo-Triassic times (Jian et al., 2010). **Method** We extracted detrital zircons from 21 sandstone samples of the AC and terrestrial sediments: from the Khentei (8 samples), Haraa (5), Bayangol (2), Khangai (5), and Zag (1) terranes. We then measured their U-Pb ages with the LA-ICP-MS equipped in the Graduate School of Environmental Studies, Nagoya University. **Results** We recognized two types of detrital-zircon-age spectra. One was a multimodal pattern with small peaks at 420-650 Ma, 700-1000 Ma, 1600-2200 Ma, and 2300-2700 Ma and had 75 % or more Precambrian zircons. Three samples from the upper part of the AC in NCM and the Zag terrane showed this pattern. The other was a unimodal pattern with the youngest peaks (YP) between the Devonian and the Early Permian and has virtually no Precambrian zircons, indicative of an island-arc setting. The Khangai terrane and lower part of the AC in NCM, and the terrestrial sediments in CM showed this pattern (17 samples). **Discussion** We assumed, from the volcaniclastic nature of most of the sandstone samples, that the YP of the spectrum is the depositional age (DA) of each sample (YP of meta-samples is the upper limit of the DA because of the absence of volcaniclasts). The DA of the multimodal-type sandstone clustered at 526-426 Ma, whereas those of the unimodal-type sandstone clustered at 409-374 Ma (Early Devonian), 358-332 Ma (Early Carboniferous), and 304-259 Ma (Early Permian). Moreover, the DA clearly showed a downward-younging polarity in the **Khangai Terrane of CM** and **NCM**. Moreover, the older interval in the DA (374-348 Ma) and the hiatus of Paleozoic igneous activity in the Tuva-Mongol Massif (385-350 Ma) roughly coincide with each other. These facts indicate that the studied AC intermittently grew downwards in front of the Tuva-Mongol Massif. The Zag sample is similar with the Cambro-Silurian sediments in NCM and contained Pan-African (550-750 Ma) zircons, indicative of their derivation from Gondwana. In particular, the zircon-age spectrum of the Cambo-Ordovician sandstone of the Kufra Basin in the Saharan Metacraton has a close affinity with the multimodal-type of NCM. The YP of the terrestrial sediments (322 Ma) indicates that CM became land by early Carboniferous, and the later collision of the Zag and southern terranes produced the syncline of CM.

Keywords: U-Pb age, (detrital) zircon, LA-ICP-MS, Gondwana continent, Paleozoic

Detrital zircon U-Pb ages from Permian clastic units within the Kurosegawa belt

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U-Pb dating of detrital zircons was performed on Permian clastics from the Kurosegawa belt, distributed in Ino district, Kochi, Shikoku, to determine the sedimentary age. The Permian clastics of the Kurosegawa belt are subdivided into three geological units such as Middle Permian accretionary complex (Ino and Agekura units), and Late Permian accretionary complex (Singai and Tosayama units, and Late Permian shallow marine sediments (Ichinose Formation). In particular, the Middle Permian accretionary complex was subjected to pumpellyite to actinolite facies metamorphism during Late Triassic to Early Jurassic.

Keywords: zircon U-Pb age, Permian, Kurosegawa belt

Zircon U-Pb dating of igneous-rock clasts from the Monobegawa and Nankai groups in Shikoku, SW Japan

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INTRODUCTION

The Lower Cretaceous strata of the Chichibu Composite Belt in Shikoku, SW Japan, are divided, from bivalve fauna and lithofacies, into the Monobegawa and Nankai groups (MG and NG; Tashiro, 1985). Tashiro (1985) also suggested that the Nankai fauna indicates lower latitude than the Monobegawa fauna. Matsukawa and Eto (1987), on the other hand, suggested that the two groups were deposited in a same basin, where the Boreal–Tethyan mixed ammonite fauna inhabited. Matsukawa and Eto (1987) further discussed that some clasts in the Hauterivian Shobu Formation (Fm) of the NG were supplied from the pre-Cretaceous rocks of the Kurosegawa Tectonic Belt (KTB) on the south of the basin. To solve the confusion, we measured the zircon U-Pb age of igneous-rock clasts from the Hibihara Fm (1 clast) and Yunoki Fm (1; MG) in central Shikoku, and the Hoji Fm (1; MG) and the Shobu Fm (2; NG) in eastern Shikoku.

METHODS

We separated zircons from igneous-rock clasts and measured the U-Pb isotopic ratios of each grain on the LA-ICP-MS equipped in the Graduate School of Environmental Studies of Nagoya University. Data with the (206Pb/238U age)/(207Pb/235U age) between 0.9 and 1.1 were used for discussion.

RESULTS

Granite clast from the Albian Hibihara Fm : We obtained 14 concordant measurements ranging in age between 133 and 120 Ma and calculated the 206Pb/238U weighted mean age of 126.4 +/- 2.5 Ma.

Granite porphyry clast from the Aptian Yunoki Fm : We obtained 12 concordant measurements with the age clusters at 129-122 Ma (N=6), 137-135 Ma (N=2), 181-174 Ma (N=2), 269 Ma (N=1), and 2,334 Ma (N=1) and calculated the 206Pb/238U weighted mean age of 125.4 +/- 2.6 Ma from the youngest 6 grains.

Granite porphyry clast from the Aptian Hoji Fm : We obtained 13 concordant measurements ranging in age between 143 and 118 Ma and calculated the 206Pb/238U weighted mean age of 130.0 +/- 4.4 Ma.

Granite clast from the Hauterivian Shobu Fm : We obtained 34 concordant measurements with the age clusters at 173 Ma (N=1), 186-184 Ma (N=2), 218-193 Ma (N=27), and 232-224 Ma (N=4) and calculated the $^{206}Pb/^{238}U$ weighted mean age of 203.9 +/- 2.5 Ma from the 27 grains forming the largest age cluster.

Granite porphyry clast from the Shobu Fm : We obtained 11 concordant measurements scattering in age at 204-203 Ma (N=2), 241-228 Ma (N=3), 263 Ma (N=1), 287 Ma (N=1), 1,910-1,879 Ma (N=2), 2,090 Ma (N=1), and 2,263 Ma (N=1) and calculated the concordant age of 203.4 +/- 2.8 Ma from the youngest 2 grains.

DISCUSSION

The igneous-rock clasts from the MG are 130-125 Ma in age. Coeval igneous rocks occur in the Kitakami Belt of NE Japan, around the Bohai Bay, and along the South China coast (e.g., Kiminami and Imaoka, 2013; Li *et al.*, 2014; Tsuchiya *et al.*, 2015). Since the measured clasts are all cobble size, the provenance was probably near the eastern shelf margin of Asia. Moreover the Late Jurassic–Early Jurassic paleophytogeography (Kimura, 1987) indicates that the MG, having the Ryoseki-type flora, must have been deposited along the Zhejiang coast of South China or on the south.

The age of the igneous-rock clasts from the Shobu Fm (NG) is 204 Ma, which does not coincide with the age of the igneous rocks in the KTB (around 400 Ma: Hada *et al.*, 2000; Murata *et al.*, 2006). Further, the sandstone on top of the Shobu conglomerate has many detrital zircons of around 200 Ma, but no 400-Ma and Early Cretaceous zircons. Hence the 200-Ma clasts of the Shobu Fm, differing in age from the igneous rocks of the KTB, must not have been supplied from the south. Hence the Hauterivian of the MG and NG was probably deposited along different parts of the East Asian coast. A possible candidate of the hinterland of the Shobu Fm is Indochina, where Triassic igneous rocks are widely exposed but Early Cretaceous igneous rocks are rare.

Keywords: U-Pb age, LA-ICP-MS, Lower Cretaceous of the Chichibu Composite Belt, Southwest Japan, East Asia, igneous-rock clast

Back-arc opening and across-arc tectonics in Cenozoic Japan

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Multiple check on U-Pb nad Pb-Pb age spectra was conducted for detrital zircons in various Cretaceous sandstones in SW Japan. Their comparison revealed a long-distance (more than 200 km across the arc) transportation of a Cretaceous back-arc sedimentary package into the fore-arc domain during the early Cenozoic, almost coeval to the back-arc spreading of the Jpan Sea. The overall configuration of the Cretaceous subduction-related arc-trench system in Japan is preserved in the current distribution of the relevant orogenic components, i.e., the coeval set of accretionary complexes at trench (the Sanbosan and North Shimanto belts), high-P/T meta-ACs along the Wadati-Benioff zone (the Sanbagawa and Shimanto metamorphic belts), arc batholiths (Ryoke-Sanyo and San-in belts), and fore-arc basin strata (Ryoseki-Monobegawa and Izumi groups). We identified unique age spectra of detrital zircons in the Cretaceous sandstones in the Atogura area in the northern Kanto Mountains, and the Maana area in western Shikoku. These strata occur on the south of Median Tectonic Line of SW Japan as allochthonous klippen. The results of U-Pb dating by LA-ICPMS showed that these sandstones have common age spectra with 4 major age groups; i.e., 120-150 Ma (Early Cretaceous), 170-200 Ma (Jurassic), 250-300 Ma (Permian), and 1600-2200 Ma (Paleoproterozoic), with minor amounts of much older grains up to 2900 Ma (Archean). This age spectrum is quite unique, when compared with other coeval Cretaceous fore-arc and/or intra-arc sandstones in Japan. The Early Cretaceous grains were obviously derived from a proximal source to the depositional site, likely the Cretaceous volcanic arc of the Ryoke-Sanyo belt in SW Japan. The dominant grains of the Jurassic and Permian ages were likely derived from coeval plutonic belts in the provenance, whereas the Paleoproterozoic grains were probably derived from the continental blocks in East Asia with crusts of the corresponding ages, such as the North and South China blocks. Except for the Cretaceous arc source, the occurrence of Jurassic and Permian granitoids is extremely rare in the major parts of Japan, and the Paleoproterozoic crust is totally absent in Japan.

The analyzed sandsotnes from the Atogura and Maana klippens are remarkably different from other coeval fore-arc sandstones, whereas they clearly show similarity to those of the Tetori/Jinzu groups in the Hida belt. The Cretaceous sandstones of the Atogura/Maana klippen were primarily deposited with a close link to the Hida belt. The tectonic emplacement onto the present position immediately above the Cretaceous high-P/T meta-ACs occurred likely during the Paleogene-Neogene time, probably in relation with the Miocene rifting of the Japan Sea. This study provides the first evidence for the material transfer from the back-arc to fore-arc on the order of 200-300 km across the arc.

Keywords: SW Japan, Cretaceous, detrital zircon, U-Pb dating

SHRIMP zircon U-Pb ages of acidic tuff layers within the Ishikari and Kushiro coal basins, in Hokkaido, Japan

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SHRIMP zircon U-Pb ages were obtained for acidic tuff layers within the Ishikari and Kushiro coal basins, in Hokkaido, Japan to understand timings of the coal formations. The sample from the Ishikari coal basin was taken from an open pit of the Sanbi Coal Mine, Bibai city. It is collected from the thin layer of white tuff in the No. 4 coal bed of the mine. The coal bed and the acidic tuff layer is members of the Bibai Formation. The sample from the Kushiro coal basin was taken from underground of the Kushiro Coal Mine. The coal bed is present in the Harutori Formation of the Urahoro Group. Analytical results show that age of the acidic tuff within the coal bed in the Bibai Formation is 43.52 ±0.41 Ma. The age of the acidic tuff in the coal bed of the Harutori Formation in Kushiro basin is 39.54 ±0.56 Ma. Katagiri et al. (2015) obtained 39.87 ±0.35 Ma from an acidic tuff in the Urahoro Group. Our result is slightly younger than the result of Katagiri et al. (2015), however those ages are identical within the analytical uncertainty. Present results show that the deposition of the coal bed in the Ishikari basin is 4 million years older than that in the Kushiro basin.

Katagiri, T., Naruse, H. and Hirata, T. (2015) Facies and depositional age of the Urahoro Group: implication to the Paleogene tectonics of the Hokkaido Island. Program and abstracts annual meeting of the Sedimentological Society of Japan. 39.

Keywords: Ishikari Coal Basin, Kushiro Coal Basin, SHRIMP zircon U-Pb age

Injection direction of a clastic dike inferred from magnetic measurements: an example from the Osa dike in central Japan

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The Osa dike is a 50–70 cm thick sandstone dike in an early Miocene sedimentary succession (named the Morozaki Group) on the Chita Peninsula, central Japan. An earlier investigation suggested that the dike formed by upward sand injection. However, a later study found microfossils from the dike, whose age could be younger than the country rock, implying downward injection. The present study was conducted to solve this problem by means of magnetic measurements. Thermomagnetic results indicate magnetite is the main magnetic mineral. Hysteresis data fall into the pseudo-single-domain range. Analyses of alternating field and thermal stepwise demagnetization results revealed a north-northeasterly paleodeclination of normal polarity characteristic remanent magnetization. The age of this paleodirection of the Osa dike is possibly younger than that of the easterly paleodirection of the Morozaki Group that represents early to middle Miocene clockwise rotation of southwestern Japan. More importantly, anisotropy of magnetic susceptibility (AMS) measurements suggest imbrication of magnetic foliations that is consistent with downward flow within the dike. Therefore, downward injection is supported by both the paleomagnetic direction and the AMS result. We suggest that magnetic measurements can be a useful tool for determining the injection direction of clastic dikes.

Keywords: anisotropy of magnetic susceptibility, clastic dike, Morozaki Group, paleomagnetism, rock magnetism

Paleostress analysis using Hough-transform based inversion method from slip data of mesoscale faults in the Dewa Hills, Akita

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Paleostress analysis was conducted using Hough-transform based inversion method (HIM; Sato, 2006) from slip data of mesoscale faults in the Dewa Hills, Akita, where both pre- and post-lift deposits are widely exposed. The Dewa Hills has been uplifting under E-W compression stress field since late Neogene, and shows a regional variety in deformation intensity and structure. Low angle faults with reverse sense are dominant in the Iwaki coastal area, where an intense shortening occurred showing N-S trending folds and thrusts associated with the activity of the Kitayuri thrust fault. Orientations of σ_1 and σ_3 are detected in E-W and nearly vertical, respectively. In the Toyokawa area at the hinge of the anticlinorium and the northeast part of the Dewa hills without intense deformation, high angle normal faults mainly occur. Stress states of relatively strong σ_1s in vertical and σ_3s diffused widely in NW-SE are obtained from the stress analyses. These are different from the regional stress field, and infer that mesoscale faults in these areas provide signals of later stage of uplifting. Under a limited influence of the regional stress state, the effect of equalization of crustal topography would be apparent. Normal faulting probably occurred resulted from the gravitational spreading (e.g., Ikeda and Yamaji, 2008) towards the structural low away from the high.

Keywords: Hough-transform, paleostress analysis, mesoscale fault, Dewa hills

Redefinition of stratigraphy from Pliocene to Pleistocene of drill core from Sendai Bay.

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We investigated stratigraphy and geological structure around Sendai Bay by geological survey, which included acoustic profiling and 80m drilling on the sea, in order to estimate the activity of NNW-SSE strike faults developed under the inversion tectonics. (Torigoe and Hashimoto, 2007)
Torigoe and Hashimoto (2007) defined five seismic stratigraphic units along seismic profiles: Unit A (Holocene), Unit B (Pleistocene), Unit C (Pliocene), Unit D (Miocene) and Unit E (acoustic basement; Pre-Neogene). They also recognized four lithostratigraphic units in the borehole drilled at the sea bottom of Sendai Bay: Unit A (0-5.17m; soft silt), Unit B (5.17-26.90m; silt or sand), Unit C-1 (26.90-51.13m; siltstone or sandstone) and Unit C-2 (51.13-78.75m; hard tuffaceous siltstone or sandstone). The core was examined by biostratigraphic (diatom and pollen) and tephrochronologic analyses. The lower part of Unit C-1 was placed in the diatom zone NPD8 of Yanagisawa and Akiba (1998) based on the existence of both *Neodenticula kamtschatica* and *N. koizumii*. The upper part of Unit C-1 was assigned to the zone NPD9 based on the presence of both *N. koizumii* and *N. seminae,* and Unit B was inferred to belong to the zone NPD10. No distinct tephra beds were found.
As for the boundary of Unit B / Unit C, comparing seismic stratigraphic and core lithostratigraphic units, although we recognized several meters difference between them: about 35m in seismic profile to about 27m in core, both almost showed good correspondence, consequently we defined the boundary of Unit B / Unit C of core (about 27m depth) as the boundary of Pliocene / Pleistocene boundary. However, there were some uncertainties in our previous diatom biostratigraphy due to extremely rare occurrence of marker species along with a current revision of Pliocene / Pleistocene boundary. In this study, we reevaluated the diatom biostratigraphy of the offshore core through reconsidering reworking of diatoms from older sediments. Furthermore, we established the tephrochronology by detecting cryptotephra in the core on the basis of mineral composition, index of refraction and principal component analysis.
As a result, we can assign the top of Unit C-2 (55m depth) to the zone NPD8, and the upper Unit C-1 (33m depth) to upper part of the zone NPD9 (2.2Ma), respectively. Moreover, we have detected five age-diagnostic tephra beds: Ata-Th (240ka) and O-Ik (240-270ka) at horizon 11m depth, Kkt (330-340ka) at 16m depth, TE-5 (350ka) 17m depth and Hap-2 (2.3Ma) at 31m depth.
These results suggest that the upper Unit C-1 (26 to 36 m) would be Gelacian in age, because of the presence of Hap-2 tephra (2.3Ma) at 31m depth and the occurrence of diatoms indicative to zone NPD9 at ca. 33 m depth. We therefore redefine the upper Unit C-1 as Unit B-2. This revised chronology leads to change of Pliocene / Pleistocene boundary from 27m to 36m depth. This horizon corresponds to the most remarkable reflection with truncation of lower sequence in seismic profile. This new redefinition can solve the discrepancy between profile and core in our previous evaluation.
Reference
Torigoe and Hashimoto (2007): Japan Soc. Eng. Geol. 2007 annual study meeting, 51-52.
Yanagisawa and Akiba (1998): Jour. Geol. Soc. Japan, 104, 395-414.

Keywords: Sendai Bay, Pliocene, Pleistocene, diatom, tephra

U-Pb geochronology of detrital zircons from the Central Hokkaido, Japan

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INTRODUCTION

The Yezo and Saroma groups in central Hokkaido, NE Japan, consist of Cretaceous (to Paleogene?) forearc-basin sedimentary sequences. Previous litho- and biostratigraphic studies (e.g., Takashima et al., 2004; Kiminami and Kontani, 1983) implied that the two groups were deposited in different arc-trench systems. In this study, we will provide detrital-zircon age spectra of the two groups as basic data for the future discussion of provenance analysis and tectonics.

SAMPLES

We studied four samples of the Yezo Group and two samples of the Saroma Group. The samples of the Yezo Group were collected from the Tomitoi Formation (lower part of the Yezo Group), Hikagenosawa and Mikasa formations (middle part), and Hakobuchi Formation (uppermost part) in the Mikasa-Hatonosu and Ashibetsu-Yubari areas. The two samples of the Saroma Group were collected from the upper part of the group on the north of Lake Saroma-ko. All the samples were of medium to coarse grained sandstone.

RESULTS

Yezo Group: We found a broad tendency that the percentage of Precambrian zircons decreases towards the stratigraphic top: from 22-26% in the lower three samples to 3.3% in the Hakobuchi Formation. The Tomitoi Formation contained about 45% of Permian to Jurassic zircons, whereas the other formations contained abundant Cretaceous zircons (50-80%). The age of the youngest zircon (YZ) from the four samples was 126 Ma (Tomitoi), 96 Ma (Hikagenosawa), 83 Ma (Mikasa), and 70 Ma (Hakobuchi).
Saroma Group: The two samples of the Saroma Group, with the YZ of 71 and 69 Ma, contained some Cambrian to Carboniferous zircons that were absent in the coeval Hakobuchi Formation. The percentage of Precambrian zircons was 13% and 21%, whereas that of Cretaceous zircons was 35% and 49%.

DISCUSSION

The Cretaceous zircons in the Yezo Group may have supplied from the igneous arc to the west of the Yezo forearc basin; i.e., the igneous rocks in the Oshima and Rebun-Kabato belts. The provenance of the Precambrian zircons in the Tomitoi, Hikagenosawa, and Mikasa formations, however, must have been in the present-day East Asia, where Precambrian igneous rocks are widely exposed. The coeval Hakobuchi Formation and the Saroma Group likely had different hinterlands, judging from the difference in detrital-zircon-age spectra.

Keywords: U-Pb age, detrital zircon, LA-ICP-MS, Hokkaido

Stratigraphic correlation of the middle and lower part of the Cretaceous Yezo Group by U-Pb geochronology of tuffaceous rocks, Hokkaido, northern Japan

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The Cretaceous sediments, which is called “Yezo Group”, are distributed widely in the axial area, between the north and the south of Hokkaido Island, northern Japan. This group was traditionally divided into three members as, the lower, middle and upper members (ex. Matsumoto, 1942). However, it was pointed out that stratigraphic horizon of the boundary between the lower and middle members of Yezo Group are different in each region. Meanwhile, it was also reported that a key layer consisting of felsic tuff and volcanic clastic sandstone, which are named “Maruyama Formation (Mastumoto, 1942; Motoyama *et al*., 1991)” in central Hokkaido, can be traced in the whole distribution of the Yezo Group. Though the depositional age of this key layer is considered to be useful for broad stratigraphic correlation of the Yezo Group, the sporadic occurrence of index fossils makes insufficient correlation in northern and southern marginal parts of the Yezo Group including Teshionakagawa and Shunbetsu area. In addition, no correlated layer to the Maruyama Formation are found in both areas. In order to specify the depositional age in above mentioned barren horizon, the detrital zircon geochronology is applied for tuff layers distributed in the Teshionakagawa and Shunbetsugawa areas. Then, the broad stratigraphic correlation of the lower to middle parts of the Yezo Group is carried out. In this study, we used LA-ICP-MS(Agilent 7500a ICP-MS and New Wave UP213 Laser Ablation System) for U-Pb geochronology in Niigata University.

As a result by zircon U-Pb dating, the tuff layers, in the Shirataki Formation, in Teshionakagawa area show the youngest graphical age peaks of 96.3-103.4 Ma. On the other hand, the youngest age peak of 98.5±0.5 Ma are obtained from the tuff layer, in Shunbetsu area. Additionally, the petrological characteristics of these tuff and tuffaceous sandstone show felsic. In nature, it is reported that the depositional age of the Maruyama Formation is 102-105Ma by previous studies using planktonic foraminifera (Takashima *et al*., 1997b). In addition, sanidine Ar-Ar radiometric age of 98.98±0.38 Ma, 99.16±0.37 Ma were reported from the tuff layer in the Hikagenosawa Formation, in the Middle Yezo Group in the central Hokkaido (Obradovich *et al*., 2002). Therefore, we concluded that the dated tuff layers in Teshionakagawa and Shunbetsu areas are comparable to these Formations, because of the similarity of these depositional ages and petrological characteristics. It is concluded that the granitic rocks yielding 96-127 Ma K-Ar ages (ex. Shibata and Yamada, 1978), distributed in the Oshima Belt, and the volcanic rocks showing 100.6±3.3 Ma Ar-Ar age (ex. Takigami, 1984) in the Rebun-Kabato Belt are potentially related to source of these tuff layers because of similarity of the radiometric ages and petrological characteristics.

Keywords: Cretaceous, Yezo Group, U-Pb geochronology

Hiatus of a basal unconformity of the middle horizon of the Cretaceous Yezo Group from detrital zircon U-Pb age

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Within the Cretaceous forearc sequence (Yezo Group) of the Sorachi-Yezo Belt, central Hokkaido, the existence of unconformity has been recognized, and a tectonic event shown by the unconformity is called the Intra-Yezo (Naka-Yezo) disturbance (Inoma, 1969). This unconformity was re-confirmed by Kawamura et al. (1999).
In the southern part of Hokkaido, “middle horizon of the Yezo Group (MYG)” unconformably overlies the “lower horizon of the Yezo Group (LYG)” and the “Iwashimizu Complex” (Cretaceous accretionary complex: ICC) (Kawamura et al., 1999;Ueda et al., 2002). Such unconformity in the forearc sequence was considered as the evidence for the appearance of a short-lived forearc ridge in the Yezo forearc basin (Kawamura, 2004). Magnitude, age of formation, and exhumation rate of forearc ridge are essential to the understanding of tectonics of forearc basin. However, the direct determination of the age concerning the unconformity has not been provided in previous studies yet.
To estimate the age of the unconformity and its hiatus, we measured detrital zircon SHRIMP U-Pb ages from three sandstone samples. (1) a sandstone clast (SBR01) in a conglomerate bed in basal part of MYG (Sakubai-gawa River, Mitsuishi district), (2) sandstone (SBR11) alternated with the conglomerate bed, and (3) turbidite sandstone (NER) in LYG (Nae-gawa River, Furano district). Zircon age distribution of SBR01 is very similar to the one of NER. Furthermore, each youngest grain ages are very close (SBR01: 126 ±4 Ma, NER: 125 ±2 Ma, Late Barremian). It is considered that the origin of SBR01 is LYG. Hiatus indicated by the original depositional age of SBR01 and surrounding sandstone (SBR11: 110 ±3 Ma, Late Albian) is 15 my.
Through the hiatus of 15 my, turbiditic sequence of LYG was deposited, buried, lithified, and then uplifted, exhumed and eroded. Duration of burial after deposition until the start of uplift of LYG is still uncertain. But it is supposed to be of several millions of years from the total thickness of LYG (800 –2500 m; Takashima et al., 2001) and general sedimentation rate for forearc basin (200 –300 m / my; e.g. Einsele, 2010). So, we considered that LYG had started to be exhumed after 120 Ma. Therefore, the formation age of unconformity is considered as 120 - 110 Ma. Exhumation of the ICC had begun since about 125 Ma (Ueda et al., 2002). So, turbiditic sedimentation of LYG had even continued after when the exhumation begun. The ‘time lag’ between the timing of uplift of ICC and LYG might indicate the delay in propagation of the effect of exhumation of ICC to LYG, which resulted from tectonic removal of mantle wedge and oceanic crust overlying ICC by detachment faults (Ueda, 2005).

Einsele (2010) Sedimentary Basins, Springer, 598.
Inoma (1968) Jour. Japan. Assoc. Petr. Tech., 34, 11-17.
Kawamura (2004) Proc. Int. Symp. "Dawn of a New Natural History", 109-119.
Kawamura et al. (1999) Mem. Geol. Soc. Japan, 52, 37-52.
Takashima et al. (2004) Cret. Res., 25, 365-390.
Ueda (2005) Tectonics, 24, TC2007.
Ueda et al. (2002) Jour. Geol. Soc. Japan, 108, 186-200.

Keywords: U-Pb age, detrital zircon, hiatus, Cretaceous, forearc basin, Hokkaido

New U-Pb ages of the Nakanogawa Group in southern Hidaka Belt, northern Japan

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Two arc trench systems have been recognized by using paleomagnetic data in the Hokkaido Central Belt, northeast Japan, during Late Cretaceous to Early Paleogene: the Paleo-Japan and the Paleo-Kuril arc-trench systems. The Hidaka Belt is composed mainly of Paleocene turbidite facies, with a small amount of hemipelagic sediment and melange facies. These sediments accumulated near the trench area, later composed accretionary bodies in the two arc trench systems. The Nakanogawa Group is typically exposed on the southern side of the Hidaka Belt and so far of many researchers have believed that this group was protolith of Hidaka metamorphic rocks. Especially depositional age of the Nakanokawa group has been unclear because there were limited point of radiolarian fossil ages (Paleocene to Early Eocene) and only two fission track dating of acidic tuff (50.4±1.2Ma, 47.6±1.3Ma) still now (Nanayama, 1992; Nanayama and Ganzawa, 1997).
We have taken two samples of turbidite sandstone and two samples of acidic tuff from the top and bottom horizon. After separating euhedral zircon grains, we tried to measure U-Pb age by using the LA-ICP-MS method. As a result, the distribution of the following three ages revealed.
(1) 66~53Ma as young ages group (euhedral zircon of high Th/U ratio from igneous rocks)
(2) 73.9, 156, and 334Ma as intermediate group
(3) 2621, 1800Ma as rework zircon group (purple zircon)
In conclusion, the depositional age of turbidite facies of Nakanokawa group may be considered ca. 53Ma (Early Eocene) because the youngest euhedral zircon grains are contained in these four samples in common.

(References)
Nanayama, F., 1992. Stratigraphy and facies of the Paleocene Nakanogawa Group in the southern part of central Hokkaido, Japan. Jour. Geol. Soc. Japan, 98, 1041-1059.
Nanayama, F. and Ganzawa, Y., 1997. Sedimentary stratigraphy, environment and age of the northern unit of Nakanogawa Group in the Hidaka belt, central Hokkaido, Japan. Mem. Geol. Soc. Japan, no. 47, 279-293.

Keywords: U-Pb dating, LA-ICP-MS, Nakanogawa Group, Hidaka Belt, Hidaka metamorphic zone, Early Eocene

Geological provenance based on detrital chromian spinels from the Lower Cretaceous in the Kurosegawa Belt, SW Japan

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The Lower Cretaceous sediments in the Kurosegawa Belt are characterized by different lithofacies, stratigraphy and fauna. In particular, a part of molluscan fossil assemblages can be divided into northern and southern types. The main cause of the difference has been discussed and are divided into the following two hypotheses. One is that different fossil assemblages was caused by gap of latitude, and large scale strike-slip fault moved after the deposition of the Lower Cretaceous (e.g. Tashiro, 1994). On the other hand, the other is that the main cause was due to deferent ocean currents from northward and southward (e.g. Matsukawa and Tsuneoka, 1993). The latter interpreted that sedimentary environment of the Lower Cretaceous sediments was not so much different from the present, while the former was assumed that large scale strike-slip fault moved after the deposition of the Lower Cretaceous sediments. Thus, the former and the latter differ in the interpretation of the paleogeography during the Early Cretaceous. However, there is a limit in the estimation of the paleogeography only with conventional approach using bivalve fauna.
The Lower Cretaceous of the Kurosegawa Belt divided into following four groups; the Monobegawa, Nankai, Pre-Sotoizumi and “Nankai” groups. The Monobegawa and Nankai groups yield the northern and southern type molluscan fauna, respectively. Meanwhile, the Pre-Sotoizumi and Nankai groups yield mixed northern/southern type molluscan fauna. On the paleobiogeography, it is considered that the Monobegawa basin was in an area relatively higher in latitude than the Nankai basin, and the Pre-Sotoizumi and “Nankai” basin was in an intermediate position between the others two. Therefore, they made arrangement in a row in order of the Monobegawa, Pre-Sotoizumi/“Nankai” and Nankai basins from high- to low-latitude areas along the eastern margin of the Asian continent.
Chromian spinels are an important component mineral of serpentinite and peridotite. Since the Kurosegawa Belt consists mainly of serpentinite mélange. If detrital chromian spinels would be found in clastic rocks, it can be expected that the mafic-ultramafic rocks occurred nearby as a source rock. Thus, the mafic-ultramafic rocks might be probably brought up as a part of serpentinite mélange. In this case, serpentinite mélange might play the tectonic role of large scale strike-slip faulting. In this study, we describe newly found detrital chromian spinels from the Lower Cretaceous sediments in western and eastern Kyushu, SW Japan, and discuss their paleogeography.
In this study, it is confirmed that detrital chromian spinels occurred from the Monobegawa, Nankai and Pre-Sotoizumi groups in the Oita and Kumamoto Prefectures, western and eastern Kyushu. The chemistry of most of spinels are very similar to those from serpentinite in the Kurosegawa Belt (low Ti, Cr#=0.5-0.7). In addition, some chromian spinels coming from island arc basalt (high Ti, high YFe^{3+}) were obtained in the Pre-Sotoizumi sandstones. Therefore, considering paleobiogeography based the molluscan fauna analysis and occurrence of detrital chromian spinels, it might be concluded that the Lower Cretaceous deposited in each basin making North-South arrangement in a row was transferred into the present position by the sinistral displacement along the mélange zone in the Kurosegawa Belt after the Cretaceous.

Keywords: Kurosegawa Belt, detrital chromian spinels, Lower Cretaceous sediments, Monobegawa Group, Nankai Group, Pre-Sotoizumi Group

Heavy mineral assemblage in deep sea sands from IODP Exp. 354, Bengal Fan.

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The Himalayan mountain range has been formed as a result of the collision between Asian and Indian continents. The principal focus of Himalayan research is the study of orogenic process and geodynamic evolution of the Himalaya-Tibetan Plateau system. The thermal modeling using radiometric ages provided variations in the timing, geological structures and rate of erosion in Himalayan orogeny (ex. Sakai et al., 2004). However, it is known that roughly 80% of the material eroded from the Himalaya and there are no complete records in foreland and adjacent basins.

Thus the sedimentary record in the Bengal fan, in where most of the detritus were deposited, provides the most complete record of Himalayan evolution.Among the drilling site that had been set on the north latitude 8 °on Bengal fan in IODP Exp. 354, the samples obtained from Site U1451 are used in this study. This site reached at the bottom of the Bengal fan deposits and recovered total 1118 m cores ranging from Late Oligocene to present. The sandstone composition and heavy mineral assemblages in the sandy sediments are examined in order to reconstruct the source rock history.Modal composition and mineral assemblage collected from 163 smear slides and 14 thin sections provide the obvious information of provenance change.

The modal composition of the sands shows recycled orogenic provenance reflecting Himalayan source rocks. In the heavy minerals, the dominance of durable grains, such as zircon, tourmaline and rutile, is significant. A small amount of amphibole and garnet grains are included in Lower Miocene section, however, its amount drastically increases in Middle and Upper Miocene sections. In the Pliocene and Pleistocene sections, variation of heavy minerals are increased.Above petrographical data indicates that the onset of the metamorphic source rocks were before Middle Miocene time and rapid increase of the metamorphic detritus occurred around Middle Miocene time. In addition, another rapid increase of source rock variation were started from Pliocene time.

Keywords: The Himalayan mountain range , Bengal fan

Late Jurassic-Early Cretaceous dextral shearing along the eastern margin of Asia

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This study aims to clarify the Late Jurassic-Early Cretaceous tectonic evolution of the Japanese Islands. To accomplish the purpose, we obtained detrital-zircon-age spectra from Middle Jurassic-Early Cretaceous strata of the Hida, North Kitakami, and Southern Chichibu belts of Japan and compared them with an age distribution map of igneous rocks in East Asia. Here follow the results and discussion. %Pc in the following sentences denotes the percentage of Precambrian zircons in the detrital zircons from a rock sample.

Hida Belt, Inner Zone of SW Japan: Middle Jurassic to Early Cretaceous Tetori Group is distributed in the Hakusan (western) and Jinzu (eastern) regions of the Hida Belt. The Tetori Group in the Hakusan Region showed a %Pc increase from 5.4 (Upper Jurassic) to more than 80 (Lower Cretaceous). The group in the Jinzu Region, on the other hand, showed %Pc increase in the Aptian (Early Cretaceous) from less than 10 to 32, together with the intercalations of red bed that indicate warm and dry climate. Kawagoe et al. (2014) suggested, from the distribution and age of igneous rocks in East Asia, that the hinterland of the Lower Cretaceous in the Hakusan Region, with very high %Pc, was the Korean Peninsula, whereas that in the Jinzu Region, with very low %Pc, was northeast China. We propose that the Aptian increase of %Pc in the Jinzu Region implies an up to 500 km western shift (in the present coordinate) of the Hida Belt relative to Asia and an approach of the Jinzu Region to the Korean Peninsula where Paleoproterozoic igneous rocks were widely exposed.

North Kitakami Belt, NE Japan: Middle Jurassic accretionary complex (AC) contained abundant Precambrian zircons (%Pc=59-87) together with some 190-170-Ma (earlier Jurassic) ones. The Lower Cretaceous cover, on the other hand, characteristically contained 140-120-Ma zircons, the age range in the magmatic hiatus in Korea (Sagong et al., 2005) and yielded the Ryoseki-type flora that flourished in South China. The data suggest that the hinterland of the Middle Jurassic AC was the Korean Peninsula, where Precambrian and Triassic to earlier Jurassic igneous rocks are widely exposed. The Lower Cretaceous cover, containing 140-120-Ma zircons and the Ryoseki-type flora, was presumably deposited along the northern segment of the South China coast where later Jurassic and Early Cretaceous igneous rocks are widely exposed. We thus propose that the geologic entity containing the Jurassic AC of the North Kitakami Belt shifted up to 1,500 km southward to South China coast in Late Jurassic to earliest Cretaceous times.

Southern Chichibu Belt, Outer Zone of SW Japan: Middle Jurassic AC contained abundant Precambrian zircons (%Pc>50) together with some early Mesozoic (250-170 Ma) ones. Late Jurassic AC, on the other hand, showed less %Pc (<30) and contained more than 50% of later Jurassic (170-150 Ma, overlapping the period of the magmatic hiatus in Korea) zircons. The data suggest that the hinterland of the Middle Jurassic AC was the Korean Peninsula, where Precambrian and Triassic to earlier Jurassic igneous rocks are widely exposed. The Late Jurassic AC, containing many later Jurassic zircons was presumably deposited along the northern segment of the South China coast where later Jurassic and Early Cretaceous igneous rocks are widely exposed with some Precambrian basement rocks. We thus propose that the geologic entity containing the Middle Jurassic AC of the North Kitakami Belt shifted up to 1,500 km southward to South China coast in a period including Middle to Late Jurassic times.

We thus found evidence for Late Jurassic to Early Cretaceous dextral movement relative to Asia from

three geologic belts. The amount of displacement seems to be larger in the Pacific side belts. North-dipping dextral shear zones in the Ultra-Tamba and northern Tamba belts, Inner Zone of SW Japan, may have accommodated the dextral motion.

Keywords: detrital zircon, U-Pb dating, Japanese Islands, East Asia, Mesozoic

Zircon U-Pb geochronology of Onogawa-Izumi Group and related geological units

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INTRODUCTION: Upper Cretaceous strata widely occur in Japan: e.g. the Yezo Group (Gp) in Hokkaido, Kuji Gp in the Kitakami Belt of NE Honshu, Onogawa-Izumi Gp in the Inner Zone of SW Japan (IZSWJ), and Himenoura Gp in the IZSWJ in Kyushu. Among them, the Izumi Gp narrowly occurs along the Median Tectonic Line (MTL) and has eastward-younging age polarity, suggesting that the group has filled a series of strike-slip basins along the MTL (e.g., Taira et al., 1981; Miyata, 1990). The Onogawa Gp along the MTL in Kyushu, having similar lithology and geologic structure with the Izumi Gp, is assumed to be a western extension of the Izumi Gp (Yamakita et al., 1995). We obtained the detrital-zircon-age spectra of these strata to discuss their tectonic setting and Late Cretaceous tectonics.

MATERIALS: We obtained detrital-zircon-age spectra of 13 sandstone samples from the following geologic units: Hakobuchi Formation (Fm) of Yezo Gp, Kunitan Fm of Kuji Gp, Izumi Gp (3 from Shikoku, 1 from Awaji Island, 2 from the Kii Peninsula), Inukai Fm of Onogawa Gp, Hamasato, Hinoshima, and Amura formations of Himenoura Gp, and Mitsuse Fm in W Kyushu. The detrital and igneous zircons from related geologic units were also measured: Sanbagawa Metaorphic Rocks, Usuki Granodiorite and Shonoharu Metamorphic Rocks in E Kyushu, and Nagasaki Metamorphic Rocks.

RESULTS: We separated zircons from rock samples and measured the U-Pb isotopic ratios of each grain on the LA-ICP-MS equipped in the Graduate School of Environmental Studies of Nagoya University. The results are summarized in Fig. 1.

Hakobuchi Fm: Cretaceous zircons (mainly 85-75 Ma) were more than 80% and Paleoproterozoic zircons were rare.

Kunitan Fm: Cretaceous zircons (140-80 Ma) were more than 70% and Paleoproterozoic zircons were about 20%.

Onogawa-Izumi Gp: The age of the youngest zircon becomes younger towards east: 81 Ma (Inukai Fm), 76 Ma (W Shikoku), 72 Ma (east-central Shikoku), 72 Ma (E Shikoku), 71 Ma (Awaji Island), 70 Ma (W Kii Peninsula), and 68 Ma (central Kii Peninsula). The Inukai Fm of the Onogawa Gp contains Cretaceous (95 Ma, 105 Ma; 50%) and Permian (30%) zircons.

Hinoshima Fm: Cretaceous zircons (95-85 Ma) were more than 60%.

Amura Fm: Cretaceous zircons (85-80 Ma) were more than 60%.

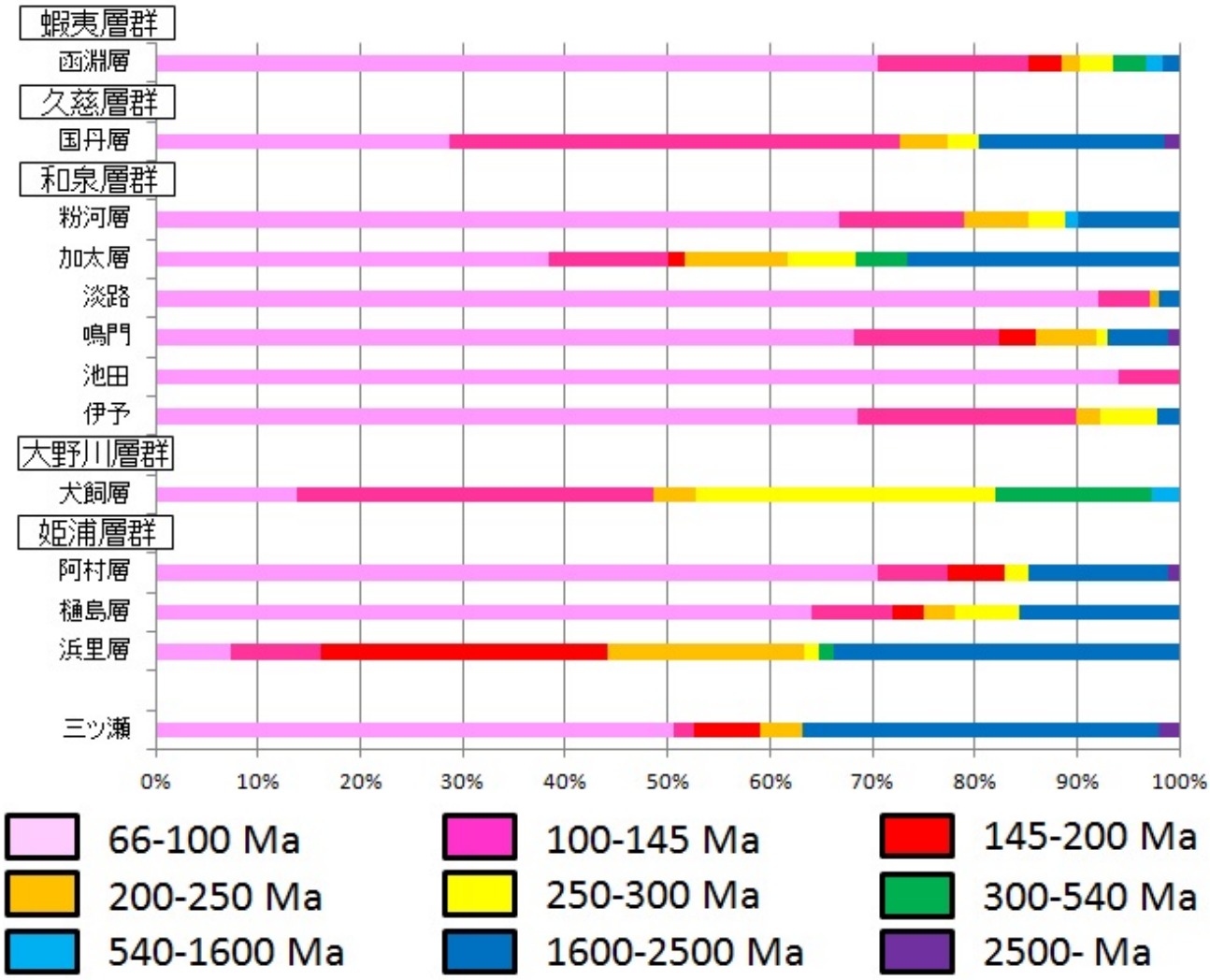
Hamasato Fm: Cretaceous zircons were less than 20%, and both Jurassic and Paleoproterozoic zircons were around 30%.

Mitsuse Fm: Cretaceous zircons (85-75 Ma) were around 50% and Paleoproterozoic zircons were a little less than 40%.

DISCUSSION: The hinterlands of most of the Upper Cretaceous strata of Japan were likely close to the present-day Japan, because many Late Cretaceous (90-66 Ma) igneous rock bodies occur in the southeastern part of the Korean Peninsula (e.g., Sagong et al., 2005) and the Sea-of-Japan side of Japan (e.g., Iida et al., 2015). Moreover, Jurassic and Paleoproterozoic igneous rocks are widely distributed in the Korean Peninsula (e.g., Kim et al., 2014, 2015). The age of Late Cretaceous zircons in the Izumi Gp coinsides with that of the igneous rocks in the IZSWJ (from E Kyushu to the central Kii Peninsula). The detrital zircons in the Onogawa Gp, lacking in Paleoproterozoic ones,

could have been supplied from nearby hinterland where geologic units with few Paleoproterozoic zircons (Suo Metamorphic Rocks, Usukigawa Granodiorite) are distributred The eastward-younging age polarity of the youngest zircons in the Izumi Gp coinsides with the age-polarity clarified by fossils, indicating that the Izumi Gp filled a series of pull-apart basins.

Keywords: Zircon, U-Pb age, Cretaceous, sedimentary rock, metamorphic rock, hinterland



Accretionary age and sandstone provenance of the Hisone unit within the Kurosegawa belt of the Kitagawa area, Tokushima Prefecture, Southwest Japan

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The Kurosegawa belt in the Kitagawa area, located on the eastern side of Shikoku island, consists mainly of Early to Middle Paleozoic granitic rocks and metamorphic rocks, serpentinite, Silurian to Jurassic shallow-marine sediments, and Permian to Early Jurassic accretionary complexes (ACs) (Hara et al., 2013, 2014). The Hisone unit, which is the representative Permian AC in this area, consists of chaotic mélange-type rocks and broken beds of sandstone with shale. We have investigated radiolarian biostratigraphic dating of shale and the petrography, geochemistry, and detrital zircon U-Pb LA-ICPMS dating of sandstone to constrain the accretionary age and provenance.
The mélange-type rocks are well exposed at Nakatani and Higashi-Semidani. A Wuchiapingian radiolarian fauna dominated by *Albaillella protolevis* has been recovered yields from a muddy matrix (black shale) of mélange (Nakamura et al., 2013). We also obtained Capitanian to early Wuchiapingian radiolarians from chert and siliceous mudstone around Nakatani.
We collected 5 sandstone samples from the Hisone unit around Nakatani and Higashi-Semidani. Based on the results of modal analysis, sandstones from Nakatani can be classified as feldspathic arenite. Qm-F-Lt ternary diagram shows that the sandstones from Nakatani plot in the 'basement uplift' and 'dissected arc' fields proposed by Dickinson et al. (1983). Detrital zircon $^{206}Pb/^{238}U$ ages of two sandstones collected from Nakatani and Higashi-Semidani yields age peaks of 261.4 ±3.1 and 247.5 ±2.7 Ma, respectively. The former age corresponds to Capitanian to Wuchiapingian, indicating that the radiolarian age of shale is in good agreement with the U-Pb zircon date of sandstone. The maximum age of sandstone from Higashi-Semidani corresponds to Early to Middle Triassic. This finding indicate that the accretionary age of the Hisone unit ranges from Late Permian to Triassic.

Keywords: accretionary complex, Permian, U-Pb dating, zircon, radiolarians, sandstone

K-Ar dating of a subduction thrust in the Mugi Mélange of the Shimanto accretionary complex, southwest Japan

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Accretionary complexes are major orogenic systems that form at plate subduction zones and are sometimes exposed on land. An improved understanding of the temporal evolution of accretionary complexes is important for geometric studies of their deformation. Then, we used illite K-Ar dating to the Mugi Mélange of the Shimanto accretionary complex, southwest Japan. The Mugi Mélange represents repeated ocean floor stratigraphy and is regarded as an underplated mélange. In this study, a mélange matrix shale and a cataclasite of a subduction thrust were collected for illite K-Ar dating.

Complications arise when dating authigenic clay minerals in sedimentary rocks because of contamination by detrital potassium-bearing minerals. We attempt to evaluate the amount of detrital material in the samples using X-ray diffraction pattern. For this purpose, samples were separated four grain-size fractions of 1.0-2.0 μm, 0.5-1.0 μm, 0.2-0.5 μm, and less than 0.2 μm.

K-Ar dating analyses were conducted at the Okayama University of Science. Ages of the mélange matrix shale decrease with decreasing the detrital mica component. A lower intercept age at 100% authigenic illite of the shale is 32.8 ±1.0 Ma and younger than the zircon U-Pb age of the Mugi Mélange by previous study. The authigenic illite probably formed by diagenetic alternation from smectite. Ages of the cataclasite of the thrust also decrease with decreasing the detrital mica component. A lower intercept age at 100% authigenic illite of the cataclasite is 56.2 ±0.8 Ma and overlapped to the youngest zircon U-Pb age of the Mugi Mélange (57.9 ±2.9 Ma) by a previous study. It shows that the thrust activity has few temporal differences with sedimentation of the Mugi Mélange.

These results are consistent with geological interpretation that the thrust was due to underplating. This thrusting had no complete ^{40}Ar diffusion. And no reactivation was occurred after the underplating. On the other hand, K-Ar ages of a northernmost boundary fault of the mélange shows complete ^{40}Ar resetting between 29 and 23 Ma (Tonai et al., in revision). These different K-Ar ages of faults in the Mugi Mélange may reflect the temporal evolution and variety of fault activities of the mélange.

Keywords: fault, accretionary complex, Shimanto Belt, K-Ar age

Intermittently uplifting of Coulomb wedges by sandbox experiments

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The critical taper model is a basic model to study developing processes of Coulomb wedges. However, the amount of change in natural Coulomb wedges varies intermittently in comparison with the critical taper model. It is important to understand the intermittent changes in order to study Coulomb wedges. We paid attention to uplift processes of Coulomb wedges and had two purposes in this study. The first is to examine spans and rates of the intermittently uplift. The second is to understand the origin of the intermittent uplifts. So, we made Coulomb wedges by scale analog model experiments, observed them, took pictures and videos and did an analysis of PIV (Particle Image Velocity).

The apparatus used in this study was a glass-sided, rectangular acrylic box of which internal dimensions were 69.3 cm x 11.8 cm x 15.4 cm. We laid a cutting seat to the bottom of the box and laid dry sand on the seat. Initial thicknesses of dry sand are between 1.5 cm and 3.0 cm. We made Coulomb wedges by pulling the seat at a constant rate and pressing sands to the rigid backstop. 25 experiments in total show some features as follows. First, the uplifted areas change repeatedly part and whole of the wedge. Second, the uplift rates at several points in Coulomb wedges by experiments change dramatically, which are divided into the rapid uplift period and the slow uplift period, although match roughly the uplift rates calculated by the critical taper model.

Based on the experiments, we point out two findings. Firstly, the feature of uplifting intermittently was revealed more concretely than previous studies. The time spans of the rapid and slow uplift periods correspond to the time of pulling the seat 1–7 cm and 1–6 cm, respectively. The uplift rates are 0.05– 0.13 mm/sec during the rapid uplift period and 0.00–0.05 mm/sec during the slow uplift period. Being converted them to the time scale in nature, two uplift periods change every 8–120 k.y. And the uplift rates were converted to 4–10 mm/yr during the rapid uplift periods and the 0–4 mm/yr during the slow uplift periods. It shows that it is possible to find intermittent uplifts of natural wedges by geological surveys. Secondly, the intermittent uplifts causes of deformation in Coulomb wedges. Especially, the origin of this deformation is to move “back strain zone”, which is one of concentrating strains in wedges, to the rigid backstop. Because of this, timing of changing uplift velocities depends on the distance from a fixed wall to a certain point.

Future prospects show as follows. The first is to research the intermittent uplifts in nature. The second is to study mechanism of “back strain zone” that is the origin of intermittent uplifts in detail. These studies will reveal the intermittent uplift’s processes more detail.

Keywords: Coulomb wedge, accretionary complex, uplift, thrust, analogue model experiments

Post Paleogene brittle deformations along the Median Tectonic Line, Chubu district

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The Median Tectonic Line (MTL) has a history of activity at least 60 million years after the paired metamorphic belts contacted each other by the MTL. The MTL from Chubu to Kanto regions bent as syntax arrangement because of the rotation of Japanese Islands and following collision of Izu-Bonin arc against the Honshu arc from c. 20Ma. Such rotation brought about the change of shear sense along the MTL (ex. Tanaka and Hara, 1990). The MTL in the south of Oshika Village has been identified as an active dextral fault due to topographic features (Sakamoto, 1977). In this study, we investigated brittle structures at the MTL exposures in the Ina and Oshika areas and determined the evidence of the latest activities. The investigated outcrop name from north to south is Hiji, Mizoguchi-kita (north), Mizoguchi in Ina City and Anko in Oshika Village. The weakest part of the MTL gouge shows dextral shear sense in all outcrops. We also found the sinking of terrace gravel into the basement rocks along the weakest MTL gouge in Mizoguchi-kita and Anko outcrops. Furthermore, the MTL fault transects overlying terrace deposit in the Hiji outcrop. Some weakly consolidated gouges in the Hiji and Anko outcrops shows sinistral shear sense. Reverse faults with little gouge materials are well developed in all outcrops, and in the Mizoguchi outcrop, reverse fault was transected by the fault with weak gouge showing dextral sense. Accordingly, the shear sense changes from sinistral to dextral, and reverse fault was developed prior to the dextral movement. We also found the gouge derived from Sanbagawa metamorphic rocks intercalated in the Ryoke granitic rocks in Anko outcrop, and it is considered due to repeated faulting of the MTL as tectonic slices. To identify the depositional age of the terrace deposits transected by the MTL in Hiji outcrop, we have extracted few grains of volcanic glass in the silt layer. We are trying to specify original sources volcano and the age, and hope to present the results in the poster.

Keywords: Median Tectonic Line, Chubu district, fault gouge, Riedel shear, volcanic glass

The structure found in Anamizu formation,formed by the Miocene andesitic volcanism in the west coast of the Noto Peninsula

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Anamizu formation, formed by the Miocene andesitic volcanism, is widely distributed in the west coast of the Noto Peninsula. We found a lot of rock structures like dike with NNE-SSW and NW-SE trending linear shape and high dip angle in the Anamizu formation. It consists of a few parallel rock facieses similar to pyroclastic rocks for example tuff breccia, lapilli tuff, and fine grain tuff. From its distribution form, we temporarily name it pyroclastic dike.
The pyroclastic dike has irregular shape and transitional boundary with the rocks of surrounding Anamizu formation. No brittle fracturing could be found, but plastic flow structure sometimes well develops especially in the fine grain tuff facies or fine matrix. It is hard as much as surrounding rocks.
Thin clay layer or crack develops along the fine grain tuff facieses. Based on X-ray diffraction analysis, this thin clay layer is mainly composed of smectite formed by the hydrothermal alteration or weathering. According to the observation of this thin clay layer by microscope, original structure of the rock and smectite(including iron saponite) is not broken.
In this paper, we report occurrences and properties of the pyroclastic dike.

Keywords: andesite, pyroclastic rock, Noto Peninsula

Identification of active fault outcrops of the Saigatao tectonic line in central-southern part of Yamaguchi Prefecture, Southwest Japan

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The Saigatao tectonic line in central-southern to-northern part of Yamaguchi Prefecture, Southwest Japan, has been known as a geological boundary fault, being approximately 40km in length. Characteristics and activity of the tectonic line have not yet been clarified. Its left-lateral offset of a few hundred meters is confirmed on the geological map (Nishimura et al., 2012). In this study, the characteristics and the activity of the southwestern part of the tectonic line are investigated by geological and topographical investigations to clarify the characteristics and activity of the tectonic line.
Tectonic reliefs can be interpreted with a topographic map, red relief image map and aerial photograph. NE-SW-trending lineaments are found on and around the tectonic line. The lineaments can be classified into Ranks C and D. Rank C lineament has a good continuity. On the other hand, Rank D lineament is not so good. These lineaments are characterized by right-lateral displacement of ridges. Total length of the lineament is 40 km.
Fault outcrops showing movement ages of the Saigatao tectonic line are found at two localities 1 and 2.
Loc. 1 (Nagaono outcrop): The boundary fault occurs between mudstone of the Ota formation and pelitic schist of the Suo metamorphic rock. No displacement is recognized in Lower river terrace deposits overlaying the fault.
Loc. 2 (Mana outcrop): A fault displaces Middle river terrace deposits. It is thought that the formational age of the terrace deposits is 70,000-130,000 y.BP.
The western Chugoku District suffered to the N-S compression since the Cretaceous, whereas the stress field switched into the E-W compression in the late Pliocene. The tectonic inversion caused the movement sense of the Saigatao tectonic line to change from left-lateral to right-lateral sense. Characteristics of the Nagaono and Mana outcrops indicates that the Saigatao tectonic line might move from 70,000-130,000 y.B.P. to the formational age of the Lower terrace deposit. If the E-W compression continues, the Saigatao tectonic line may move with the right-lateral sense.

Keywords: active fault, characteristics, activity, outcrop

Geological characterization of reactivated NE-SW trending basement faults in the northwestern Hiroshima City

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Many left-lateral faults along NE-SW trending lineaments that are clearly recognizable on the topographic map or satellite image are well known in the western Hiroshima Prefecture. Some of them are reactivated as right-lateral active fault in the northwestern Hiroshima City. The aim of this study is geological characterization of reactivated faults, i.e. how different they are from other faults. K-Ar ages of clay veinlet injected into fault gauges show that those faults were formed at least in the end of Cretaceous (Kitagawa et al., 1996). As the displacement of pre-Cretaceous accretionary complex along these faults is larger than that of late Cretaceous granitic rocks, the fault movement might have been initiated from as far back as early Cretaceous. Nureki (1969) stated that some of these faults experienced 20-60 km left-lateral displacement by the reconstruction of E-W trending zonation of pre-Cretaceous terranes. However, there are some obvious mistake in his terrane classification (Hayasaka, 1987). As any microfossils have not been described from the pre-Cretaceous formations in this area due to strong contact metamorphism by the Cretaceous granites, detailed re-examination has not been made until now. In order to approach this problem, we conducted the detrital zircon U-Pb chronology and geochemical characterization of greenstone. The results are as follows.

Many lenses of greenstone with amphibolite are cropped out on the Ota-River basin at the southeast of Imuro. Their whole rock chemistry is similar to High-μ type basalt in the Tamba Terrane.

All samples collected from Ota-River basin can be correlated with Tamba Terrane by their detrital zircon ages. Further, the basement complex distributed between Kabe and Imuro can be correlated to the Type Ⅱ Unit of Tamba Terrane, while that of the Fukawa area on the east of Kabe and Kuchi area on the west of Imuro to the Type I Unit.

The age population of detrital zircon from roof pendant distributed at Mt. Bizenbou in the north of Kabe shows its belonging to the Maizuru Terrane, though it had been thought to belong to the Tamba Terrane until now.

Recently, Saito et al. (2015) reported that crystalline schist origin hornfels derived from Suo Terrane is distributed in the Mt. Abu area to the south of Kabe. But the most of the rocks are moderately deformed pebbly mudstone and its detrital zircon shows the age population identical to that of Tamba Terrane.

Conclusion

Northeastern extensions of all three active faults in this area; Itsukaichi fault, Koi fault and Hiroshima western margin fault coincide with the basement faults as the high-angle terrane boundary or unit boundary of pre-Cretaceous basement complex. Thus, we conclude that, among so many NE-SW trending basement faults, only those having relatively larger amount of displacement were reactivated as active faults.

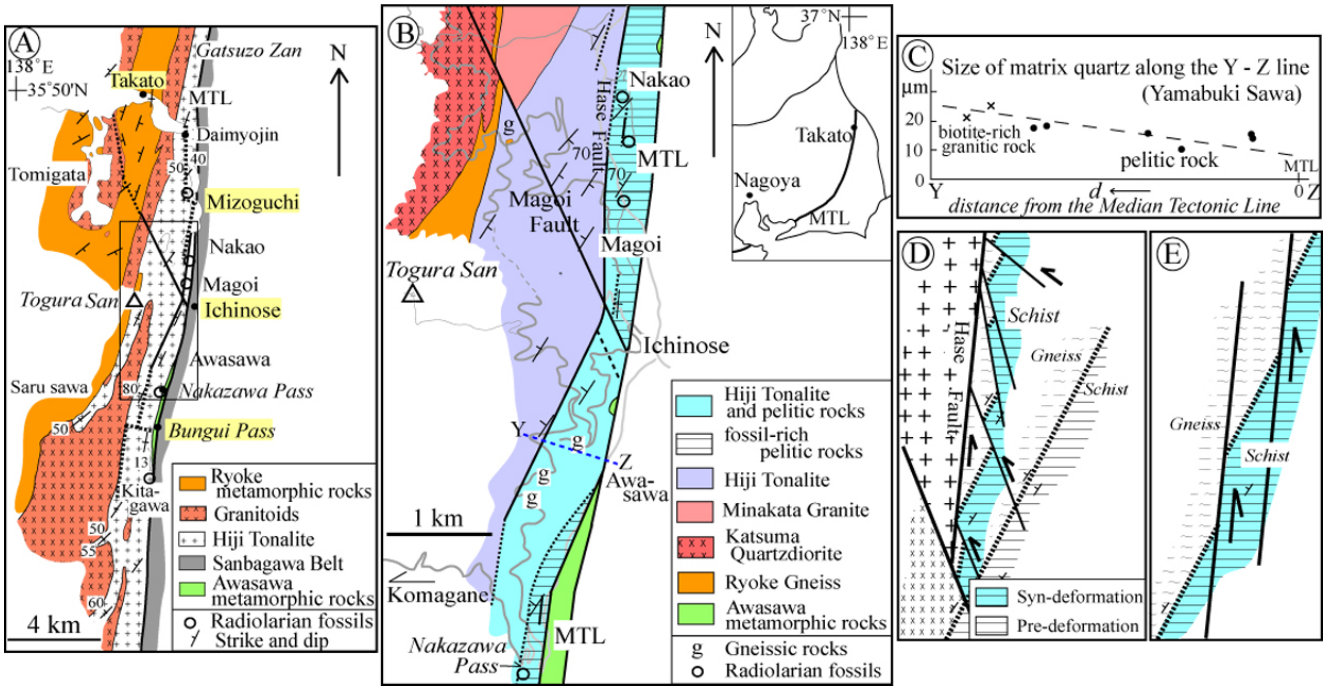
Keywords: active fault, western Hiroshima Prefecture, seismic basement, detrital zircon, U-Pb dating, Tamba Terrane

Miocene tectonics of the Ryoke belt near the Median Tectonic Line of the Hase area, Ina city, central Japan

*Akira Ono

The Hiji tonalities are gneissose and banding granitoids with various rock textures which are exposed near the Median Tectonic Line (MTL) of the Hase district (Figures A and B). The Hiji tonalities suffered deformation and recrystallization during the cooling periods of the solidified magmas. Meta-granitoids were formed at high temperatures and mylonites were formed at about 420°C. The strikes of the planar structures are N10-30°E in the area to the south of the Bungui Pass. They are N30-50°E to the north of the Bungui Pass. The mylonites are distributed along the MTL. The sizes of groundmass minerals of the mylonites were measured along the Y-Z line (Figure B). They decrease toward the MTL (Figure C). However, they are nearly constant along the strikes of the planar structures [1]. The relationship between the sizes of recrystallized minerals and strikes of foliations is unclear in the Magoi-Nakao area because of the existences of the N-S trending Hase fault and the absence of outcrops due to the Mibu River.
Pelitic, psammitic and siliceous metamorphic rocks are often exposed in the surveyed area. Radiolarian fossils are found in many fine-grained mylonites which are distributed along the MTL (Figure A). This fact suggests that low- or medium-grade schistose meta-sediments were metamorphosed to fine-grained mylonites. On the other hand pelitic gneisses and coarse-grained pelitic mylonites are distributed in the western parts of the surveyed area. Small amounts of partially dissolved garnet crystals are found in the coarse-grained pelitic mylonites. They are relict garnets of gneissic rocks. A fault is supposed between the gneissic rocks and schistose rocks. The fault was formed before the late Cretaceous intrusions of the Hiji tonalites.
The supposed fault was deformed during the formation of the Miocene MTL. The Hase fault (Figure B) is important to reveal the Miocene tectonics. In the Magoi area, pelitic and siliceous very fine mylonitic rocks are widely distributed to the east of the Hase fault, while granitic rocks are exposed to the west of the Hase fault. Granitic rocks were highly altered near the Hase fault. In the Nakao region, the Hase fault is supposed near the Mibu River. Many N-S trending faults are observed near the supposed Hase fault. The extension of the Hase fault actually exists to the north of the village Nakao [1]. The strikes of planar structures in the Magoi-Nakao area are approximately N40±10°E regardless of the existence of the Hase fault (Figure B).
Based on the above-mentioned geology the tectonic history of the surveyed area may be described as follows. Gneissic rocks and schistose rocks were in contact with a fault. The strike of the fault plane was about N45°E. The Hiji tonalities were intruded into the metamorphic rocks in the late Cretaceous time. Gneissose granites, meta-granitoids and mylonites were formed during the cooling stages of the Hiji tonalities. Strikes of the planar structures of the granitic and metamorphic rocks were about N45°E. The geological structure suffered intense deformations during the formation of the Miocene MTL. Anti-clockwise rotation of the planar structures took place in some areas. In other areas many faults trending N-S or NW-SE were formed. These faults were characterized by systematic left-lateral displacements as shown in Figures D and E. The distribution of the fine-grained mylonites was changed from the NE-SW trend to the N-S one after the fault movements. Thus the late Cretaceous geological structure of the surveyed area was largely changed during the Miocene opening of the Japan Sea.
[1] A. Ono, 2012, Japan Geoscience Union Meeting 2012, SGL44-P04.

Keywords: Kashio mylonite, Miocene tectonics, Hase fault



Basin architecture of the lower Pleistocene Handa Formation of the Sekinan Group in the south of Beppu Bay, southwest Japan

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Median Tectonic Line (MTL) has large influence on the deformation of the crust of southwest Japan in Quaternary. Itoh et al. (1998) argued that the active trace of MTL in early Pleistocene around Beppu Bay was located in the south of the modern one, and a dextral slip occured along it. Their argument is based on the observation by Yoshioka (1992) on the lower Pleistocene Handa Formation and Notsuharu Formation of the Sekinan Group, which are located near the old trace of MTL. Yoshioka (1992) inferred that the formations filled pull-apart basins formed by dextral slip of south boundary faults between the formations and basement rocks.
However, the dextral slip of the boundary faults are still uncertain in the following points.
1) The striations of the boundary faults, which indicate the slip directions of the faults, have not been observed
2) As the result of fault-slip analysis in the Handa Formation, strike-slip faulting stress regime was not detected
This study aims to reveal the basin architecture of the Handa Formation by measuring the directions of the striations of the boundary faults and by analyzing fault-slip data to obtain stress condition. As a result, dip-slip striations predominated on the boundary faults, and only normal faulting stress regime was detected. Thus, the basin of the Handa Formation seems to have been formed as a half graben along the boundary normal fault. We should note that the strike of the boundary fault of the Handa Formation is oblique to the strike of the old trace of MTL. So there still remains the possibility that the motion of MTL was dextral slip in Early Pleistocene and the half graben of the Handa Formation was formed at a releasing bend of MTL.

References

Itoh, Y., Takemura, K., Kamata, H., 1998. Tectonophys., 284, 135-150.
Yoshioka, T., 1992. J. Geol. Soc. Jpn. 98, 53-55, in Japanese.

Keywords: Beppu Bay, the lower Pleistocene Sekinan Group, fault-slip analysis, boundary fault, Median Tectonic Line

The lithostratigraphy and geological structure of The Himenoura Group in Makishima and Yokourashima Islands of Amakusa area

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Himenoura Group, exposed in Makishima and Yokourashima Islands of Amakusa area,Kumamoto Prefecture, is assigned to Santonian to Campanian in age according to previous biochronological studies. It is underlain nonconformably by granitic and metamorphic rocks of the Higo Belt and unconformably by the Lower Cretaceous Gosyoura Group, and is overlain unconformably by the Paleogene Miroku Group on the west. The Group in this area strikes NE and dips 30-80°NW with some local undulations of the trend in the northern part of Makishsima and Yokourashima Islands. An anticline could be inferred in the central part of Yokourashima Island.
Lithostratigraphy and geologic structure of the Himenoura Group in Makishima and Yokourashima Islands were described through precise mapping and logging of facies succession along the coasts. In Makishima Island, the Group consists of a variety of coarse- to fine-grained sandstones interbedded with mudstones, and subordinate of small amount of pebbly mudstone, slump deposits and tuffaceous beds. This study reveals that the Himenoura Group of Makishima Island is divided lithostratigraphically into 5 units in ascending order, as follows: The first unit (200m+ in thickness) is characterized by thin-bedded fine-grained sandstone and mudstone. The second unit (about 180m in thickness) is composed of sandstone-dominant alternating beds of sandstone and mudstone in the lower and upper parts and of thin- bedded sandstone and mudstone couplets in the middle part. The third unit (about 170m in thickness) consists of thin-bedded fine-grained sandstone and mudstone in the lower and sandstone-dominant alternating beds of sandstone and mudstone in the upper. The fourth unit (about 170m in thickness) is made up of thin-bedded fine-sandstone and mudstone in the lower and sandstone-dominant alternating beds in the upper. The fifth unit (80m+ in thickness) is exposed as thin-bedded fine-sandstone and mudstone in the lower and sandstone-dominant alternating beds of sandstone and mudstone in the upper part. Each of the third, fourth and fifth units shows a similar facies succession that begins with mudstone-dominant interbeds of thin-bedded sandstone and mudstone in their lower parts and passes to thick- and intermediate sandstones with mudstone beds in their upper parts.
Intermediate- to thin-bedded sandstone beds show largely grading so that they are comparable to turbidites. Some thick to intermediate sandstones exhibit internally a structure-less or dish and convolute structures diagnostic features of fluidized flow or grain-flow deposits, and show an amalgamation with mud clasts due to hydraulic fractuation frequently. This study recognized a similar cyclic sedimentation at interval of 100 to 180meters for the upper half of the second unit and the third, fourth and fifth units in which a coarsening- and thickening-upward cycle was formed commonly as facies succession. Each cycle boundary is represented by a remarkable facies change from thick-bedded, medium- to coarse-grained sandstone to mudstone.
The lithofacies of the Himenoura Group in the Yokourashima Island located on the southwest of Makishima Island is similar to that of the Makishima Island. However, the lithostratigraphic correlation between both islands has not been made clear because of regional facies change, lacking of marker beds and fold structure in Yokourashima Island.
Although the channel facies was not confirmed in this study, the depositional environment of the Himenoura Group is comparable to the lobe and lobe fringe of deep-sea fan system doubtlessly. Further research on paleocurrents should be necessary to clarify the relation between the cyclic sedimentation and basin evolution.

Depositional environment of mudstones interlayered with the Cretaceous volcaniclastic rocks in the Yanahara district, Okayama Prefecture, SW Japan

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Cretaceous volcaniclastic rocks and related intrusive rocks in this district feature a cauldron, measuring 20x7km^2 in size. The volcaniclastic rocks consist mainly of welded to non-welded rhyolitic pyroclastic rocks 1700m+ thick, containing intercalated mudstone beds (100m thick) at the lower part. This mudstone is lacustrine sediment characterized by continuous parallel laminations several milimeters thick and normal grading. It suggests a temporal caldera lake during the intra-caldera ignimbrite accumulation.

CHNS analyses for this mudstone reveal the following results: Total nitrogen content is less than 0.1% (0.087 -0.089%); Total organic carbon content is less than 1.0% (0.33 -0.38%); C/N ratio is small (3.8 -4.3); No sulfur content is detected in. These results suggests that organic matter contents of this mudstone were derived not from forests surrounding the caldera lake but from planktonic origin in the lake water, though minor nutrient salts were probably fed.

The mudstone is the caldera infill, but nevertheless includes no sulfur content derived mainly from volcanic activity. This suggests the hiatus of the volcanic activity during the deposition of the mudstone. The environment of the caldera lake is characterized by no eruption and lesser planktonic inhabitant in the poor nutrient salts water. The total thickness of mudstone devided by each lamina thickness gives an estimate of several tens of thousand years for the depositional period. A drainage area of this caldera was not so large, but rather the narrow zone restricted just inside of the caldera rim.

Keywords: mudstone, CHNS analyses, caldera lake deposits

An integrated chronostratigraphy of Pliocene the Anno Formation, the Awa group, central Boso Peninsula, central Japan.

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Since the Awa Group, distributed in the central Boso Peninsula, has a good continuous exposure, abundant microfossils and many intercalated traceable tephra beds, a lot of stratigraphic studies have been conducted so far. Therefore the Awa Group is recognized as a stratotype of a period between mid-Miocene and Pliocene, which can reveal paleoceanographic conditions at the Kuroshio-Oyashio mixing area during that period, in Japan. Because most of these studies, however, published before key tephra beds were coordinated, strata at which data were obtained are hard to identify. Thus, we propose a refined chronostratigraphy based on magnetostratigraphy and oxygen isotopic stratigraphy with defining correspondence relation of horizon of key tuff beds and strata at which data are obtained, and show new data continuously from last year.
For paleomagnetic, rockmagnetic and oxygen isotopic measurements, we newly sampled 1-4 mini-cores at 86 sites and sedimentary rocks with about 300g by dry-weight at 83 sites, respectively. The samples were taken downward between key tuff An123 to base of the Anno Formation along the Shikoma River route.
We performed progressive alternating-field demagnetization (pAFD), progressive thermal demagnetization (pThD) and various rockmagnetic analysis in order to extract primary components from the specimens and verify them stability. The results exhibit that most specimens consist pseudo-single domain magnetites as the magnetic carrier of natural remanent magnetizations.
We confirmed polarity boundaries at thicknesses, base of the Anno Formation is 0 m, of 9.1-10.9 m (nearly a key tuff bed An4), 52.5-55.3 m (between key tuff beds An22 and An30) and 64.15-70.05 m (below 2 m from a key tuff bed An51 correlated with the Trb-Ya4 tephra). They are corresponded to the upper boundary of the Nunivak normal subchronozone, the lower and the upper boundaries of the Cochiti normal subchronozone, respectively.
At the uppermost section of the Anno Formation, between the Kurotaki Unconformity and a key tuff bed An127 (thicknesses between 213.1 m and 315.4 m), we carried out benthic foraminifers oxygen isotopic analysis. Accordingly, we obtained an oxygen isotopic curve from the results of analysis, corresponding to a period between MIS KM5 and MG12 based on correlation with the LR04 stack curve. Our of age model oxygen isotopic stratigraphy constrain key tuff beds An129 and An130 (corresponded wide-spread tephra the Hgs-An129 and the Sr-Ity, respectively), these age are 3.598±0.0006 Ma and 3.586±0.0023 Ma, respectively. These tephra, interleaving the Gilbert-Gauss polarity boundary, are possible to be very usable markers at other area.

Keywords: the Anno Formation, Pliocene, chronostratigraphy

Paleostress analysis in the most southern part of the Boso Peninsula, central Japan.

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The most southern part of the Boso Peninsula has been situated under the special geologic setting that is a forearc basin fill close to the only T-T-T type triple junction assosicated with the collision zone between the Izu-Bonin arc and the Japanese island arc. Therefore, to reconstruct a paleostress history in this area has a key to understand a kinematic history of Philippine Sea plate which is thought to have controlled the tectonic development in this area. However, because of complex geologic structures in this area, quite a few studies have been done to reconstruct histories for paleostress and forming of geologic structure in this area. In this study, the authors applied the multiple inversion method (Yamaji, 2000; Otsubo and Yamaji, 2006) for fault-slip data to meso-scale faults observed in the southern most part of the Boso Peninsula to reconstruct a paleostress history developed in this area.
The authors collected fault slip data from the Nishizaki, Shiramazu, Mera and Hata Formations to use for the multiple inversion method. As the results, reverse faulting regimes with a NE-SE trending σ1-axis are obtained from the Nisizaki Formation, strike-slip faulting regimes with a NE-SW trending σ1-axis and reverse faulting regimes with a NW-SE trending σ1-axis are from the Shiramazu Formation. On the other hand, strike-slip faulting regimes with a NNW-SSE trending σ 1-axis and with the N-S trending σ1-axis are obtained from the Mera Formation, normal faulting regimes with a SW trending σ3-axis are from the Hata Formation. The authors observed that reverse faults strike-slip cut faults in the coast outcrops of the Shiramazu Formation.
Observations mentioned above suggest that the paleostress has developed through the time in this area as follows; a NE-SW horizontal compression as the first stage, a NNW-SSE horizontal compression as the second stage, then a NE-SW horizontal extension as the last stage. The authors suppose that the transition of paleostress observed between the first and the second stages probably be related to the directional change of the Philippine Sea plate motion.

Keywords: minor fault analysis, paleostress history

Japanese islands of extraterrestrial elements by ocean deposits : Aliyoshi case

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1. Characteristics and purpose of dynamic resources formed at the Japanese Islands: The formation of the Japanese Islands has been explained from local sedimentation to dynamic place movement theory. This is why proposed subduction zones to explain various quake centers have been discovered at ocean and island-continental borders by marine-plate movement with the continental drift to resolve various rocks with different time and location. However, different research fields make different thoughts to change individual formation model (except data). In this sense, it should be explained new scope of mineral materials for previous geological sciences for dynamic formation process. In this paper, the Akiyoshi limestone blocks of main old Japanese Islands-basement might be explained by they are old marine-sediments originally supplied from extraterrestrial elements [1-2].
2. Characteristic of various rocks-minerals and geologies of the Japanese Islands: The Japanese Islands of the Asian side of the Pacific, show not only simple same changes of young volcanoes, but also various mineral deposits and wide geological features. This suggests that various sea-bottom sediment has been formed before quick landing-lift, which is considered to be material evidences for present dynamic plate growing-up (plate-tectonic) process globally. As a result, the Japanese Islands are "mixed-like chain of islands rocks beyond the time-space" , which include local-mixtures globally [2].
3. A characteristic of various sea-bottom rocks and environments of Japanese Islands: Japanese Islands show different environments from the Paleozoic to Cenozoic rock-minerals widely. In fact, the Paleozoic rocks (Akiyoshi-limestone) show only wide ocean floor. The Mesozoic rocks main igneous origins of four type-rocks show both floor and mixed continental border of igneous activity. The Cenozoic rocks show main sediments near at present continental activity (including the Sea of Japan). The iron-bearing spherules reveal also extraterrestrial compositions fallen to sea sediments. Therefore, materials of the Japanese Islands show changes of environments from the sea, igneous sea-floors to present continental border [1-2].
4. Characteristics of mineral resources and environment of the Japanese islands: It is about more than 10% only to be concentrated mineral resources of all natural elements, and approximately 30% elements of extraterrestrial sources from them. In fact, natural mine resources shows ca. 40% of extraterrestrial origin (from meteorites) and others for minor contents widely throughout all Japanese separated prefectural sites. This shows that the environments of the Japanese Islands-basements are changed from marine to igneous activity near at islands-continent environment finally [2].
5. Characteristic of the Paleozoic Akiyoshi-dai limestone blocks: The large Akiyoshi-dai limestone mixed blocks of the Paleozoic Japanese Islands-basements are limestone resources concentrated by extraterrestrial element carbon under ocean water. The metallic elements (Co, Cu, and Mn etc.) near at the Akiyoshi limestone blocks are also co-existed with the ocean-blocks. This shows that old Akiyoshi rocks are remained from separated ocean-bottom formation [2]
6. A summary: The formation of the Japanese Islands can be confirmed from the included mineral-rock resources. The Japanese Islands include different mineral-rocks beyond the time-space, and extraterrestrial elements-included mine-deposits formed at ocean bottom from fallen meteorites widely. Old Akiyoshi limestone blocks are newly confirmed from the natural mineral resources to be formed from ocean bottom of the sea, and ocean-floor movements, to be lifted up near continental

margin to form the present Japanese Islands finally.
References : [1] Yasunori Miura (1996): Shock wave handbook (SV Tokyo), p.1073-1209. [2] Yasunori Miura (2006-2015): Geol.Soc. Japan, and Japan Geophysics Union.

Keywords: Akiyoshi Japan, extraterrestrial elements , ocean deposits

RIFT SEQUENCE STRATIGRAPHY OF TALANG AKAR FORMATION, SOUTH SUMATERA BASIN, INDONESIA: BASED ON WIRELINE LOG, PALEONTOLOGY, AND CORE DATA

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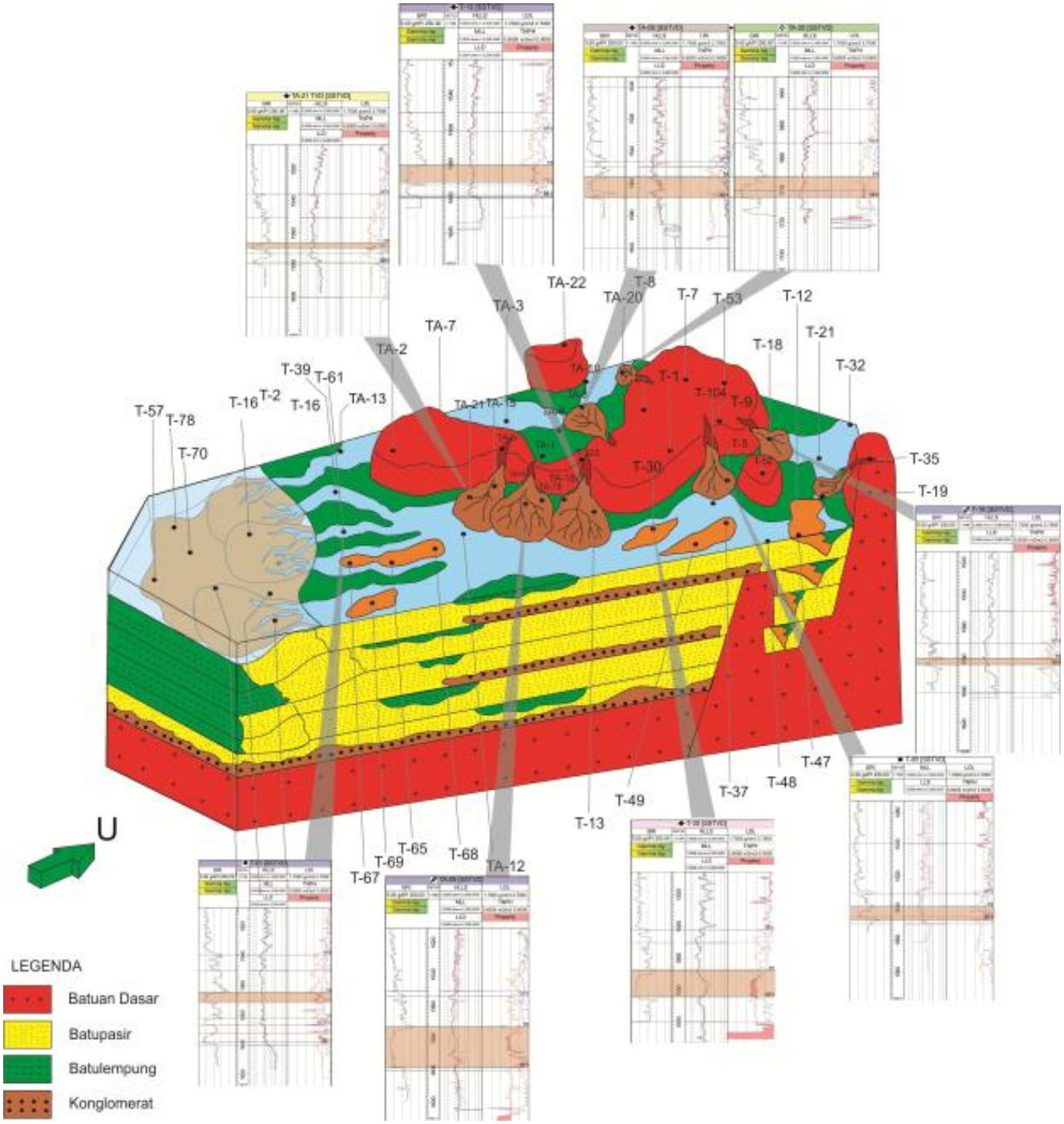
Field “X”, Talang Akar Formation is one of hydrocarbon producing field located in South Sumatera Basin, Indonesia. Based on well log, paleontology, and core interpretation it is predicted that there are syn-rift deposit which support tectonic as a major factor of accommodation space controlling. In this area, a sequence stratigraphy research was conducted to define the architecture of syn-rift sediment, deposition systems, and the history of basin. The analysis consists of paleontology, lithofacies, facies association, depositional environment, electrofacies, sequence stratigraphy correlation, isopach map, and paleogeography model each sequence.
The facies association are Alluvial Fan, Fluvial Channel (Braided Channel and Meandering Channel), Floodplain, Distributary Channel, Mouth Bar Delta, and Prodelta. There are three sequences bounded by sequence boundary and six parasequences bounded by flooding surface and maximum flooding surface. The sequence stratigraphy marker consist of 3 SB, 1 TS, 2 FS, and 1 MFS. This area were established by LST 1, TST –HST, LST 2, HST, and TST. The result are six models of isopach map and paleogeographic block diagram, showing the overall coarsening upward stacking pattern through the progradation of fluvial facies over deltaic facies.

Keywords: Sequence Stratigraphy, Sequence Model, Rift Basins, Talang Akar Formation, South Sumatera Basin



Origin of the Greenstone Blocks of the Northern Chichibu Belt in the Kanto Mountains

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The study of the Jurassic accretionary complexes has become an important subject in terms of tectonic subdivision of the Japanese Islands. In particular, relationships among the Northern Chichibu Belt and the Southern Chichibu, Kurosegawa, and Mino-Tamba belts are one of the main subjects of the discussion on the Jurassic accretionary complexes. Greenstone blocks in the accretionary complexes provide key information of oceanic plate materials before the accretion. The stratigraphy of the Northern Chichibu Belt are, however, based mainly on oceanic plate stratigraphy, while there are few works focusing on the origin of greenstone blocks. In this study, we present the results of field investigation and geochemical analysis for greenstone in the southernmost part of the Northern Chichibu belt.
In the study area, the Northern Chichibu Belt is divided into the Hebiki (Yusugawa), Sumaizuku, and Kamiyoshida units from south to north. The Hebiki Unit consists of strongly sheared shale matrix with sandstone block. The contact between the Hebiki and the Sumaizuku units dips steeply to the north. Gigantic limestone blocks called Kano-yama and Futago-yama limestones crop out along the boundary in the Sumaizuku Unit. The shale matrix of the Sumaizuku Unit is strongly sheared, and contains chert and greenstone blocks. The Sumaizuku Unit is overlain by coherent layers composed of chert, shale, and alternation of sandstone and shale. Main component of the sandstone in the coherent layer is chert fragments, which is a characteristic of the Kamiyoshida Unit. However, we need further investigation to reveal the nature of this layer. The Kamiyoshida Unit is dominated by greenstone blocks, in the study area. Accretion age of the Hebiki Unit was estimated to Early Jurassic, while the Sumaizuku and Kamiyoshida units are considered Middle Jurassic (Matsuoka et al., 1998).
Greenstone blocks in the Sumaizuku Unit occur as green or reddish brown colored, lenticular shaped, tens of meters to a few hundred meters blocks. They are highly deformed near the marginal part of lenticular blocks, but *in situ* structure is preserved in the central part. Pillow like structures are rarely recognized. Some greenstone blocks are associated with limestone. One sample contains crinoid fossil fragments. Greenstones in the Kamiyoshida Unit are pale green or purple, foliated greenstones laterally extend a few hundred meters. Foliations in the greenstones are parallel to those of surrounding shale matrix, dipping 30 - 40° to the south.
We determined bulk-rock chemical composition of greenstones in the Sumaizuku (11 samples) and Kamiyoshida (6 samples) units. They are divided ocean island basalt (OIB) and mid ocean ridge basalt (MORB) types depending on enrichment of light rare earth element (LREE). The Sumaizuku Unit contains both high-LREE OIB and low-LREE MORB types. MORB type greenstones are associated with the Kano-yama and Futago-yama limestones, while OIB crops out in the northern part of the Sumaizuku Unit. In contrast, composition of all greenstones in the Kamiyoshida Unit shows they are OIB type. These lines of evidences suggest that the Sumaizuku and Kamiyoshida units were taking different

positions in the accretionary complex. In the Sumaizuku Unit, accretion of both OIB (i.e. seamount) and MORB (i.e. ocean floor) occurred in the Jurassic time, while only OIB was accreted in the Kamiyoshida Unit. Based on field mapping, the Sumaizuku Unit is overlain by the Kamiyoshida Unit, which may indicate that the Sumaizuku Unit was located in the deeper part of the accretionary complex during the Jurassic. By comparing this result with studies in other areas of Jurassic accretionary complexes, we will discuss tectonic subdivision of Jurassic accretionary complexes. Furthermore, our new data may contribute to reconstructing volcanic history in the late Paleozoic Panthalassan Ocean.

Keywords: Jurassic accretionary complex, greenstone, Kanto Mountains, Chichibu Belt

Petrography and correlation of schistose clasts from the Aso-4 pyroclastic flow deposit

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The pre-Neogene basement rocks are widely covered by Quaternary volcanic deposits in middle Kyushu, therefore it is difficult to detect geotectonic zoning there. In this study, we have found a clue to detected subsurface geology by using accidental clasts included in the Aso-4 pyroclastic deposits on the east of the Aso caldera.
62 clasts isolated from the exposures of the Aso-4 pyroclastic flow deposit are collected along the upper stream of the Onigajo River in the Namino Plateau. The collected clasts are dominantly composed of actinolite rock (50), and subsidiary of actinolite-talc schist, talc schist, websterite, biotite hornfels, cpx-plagioclase rock, opx-quartz schist, quartz-cpx schist, and quartzose rock.
These clasts can be divided lithologically into three groups: (1) metasomatic rocks; actinolite rock, actinolite-talc schist, talc schist. (2) ultramafic and mafic rocks; websterite, cpx-plagioclase rock, opx-quartz schist, quartz-cpx schist, and (3) silicicrocks; biotite hornfels, quartzose rock.
The actinolite rocks consist of oriented fine-grained aggregate of actinolite commonly forming schistosity. Some of them are nephrite appearance. The actinolite rocks are highly possibly formed by metasomatic interaction between serpentinite or serpentinized peridotite and silicic rocks (Harlow and Sorencen, 2005). The metasomatism needs fluid transport along the contact between serpentinite and silicic rocks. Schistose structure can be made by this fluid flow and such metasomatic reaction (Harlow and Sorencen, 2005, Nishiyama, 1989). The ultramafic clasts also have foliation and lineation such as oriented chlorite corona around chromian spinel and oriented diopside. The biotite hornfels clasts are composed of fine-grained biotite, quartz, plagioclase, chlorite and K-feldspar and banded structure derived from protolith sediments exists.
For the petrography of the clasts described above, and the existence of the mylonitic granite clasts, which correlative with the Nioki granite in Asaji metamorphic terrane, from the Aso-4 pyroclastic flow deposit on the north of Aso caldera (Takagi et al., 2007), the actinolitic rocks with hornfels clasts are correlative with the metasomatic rocks in the Asaji metamorphic terrane where large serpentinite body exposed with low P/T metamorphics.

Keywords: Aso-4 pyroclastic flow deposit, actinolite rock, metasomatism, ultramafic rock, Asaji metamorphic terrane

