

Geochronology and geochemistry of the early Paleozoic metamorphics-igneous complexes of Japan

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Early Paleozoic igneous – metamorphics complexes are sporadically distributed over the Japan Arc. These complexes are important to describe beginning of the Japan Island. Each complex has been studied in detail, however, chronological relationship and whole view of them clarified insufficiently.

The metagabbro – amphibolite complex in the Nomo Peninsula is located on the western end of the early Paleozoic igneous – metamorphics complexes. Isozaki et al (2010) pointed out this complex is one of the oldest igneous rocks in Japan. The zircon U – Pb ages of the metagabbro show 491 – 458 Ma. Re-examined amphibole K – Ar ages of the amphibolite are 534 Ma and 468 Ma.

The Kiroko amphibolite (Takeuchi and Makimoto, 1995) is located Yorii-machi, Saitama Prefecture, and situated in the middle part of the early Paleozoic igneous – metamorphics distribution, this rock has 420 Ma amphibole ³⁹Ar – ⁴⁰Ar age, and 555 – 463 Ma zircon U – Pb ages.

The Miyamori ophiolite complex and the Motai metamorphic rocks are north-eastern end of the distribution of early Paleozoic complex in Japan (Ozawa, 1984). The zircon U – Pb ages of gabbro of Miyamori ophiolite are 544 – 420 Ma. The Miyamori ophiolite complex often includes metamorphic rocks that correlate to the Motai metamorphic rocks. The amphibole K – Ar ages of the Ohachimori amphibolites in the Motai metamorphic rocks are 431 – 392 Ma. The amphibole ⁴⁰Ar – ³⁹Ar spectra has not good plateau, however the total ⁴⁰Ar – ³⁹Ar ages show 508 – 432 Ma.

The zircon U – Pb ages and amphibole K – Ar ages have good agreement with these complexes. An important note is that these amphibolites of early Paleozoic age were not suffered HP metamorphism, suggesting that their geochemical characteristics will be used to estimate tectonic setting.

The bulk rock chemistry of amphiboles belongs to basalt or basaltic andesite. The chemical feature of metagabbros and amphibolites belongs to calc-alkaline series, and is supposed to have an intra-oceanic arc/remnant arc characteristics.

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Keywords: early Paleozoic, metamorphics-igneous complex, zircon U-Pb age, K-Ar age, bulk rock chemistry

Study of brecciated process of iron and carbon-bearing veins of the Akiyoshi-dai drilled samples

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1. Characteristics of the Japanese islands: The present Japanese Islands has less young volcanic rocks compared with much sedimentary rocks (ca.60% in volume). This is mainly because the Paleozoic basement rocks (including the Akiyoshi limestone) are remained from ocean-floor aggregates before formation of the Japanese island-arc (ca.15Ma) characteristically.

2. Characteristics of the Akiyoshi-dai limestone: Japan Islands are geologically recently emerged from the ocean floor and situated North-South arc, though vast and old Akiyoshi sedimentary limestone is remained now on the plateau. This indicates that Main-land (West) mixed with different formation-time and locations is moved though ocean-floor movements before formation of the Sea of Japan.

3. Research results of Akiyoshi-dai drilling limestone samples (powder): The Akiyoshi underground samples (up to 250m in depth from the Kaerimizu site) drilled by the Akiyoshi Science Museum (at Kaerimizu, 250 m) show significant changes of 1) physical properties (structure and ESR signals) of powdered calcite minerals along the fossil reversal distributions [1-5], 2) elemental abundances of siderophiles from bulk XRF data analysis at the bottom of 243m in depth, and 3) re-crystallized calcite and minor contents of feldspars and quartz of the samples of the bottom (243m) and surface colored marble with iron contents [4].

4. FE-SEM study of the thin and massive drilled samples: The brecciated drilled thin-section samples prepared in the United States show the following the FE-ASEM and Raman data:

1) Shallow sample (50 m in depth) with small calcite decomposition and few carbon-grains. 2) Medium sample (160 m) to deep (217 m and 243 m) with nano-crystals of separated carbon grains, re-crystallized calcite and halite. 3) Massive deep samples with nano-carbon (the Raman peaks of high-pressure carbon) and shocked nano-calcites (related with artificial products) [3-5].

5. Comparison with overseas Paleozoic limestone: Four overseas Paleozoic samples are investigated in this study as follows [5]: 1) Carlsbad limestone of 300Ma (New Mexico) of coral reef origins with deep underground cave. 2) Sierra Madera Permian limestone (Texas) of impacted shuttered cone with significant siderophiles elements. 3) Alamo breccias 367Ma(Nevada) of shocked quartz and fine calcite without clear impact crater. 4) Santa-Fe breccias 350Ma(New Mexico) of shocked quartz and limestone with fluid-tube texture and separated nano-carbon grains.

6. Proposed formation of the Akiyoshi-dai limestone: Breccias of the Akiyoshi-dai Kaerimizu (243m in depth) are not simple sediments, but impact-related materials contains complicated activities of significant siderophiles, nano-carbon separated from limestone and two types of calcite (re-crystallization and nano-calcites), which cannot be explained only by simple volcanic and earthquake events, but also impact processes of remained sea-floor and weathering after uplift ground) [4, 5] .

7. Summary: The Paleozoic Akiyoshi-dai limestone-breccias which are remained in the Japanese islands with different time-location blocks show clear example of various colors, minerals and compositions with different eras and places on ocean-floor process, where they are difficult to explain by general shock-wave processes (earthquakes and volcanoes). In this study, oversea Paleozoic limestone investigations are compared with old limestone of the Akiyoshi-dai drilled samples.

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Keywords: Akiyoshi-dai limestone, Drilled samples, Iron-carbon grains, High-pressure carbon, Siderophiles, Re-crystallized calcite

Emplacement process of oceanic seamount origin limestone in the Northern Chichibu Belt

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Limestone blocks in the accretionary complex can be regarded as accreted fragments of seamount capping atoll carbonate in origin. To discuss emplacement process of such limestone blocks into the accretionary complex is significant for understanding subduction zone tectonics, but it has not been fully discussed except for some works. This study examines Kano-yama limestone in the Jurassic accretionary complex, the Kanto Mountains, central Japan and documents imbricate structure developed in the gigantic limestone block.

Kano-yama limestone and other adjacent limestone blocks such as Tatoro-yama, Futago-yama, and Hakuseki-san are embedded in the strongly sheared zone along the boundary of the Northern Chichibu Belt and the Sanchu "Graben". This sheared zone comprises two formations: the Sumaizuku in the north and Hebiki formations in the south. The Sumaizuku Formation contains mainly chert and greenstone blocks whereas Hebiki Formation contains mainly sandstone blocks. Matsuoka et al. (1998) estimated accretion ages of the two formations to be Early to Middle Jurassic. Kano-yama limestone is accompanied by greenstones and volcanoclastic rocks. They are hyaloclastite and pillow lava, and according to chemical composition and petrology, they are N-MORB type basalt, except for one E-MORB. Thus, these greenstones are interpreted to have co-occurred tectonically with limestone, and almost all parts of volcanic body of a seamount seems to have subducted deeper.

Kano-yama limestone trends from WNW to ESE and is a limestone block 1 km × 200 m in size. The SW dipping bedding planes are observed in Kano-yama limestone, and on the basis of geopetal fabrics in boundstones, they represent normal sequence. Depositional facies of Kano-yama limestone are interpreted to be sand shoal and lagoon environment. Late Carboniferous to middle Permian fusulinacean genera are identified in Kano-yama limestone. Based on the fusulinacean age and lithology, Kano-yama limestone is divided into at least three units: Units 1, 2, and 3 in the seemingly descending order. Unit 1 contains components of sand shoal facies, and on the other hand, Units 2 and 3 contain both back reef and lagoon facies components. Fusulinacean age is younging upward within a single unit, but the older limestone overlies the younger limestone in a fault contact. They show totally imbricate structure. Limestone breccia is generally absent in Kano-yama limestone.

A lack of limestone breccia suggests that Kano-yama limestone is not an aggregate of redeposited collisional collapse products of oceanic reef complex at trench. Compared with sandbox experiment by Dominguez et al. (2000), a formative process of imbricate structure in the capping carbonate is rather explained by off-scrape of superficial part of a seamount. In conclusion, Kano-yama limestone was probably formed by off-scraping of back reef to lagoon deposits of cap carbonate, forming imbricate structure.

Keywords: seamount accretion, the Northern Chichibu belt, the Kanto Mountains, limestone, greenstone

Duplexes and other structures in the Misaki Formation of Shonan-Ubajima and their significance

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The Hirajima and Ubajima Islands in Sagami Bay off the Chigasaki fishly port are part of ridges arranged in a WNW-ESE line from the Hayama district in the Miura Peninsula. Although lithostratigraphic and nannofossil biostratigraphic analyses have been studied in the Ubajima Islands, geologic structures of the Ubajima and Hirajima Islands remain incompletely understood. Our stratigraphic and structural study revealed that Ubajima Islands have distinctive structures characteristic in an accretionary complex, represented by a decollement zone with duplexes, thrust-anticlines and bedding-parallel shortening structures.

The Hirajima Islands located immediately on the south of the Chigasaki port is composed of tuffaceous fine sandstones correlated with the Oyama Formation of the Hayama Group. The Ubajima Islands located 2 km southeast from the Hirajima Islands is of tuffaceous muddy sandstones, more than 290 m in thickness, intercalating pumiceous and scoriaceous tuff beds. Middle to lower horizons of the Eboshi Honto and Odaira Island are dated at between 8.2-9.9 Ma based on co-occurrence of radiolarian species *Stichocorys delmontensis* and *S. peregrina* and no occurrence of *Cyrtocapsella japonica*, the combination of which is correlated with the Misaki Formation of the Miura Group. Geologic structure of the Ubajima Islands is divided largely into eastern part and western part. Eastern part strikes N-S with dips to west showing an anticline trending WNW-ESE and western part strikes E-W to ENE-WSW with dips to north. The thrust faults trending E-W at the central and south areas of western part bound its geologic structures and stratigraphy. At the southern area across the thrust fault in the Odaira Island in the western part of Ubajima Islands, decollement zone is identified, as consisting of the main share zone, fold and share zone, from the north to south, being accompanied with some duplex structures and layer parallel faults. On the other hand, the northern area of the thrust showing an anticline trending WNW-ESE that thrusts up onto southward, representing sinistral strike-slip fault in appearance. The decollement zone with thrust-anticlines observed in the Ubajima Islands is characteristic within accretionary margin in many toe areas of the Nankai Trough (Kawamura *et al.*, 2009; Michiguchi and Ogawa, 2011). Normal fault trending NNW-SSE cut these duplexes and thrust trending E-W.

The structures observed at the Ubajima Islands should be formed in the following steps. Stage 1 (formation of multiple fault-bend folds (duplex structures)): The formation of the antiformal stack underneath resulted in development of multiple fault-bend folds for a series of duplexes during a period of N-S trend compression. Stage 2 (formation of fault-propagation fold): Fault related deformation induced by large scale folding and associated thrust was formed. Synclines of the Odaira Island in western area and the Ujima Island in eastern area and anticline in intermediate area were developed at this stage. Stage 3: Normal faults trending N-S were formed under an E-W compression after the changes of stress field, which is thought to stem from collision of Izu Arc, and is correlated with an E-W trending normal fault observed in Sagami Bay (Mori *et al.*, 2010).

Maximum principal stress axis (σ_1) inferred from the fold axis (average N36E) is oriented NE-SW, which is corrected N-S compressional stress field considering rotational angle of 55 degrees in a clockwise direction estimated at the Oiso Hills (Koyama *et al.* 1986). It corresponds with stress field in the South Fossa Magna before 1 Ma (Mori *et al.*, 2010, 2012)

[Reference]

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Keywords: Sagami Bay, Ubajima, Misaki Formation, duplex, thrust-anticline, accretionary prism

Duplexes and other geologic structures in the Misaki Formation of the southernmost Miura Peninsula: Revisited

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The Jogashima Island in the southernmost Miura Peninsula, Miura City, Kanagawa Prefecture has been studied since Kodama (1968) and many others. We independently studied the geologic structures of the Misaki Formation for these 40 years (Ogawa & Taniguchi 1988; Hanamura & Ogawa, 1993; Stow et al., 1998; Yamamoto et al., 2009), and reached many interesting conclusions including duplex structures. They are summarized as follows; The Tsurugizaki anticline trends not westward but northwestward in an en echelon pattern, whose south wings dip steeply while north wings gently dip, similar to the Nankai prism toes (Kawamura et al., 2009; Anma et al., 2011). The Toriya anticline is overturned southward, displaying many thrust faults and duplex structures, as the western extension of the Sengen thrust as a fault-propagation fold (Yamamoto et al., 2005). Not all the thrust duplex structures have south-vergency but some north, also resembling the Nankai. Both thrust duplexes and conjugate thrust systems have northwest-trending P-axes in horizontal reference frame (Ogawa & Horiuchi, 1978). Those duplexes and thrust faults are either of tectonic origin or slump origin, the latter may relate to liquefaction and mud-diapirism. At Awazaki, easternmost tip of the Jogashima, the subsequent Misaki Formation is eroded more than 300 m with 30 degrees discordance, suggesting the anticline-syncline formation began during deposition of the superjacent Hatsuse Formation. N-S or N30E-trending left-lateral fault system that is overwhelmed in the peninsular and Tokyo Bay areas to the Sagami trough as discussed by Mori et al (2010). As a result both the Miura and Boso tectonics are characterized by the Izu forearc collision, but the internal structures are similar to those in the Nankai prism (Yamamoto, 2005; Yamamoto et al., 2009; Michiguchi and Ogawa, 201).

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Keywords: Jogashima Island, Misaki Formation, duplex, thrust system, fault-propagation fold

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

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Introduction Mongolia occupies a part of the Central Asian Orogenic Belt and consists of complicated collage of terranes. Despite various previous geological studies, we do not share a common scenario on the origin and assemblage process of these terranes. This study aims to clarify the origin and tectonic evolution of an accretionary complex (AC) in north-central Mongolia from detrital zircon geochronology.

Geologic setting North-central Mongolia consists of the following three terranes: **Haraa** and **Bayangol terranes** consisting of shallow-marine formations and an AC with many pyroclastic-rock layers, and **Khangai-Khentei terrane** consisting of an AC overlain by shallow-marine formations. The AC of the Khangai-Khentei terrane trend northeast and dip north. The pelagic chert of the AC yields Late Silurian conodonts and Early-Late Devonian radiolarians (Kurihara et al., 2009), whereas the overlying mudstone yields Early Carboniferous brachiopods.

Method We extracted detrital zircons from 13 sandstone samples of the accretionary units in the Khangai-Khentei (6 samples), Haraa (5), and Bayangol (2) terranes and measured their U-Pb ages with the Laser Ablation Inductively Coupled Plasma Mass Spectrometer equipped in the Graduate School of Environmental Studies, Nagoya University. In addition, we compiled detrital-zircon-age data of 19 sandstone samples from previous studies (Kelty et al., 2008; Bussien et al., 2014).

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 showed this pattern. The other was a unimodal pattern with a large single peak between the Devonian and Early Triassic and has virtually no Precambrian zircons, indicative of an oceanic-island-arc setting. Eleven samples from the lower part of the AC showed this pattern.

Discussion We assumed, from the volcanoclastic nature of most of the sandstone samples, that the youngest peak of the spectrum is the depositional age of each sample. The depositional ages of multimodal-type sandstone clustered at 526-426 Ma, whereas those of unimodal-type sandstone clustered at 409-374 Ma (Early Devonian), 358-339 Ma (Early Carboniferous), and 289-245 Ma (Early Permian-Early Triassic). Moreover the depositional age clearly showed a downward-younging age polarity. There is a rough coincidence between the older time-interval (404-348 Ma) and the hiatus of Paleozoic igneous activity in the Tuva-Mongol Massif to the northeast of the study area (385-350 Ma). These facts indicate that the studied AC intermittently grew downwards in front of the Tuva-Mongol Massif. The multimodal-type sandstone, on the other hand, settled in the Cambrian-Ordovician and contained Pan-African (550-750 Ma) zircons indicative of their derivation from Gondwana. Among Cambrian-Ordovician sandstone along the northern Gondwana margin, that of the Kufra Basin in the Saharan Metacraton has close similarity with that of north-central Mongolia. The detrital zircons from the Kufra Basin have age peaks at 450-750 Ma, 800-1000 Ma, 1600-2200 Ma, and 2300-2800 Ma. This study hence concludes that the unimodal-type AC of north-central Mongolia grew along the subduction zone in front of the oceanic island arc of the Tuva-Mongol Massif, rifted from the Saharan Metacraton in the northern margin of Gondwana.

Keywords: U-Pb age, detrital zircon, LA-ICP-MS, Mongolia, CAOB, province

Detrital zircon geochronology of Early Mesozoic evolution of a northeastern part of the Pangea Supercontinent

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Introduction In the Paleo-Mesozoic succession of the South Kitakami Belt in NE Japan, the detrital-zircon-age-distribution pattern on a probability density plot changed from multimodal type II (see below for pattern names; Silurian-Carboniferous) through unimodal (Permian-Lower Jurassic) to bimodal (Middle Jurassic-Lower Cretaceous). Okawa *et al.* (2013 *Mem. FPDM*) explained these transition by the Middle Jurassic collision of Gondwana-derived (multimodal) oceanic island arc (unimodal) with Asia (bimodal). This study reviews similar temporal transition in geologic belts of Japan and Mongolia and discusses Early Mesozoic assembly of a northeastern part of the Pangea Supercontinent.

Method We measured the LA-ICP-MS U-Pb age of detrital zircons at the Earthquake Research Institute of the University of Tokyo and the Graduate School of Environmental Studies of Nagoya University.

Age-distribution patterns

The unimodal type consists of a single peak at the age of deposition, indicating an environment along the active margin of an oceanic island arc.

Multimodal type I consists of large peaks at the age of deposition, 500 Ma, and 900 Ma, indicating an environment along a margin of the **Khanka-Jiamusi Block**, which was likely a part of Gondwana and contains 500-Ma and 900-Ma igneous and metamorphic rocks.

Multimodal type II consists of a large peak at the age of deposition and small Neo- to Paleoproterozoic peaks, indicating an environment along a margin of Gondwana.

The bimodal type consists of large peaks at the age of deposition and Paleoproterozoic, indicating an environment along a margin of the **North China Block**.

Temporal and special change of age-distribution patterns

North-central Mongolia: The pattern in a downward-younging accretionary complex (AC) changes from multimodal type I (Cambrian-Silurian) to unimodal (Devonian-Early Triassic; Ueda *et al.*, 2015 *JpGU*). North-central Mongolia has widely been cut by Triassic-Jurassic granitoids.

Hida Gaien Belt: The pattern changes from unimodal (Middle Permian-Lower Triassic) to multimodal type I (Middle Triassic; Kawagoe *et al.*, 2013 *Mem. FPDM*).

Renge Belt: The pattern changes from multimodal type II (Devonian: depositional age) to bimodal (Lower Jurassic cover).

Akiyoshi Belt: The pattern changes from unimodal (Permian AC) to bimodal or multimodal type I (Upper Triassic cover).

Suo Belt: The pattern of downward-younging metamorphic rocks changes from unimodal (Permian) to bimodal (Triassic-Jurassic; Obara *et al.*, 2012 *JpGU*).

Ultra Tamba and Tamba belts: The pattern of a downward-younging AC changes from mostly unimodal (Permian) to bimodal or multimodal type I (Triassic-Jurassic).

Northern Chichibu Belt: The pattern of a downward-younging AC changes from unimodal or multimodal type I (Permian) to bimodal (Jurassic; Morita *et al.*, 2012 *JpGU*; Yokogawa *et al.*, 2013 *JpGU*).

Discussion The above data set suggests that the Middle Paleozoic of Japan and Mongolia (Central Asian Orogenic Belt: CAOB) was mostly formed along a margin of Gondwana. The paleobiogeographic analysis of Williams *et al.* (2014 *Isl. Arc*) indicates close affinities between Ordovician-Devonian strata of Japan and CAOB. Because Late Paleozoic igneous activity in East Asia is only recorded in CAOB and Hainan Island-Malay Peninsula region (Ikeda *et al.*, 2015 *JpGU*), we suggest that the Late Paleozoic AC's of Japan and Mongolia formed oceanic island arc-trench systems together with some "island-arc terranes" in the CAOB. Triassic-Jurassic times are characterized by (1) introduction of Precambrian zircons to the sandstones in Japan and (2) wide occurrence of igneous rocks in the North and South China blocks (Ikeda *et al.*, 2015 *JpGU*). These facts suggest the successive collision of the above oceanic island arcs with supercontinent Pangea, including the North and South China blocks. Further study will clarify the timing of introduction of Precambrian zircons to each geologic belt and collision of each oceanic island arc.

Keywords: U-Pb age, detrital zircon, LA-ICP-MS, accretionary complex, Japan, CAOB

Provenance analysis of Jurassic-Cretaceous formations in Japan using detrital-zircon-age spectra

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Several patterns of detrital-zircon-age distribution are discriminated of pre-Jurassic clastic rocks of Japan and Mongolia, and transition of the tectonic setting of each geologic body or stratigraphic succession can be traced from the temporal change of these patterns. In the following geologic belts, the pattern changed from (1) a multimodal pattern with Meso- and Neoproterozoic small peaks through (2) a unimodal pattern to (3) a bimodal pattern without Meso- and Neoproterozoic zircons: the Hida Gaien, Renge, Akiyoshi, Suo, Ultra Tamba-Tamba, and Northern Chichibu belts of Japan and north-central Mongolia. Okawa *et al.* (2013 *Mem. FPD*), Kouchi *et al.* (2015 *JpGU*), and Ueda *et al.* (2015 *JpGU*) interpreted that the transition indicates the following tectonic evolution: (1) Gondwana margin ->rifting ->(2) oceanic island arc ->collision ->(3) northeastern margin of Pangea.

From the Triassic, the northeastern margin of Pangea or Laurasia changed to a large igneous province and the provenance analysis with detrital-zircon-age distribution become more difficult. However, compilation of the zircon U-Pb ages of igneous rocks in (present-day) East Asia has revealed certain provinciality at the age of igneous rock bodies. On the other hand, we made classification of Jurassic-Cretaceous geologic units in Japan from a simple verification of the similarity in detrital-zircon-age distribution. By comparison of a certain detrital-zircon-age spectrum with the age-distribution of igneous rock bodies in East Asia, we induced the provenance that could make the age spectrum. Moreover, we induced relative displacements of geologic bodies from the analysis of provenance transition of each geologic belt or stratigraphic succession.

Ikeda *et al.* (2015 *JpGU*) presented preliminary results of our study. In the poster presentation, we will introduce and discuss the detailed results.

Keywords: detrital zircon, U-Pb age, East Asia, Jurassic, Cretaceous, tectonics

U-Pb geochronology of detrital zircons from the Lower Cretaceous formations of the Chichibu-Shimanto belts, SW Japan

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Introduction The Japanese Islands record signs of Cretaceous igneous activity and crustal movements. To decode the Cretaceous tectonic evolution, we have started the provenance analysis of the Lower Cretaceous formations in the Chichibu-Shimanto belts from detrital-zircon-age spectra.

Samples

Northern Chichibu Belt:

Sebayashi Formation (Fm.) (01) and Sanyama Fm. (02) of the Sanchu Cretaceous; Idaira Fm. (03); Ryoseki Fm. (04), Monobe Fm. (05), Yunoki Fm. (06), and Hibihara Fm. (07) of the Monobegawa Group; Haidateyama Fm. (08)

Kurosegawa Tectonic Belt:

Birafu Fm. (09), Funadani Fm. (10), and Hagino Fm. (11) of the Nankai Group; Yamabu Fm. (12)

Southern Chichibu Belt: Torinosu Group (13)

Shimanto Belt: Doganaro Fm. (14)

Results We measured the U-Pb age of zircons with the LA-ICPMS equipped in the Graduate School of Environmental Studies, Nagoya University. We discriminated three patterns of detrital-zircon-age spectra.

Pattern I contains some 70% of Early Cretaceous zircons (02 and 07).

Pattern II contains more than 40% of Jurassic zircons and minor (15%) Early Cretaceous zircons (01, 05, 06, 09, and 11).

Pattern III contains some 70 % of Permo-Triassic zircons (03, 04, and 08).

Pattern IV contains all the remaining spectra (10, 12, and 14). See the attached figure for details.

Age distribution of igneous rocks in East Asia

Paleoproterozoic: Widely in the North China Block and Korean Peninsula; sporadically in the South China Block.

Permian: Hainan Province in SE China to the Malay Peninsula and the Maizuru and Akiyoshi Belts in SW Japan.

Triassic: Western Guangdong and Hunan provinces in SE China, Northeast China, the Korean Peninsula, and Hida-Hida Gaien Belts in SE Japan.

Jurassic: Northeastern to eastern Guangdong Province, Northeast China, and the Korean Peninsula.

Early Cretaceous: (140-120 Ma) Part of Guangdong Province and Anhui-Zhejiang provinces in China, and Kitakami Mountains in NE Japan; (120-110 Ma) Zhejiang Province and Kitakami Mountains; (110-90 Ma) Zhejiang-Fujian-Guangdong coast and the Abukuma and a part of the Higo-Ryoke belts in Japan.

Provenance analysis The 158-110 Ma magmatic hiatus in Korea (Sagong *et al.*, 2005 *Tectonics*) precludes the Korean Peninsula from the provenance of the sandstone with Early Cretaceous zircons. The pattern I spectrum indicates the deposition **near the Zhejiang Province** with abundant Early Cretaceous (120-110 Ma) igneous rocks.

The pattern II spectrum indicates the deposition **near the Guangdong-Fujian provinces** with abundant Jurassic and minor Early Cretaceous (130-120 Ma) plutons.

Among the pattern IV samples, the provenance of 10 and 12 was likely the Guangdong-Hainan coast, because the two samples contained Permian to Jurassic zircons. For sample 13, the inclusion of 48% Paleoproterozoic zircons likely indicates its deposition near the **Korean Peninsula**, although the derivation of Jurassic zircons (34%) from the **Guangdong Province** cannot be ruled out.

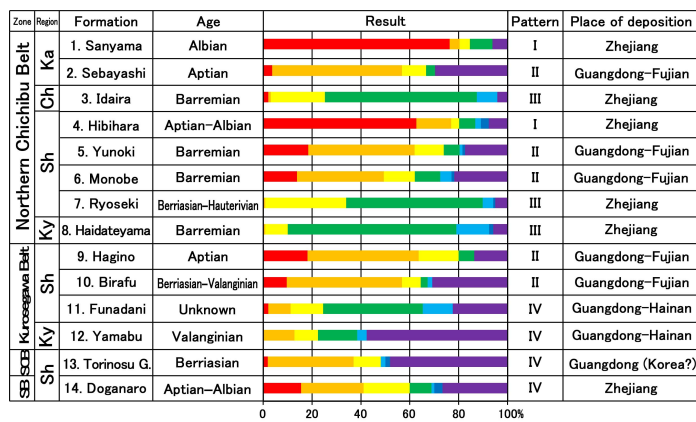
In the pattern III spectrum, on the other hand, only Permian (270-240 Ma) peak predominated. However, there is no place in and around China where Permian igneous rocks predominate. We propose that the Permian zircons in pattern III were originated from the Permian sandstones in the accretionary complex (AC) of the Northern Chichibu Belt, because 1) the Ryoseki Fm. unconformably covers the Permian AC (Yamakita, 1998 *JGSJ*) and the clasts in the Monobegawa Group were likely supplied from the AC (Matsukawa and Tsuneoka, 1993 *Mem. GSI*), and 2) the sandstone in the Permian AC contains abundant Permian zircons (Morita, 2012 *JpGU*). Moreover, the Idaira Fm. (03) of pattern III contains small amounts of 120 Ma zircons, suggesting that the Permian AC was in front of the Early Cretaceous igneous rocks of the **Zhejiang Province**.

Keywords: U-Pb age, detrital zircon, LA-ICP-MS, SW Japan, Lower Cretaceous

SGL40-P04

Room:Convention Hall

Time:May 27 18:15-19:30



SCB: Southern Chichibu Belt, SB: Shimanto Belt, Ka: Kanto region, Ch: Chubu region, Sh: Shikoku region, Ky: Kyushu region
 ■ Cretaceous ■ Jurassic ■ Triassic ■ Permian ■ 540-300 Ma ■ 1600-540 Ma ■ -1600 Ma

Zircon U-Pb geochronology of Nagasaki Metamorphic Rocks and related geological units in Kyushu, SE Japan

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Introduction Nagasaki Metamorphic Rocks (NMR) occupy the Nishisonogi (NsP) and Nomo (NmP) peninsulas of Nagasaki Prefecture and the western part of the Amakusa Shimoshima Island (ASI) of Kumamoto Prefecture, SW Japan. Nishimura et al. (2004), Takeda et al. (2002), and other researchers proposed that NMR consist of Late Cretaceous Sambagawa Metamorphic Rocks (SMR), Early Cretaceous Higo Plutonic Rocks, Triassic Suo Metamorphic Rocks, and Late Cambrian Metagabbro Complex. In addition, Late Cretaceous-Paleogene sedimentary rocks cover NMR. In this study we measured the zircon U-Pb ages of NMR and related rocks and to propose a model of tectonic evolution of NMR.

Geologic Setting Geologic setting of each distribution area of NMR is as follows.

The NsP consists of SMR and Late Cretaceous Oseto granite, in apparent ascending order, and the Paleogene cover of the Akasaki, Terashima, Matsushima, and Nishisonogi groups.

The NmP consists of SMR, Higo Plutonic Rocks, Suo Metamorphic Rocks, and Nomo Metagabbro Complex, in apparent ascending order, and the overlying Upper Cretaceous Mitsuzue and Paleogene Koyagi formations and Paleogene Takashima and Iojima groups.

The ASI consists of SMR, Higo Plutonic Rocks, Upper Cretaceous Himenoura Group, and Paleogene sedimentary rocks, in apparent ascending order.

Materials and method The samples we studied were as follows.

ASI: SMR

NmP: Metagabbro Complex from the eastern and western coasts, and a metamorphic-rock cobble from the Lower Eocene Koyagi Formation

The U-Pb age was measured with the LA-ICP-MS equipped in the Graduate School of Environmental Studies, Nagoya University.

Age dating results

SMR from the ASI: The age composition of zircons (%) was as follows: Early Cretaceous (7.1), Jurassic (30.3), Triassic (19.6), Permian (7.1), Paleoproterozoic (33.9), and Archean (1.8). The youngest zircon age (YZ) was 117.4 +/- 3.7 Ma.

Metamorphic-rock cobble: The age composition of zircons was as follows: Late Cretaceous (18.4), Early Cretaceous (47.4), Jurassic (7.9), Triassic (10.5), Permian (5.3), Carboniferous-Cambrian (2.6), and Paleoproterozoic (7.9). The youngest zircon age was 87.4 +/- 2.0 Ma.

Metagabbro Complex: U-Pb data from three spots out of five gave the concordia age of 526 +/- 19 Ma.

Discussion

NsP: SMR with the YZ of 74 Ma (Late Cretaceous) lacked zircons of 130-160 Ma (including the magmatic hiatus in Korea: 110-158 Ma; Sagong et al., 2010), suggesting that the protolith was deposited in the trench near the Korean Peninsula in the Late Cretaceous (Kouchi et al., 2011). The Oligocene Matsushima Group contains pebbles of metamorphic rocks (Nagahama, 1962).

NmP: The metamorphic-rock cobble differed from the SMR of ASI and NsP, because it contained many Late Cretaceous zircons. The cobble bearing bed has paleocurrent indicators showing that the cobble was derived from SMR in the NmP (Nagahama, 1965). The SMR in the NmP were hence exhumed by the Early Eocene.

ASI: SMR in the ASI contained zircons formed during the magmatic hiatus in Korea and may have had different hinterland from the SMR in the NsP. 110-158 Ma igneous rocks widely occur in Zhejiang-Guangdong provinces Southeast China, suggesting that the protolith of the SMR in the ASI was deposited in the trench off Southeast China in the Early Cretaceous (around 117 Ma). In the ASI, the Late Cretaceous Himenoura Group contains pebbles of metamorphic rocks (Yamaguchi et al., 2008).

Tectonic evolution of the SMR in NMR: The protolith of the SMR in NMR was deposited after 121 Ma in different parts of the trench along the eastern margin of Asia, metamorphosed, and was successively exhumed in latest Cretaceous-Oligocene times in the ASI ->NmP ->NsP.

Metagabbro Complex: The complex (ca. 500 Ma) in the eastern part of the NmP occurs along the axis of a small syncline, suggesting that the complex as a whole occupies the uppermost part of NMR as a low-angle sheet-like body.

Keywords: U-Pb age, zircon, LA-ICPMS, Nagasaki metamorphic rocks, Sanbagawa metamorphic rocks

Sr-Nd-Pb isotopic ratios of the Miocene accretionary complex on southern Boso Peninsula, Japan

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In the southern regions of the Boso peninsula, shallow levels of the accretionary prisms and their cover sediments, which were formed in the late Miocene age, are exposed (Yamamoto and Kawakami, 2005; Yamamoto et al., 2005). These strata are valuable in that they preserve much of the original physical information (Yamamoto 2003). This means that they can provide information about the ongoing accretionary process under the floor of deep sea as an analogue. We conducted Sr-Nd-Pb isotope analysis of mudstones from the accretionary prisms and their cover sediments on the Boso peninsula with the aim of reinforcing the existing lithologic classification (e.g., Mitsunashi, 1989; Saito, 1992). Isotope ratios of Sr, Nd, Pb in detrital fine particles preserve their original source-area signatures. Mudstones were taken from the Aokiyama Formation of the Hota Group, the Nishizaki Formation, the Kinone Formation and the Amatsu Formation of the Miura Group. The former two formations are supposed to be the accretionary prism sediments, and the latter two are their cover sediments. The Nishizaki Formation, the Amatsu Formation, and the Kinone Formation can be differentiated each other by considering comprehensively the Sr-Nd-Pb isotope ratios. The mudstones of the Nishizaki Formation show higher Sr and Pb isotope ratios than the Amatsu Formation. Mudstones of the Kinone Formation is characterized by lower isotope ratios of Pb than those of the Nishizaki and Kinone Formations of similar isotope ratios of Sr and Nd. In the Kinone Formation, Sr isotope ratio of mudstones increases, while Nd isotope ratio of them decreases westward. This suggests that the sediment feeding system of the Kinone Formation was different between east and west. Unlike the others, the Aokiyama Formation shows large isotopic variation. This makes differentiation of the Aokiyama Group from the others difficult. The isotopic ratios of the Aokiyama Formation may be influenced by diagenesis due to deep burial.

Keywords: accretionary prism, Sr-Nd-Pb isotope ratios, The Miura Group, The Hota Group

Paleostress study with the multiple inverse method using fault-slip data from southern end of Miura peninsula

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Kenzaki anticline, which is ~8km along with a E-W trend, is located at the south end of Miura peninsula, Kanagawa prefecture. Around Kenzaki anticline, some researches on paleostress have been done using the conjugate fault method (Kodama, 1968; Kuniyasu, 1980). However, new methods which solved the theoretical problems of the conjugate fault method have not been applied to Kenzaki anticline area. In this study, the multiple inverse method(Yamaji, 1999) is applied to the fault-slip data from limbs of Kenzaki anticline and some paleostresses are detected. The order of these paleostresses and its relation to the formation of Kenzaki anticline are considered from the result of this method and cross cutting relation among observed faults.

Chronology of Early Cretaceous tectonic evolution of the North Kitakami Belt, Northeast Japan

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Introduction We measured the U-Pb zircon age of Lower Cretaceous rocks (part of which is age unconstrained) in the Taro-Tanohata area of the North Kitakami Belt, Northeast Japan, to constrain the age of tectonic evolution. The rock units we studied are the Omoto (sandstone) and Harachiyama (sandstone and dacitic lapilli tuff) formations, the Taro pluton (diorite), and the Raga Formation of the Miyako Group (sandstone).

Geologic Setting Jurassic to earliest Cretaceous accretionary complex (AC) and Early Cretaceous plutonic and shallow-marine sedimentary rocks occur in the Taro-Tanohata area. The Omoto Formation consists of sandstone, mudstone, and minor felsic pyroclastic rocks. The formation was correlated with the Berriasian-Valanginian because of its stratigraphic position and the common occurrence of the Ryoseki-type flora with the Berriasian-Valanginian Ayukawa Formation of the South Kitakami Belt (Sugimoto, 1974). The overlying Harachiyama Formation consists mainly of andesitic to dacitic lava and pyroclastic rocks with the K-Ar hornblende age of 122 ± 5 Ma although the age has been interpreted to be of contact metamorphism by later granitic plutons. (Shibata et al., 1978). The Taro diorite cutting the two formations has K-Ar hornblende ages of 120-110 Ma (e.g., Kawano and Ueda, 1965). The Miyako Group, covering the Taro diorite, yields ammonoids such as *Hypacanthoptes subcornuerianus* and *Valdedorsella akuschaensis* and has been correlated with the Upper Aptian-Albian (Hanai et al., 1968). In summary, the magmatic or depositional age of the Early Cretaceous rocks except for that of the Miyako Group has not well been constrained.

Age determination The U-Pb age of igneous detrital zircons extracted from the studied rock units was measured with the LA-ICP-MS equipped in the Graduate School of Environmental Studies of Nagoya University. The results were as follows. The age of the youngest zircon from the sandstone sample of the Omoto and Harachiyama Formations was 132.3 ± 3.5 Ma and 119.0 ± 4.7 Ma, respectively. The zircon ages from the lapilli tuff sample of the Harachiyama Formation clustered around 126 Ma and 133 Ma, with the concordia age of the former cluster (5 grains) of 126.3 ± 2.0 Ma. The zircon ages from the Taro diorite clustered around 120 Ma and 128 Ma, with the concordia age of the former cluster (5 grains) of 121.0 ± 2.2 Ma. The age of the youngest zircon from the sandstone sample of the Raga Formation of the Miyako Group was 117.5 ± 3.1 Ma.

Discussion Previous studies have proposed that the Omoto and Harachiyama formations, together with the underlying AC, were involved in NS-trending folding and sinistral strike-slip shearing. Granitic plutons cut these geologic units and structures coevally with NS-trending dip-slip shearing (e.g., Minoura and Tsushima, 1984). Our new U-Pb data constrain the age of tectonic evolution as follows. The Omoto Formation was deposited at 136 Ma (Valanginian) or later and was covered with the Harachiyama Formation with the dacitic lapilli tuff of 128.2-124.2 Ma (Barremian-Early Aptian) and sandstone of 123.7 Ma (Early Aptian) or younger. NS-trending folding and sinistral shearing followed and were cut by Taro diorite at 121.2 ± 2.2 Ma (Aptian) coevally with NS-trending dip-slip shearing. Finally the Miyako Group covered all of the above elements at 120.6 Ma (Late Aptian) or later.

Keywords: U-Pb age, zircon, LA-ICP-MS, Northeast Japan, North Kitakami Belt

Stratigraphy of the Tetori Group in the Nagano area, Ono City, Fukui Prefecture, Central Japan

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The Middle Jurassic to Lower Cretaceous Tetori Group is distributed in the Jinzu and Hakusan regions. The Group is divided into the Kuzuryu, Itoshiro, and Akaiwa Subgroups in ascending order (Maeda, 1961).

The Nagano area is located in the upper reaches of the Kuzuryu River. It is known the Kuzuryu, Itoshiro and Akaiwa Subgroups are distributed in the Nagano area in ascending order (e.g. Yamada et al., 1989 ; Fujita, 2002 ; Matsukawa et al., 2006). It is also known the formation in the area contains ammonite fossils. The formation containing Bathonian-Calloviaian ammonite fossils is regarded the Kaizara Formation or Middle Formation of the Kuzuryu Subgroup. However, the ammonite in the formation shows the geological age of Oxfordian (Sato and Westermann, 1991). Therefore, the formation is younger than the Kaizara Formation.

The Itoshiro area is type locality of the Kuzuryu and Itoshiro Subgroups. There are problem of stratigraphical correlation.

The Tetori Group in the Nagano area is divided into the A , B and C Formations in ascending order. The A Formation consists of mudstone. The B Formation consists of alternation of sandstone and mudstone. The C Formation consists of alternation of conglomerate, sandstone and siltstone. The A Formation contains molluscan fossils and trace fossils. Thickness of the A Formation is over 360m. The B Formation contains trace fossils in the lower part, leaf fossils in the middle to upper part. The B Formation also contains roots in the upper part. Thickness of the B Formation is 280 to 380m. The C Formation scraped the B Formation. The lowest part of the C Formation contains cobbles. Siltstone of the C Formation contains leaf fossils. Thickness of the C Formation is over 190m. The A, B and C Formations are limited by monoclinical structure. The structure has E-W strike and N dip.

The result of lithostratigraphical correlation, the A Formation to the C Formation in the Nagano area is similar to the Kaizara Formation to the Yambara Formation in Itoshiro area. However, there are some difference including lithostratigraphy, conglomerates and fossils. We found the change of marine sediments to continental sediments, because B Formation contains trace fossils and roots. We reviewed lithostratigraphical correlation between formations in Nagano and Itoshiro areas. Result of conglomerates correlation in the B and C Formations, they are granite-dominant type. However, the amount of chert becomes larger to the C Formation. This changing pattern is similar to Fujita (2002). On the other hand, the changing pattern is upperpart of the Ashidani Formation to the Obuchi Formation in Fujita (2002). It is not harmonic in lithostratigraphy.

There is a little gap in the two areas such a lithofacies and geological age. Therefore, we think the setting of basin is similar between the Itoshiro and Nagano areas. We need to survey in the Kamihambara area.

Keywords: Tetori Group, Kuzuryu Subgroup, Itoshiro Subgroup, Stratigraphy, Conglomerates, Nagano area

Geologic age of the Nishino-omote Formation in the Tanegashima Island based on radiolarians and calcareous nannofossils

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¹Chiba University, ²Utsunomiya University

<Introduction>

The Paleogene Kumage Group (Hanzawa, 1934) is widely distributed in the Tanegashima Island, Kagoshima Prefecture, southwest Japan. The Kumage Group is divided into the Kadokurazaki, Tateishi, and Nishino-omote Formations in ascending order (Okada, 1982). Because of the lack of detailed lithological distribution map and reliable chronological data of the formations, geological structures and ages of them are still unclear. In this study, detailed field observation of the northern part of the Tanegashima Island was carried out and we also examined radiolarians and calcareous nannofossils from the Nishino-omote Formation in order to clarify its geological age.

<Materials and Methods>

A total of 110 mudstone were collected from mudstone dominant intervals of the Nishino-omote Formation and we examined radiolarians and calcareous nannofossils. To avoid collecting turbidite mudstone, monotonous, intensely bioturbated mudstones were selected. Fifty and 60 samples were used for analyses of radiolarians and calcareous nannofossils, respectively.

<Results and discussion>

Detailed geological survey revealed that a lot of NNE-SSW trending fold structures and thrust faults were developed in the northern part of the Tanegashima Island and an interval of "trace fossils concentration beds" is repeatedly recognized as a key horizon in the studied area. Thus, total thickness of the Nishino-omote Formation by previous study is overestimated. Within the examined samples, 11 samples contain radiolarians fossils. Occurrences of *Artophrmis gracilis*, *Eucyritidium plesiodiaphanes*, *Theocyrtis setanios*, *Theocorys perforalvus* and *Lithocyclia angusta* are recognized in a single sample from the upper part of Nishino-omote Formation and the preservation of the radiolarian fauna in this sample is moderately. Co-occurrence of *E. plesiodiaphanes* and *T. setanios* coincides with the radiolarian zone RP20c to RP21a (Kamikuri et al., 2012) and its age is considered to be 31.1 to 28.5 Ma. Calcareous nannofossils are observed only in 3 samples in the lower part of Nishino-omote Formation. Paleogene species consistently occur even though preservation of specimens is not good. *Sphenolithus distentus* and *S. predistentus* are stratigraphically important and geologic age of samples are 30.00-26.8 Ma based on total range of *S. distentus*.

Our field observation and microfossil investigation indicate that the Nishino-omote Formation seems to be deposited during a short period between 31.1 and 26.8 Ma and the Nishino-omote Formation is characterized by repetition of simultaneous intervals associated with holds and thrusts.

Keywords: Nishino-omote Formation, Kumage Group, Tanegashima Island, radiolarian, calcareous nannofossil

A Cretaceous cauldron in the Yanahara area,

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Cretaceous volcanic rocks (volcanic, pyroclastic and lesser sedimentary rocks) unconformable overlying the basement rocks composed of the Maizuru Group and the Yakuno complex are widely distributed in the region from Okayama to Hyogo Prefectures, central Chugoku, SW Japan.

Low gravity anomalies concordant with the thick Cretaceous volcanic rocks and the surrounding high gravity anomalies concordant with the basement rocks are observed in the Yanahara area, Okayama Prefecture (Ishikawa et al. 2014). These low gravity anomalies suggest concealed calderas (cauldrons) filled-up with ignimbrite. Its age was estimated as ca. 80Ma by the K-Ar dating of quartz diorite intruded into this ignimbrite. 3-D inversion analysis for gravity anomaly reveals that the cauldron floor lies 1 to 3km deep (Ishikawa et al. 2014b).

The lithofacies and geologic structure of the Cretaceous volcanic rocks in the Yanahara area are as follows. The volcanic rocks in this area consist of welded tuff, crystal tuff, andesite lava, rhyolite lava, tuffaceous sandstone, lapilli stone and lapilli tuff, in ascending order. The felsic rocks are dominant in these secessions, whereas the andesite lava is not so thick as the previous study described (Okayama Geologic map project, 2009). The rhyolite lavas laterally attenuate and change to well-bedded rhyolitic lapilli stones and tuffaceous sandstones.

These volcanic, pyroclastic and epiclastic sedimentary rocks, which gently incline northward in the main part, shows nearly vertical attitude along the basement rocks. Some ring dikes of quartz porphyry and andesitic porphyry are also found along these boundary faults, and some fracture zones intercalating fault breccias are observed in the peripheral basement rocks. These structures suggest the syn-eruptional subsidence along the boundary faults. No unconformable relationship is observed. The fault displacement is estimated more than 1km by the borehole evidence (MMAJ 1980).

Keywords: cauldron, Yanahara, Cretaceous volcanic rocks

Greenstone melange of the Atogura Nappe in the Iyou district, Saitama Prefecture, central Japan

ONO, Akira^{1*}

¹None

The Atogura Nappe in the northeastern margin of the Kanto Mountains consists of various kinds of geological units. The Kiroko greenstone melange is a geological unit distributed in the southern part of the Atogura Nappe. It is composed of the Kiroko metamorphic rocks, serpentinites and various kinds of tectonic blocks. The Kiroko metamorphic rocks mainly consist of weakly metamorphosed slate, sandstone, mixed rock, chert, greenstone and actinolite rocks. These rocks are usually exposed separately. However, slate, psammitic rock, mixed rocks, chert, greenstone and conglomerate of serpentinites are conformably piled up at locations *a* and *f* of Figure-Kiroko. Hornblendite, amphibolite, epidote amphibolite, psammitic metamorphic rocks, meta-tonalite and acidic tuff are representative tectonic blocks. The Kiroko metamorphic rocks and tectonic blocks were intruded by serpentinites.

The important geological data obtained to date for the Kiroko greenstone melange are as follows. 1) The K-Ar whole rock age of a greenstone at loc.*a* is 57.4Ma. Thin pelitic lenses mainly consisting of fine-grained actinolite, chlorite, white mica, carbonaceous material and quartz exist in the studied greenstone. The dating result suggests that the Kiroko metamorphic rock is a member of the Sanbagawa metamorphic rock. 2) The K-Ar hornblende age of a small amphibolite block included in an actinolite rock is 402Ma. 3) A thin layer of muscovite-biotite-garnet schist was found in a psammitic metamorphic rock exposed in the Iyou area, Higashi-chichibu village. The K-Ar age of white mica from the muscovite-garnet schist is 109Ma (Figure-Iyo). The metamorphic rocks are considered to be members of the Higo- Abukuma metamorphic belt [1,2].

The following facts are revealed by a recent geological study of the Iyou area (Figure- Iyo). (a) Psammitic metamorphic rocks and thin aplitic granites are distributed in the northern part of the Kiroko greenstone melange. The metamorphic and granitic rocks show no evidence for suffering from the Kiroko metamorphism. (b) Similar metamorphic and granitic rocks occur as a small block of approximately 30m long and 12m wide to the south of the above mentioned psammitic metamorphic rocks. (c) A tectonic block of meta-tonalites was found to the southwest of the small psammitic metamorphic block. Plagioclases of the meta-tonalites are replaced by fine zoisite grains. Some meta-tonalites show mylonitic textures, but others show weak schistosity. In the latter case, most of plagioclase grains have many tension cracks which are filled with quartz and plagioclase. Chlorite-rich veins and pools are not rare. Edges of large amphibole crystals are replaced by colorless amphiboles. The K content of a whole rock sample is less than 0.05% by weight. (d) Floatstones of psammitic metamorphic rocks are found near the western part of the meta-tonalite.

The present study has revealed the existence of melange structures in the Iyou area. Allochthonous blocks were captured during the exhumation of the Kiroko metamorphic rock before the intrusion of serpentinite. The finding of tectonic blocks of mid-Cretaceous metamorphic and granitic rocks suggests that the intrusion of serpentinite and the exhumation of the Kiroko metamorphic rocks took place in the eastern marginal portion of the early Paleogene forearc region where Higo-Abukuma metamorphic and granitic rocks are distributed in the upper crust [1,2]. The shift of the Higo-Abukuma belt toward the late Cretaceous trench was caused by nappe tectonics.

[1] A. Ono, 2011, Abs. Geol. Soc. Japan, Meeting, R9-P-9, p. 196.

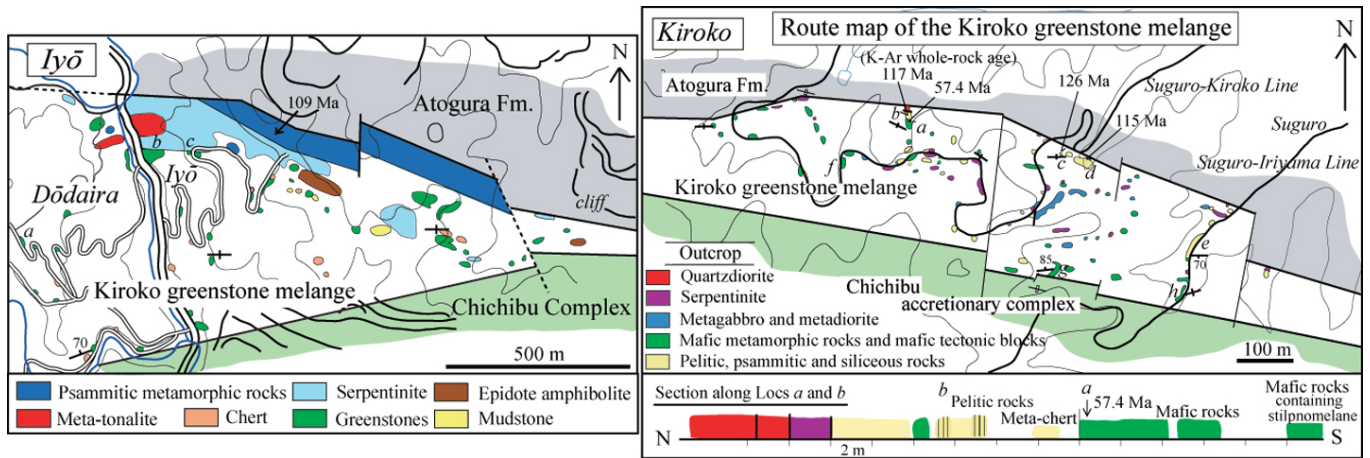
[2] A. Ono, 2013, Abs. Japan Geosci. Union Meeting, SMP43-P16.

Keywords: Atogura Nappe, Greenstone melange, Tectonic blocks, Higo-Abukuma Belt, Serpentinite

SGL40-P12

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Active and subsurface structure in the middle Ryukyu Islands around Yoron Island

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The Ryukyu arc lies along the Ryukyu trench in the south of Kyushu island. Geology in the middle Ryukyu arc consists of Chichibu belt, Shimanto belt and overlying limestones with sporadic igneous intrusions. Yoron island which locates in the questioned area have two active faults whose strikes are highly oblique each other and they are probable normal faults. To evaluate these active faults in terms of documenting present tectonic framework, we carefully reviewed topography, degree and direction of surface slope and gravity anomaly. As a result, accurate trace of the active faults is drawn. Positive free air gravity anomaly suggests plutonic body beneath the Yoron island although there is no outcrop on the island surface. This upwelling pluton can be a reason for the unexpected normal faults in this island.

Keywords: Shimanto Belt, Chichibu Belt, Active fault

Geology of the area of 1:200,000 quadrangle geological map of the Matsuyama district

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The Matsuyama district, located in the northwestern part of Shikoku Island and western part of the Seto Inland Sea, geologically comprise various rock types from Paleozoic to Quaternary in age.

The following Paleozoic units are distributed in the district, 1) Late Cambrian ultramafic rocks, 2) Late Devonian to Early Silurian plutonic-metamorphic complex, 3) Silurian to Devonian Okanaro Formation, 4) Early Permian high-pressure metamorphic complex, 5) Permian accretionary complexes.

Mesozoic units on the north side of the Median Tectonic Line (MTL) are 1) Cretaceous Ryoke Pluton-metamorphic Complex, and 2) Upper Cretaceous Izumi Group. Mesozoic units on the south side of the MTL are 1) Late Triassic to Early Jurassic high-pressure metamorphic complex, 2) Early to Middle Jurassic accretionary complex in the north Chichibu belt (Yusugawa, Sumiizuku, and Kamiyoshida units), 3) Middle Jurassic to Early Cretaceous accretionary complex in the south Chichibu belt (Ohirayama, Togano, Shirahigeyama, and Sanbosan units), 4) Early Cretaceous accretionary complex in the Shimanto belt, 5) Early Cretaceous high-temperature metamorphic complex, 6) Cretaceous Sanbagawa Metamorphic Complex (Iyo, Uchiko, Ozu, Hijikawa, and Mikabu units and Karasaki Mylonite), 7) Triassic shallow marine sediments, and 8) Jurassic shallow marine sediments, 9) Cretaceous shallow marine sediments (Nankai, Monobegawa, and Sotoizumi Groups).

The Jurassic to Early Cretaceous accretionary complexes tectonically underlie the mentioned-above Paleozoic units and early Mesozoic high-pressure metamorphic complex. The age of each Mesozoic accretionary complex becomes younger towards the apparent lower structural levels.

Neogene System in this area is divided into the Kuma and Ishizuchi Groups. The Kuma Group consists of three stratigraphic units of the Hiwadatoge (shallow marine calcareous sandstone), Furuiwaya (talus breccia) and Myojin Formations (conglomerate and lacustrine sediments) in ascending order. The Ishizuchi Group, horizontally overlies the Kuma Group unconformably, is composed of the Takano (tuff) and Kuromoritoge (welded tuff and andesite lava) Formations. These clastic and volcanoclastic sediments are intruded by a large number of andesitic to rhyolitic dykes and stocks.

The Setouchi-volcanic rocks in this area are olivine andesite, pyroxene hornblende andesite and biotite dacite. The reported radiometric ages of these rocks range from 16 Ma to 12 Ma, and most of them concentrate between 15.5 Ma and 14 Ma. The Gogoshima formation and the Takahama formation are composed of volcano-clastic rocks and volcanic rocks, which is similar to the Setouchi-volcanic rocks.

The early to middle Pleistocene fluvial sediments such as the Gunchu, Tomisuyama, Yakura, Torinoko and Iyoki Formations are exposed in the Matsuyama plain and in the middle to upper area of the Hiji River. The terrace deposits and Holocene sediments are distributed in and around the Matsuyama plain and sporadically along many rivers.

In the Matsuyama Plain, many E-W trending active faults are developed. These are called the Median Tectonic Line fault. This fault system extends to the Iyonada of the Seto Inland Sea.

In this area, two of mineralization belts are running to east and west. One is a Bedded Deposits of Cupriferous Pyrite in the Sanbagawa metamorphic complex, and another is bedded manganese ore deposit in the Jurassic accretionary complex in the southern Chichibu belt.

Large horizontal gradient zone of the Bouguer anomalies (assumed density 2.59 g/cm³) shown in central region corresponds to northern edge of the MTL. Northwestern part of the MTL shows negative anomalies and minimum value is approximately - 50 mgal near Iyo-nada in the Seto Inland Sea. Southeastern part of the MTL shows a mix of negative and positive anomalies in the middle and the other region, respectively. It is noted that small high anomalies correspond to areas of the Mikabu unit.

Keywords: Matsuyama, Geological map, gravity, active fault, mineral resource

Geological Map of Japan 1:200:000, Oita

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The Oita district, located in the northeastern part of Kyushu Island, geologically comprises various rock types of Paleozoic to Quaternary in age.

The following Paleozoic units are distributed: 1) Late Cambrian ultramafic rocks consisting of serpentinite and pyroxenite with small amounts of gabbro and amphibolite, 2) Late Devonian to Early Silurian Mikuni Cataclastic Granitic Rocks and Honjo Metamorphic Rocks, 3) Silurian to Devonian formations, 4) Permian accretionary complexes, and 5) Early Permian Usukigawa Quartz Diorite.

Mesozoic units on the north side of the UYTL (Usuki-Yatsushiro Tectonic Line) are 1) Cretaceous high-temperature, low-pressure Asaji Metamorphic Rocks and plutonic rocks and Cretaceous low-temperature and high-pressure Sanbagawa Metamorphic Rocks, and 2) a small body of an Early Jurassic accretionary complex of the Nishikawauchi Formation and cataclasite of Cretaceous quartz diorite mylonite.

Mesozoic units on the south of the UYTL are 1) Early Cretaceous high-temperature metamorphic rocks, 2) Late Triassic to Early Jurassic low-temperature and high-pressure metamorphic rocks, 3) Jurassic to Early Cretaceous and Cretaceous accretionary complexes, 4) Late Triassic, Late Jurassic and Cretaceous formations, and 5) Eocene formations. The Mesozoic accretionary complexes are younger approaching apparent lower structural levels, and the thrusts between the each accretionary complex originally dip gently northwest.

The Jurassic to Early Cretaceous accretionary complexes tectonically underlie the serpentinite complex composed of Paleozoic plutonic and metamorphic rocks, low-temperature and high-pressure metamorphic rocks, Permian accretionary complex and Paleozoic and Mesozoic formations.

The Miocene Okueyama Volcano?intrusion Complex is composed of effusive rocks, granitic rocks, and ring dikes. The Ono Volcanic Rocks comprise pyroclastic flow deposits, lava, and tuffaceous sediments.

The Late Pliocene and Early Pleistocene volcanic rocks are composed of Yoshinomoto Andesite, Kantodake Andesite, Hitomidake Andesite, the Shonai, Komatsudai, Tsuetate, Kusu, and Karutoyama volcano groups (VGs), and the Shishimuta Caldera. The Middle Pleistocene to Holocene volcanic rocks are the Tokisan, Kanagoe, Pre-Aso, Haneyama, Ogidake, and Waitasan VGs, the Amagoidake, Takasakiyama Volcano, the Noinedake, Tateishiyama, and Takahirayama VGs, the Ayukawa, Kamiyashiki, Nakatoge, and Yufugawa pyroclastic flow deposits (PFDs), and the Nekodake, Aso, Kuju, Yufu, and Tsurumi Volcanoes.

Pliocene to early Middle Pleistocene fluvial sediments, such as the Sekinan and Oita Groups, the Otagawa Formation, and Tanaka and Hiraishi Gravel members are exposed in the downstream basin of the Oita and Ono Rivers where marine sediments are included in and around the Kusu Basin and in the middle area of the Ono River.

In the northern part of the district, many E?W trending active normal faults are developed. This is called the Beppu?Haneyama Fault Zone.

This area is famous as a dense deposit zone. Especially, Tin deposits in the vicinity Furusobo San (Obira, Mitate and Toroku mine) and limestone of Tsukumi City (Todaka and Shintukumi mine) are well-known. In addition, oldest sulfur mine of Japan was present in the Kuju Volcano.

A high-gravity anomaly trending ENE-WSW is located in the northeastern part of this region. This high-gravity anomaly is consistent with the distribution of high-density metamorphic rocks. Four segments of low-gravity anomalies are observed in the northern part of the region. The northwest low-gravity anomaly segment may be a volcanic basin, namely the Shishimuta Caldera. The other three low-gravity anomalies correspond to tectonically formed basins. The low-gravity anomaly at the west edge of this region originated in the Aso caldera. A wide low-gravity anomaly is observed at Okue Yama in the southern part of this region. This low-gravity anomaly might reflect the physical property of batholithic mass beneath Okue Yama.

Keywords: regional geology, Sanbagawa Metamorphic Rocks, Onogawa Group, Cretaceous accretionary complex, Oita Group, Aso Caldera