The developmental process of the Kazusa basin inferred by high-resolutional seismic reflection data

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The Kazuya Group distributed in the middle part of Boso peninsula includes strata deposited from basin to coastal area and the thickness of this group is over 3000 meters (Ito and Katsura, 1992). The forearc basin depositing the Kazusa Group is called the Kazusa basin (Watanabe et al., 1987) and this basin migrated toward northwest (Mitsunashi, 1990). However the cause of this migration is not understood sufficiently. This study provides a high-resolutional data from the costal area in the eastern part of Boso peninsula and discusses a tectonic background of the migration.
The survey area is 35°10′N~35°50′N and 140°20′E~141°10′E (the Kujukuri-oki are). We obtained seismic data of ca. 1100 km in total length with a boomer and multi-channel streamer (24 channel with 3.125 m spacing). Seismic data are processed by SPW (Parallel Geoscience Corporation) and provide seismic reflections at 100 m below seafloor.
In the Kujukuri-oki area, we recognize three strata bounded by distinct unconformity and define them as the Kujukuri-oki C Formation, the Kujukuri-oki B Formation and the Kujukuri-oki A Formation in ascending order. Calcareous nannofossils (Nishida et al., 2016) from the Kujukuri-oki B Formation show that this formation correlates to the Kazusa Group. In the Kujukuri-oki B Formation, some anticlines at shelf edge and normal faults dipping eastward off Taitouzaki extend from north to south. Seismic facies of the Kujukuri-oki B Formation is distinct stratification deformed by these anticlines and faults. In addition, the characteristics of normal faults in Kujukuri-oki area are consistent with those of normal faults recognized in the Kazusa Group. Some faults in sea area dip westward and then they compose a graben with normal faults dipping eastward off Kujukuri town.
Our high-resolutional seismic data show that anticlines formed in compressive stress field and normal faults formed in tensile stress field exist closely in the Kujukuri-oki area. The anticlines at shelf edge would work outer ridge and migrate the Kazusa basin toward northwest.

Keywords: Seismic reflections, the Kazusa Group, tectonics

Paleomagnetism and Neogene tectonic rotation of the upper Amatsu Formation, the Awa Group, distributed in the Boso Peninsula, central Japan

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The Awa group, consisting of a Neogene marine sedimentary sequence, is distributed in the Boso Peninsula, central Japan. The Awa Group is divided into four units: the Anno, Kiyosumi, Amatsu, and Kinone formations (in ascending order). Since the upper Awa Group is exposed very well in the middle part of the peninsula, many stratigraphic studies have been conducted in this region (e.g., Niitsuma, 1976; Kameo et al, 2002; Nakajima and Watanabe, 2005). Okada and Okamura (2005) constructed a paleomagnetic study for the group in the north from the Mineoka Mountain, reported that the average paleomagnetic declination from the upper Amatsu Formation is approximately 50°. The data showed that a clockwise rotation occurred at around 5 Ma in the Boso peninsula which was supposed to be due to the collision of the Tanzawa Massif to the Honshu Island. But there was a possibility that secondary components remained on those data. Therefore, it is necessary to re-examine paleomagentic data from this area to extract primary components by means of refined demagnetization and measurement methods. Here, we report a reliable magnetostratigraphy and try to discuss about the tectonic rotation suggested by Okada and Okamura (2005).
Shimota et al. (2016) obtained paleomagnetic data from the entire Amatsu Formation exposed along the Shikoma River, which shows more tuffaceous lilthofacies rather than other region, which might have stable magnetic signals. Demagnetization results were displayed on both of the Zijderveld and equal area projection diagrams. Characteristic remanent magnetization (ChRM) was determined by fitting the least squares line to the linear vector endpoint trajectory (Kirschvink 1980). For each site, a site-mean direction was calculated from the ChRM directions. The reversal test (McFadden and McElhinny., 1990) on those results passed as the class C, indicating that the polarities are reliable. Therefore, those site-mean directions were estimate as primary component, the overall mean direction (D = 29.5°, I = 53.0°, $\alpha 95$ = 9.3°) is calculated. Comparing a declination of Okada and Okamura (2005), this declination was smaller by about 20°. As this cause, we presumed that the central part of the Boso Peninsula has complica ted geologic structure due to the development of numerous folds, faults and flexures (Kodama et al., 1990). So, a difference block rotation possibly occurred at the each block.
To discuss the above, we present new paleomagnetic data from the upper Amatsu Formation exposed along the Aikawa River in Takeoka area, Futtsu city, Chiba Prefecture on the west side and the Kanayama River reservoirs along the Kamogawa river in the Kamogawa city, the same prefecture on the east side. Based on the key beds, we correlated the result of paleomagnetic direction in the same time slice at area by area.

[Reference]

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Keywords: The Amatsu Formation, Paleomagnetism, Neogene tectonic rotation

Distribution and evolution process of E-W strike fault system in Shimane Peninsula, western Japan

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The Shinji fault developed in the Shimane Peninsula is an E-W strike fault system which extends from Etomo to Miho Bay in Shimane Prefecture. Nakata and Goto (1998) named in part of the Shinji Fault as the Kashima Fault which is an active fault. In the recent research reported that the Kashima Fault extend about 25km with right-lateral offsets (Chugoku Electric Power Co. Ltd., 2016), and the average horizontal slip rate is about 0.4-0.6m / 1000 year, and the latest fault’ s activity is after the Nara Period (710-794) and before the Kamakura Period (1185-1333) (Earthquake Research Promotion, 2016).
Although clear lineament and fault topography are observed in western side of Kashima Fault (Minamikobu area), poorly observed in eastern side. Previous surface peels survey, trench survey and boring survey are conducted at the eastern side of the Kashima Fault and it is pointed out that the fault activity is not recognized in the Quaternary bed. However, we can confirm the weak lineament in eastern side of the Kashima fault. In addition, many fault branched from the Shinji Fault is reported in the Shimane Peninsula (Kano and Yoshida, 1996). There are various opinions about the location of the eastern end of the Kashima Fault system, and not well understood about the detailed distribution and evolution processes of these faults.
The purpose of this study is to understand the fault distribution and clarify their features in eastern part of the Shimane Peninsula by field survey and detailed description of the fault rocks.
In this study area, early Miocene to middle Miocene Koura Formation and Josoji Formation are widely distributed in the eastern part of the Shimane Peninsula. The survey was mainly conducted on the area where the weak lineament was confirmed. In this study area, a large scale fault outcrop corresponding to the Shinji fault was observed. The fault divides the rhyolitic sandstone of the Koura Formation and the rhyolitic lava of the Josoji Formation. Some small faults developed around the Shinji fault. The strike and dip of fault is N80°E74°N. A fault gouge of thickness about 5cm was recognized in the fault. Rhyoliteic dyke along the fault was also observed.
In this study, we report the distribution and the structure of fault rocks.

Keywords: Shinji Fault, Kashima Fault

The Mikabu thrust of the KasaYama–DodairaYama area in the northern part of the Kanto Mountains

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The Mikabu Unit of the Sanbagawa Belt and the Kashiwagi Unit of the Chichibu Belt are distributed in the KasaYama- DodairaYama region of the northeastern part of the Kanto Mountains (Figure E). The unit boundary is fundamentally low-angle fault (Mikabu thrust). Siliceous tuff and chert of the late Jurassic to early Cretaceous Kashiwagi Unit are superimposed on middle Jurassic greenstones of the Mikabu Unit [1]. A sharp change of metamorphic temperature across the Mikabu thrust has been suggested [2]. In this study, modes of occurrences of the Mikabu thrust and metamorphic rocks exposed within about 2m from the thrust are studied at the outcrops of Obisawa and Hagidaira (Figure E, locs. 2 and 3). The significant gap of metamorphic grade between the Mikabu and Kashiwagi Units is revealed on the basis of petrographic investigations of pelitic, tuffaceous and siliceous metamorphic rocks in the KasaYama-DodairaYama area.

The thrust plane of the Hagidaira outcrop exhibits very wavy features (Figure A). The thrust plane of the Obisawa outcrop is relatively flat with a step of about 40 cm. Schistosity of greenstones of the Mikabu Unit is consistent with the wavy thrust plane and the flat thrust plane with a large step. On the other hand, the strike and dip of the schistosity of the Kashiwagi Unit are substantially constant (Figure A). Fault gouge is almost non-existent. However, small amounts of finely crushed mudstone are rarely found at the Obisawa outcrop. Many fine quartz veins and chlorite veins occur in the greenstones near the Mikabu thrust of the Obisawa outcrop. Prehnite vein and calcite vein are not observed. Chlorite and epidote are main constituent minerals of the greenstones. Fine acicular actinolite occurs as a subordinate mineral. Many tension cracks develop in the greenstones (Figure B). The cracks are mainly filled with chlorite and fine actinolite (Figure C). One of greenstones collected from the Obisawa outcrop is rich in sericite. Greenstones are intensely sericitized at the Hagidaira outcrop.

The Kashiwagi Unit is mainly composed of pale green siliceous tuff, white tuff, tuffaceous phyllite, phyllitic bedded chert, muddy chert and mudstone. Quartz grains of about 5 μm in diameter are common for mudstone, white tuff, muddy chert and pale green siliceous tuff near the Mikabu thrust. Alkali amphibole and stilpnomelane are found in pale green siliceous tuff. Phyllitic rocks are characterized by the alternation of thin layers of white tuff and chert or mudstone. Thickness of interbedded chert or mudstone is about 1-5 mm. Thin layers of white tuff are rich in fairly large white mica grains. Quartz grains of about 5 μm in diameter are common in the chert and mudstone layers (Figure D) although quartz grains of about 10-60 μm in diameter are often present in the chert layers.

The Mikabu Unit mainly consists of greenstones. However, pale green tuffaceous schists, white tuffaceous schist, pelitic schist, psammitic schist and quartz schist are exposed at localities shown in Figure E, loc.4-8. Original rocks of these schists appear to be similar with those of the weekly metamorphosed rocks of the Kashiwagi Unit. Sampling localities and dominant sizes of quartz grains of the studied rocks are listed in Figures E and F. Data of similar rock types are arranged in the same column. Quartz grains of the schistose rocks of the Mikabu Unit are clearly coarser than those of the weakly metamorphosed rocks of the Kashiwagi Unit. The same conclusion can be applied to phengite grains. Further, quartz schist shows remarkable plastic deformations. Quartz pools of various sizes have been formed commonly. In addition, the K-Ar whole rock age of quartz schist (loc.8) is 112Ma [2]. In view of the very good re-crystallization and strong shear deformations, the result of radiometric dating indicates the age of the Sanbagawa metamorphism of the Mikabu Unit studied.

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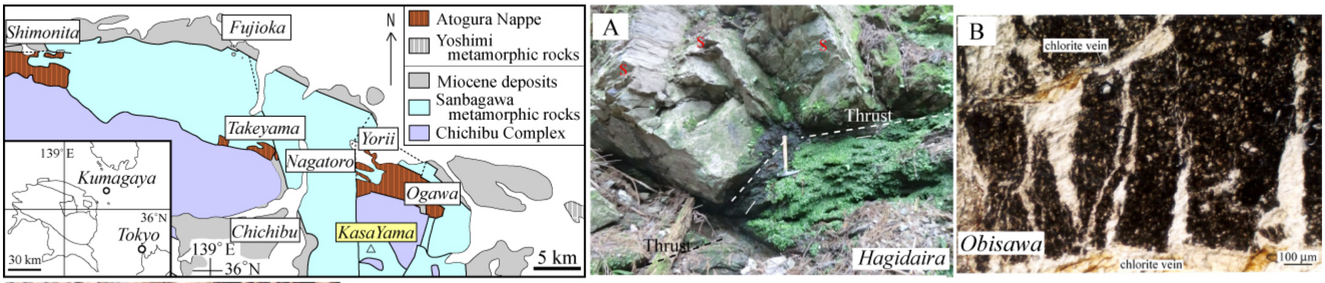
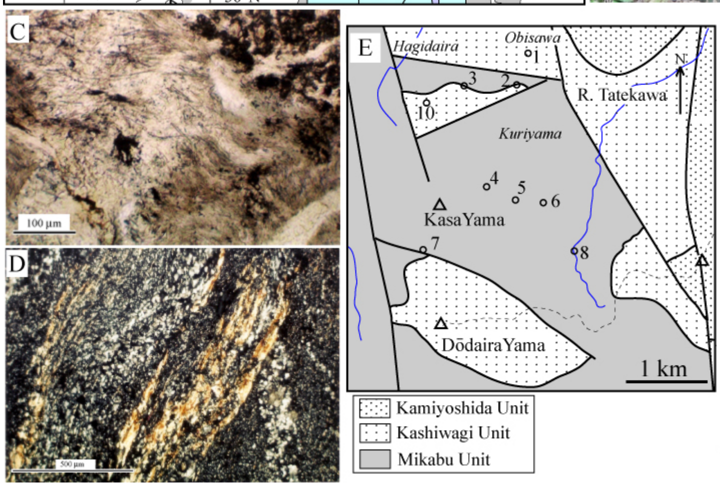
Keywords: Mikabu Unit, Kasiwagi Unit, Mikabu thrust, sericite, size of quartz grains





F

Dominant size of quartz grains /µm				
<Kashiwagi Unit>				
Mudstone loc.1	White tuff loc.1	Pale-green tuff loc.2	Bedded chert loc.1	Phyllite loc.1
4 - 10	4 - 10 (< 15)	4 - 10	fine part 4 - 10 coarse part 10 - 50	mica-rich part 4 - 8 quartz-rich part 8 - 17
<Mikabu Unit>				
Pelitic schist loc.5, loc.7	Phengite schist loc.7	Chlorite-garnet schist loc.6	Quartz schist loc.8	
10 - 25, 6 - 15	10 - 25	15 - 40	fine part 6 - 20 coarse part 25 - 80	

Accretion History of Basaltic Rocks of the Jurassic Northern Chichibu Accretionary Complex in the Kanto Mountains, Central Japan

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Basaltic rocks are widely distributed in the Jurassic accretionary complexes in the Japanese Islands. These rocks are regarded as fragments of ancient seamount or oceanic crust in the Panthalassa ocean. Previously, volcanic activities of oceanic seamounts and plateaux accreted to the Jurassic accretionary complex were reconstructed in the Jurassic accretionary complex of the Mino-Tamba Belt (e.g. Ichiyama et al., 2008, Lithos; Tatsumi et al., 2000, Geology). However, these studies mainly focused on specific tectonostratigraphic units containing large blocks of basaltic rock, and accretion history of basaltic rocks has not been fully discussed. In this study, we estimate the origin of basaltic rocks distributed in different tectonostratigraphic units with different accretion age in the Jurassic accretionary complex of the Northern Chichibu Belt, and reconstruct accretion history of the basaltic rocks.

The Northern Chichibu Belt in the Kanto Mountains are divided into the Kashiwagi, Kamiyoshida, Sumaizuku, and Hebiki (Yusugawa) units. The accretionary ages of these units are estimated to be Late Jurassic to Early Cretaceous, Middle Jurassic, Early to Middle Jurassic, and Early Jurassic, respectively (Matsuoka et al., 1998, Jour. Geol. Soci. Japan). The Kashiwagi Unit consists of pale green siliceous shale, while the other units are chaotic rock unit that consists of shale matrix with chert, basaltic rock, limestone, and sandstone blocks. The lower part of the Kamiyoshida Unit is dominated by basaltic rocks, while sandstone blocks are included in the upper part. The blocks in the Sumaizuku Unit are mainly basaltic rock and chert, and the unit includes huge limestone blocks of the Kano-yama, Futago-yama, and Hakuseki-san limestones. The blocks in the Hebiki Unit are dominated by sandstone. The basaltic rocks in the Kashiwagi and Kamiyoshida units are accompanied by limestone and contain Ti-augite phenocrysts. The basaltic rocks in these two units are discriminated as within-plate basalt (WPB) by bulk rock chemical composition. In contrast, the basaltic rock in the Sumaizuku Unit is accompanied by chert. The phenocrysts in the basaltic rock are composed of olivine, which are now replaced by chlorite. The chemical characteristics of the basaltic rock in the Sumaizuku Unit show both mid-ocean ridge basalt (MORB) and ocean island basalt (OIB) affinity. The occurrence of basaltic rock in the Hebiki Unit is limited but its chemical composition is similar to MORB.

These occurrence and geochemical evidences indicate that the basaltic rocks in the Kashiwagi and the Kamiyoshida units originated from OIB (=seamount). In contrast, the Sumaizuku and Hebiki units contain both OIB and MORB (=ocean floor). Compared with the previous studies of basaltic rocks in the Northern Chichibu belt, the Kamiyoshida Unit contains OIB (Fujinaga et al., 2006, *Resource Geol.*; Umeki & Sakakibara, 1998, Jour. Geol. Soci. Japan), while the Sumaizuku and Hebiki (Yusugawa) units includes MORB and OIB (Nozaki et al., 2005, Resource Geol.; Umeki & Sakakibara, 1998, Jour. Geol. Soci. Japan), implying that the relationships between the origins of basaltic rocks and the tectonostratigraphic unit division, are probably common characteristics of the Northern Chichibu Belt. Based on these characteristics of basaltic rocks and oceanic plate stratigraphy of each unit, accretion events of the basaltic rocks in the Northern Chichibu Belt are classified into three phases; 1) Ocean floor and seamount accretion in the Early to Middle Jurassic (the Sumaizuku and Hebiki units), 2) Carboniferous-Permian seamount accretion in the Middle Jurassic (the Kamiyoshida Unit), and 3) Triassic seamount accretion in the Late Jurassic to Early Cretaceous (the Kashiwagi Unit). This result contributes to understanding of volcanic activity in the Panthalassa ocean.

Keywords: Chichibu Belt, Jurassic Accretionary Complex, Ocean island basalt, Ocean floor basalt, Kanto Mountains

Green schist facies metamorphic rocks in the Richo formation, Yoron-jima, Ryukyu Islands, Japan

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Yoron-jima, a member of the Ryukyu arc, is located in approximately 20 km NE of Okinawa-jima almost 27 km SW of Okinoerabu-jima the nearly center of the Ryukyu Islands, southwest Japan. Yoron-jima has no tranquil-flow river and terrace topography is developed. Two active fault result in fault scarp in the N-S and E-W direction, and divide the island into three regions topographically. For the relationship between the two active faults, it is currently interpreted that Tsujimiya fault, which extends from N-S to NNW-SSE in the central part of the island, is cutting the Asado fault in the east-west direction (Ota and Hori, 1980; Katsudansou-Kenkyukai, 1980). The duration of activity of these faults is still unclear. Yoron-jima is a small island with a diameter of 5 km in the N-S direction and, 6 km in the east-west, an area of 20.82 km^2, and the highest point of 97.2 km. The island is, A fringing reef and barrier reef are developed along the coast with a little exception. Most of the island is covered by the Ryukyu Group formed by Quaternary limestone, which derived from coral and foraminiferal shell, and gravels derived from the basement rock. In the middle and south east of the island the Richo Formation, which is a basement rock below the Ryukyu Group, is exposed. According to Nakagawa (1967), Richo formation consists of limestone, slate, quartzite, sandstone and tuff, and they are suffered by low-grade metamorphism to be phyllites with quartz and calcite veins. Regarding Ryukyu Group, stratigraphy has been established by Odawara and Iyu (1999), but the details of the Richo formation is still unclear. Richo formation was considered to be Paleozoic (Oba, 1955) and Mesozoic (Odawara and Iru, 1999), however, no precise work on dating has been done.

In this research, we aim to determine the affiliation and the possible formation age of the Richo formation, which hasn’t been discussed much so far. We conducted field survey, sample collection, optical microscope observation and X-ray diffraction (XRD). For the estimation of age, we compared with the work by Nakagawa (2007, 2010) at the Okinawa-jima southern neighboring island of the Yoron-jima.

We confirmed that the exposure of the outcrops of the Richo formation as previous works reported. We recognized that green schists and limestones, suggesting that the basement rocks are suffered by green schist facies metamorphism. The results of XRD analysis reveals that the mineral composition between the Richo formation and the Motobu unit in Okinawa-jima resemble each other so that the Richo formation is assumed to be Mesozoic in its geological age belonging to the Chichibu belt.

Keywords: Ryukyu arc, Chichibu belt, Okinawa-jima

Estimation of provenance rocks of the Toki Sand and Gravel Beds, the Tokai Group, based on EPMA analyses of the heavy minerals –a case study of the Byobuyama fault

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Heavy minerals generally show variation in chemical composition with rock bodies. Chemical compositions of heavy minerals as well as their classifications and abundance ratios have the potential to be leveraged for provenance analysis (Takeuchi, 1994). In this study the quantitative analysis method of minerals using EPMA by Shimizu et al. (2016) has been applied to the sediment samples from an outcrop of the active, Byobuyama fault (Research Group for Active faults of Japan, 1991). Here the swiftness of measurement is prioritized over accuracy. The measurement time for a spot is about 3.5 min.
The studied samples (By-M1, By-M2, By-M3, By-M4) were obtained from the outcrops of sand and gravel. The outcrops are located near a fault outcrop of the Byobuyama fault (Katori et al., 2015, 2016). On the fault outcrop the Inagawa granite (Late Cretaceous) of the southeast side overlies the Toki Sand and Gravel Beds (Pliocene), Tokai group. By-M1 was obtained from a medium-sand layer in the Toki Sand and Gravel Beds (Outcrop 1), composed of gravels of the sedimentary rocks of the Mino terrane and the Nohi rhyolite, and the location is about 5 m apart toward the west from the fault. Sampling location of By-M2, By-M3 and By-M4 (Outcrop 2) is at about 10m down along a stream toward north from Outcrop 1. At Outcrop 2 the white and unconsolidated sand layer is dominant and the sediment may be younger than the Toki Sand and Gravel Beds. The sediment consists mainly of medium sand, in which fine gravels of the sedimentary rocks of the Mino terrane are partly included.
The mineral identification shows that all of the four samples are rich in ilmenite, rutile and zircon. The compositions of heavy minerals are similar among these four samples. Alternatively the contents of MnO in ilmenites and Y_2O_3 in zircons are used as the indexes of provenance rocks and charted as histograms. The histograms of the four samples show approximately the same patterns. The MnO contents in ilmenites show bimodal distributions of about 1 wt.% and about 3 wt.%. The Y_2O_3 contents in zircons are 0 to 0.5 wt.%. The group of ~3 wt.% MnO in ilmenites shows similar to those dominant in the host rock of the Nohi rhyolite rather than the Inagawa granite. No zircon grains containing Y_2O_3 of >3 wt.%, which is characteristically contained in the Naegi-Agematsu granite (Suzuki and Yogo, 1986) were identified in all the four samples. The Y_2O_3 contents in zircons are similar to that of the Nohi rhyolite.
These results are consistent with the fact that there is no granite gravel in the outcrops. Furthermore, the heavy-mineral compositions of By-M2, By-M3, and By-M4 are similar to that of By-M1. This shows the possibility of redeposition of the Toki Sand and Gravel Beds.
The Inagawa granite is widely distributed in the southern side of the Byobuyama fault where is topographically high. This study suggests that the deposition of the Toki Sand and Gravel Beds completed prior to the recent upthrust of the Byobuyama fault.
This study was carried out under a contract with Agency of Natural Resources and Energy, part of Ministry of Economy, Trade and Industry of Japan as part of its R&D supporting program for developing geological disposal technology.

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Keywords: EPMA, heavy mineral, provenance analysis

U-Pb zircon ages of the Nakanogawa Group in the southern Hidaka Belt, northern Japan: Implications for its depositional age and provenance

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We measured zircon U-Pb ages of the Nakanogawa Group in the Hidaka Belt, Hokkaido to estimate its depositional age and to investigate the development of the Paleo-Japan and Paleo-Kuril arc trench systems in the Hokkaido Central Belt, northeast Japan. Two acidic tuff samples from both the top and bottom horizons and two turbidite sandstone samples were used. The depositional age of the base of the Nakanogawa Group was determined to be 57 Ma by date of homogeneous zircon from acidic tuff. On the other hand, the youngest zircon groups indicated 55 Ma for sandstone from the upper part and 58 Ma for acidic tuff from the uppermost part, both of which are significantly older than the published zircon fission-track ages (50–48 Ma). This inconsistency probably resulted from U-Pb ages of detrital (reworked) grains, therefore these showed the maximum depositional ages. We estimate the depositional age of the Nakanogawa Group between 57–48 Ma. The resulting U-Pb age distribution of all data from the Nakanogawa Group has most of ages clustering younger than 80 Ma with a main peak at 60 Ma. This implies volcanic activities had occurred mainly after 80 Ma around Hokkaido. We also found some older grains dated to be 120–80 Ma, 180–140 Ma, 240–220 Ma, 340–320 Ma and much older (2.6 and 1.8 Ga), giving an information about the provenance of the Hidaka Belt. We also infer that the Nakanogawa Group is the protolith of the upper sequence of the Hidaka metamorphic rocks. Therefore, the depositional age of the upper sequence is the same as the depositional age of the Nakanogawa Group between 57–48 Ma.

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Keywords: Depositional age, U-Pb dating, LA-ICP-MS, Nakanogawa Group, Hidaka Belt

Stratigraphy, sandstone composition, and detrital zircon U-Pb ages of Permian strata in the Hongo-Moribu area of the Hida-gaien belt, central Japan

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Paleozoic and Mesozoic shallow marine strata are widely distributed in the Hongo-Moribu area of the Hida-gaien belt, Takayama City, Gifu Prefecture. A complicated geologic structure has been recognized for these rocks that are subdivided into the Devonian Rosse Formation, the Carboniferous Arakigawa Formation, the Permian Moribu Formation, and the Triassic Tandodani Formation (e.g., Isomi and Nozawa, 1957; Tsukada et al., 1997; Tazawa et al., 2000). Among them, the Moribu Formation has been studied mainly in the type locality (Moribudanigawa River) in terms of the stratigraphy and sandstone composition (e.g., Yoshida and Tazawa, 2000). Middle Permian fusulinids and brachiopods were reported from several localities along the Moribudanigawa River (e.g., Horikoshi et al., 1987; Tazawa, 2001; Niwa et al., 2004). In addition, sparse occurrences of fusulinids and radiolarians from sandstone and tuff at Rosse-Kanayama indicate the presence of various lithologies ranging in age from the Late Carboniferous to Middle Permian (Tazawa et al., 1993, 2000; Umeda and Ezaki, 1997). In contrast, no age-diagnostic fossils have been reported from the "Moribu Formation" in the Hongo area. In the present study, we reinvestigated the stratigraphy and sandstone composition of Permian strata in the Hongo-Moribu area. The U-Pb ages of detrital zircons from sandstone of the Moribu Formation are also reported.
In the present study, the "Moribu Formation" in the Hongo area is subdivided into units I to IV based on their lithology. Unit I consists of dark gray fine- to medium-grained sandstone with interbedded limestone. Units II to IV are characterized by dark gray fine- to medium-grained sandstone and alternating sandstone and shale. These characteristics are similar to the lower to upper parts of the Moribu Formation in the type locality. This correlation indicates that the stratigraphy of the "Moribu Formation" in the Hongo area lacks the basal part consisting of conglomerate of the type locality. We collected 10 sandstone samples from units I to IV in the Hongo area. Based on the result of modal analysis, the sandstones can be classified as feldspathic to lithic wacke. Qm–F–Lt ternary diagram shows that the examined sandstones plot in the dissected arc to basement uplift fields proposed by Dickinson et al. (1983). According to Yoshida and Tazawa (2000), the sandstones of the basal to middle parts of the Moribu Formation are characterized by the composition of undissected arc to basement uplift. Therefore, our result indicates that a more extensive distribution of a granitic basement was present in the provenance of the Permian strata.
The U-Pb ages of detrital zircons were examined for medium-grained sandstone of the middle part of the Moribu Formation. A clear youngest age peak of 272.4 ±2.6 Ma was recognized, which corresponds to late Kungurian to early Roadian. This result is in good agreement with biostratigraphic age constraints by fusulinids and brachiopods for the formation.

Keywords: Permian, Hida-gaien belt, sandstone composition, detrital zircon, U-Pb age

New zircon U-Pb age data from "Nagasaki Metamorphic Rocks" (*sensu lato*) in the Nomo Perninsula, Southwest Japan

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Introduction

Nagasaki Metamorphic Rocks (NMR) are distributed in the Nishisonogi and Nomo peninsulas of Nagasaki Prefecture and the Amakusa Shimoshima Island of Kumamoto Prefecture, SW Japan. Miyazaki and Nishiyama (1989), Nishimura et al. (2004), Takeda et al. (2002), and other researchers proposed that NMR in the Nomo Perninsula consist of Sanwa Formation (=Late Cretaceous Sambagawa Metamorphic Rocks), Joyama Mylonite (=Early Cretaceous Higo Metamorphic (Plutonic) Rocks), Nomozaki Formation (=Triassic (to Jurassic?) Suo Metamorphic Rocks and Late Cambrian Nomo Metagabbro Complex). Miyazaki et al. (2016) proposed to exclude Nomozaki Formation from NMR. In this study, we measured the zircon U-Pb ages of NMR (including the Nomozaki Formation) and organized geochronological data (see attached table).

Geologic Setting

NMR consist of Sanwa Formation, Joyama Mylonite, and Nomozaki Formation, in apparent ascending order. Sanwa Formation is composed mainly of pelitic schist in the garnet to biotite zone and mafic schist that contain albite spot. K-Ar phengite ages of the pelitic schist are 86-68 Ma (Ueda and Onuki, 1968).Joyama Mylonite is composed pelitic-psammtic gneiss and granitic mylonite, and contains hornblende metagabbro and amphibolite. K-Ar phengite ages of the pelitic-psammitic gneiss are 92 Ma and 84 Ma (Takeda et al., 2002). Nomozaki Formation is composed mainly of interlayered mafic, psammtic and pelitic phyllites in the chrolite zone, accompanied by limestone lenses. K-Ar phengite ages of the pelitic phyllite are 254-153 Ma (e.g. Nishimura, 1998).In addition, above the phyllites, there is Nomo Metagabbro Complex, which consists mainly of metagabbro and amphibolite (Igi et al., 1979), accompanied by calcareous, mafic and pelitic phyllite blocks. Cretaceous granite and aplite have baked Nomozaki Formation (e.g. Nishimura,1998 ; Oshima, 1968).

Samples and method

We separate zircons from the pelitic schist in the garnet zone (Sanwa Formation), the hornblende metagabbro and granitic mylonite (Joyama Mylonite), and the pelitic phyllite block (Nomo Metagabbro Complex). The U-Pb isotopic analysis was conducted with the LA-ICPMS equipped in the Graduate School of Environmental Studies, Nagoya University.

Age dating results

Pelitic schist: The age composition of zircons (%) was as follows: Late Cretaceous (6.7), Early Cretaceous (4.4), Jurassic (48.9), Triassic (8.9), Permian (8.9), and Paleoproterozoic-Archean (22.2). The $^{206}Pb/^{238}U$ age of the youngest zircon (YZ) was 90.3 +/- 3.5 Ma, and the weighted average of the $^{206}Pb/^{238}U$ ages of the zircons in the youngest cluster (YC) was 92.1 +/- 1.8 Ma.
Hornblende metagabbro: U-Pb data from 16 spots out of 33 gave the concordia age of 113.5 +/- 1.3 Ma.
Granitic mylonite: Details are shown in the poster presentation.
Pelitic phyllite block: The age composition of zircons was as follows: Ordovician (83.4) and Neoproterozoic-Mesoproterozoic (16.6). The YZ was 444.3 +/- 9.9 Ma and the YC was 457.8 +/- 6.2 Ma.

Discussion

Pelitic schist (Sanwa Formation) : The YZ and YC corresponded to the Turonian (ICS, 2016), suggesting that the depositional age of Sanwa Formation is the Turonian or later. The metamorphic ages of Sanwa Formation (86-68 Ma: Coniasian to Maastrichtian) are concordant with this depositional age.

Hornblende metagabbro (Joyama Mylonite) : It was formed at ca. 113 Ma. This age is similar to that of Karasaki Mylonite and Oshima Metamorphic rocks in western Shikoku, Higo Plutonic Rocks in western Kyushu, and Upper Unit of NMR in Amakusa Shimoshima Island (Sakashima et al., 1998 ; Sakashima et al., 2000 ; Sakashima et al., 2003 ; Miyazaki et al., 2013).

Pelitic phyllite block (Nomo metagabbro complex) : The YZ and YC were Ordovician (ICS, 2016), indicating that its depositional age is the Ordovician or later. The age is younger than the age of crystallization of the metagabbro in Nomo Metagabbro Complex (ca.526-474 Ma). The zircon age spectrum of the pelitic phyllite is similar to that of the psammitic schist in Renge Metamorphic Rocks (Kouchi et al., 2013) .

Keywords: Zircon, Nagasaki metamorphic rocks, Cretaceous, LA-ICPMS, SW Japan

Unit name	Lithology	Previous study		This study
		K-Ar age	Zircon U-Pb age	Zircon U-Pb (formation) age
Nomo metagabbro complex	metagabbro and amphibolite	592–457 Ma	**526–474 Ma**	
	(phyllite blocks)			**458 Ma or later**
Nomozaki Formation	phyllite (chlorite zone)	252–153 Ma	238 Ma	
Joyama Mylonite	Hbl metagabbro–amphibolite			**113.5 Ma**
	granite mylonite			**120–100 Ma**
	high-T metamorphic rocks	92 Ma, 84 Ma		
Sanwa Formation	schist (garnet zone–biotite zone)	86–68 Ma		**92 Ma or later**
	serpentinite	(91 Ma)	(108–105 Ma)	

Pressure solution deformation and its chemical composition in the rocks from Kumage Group, Shimanto belt in Tanegashima, Japan

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Along the Japanese island arc, there are outcrops of accretionary complex which have formed at various depths from the Paleozoic to the Quaternary in a relatively narrow range. Since 1980, various studies on accretionary complex of Japan have been conducted (Kano, 1998). The Kumage Group in Tanegashima belongs to the Southern Shimanto Belt and is composed of Nishi-no-omote Formation, Kadokurazaki Formation and Tateishi Formation. The geological age of the Kumage Group ranges from Middle to Late Eocene (Okada et al., 1982).Recently, Sakai (2010) proposed that the Kumage Group can be subdivided into Kumage Complex and Kadokurazaki Complex which are correlated with the geology in South Kyushu, the Hyuga Group and the Nichinan Group, respectively,. The Kumage Complex is composed of turbidites deformed associated with accretion, where the Kadokurazaki Complex is of olistostrome that consists of various size of blocks in mudstone without clear bedding. Deeply buried subducting material is often suffered by sheare along the plate boundary. Pressure solution deformation has been observed in the Shimanto Belt in Shikoku (Kawabata et al., 2007), showing positive correlations between pressure solution seam (PSS) density and concentration of the immobile chemical component (TiO2) and between PSS density and paleotemperature. This study aims to investigate relationship between development of pressure solution deformation and chemical composition in the Kumage Group of Tanegashima. We performed thin section observation, chemical component analysis using Electron Micro Probe (EMP), and examined data statistically using principal component analysis.
PSS was observed under optical microscope in the samples from middle (Kumage Complex) and southern (Kadokurazaki Complex) part of the island. In contrast, samples from northern part of the island (Kumage Complex) show almost no sign of pressure solution deformation. The results of the Electron Micro Probe (WDS area analysis) revealed positive Ti anomalies in the inner hinges of the micro-folded sandstone. The principal component analysis of the chemical composition data yielded principal components with major loading not only on Si component but also on Ti.
Our observation revealed pressure solution deformation was selectively developed along the boundary between sandstone and mudstone. As the samples from the Kadokurazaki Complex showed intense development of PSS, resulted probably from the higher content of sand/mud interface in the unit volume. Our results on the Electron Micro Probe (WDS area analysis) and principal component analysis confirmed that not only Ti but also other elements are capable of being the immobile reference and partially supports the validity of the work by Kawabata et al. (2007). Lower concentration of Ti in the PSS may be resulted from less shear stress compared to that of in the Kawabata et al. (2007)’s case from Shikoku.

Paleostress orientation estimated from microcracks in quartz grains of the Toki Granite using mixed Bingham distribution method

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Healed microcrack (HC) is a fluid inclusion plane which was healed by the same mineral as the host mineral whereas sealed microcrack (SC) is a microcrack sealed by secondary material. These cracks are preferably formed perpendicular to the minimum principal stress ($\sigma 3$) axis. In the previous study, only $\sigma 3$ orientation has been estimated using HC, SC and mesocracks from the JAEA borehole core (DH-15) in the Late Cretaceous Toki Granite, central Japan (Takagi et al., 2008). The microthermometry analysis for fluid inclusions constituting HCs in the Toki Granite suggests that the HCs were formed around 60 Ma (Takagi et al., 2008).

Recently, a new analytical method that can estimate the orientation of all principal stress ($\sigma 1$, $\sigma 2$, $\sigma 3$) axes was developed (Yamaji et al., 2010; Yamaji and Sato, 2011). Kanai et al. (2014) proposed a precise calibration method to estimate an orientation distribution of microcracks applying that new analytical method. In this study, we re-examine the previous data after Takagi et al., (2008) and comprehensively estimate the paleostress orientation using those new methods. Twenty oriented granite pieces from 200–1000 m depth were used and three orthogonal thin sections prepared for previous study were re-used to measure the microcracks in each sample. The distributions of HC and SC display one to three concentrations and those are commonly orthogonal each other. Since several paleostresses were detected from each sample, the paleostress that has $\sigma 3$ axis closest to the orientation of maximum density address as prominent stress in the sample at the timing of microcrack formation. Most of the prominent stress of the HCs show $\sigma 3$ axis trending E-W, subhorizontal, whereas $\sigma 1$ and $\sigma 2$ axes form a single girdle parallel to N-S orientation, in which $\sigma 1$ tends to be more horizontal than $\sigma 2$. These results suggest that the HC is formed in NW-SE orientation before the rotation of the SW Japan together with the opening of the Japan Sea in 20-15Ma. This restored NW-SE compressive orientation is presumably because of the influence of the regional compression due to the Pacific plate subduction in early Paleogene. The paleostress orientations using SCs give quite different result from those using HCs. Most of the prominent stresses show N-S subhorizontal $\sigma 3$ axis, E-W subhorizontal and subvertical $\sigma 1$ axis, and E-W subhorizontal and vertical $\sigma 2$ axis. If the SCs were formed before the opening of Japan Sea, the results of $\sigma 1$ E-W axis trending should be NE-SW before the rotation of SW Japan. However, it seems difficult to consider that this orientation is related to orientation of the Oceanic plate subduction before the opening of Japan Sea (20-15Ma). This paleostress orientation using SCs is left as future’ s problem to be solved.

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Keywords: paleostress analysis, healed microcrack, sealed microcrack, Toki granite

Provenance of the Late Triassic Langjiexue Group south of the Yarlung-Tsangpo Suture Zone, southeastern Tibet

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The Upper Triassic flysch sequence of the Langjiexue Group in the Shannan area, southeastern Tibet, which was thrusted northwards over the Yarlung-Tsangpo Suture Zone (YTSZ) by the Great Counter Thrust (GCT), was conventionally attributed to the typical Tethyan Himalayan Sequence (THS) and interpreted to be genetically related to the Indian origin. Recent results, mainly from analyses of detrital zircon age spectrums and Hf isotope signatures of the Triassic rocks in the southern Tibet, challenged this opinion and considered the Triassic sequences as a relatively independent tectonic unit from the THS. Our data, including detrital mode analysis, heavy mineral assemblage study, whole rock geochemistry and detrital zircon geochronology, provide new evidence to constrain the provenance of the Langjiexue Group. Domination of quartz grains and acid volcanic lithic fragments indicate recycled orogeny provenance. Stable heavy mineral assemblages with the majority of zircon and rutile reflect acid magmatic and continental metamorphic sources. Characteristic geochemical indicators ($Al2O_3/TiO_2$, Cr/V-Y/Ni, Co/Th-La/Sc, Eu/Eu^*-Th/Sc, LREE enrichment, Th-Sc-Zr/10, Th-Co-Zr/10) point to felsic igneous sources in the tectonic setting of continental island arc or active continental margin. Three major age clusters from the detrital zircons were identified: 1150-850 Ma, 750-480 Ma and 300-200 Ma, among which the Neoproterozoic to Late Cambrian signal is the most remarkable exhibiting the Gondwana affinity for the Langjiexue Group. The youngest age peak is inconsistent with sources from any surrounding terranes, including the South Qiangtang, Lhasa terrane, Tethyan Himalayan Sequence (THS), Higher Himalayan Sequence (HHS), NW-W Australia and Banda Arc. We propose the Tasmanides, including the New England Orogen (300-230 Ma), along the eastern Australian margin as the supplier of magmatic materials for the Langjiexue Group. The age peak of 300-200 Ma of the Langjiexue Group can be correlated well with the widespread magmatism in the age ranging between the Late Paleozoic to Early Mesozoic from the Bird’s Head (New Guinea) in the north to New Zealand in the south, which results from subduction of the Paleo-Pacific ocean beneath the eastern Australia. We conceive of such long-distance drainage system in the Late Triassic as similar to modern Yarlung-Tsangpo-Brahmaputra and Amazon rivers, which transport detritus from mountain chains to sedimentary basins for thousands of kilometers.

Keywords: Langjiexue Group, Late Triassic, Southeastern Tibet, Provenance

Sandstone petrology of the Permian Altan-Ovoo formation in the Hentey Range, central Mongolia

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The Permian Altan-Ovoo formation is the major member of the Hentey Range in the Central Mongolia. In this abstract we present geotectonic settings, source rocks, and its composition of the Altan-Ovoo formation. The Hentey Range is located in the northern part of the Adaatsag terrane and in the eastern part of Haraa terrane (Badarch, 2002), formerly known as Mongol -Okhotsk zone, is located in the central part of the Central Asian Orogenic Belt (CAOB). Altan -Ovoo formation conformably overlies Carboniferous to Permian Gorkhi formation (Dorjsuren, 2012) and conformably covered by the Lower Triassic Orogchin Uul formation.

Samples collected from the study area include 56 sandstones, 17 siltstones and 24 gravelstones. We have examined sandstone samples under microscope. The size of mineral and rock fragments varies from 0.06 mm to 2.2 mm. Argillite, andesite, dacite, rhyolite particles are predominant among rock fragments, there are rarely noticed siltstone, tuff, schist fragments. These rock fragments show variable textures such as porphyritic, microlitic, microfelsitic, aleurolitic, microgranophyric and microgranolepidoblastic textures. Hornblende, quartz, plagioclase, K-feldspar are identified as mineral fragments. The feldspar clasts are altered into sericite, rarely epidote. Accessory apatite, sphene, zircon, monazite, tourmaline, allanite are found.

We have classified sandstones according to the methods of Folk (1968) and Dickinson (1985), and most of them fall in the fields of lithic arkose and arkose. The ternary Qt-F-L plot by Dickinson (1985) suggests that most samples of Altan-Ovoo formation were supplied from dissected arc and transitional arc. Result of major elements geochemical analysis of three samples suggests that they are from active continental margin.

It can be concluded that rock and mineral fragments of the Permian Altan-Ovoo formation were supplied from various source areas. Among them, arkose deposited in active continental margin originally supplied from volcanic rocks of the continental magmatic arc is significant.

Keywords: Altan-Ovoo formation, Mongolia, arkose, sandstone

Slow landslide induced by Typhoon Morakot in central Taiwan via PIV analysis

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In 2009, Typhoon Morakot brought heavy rainfall and triggered at least 304 landslides in Yuchenliao, Meishan Township, central Taiwan. Typhoon Morakot produced copious amounts of rainfall, peaking at least 2,888 mm, far surpassing the previous record, 1,736 mm by Typhoon Herb in 1996. Throughout the disaster, various data indicates a great potential of multiple magnitude landslides in these areas. We analyzed three orthorectified aerial photographs of the Yuchenliao area, which were taken in January 2001, January 2007 and August 2009, using the Particle Image Velocimetry (PIV) technique. The sub-pixel correlation of PIV analysis in the Yuchenliao area covers a dimension of 2801×3001 pixels. Our results of the PIV analysis revealed that the maximum horizontal displacement of the landslide in the study area is up to 70 m towards south, and the dimension of the Yuchenliao landslide area is measured about 0.28 km^2. In spite of the shallow landslide, the results of PIV show bigger landslide area than the previous research estimated by the movement of characteristic geomorphological features from orthorectified aerial photographs before and after Typhoon Morakot. In addition, the PIV technique could provide the displacement field of slow landslide area which be used to inverse the slip distribution of sliding area to assessment the potential landslide hazard of this slow slide event.

Keywords: landslide, Morakot, Yuchenliao, Particle Image Velocimetry

Geochemistry of peridotite and basalts from Yap trench: implication for its tectonic evolution

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On the east side of the diamond shape Philippine Sea Plate, it is the trench system which concludes Izu-Bonin-Mariana trench, Yap trench, Palau and Ayu trench, there is the deepest trench in the world. The Yap Trench, together with the Palau Trench, is located at the southern end of the long chain of trench-arc systems. At the ultra deepest bottom, there is not only unique depositional and digenetic environment, but also frequent geologic activity caused by plate subduction such as serpentinization, gas release and volcanic earthquake. The Yap and Palau Trenches differ from the Izu-Bonin-Mariana (IBM) Trenches to the north. On seismology, it is markedly lower at Yap and Palau with no evidence of a Benioff zone compared with IBM which has well-developed Benioff zones. The distance between the arc and the trench axis is less than 50 km, much less than those found for other arc–trench systems and it lacks active arc volcanism, which maybe the consequence of the Cenozoic collision with the Caroline Ridge. Moreover, the Yap trench is very short which is from 7°30′N to 11°30′, and there is a typical trench-trench junction existing near 11°7′where Mariana trench intersect as a perpendicular angle, and its northern part is the deep valley named North Yap Escarpment. Some researchers suggested that subduction at the Yap Trench may have been terminated by collision of the Caroline Ridge. However, recent studies suggest that the Yap subduction zone is still active. In the inner slope of the Yap Trench at about 6000m deep, ultramafic and gabbroic rocks were observed and considered as the similar one to those exposed in the Parece Vela basin. Since lower crustal and even upper mantle sections of the PSP are exposed on the inner slope of the Yap Trench, it is extremely important for correctly interpreting the petrological and chronological data collected along that arc. There are still very little samples and data from Yap trench, more are needed to understand the geology of it. In this paper, we will report some new samples and it petrology and geochemistry of new peridotite and basalts collected by manned submersible of China ‘JiaoLong’ at more than 6000m depth from the inner slope of Yap trench, and discuss its evolution implication for the PSP arc system.

Keywords: Geochemistry , Peridotite , Yap trench