Japan Geoscience Union Meeting 2014
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SMP46-P01 Room:Poster Time:April 28 18:15-19:30

Comparison of UHP chromitites from the Higo and Nishisonogi Metamorphic Rocks, Kyushu, Japan.

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We have found microdiamond - bearing ultrahigh-pressure (UHP) chromitites from two metamorphic terranes in Kyushu: the Higo (HMR)[1] and Nishisonogi (NMR)[2] Metamorphic Rocks. This paper describes the similarity and difference between the two UHP chromitites. The HMR are located in west-central Kyushu with an E-W trend. They have undergone low P /T metamorphism, however, precursor HP or UHP metamorphism of ca. 250 Ma has been inferred[3]. The protoliths have affinity to continental shelf deposits[4], consisting mainly of pelitic gneisses and meta-carbonates with minor metabasites and metaperidotites (partly serpentinite). Chromitite occurs very rarely as a nodular form in serpentinized metaperidotites which shows spinifex-texture. The NMR is located in western Kyushu with a N-S trend. They have undergone high P /T metamorphism of epidote-blueschist subfacies. They consists mainly of pelitic and psammitic schists with minor basic schists and serpentinites, some of which show a character of serpentinite melange[5]. Detrital zircon from the pelitic schists show the age of 89-86 Ma[6], whereas zircon from jadeitites in a serpentinite melange does 136 -126 Ma in the core and 84 - 80 Ma in the rim[7,8]. Chromitite occurs as a deformed schlieren-like layer in serpentinite with no reilc minerals. The P-T condition of the HMR has been estimated to be 200 - 600 MPa and 600 - 800 ℃ [3,9,10,11,12,13]. Higher pressure and temperature conditions are reported from the following two samples: a sapphirine-bearing granulite[3,10] as a tectonic block in the spinifex-textured metaperidotite (900 MPa and 950 ℃) and a calc-silicate granulite[13] (900 MPa and 820 ℃) intercalating with garnet - biotite gneiss. We newly estimated the peak P-T condition of Al-spinel and chlorite -bearing metaperidotite as 2.0 GPa and 780 - 990 ℃. In the case of the NMR, the peak metamorphic condition of the crystalline schists is 1.4 GPa and 520 ℃ for a garnet galucophanite[14]. Jadeitites[15] as tectonic blocks in the serpentinite melange shows the peak condition of 1.5 GPa and 500 ℃. Chromite from the HMR has the composition $(Mg_{0.34}Fe^{2+}{}_{0.75}Mn_{0.02})(Cr_{0.81}Al_{0.06}Fe^{3+}{}_{0.04}Si_{0.05)}{}_2O_4$, whereas that from the NMR has similar composition $(Mg_{0.33}Fe^{2+}{}_{0.65}Mn_{0.03})(Cr_{0.84}Al_{0.12}Fe^{3+}{}_{0.04})_2O_4$ in the core and Fe-rich composition $(Mg_{0.06}Fe^{2+}{}_{0.89}Zn_{0.02}Mn_{0.03})(Cr_{0.85}Al_{0.12}Fe^{3+}{}_{0.04})_2O_4$ in the rim. Microdiamonds occur as i*n situ* inclusions in chromite in both chromitites. They are 1 to 10 μm in size in HMR chromite, and those in NMR chromite is much smaller, mostly $<$1 μm with small number of larger grains. In both chromitites microdiamonds occur in some cases as numerous aligned grains, making diamond - rich zones. Both microdiamonds are identified with Raman spectra. HMR microdiamonds show a broad peak at 1333 cm^{-1}. NMR microdiamond, also shows a broad peak at 1331 cm^{-1} with graphite peak at around 1600 cm^{-1}, suggesting partial graphitization. Both UHP chromitites will be deep subduction origin. HMR can be an eastern extension of the Dabie-Sulu UHP terrane in China, however, NMR is more problematic. No corresponding UHP terrane of ca. 80Ma is found around Kyushu. Our findings of UHP chromitites require reexamination of micro-tectonics in Kyushu, a peculiar location of an arc-arc junction at the continental margin.

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Keywords: microdiamond, chromitite, UHP, Higo metamorphic rocks, Nishisonogi metamorphic rocks, subduction

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SMP46-P02 Room:Poster Time:April 28 18:15-19:30

3D imaging of the Mn-caldera shaped zoning of the garnet found from the Sanbagawa metamorphic belt and its origin.

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Garnets with a complex compositional zoning were found from the northern proximal area of the Western Iratsu body of the Sanbagawa metamorphic belt of the Besshi district, southwest Japan. The studied garnet shows incipient Mn-reverse (increasing) zoning part (defined as core) and subsequent Mn-bell shape (decreasing) zoning part (defined as mantle), which is almost identical to the " Mn-caldera shaped zoning " described by Banno et al. (2004) in the Asemigawa region of the central Shikoku. In order to describe the chemical characteristic sterically, X-ray chemical mapping were performed by each 0.2-0.3 mm depth step, for one very-coarse-grained garnet with ca. 11 mm in diameter. The result clearly shows that the core/mantle boundary has the highest Mn content with euhedral shape, and that the chemical composition continuously changes through the grain. Internal schistosity defined by sigmoidal inclusion arrays cross-cuts the core/mantle boundary. This fact also suggests the continuous growth of garnet from the central part to the outer part. In the same sample, garnets with Mn-bell shape type zoning are also observed, which are relatively fine-grained up to 5 mm. Raman barometry and thermodynamic modeling suggest the climax *P-T* conditions of the studied sample did not reach the eclogite facies, which are consistent with the conditions of the oligoclase-biotite zone of the Sanbagawa metamorphic belt (610 ℃ and 1.0 GPa, Enami, 1994).

Contrary to the simple Mn-bell shape type zoning which grown up with progressive regional metamorphism, " Mn-caldera shaped zoning " could be generated from the crystal nucleation under oversaturated environment (Matsumoto and Kitamura, 2004). Such oversaturation is expected in a rapid increase of temperature. Recently, Aoya et al. (2013) proposed the eclogite nappe covering the large part of the Besshi district. However, the exact boundary between the eclogite nappe and lower grade surrounding rocks is still under the debate. The conjunction of the eclogite nappe and the lower-grade surrounding rocks are thought to have taken place near the peak metamorphic stage of the surrounding rocks (500-600 ℃ and ca. 1 GPa, Aoya et al., 2013). Mn-caldera shaped zoning garnet found in the Besshi district (this study; Xu et al., 1994) are both found from the northern proximal of the hypothesized eclogite nappe. Those Mn-caldera shaped zonings are possibly originated from the conjunction of the eclogite nappe and surrounding crystalline schist, and corresponding rapid heating. Such features of garnet can help to determine the boundary of the eclogite nappe in the Besshi district.

Keywords: garnet, Sanbagawa metamorphic belt, compositional zoning, disequilibrium crystal growth

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SMP46-P03 Room:Poster Time:April 28 18:15-19:30

Widespread analyses of pressure-temperature trajectory and timing in the Altai Range, Mongolia

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This study performed large-scale petrographical and geochronological investigation in the Altai Range, Mongolia distributed in the Central Asian Orogenic Belt, which is the typical subduction-accretion-collision orogeny on the Earth. Based on the petrographical observation, clockwise and anti-clockwise pressure-temperature trajectories were identified in whole of the studied area (400 km long). U-Th-Pb monazite dating yields c. 350 Ma and c. 260 Ma. Samples with clockwise pressure-temperature path, containing kyanite in garnet and sillimanite in the matrix, commonly have c. 350 Ma monazite in garnet and c. 260 Ma monazite in the matrix. In contrast, samples with anti-clockwise pressure-temperature path containing sillimanite in garnet and kyanite in the matrix have monazites showing (i) c. 350 Ma both in garnet and the matrix, (ii) c. 260 Ma both in garnet and the matrix, and (iii) c. 350 Ma in garnet and c. 260 Ma in the matrix. Ca zoning pattern in garnet shows either continuous or discontinuous zoning. Samples containing single monazite age cluster (either c. 350 Ma or c. 260 Ma) have continuously zoned garnet, in which samples with anti-clockwise pressure-temperature trajectory at both periods show Ca zoning increasing from core to rim or mantle, whereas some samples with unknown pressure-temperature path at both periods show opposite zoning. These features strongly suggest both clockwise and anti-clockwise evolutions occurred at both periods. Discontinuous Ca zoning in garnet is observed in samples that contain c. 350 Ma monazite inclusions in garnet and c. 260 Ma monazite grains in the matrix, and the zoning patterns show a decrease in Ca at the rim for samples with clockwise paths and an increase in Ca at the rim for those with counterclockwise paths. In some cases, c. 350 Ma monazite grains are included in the large garnet cores but c. 260 Ma monazite grains are found in the garnet rims as well as in the matrix. These rocks might be metamorphosed at c. 350 Ma, whereas they did not exhume to the surface and have remained deep crustal level. Subsequent compression and decompression event formed garnet rim and monazite at c. 260 Ma, which should be caused by same tectonic regime to clockwise and anti-clockwise pressure-temperature path at the period. The presence of the regional-scale clockwise and anti-clockwise trajectories and their repetition during less than 100 My have never reported from any other orogenic belts in the world. Further studies may allow to realize the complex tectonic evolution of the Altai Range.

Keywords: P-T trajectory, U-Th-Pb monazite age, Altai Mountains, Mongolia, Central Asian Orogenic Belt

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SMP46-P04 Room:Poster Time:April 28 18:15-19:30

Temporal change of modal abundance of minerals during formation of arrested charnockite from Sri Lanka

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Charnockite occurs as a number of several-decimeters patches in hornblende-biotite gneiss in central Sri Lanka. This type of charnockite has been called arrested charnockite. Local condition of low-H_2O activity or low-oxygen fugacity could explain the difference of mineral assemblage in local scale. They might be caused by fluid influx and/or partial melting (e.g. Newton et al., 1980; Hiroi et al., 1990; Burton and O'Nions, 1990; Ravindra Kumar, 2004; Endo et al., 2012). The temporal and spatial development of charnockite has been unclear. This study describes variation in modal abundance of hornblende, biotite and orthopyroxene in melanocratic and leucocratic parts from surrounding gneiss to charnockite.

Charnockite and surrounding gneiss have layer structure composed of melanocratic and leucocratic parts. Each part can be traced continuously between the two rock types. Melanocratic parts consist mainly of hornblende and biotite in gneiss, and orthopyroxene added in charnockite. Leucocratic parts are composed of biotite and colorless minerals in gneiss, while biotite is absent in charnockite. Modal abundances of hornblende and biotite have no systematic trend in melanocratic parts of gneiss. Hornblende and biotite decrease drastically and gradually, respectively, while orthopyroxene increases gradually in melanocratic parts of charnockite. Biotite decreases gradually toward charnockite in leucocratic parts in gneiss.

Biotite of leucocratic parts breaks down within gneiss. Orthopyroxene appears in the location of dehydration reaction of biotite and hornblende in melanocratic parts. This suggests that the element released due to break down of biotite in leucocratic layer diffused from leucocratic part to melanocratic part to produce orthopyroxene. It is a possible that hornblende broke down first to produce significant amount of orthopyroxene in melanocratic part. The element released due to break down of biotite in leucocratic part transported to the location of preexisting orthopyroxene in order to grow the crystals. Biotite in leucocratic layers is enriched in Fe as compared with that in melanocratic part. Fe-rich biotite breaks down under lower temperature (or higher activity of H_2O) than Mg-rich biotite. This could explain the decrease of biotite in leucocratic layer in gneiss.

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Keywords: Sri Lanka, Charnockite, Hornblende-biotite gneiss, modal abundance

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SMP46-P05 Room:Poster Time:April 28 18:15-19:30

Thermal structure and water transportation in subduction zones: a comparison between NE and SW Japan

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Northeastern and southwestern Japan are considered to be typical examples of cold and hot subduction zones, respectively. The old Pacifc plate subducts beneath northeastern Japan at high rate and the young Philippine Sea plate subducts beneath southwestern Japan at low rate. These contrasts in the subduction conditions reveals in several aspects including higher activity of arc volcanism and deeper down dip limit of inter-plate earthquake in northeastern Japan, and deep low-frequency tremors at plate boundary of southwestern Japan. We have investigated thermal structure and geophysical and geochemical processes in these subduction zones using a numerical model. The model includes hydration and dehydration of the slab and mantle wedge, melting and solidification of mantle peridotites, permeable flow of melt and aqueous fluids, and temperature-dependent solid flow of mantle peridotites with water- and melt-induced weakening. We will discuss effects of the subduction conditions on the volcanic and seismic activities through the processes, especially water transportation.

Keywords: subduction zones, NE Japan nad SW Japan

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SMP46-P06 Room:Poster Time:April 28 18:15-19:30

Stress and strain history during the microboudinage for granite intrusion: Mt. Edger granite complex, East Pilbara

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Stress and strain analysis is essential to improving the understanding of deformation process. Microboudinaged columnar minerals can be used as an indicator of stress and strain during the microboudinage for quartzose and calcareous metamorphic tectonites. In this presentation, we discuss the stress and strain history during the microboudinage deduced by the microboudin method with a collaboration of the strain reversal method.

We collected samples of metachert from the Archean Warrawoona greenstone belt around Mt. Edger granite complex, East Pilbara, Western Australia, and identified microboudinaged tourmaline grains embedded within quartz matrix in 10 samples. The result revealed that the samples experienced extensional strain at least -0.56 and differential stress in the range from 3.9 to 11.9 MPa. We obtained stress-strain curves which show increase in differential stress with increasing inverse natural strain (ε_{inv}). The frequency distribution of interboudine gaps between separated grains with respect to ε_{inv} for boudinaged tourmaline grains shows that end of microboudinage occurred immediately after the peak frequency of fracturing. This occurrence commonly appeared in all the 10 samples. These results provided us with keys to discuss a stress-strain history during the microboudinage in relation to evolution of the granite complex. The spectacular implication would be a drop or relaxation in increased differential stress at the end of the microboudinage.

Keywords: microboudin structure, stress, strain, granite complex, Archean

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SMP46-P07 Room:Poster Time:April 28 18:15-19:30

Time scale for formation of diffusion zoning in response to breakdown reaction

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In high-grade metamorphic rocks, garnet commonly represents an increase in Mn or Fe toward margin. This feature has been interpreted as diffusion zoning owing to garnet-consuming reactions during retrograde metamorphism. In this process, the zoned thickness can be described in terms of distances of internal diffusion and surface retreating. This study preliminaly formulated to express these distances as a function of time and retreating velocity of the surface. Applying the formulation to some high-temperature metamorphic belts yielded that the diffusion zoning with zoned thickness of 0.04 to 0.1 mm was formed by 1 to several million years. This result may be applied to estimate cooling rate provided that the surface equilibrium was mainetained during the formation of diffusion zoning.

Keywords: diffusion zoning, duration time, cooling rate

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SMP46-P08 Room:Poster Time:April 28 18:15-19:30

Integrated radiometric dating of schist clasts from the Eocene and Miocene conglomerates in Shikoku

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The age that the high P/T type Sanbagawa metamorphic rocks reached at erosion level gives an important constraints for considering exhumation processes of the Sanbagawa metamorphic rocks. It is shown by the oldest age of the conglomerate containing schist clasts derived from the Sanbagawa Belt. Integrated radiometric dating has been carried out for schist clasts from the Paleogene and Neogene conglomerates in Shikoku. The results of K-Ar and fission-track (FT) ages for the schist clasts from the Eocene Hiwadatoge Formation and the Miocene Furuiwaya Formation (Kuma Group) were already reported (Takagi and Sakisaka, 2012; Takagi et al., 2013). We have been doing U-Pb dating of zircon grains from the same clasts for the FT dating using NanoSIMS 50 ion microprobe of AORI. The youngest U-Pb age of zircon grains approximates the sedimentary age of the protoliths of the schist, because the zircon grains in the low-grade metamorphic rocks are detrital origin. The tentative results shown by the youngest peak yield around 110 Ma in all samples. We will report on details of the U-Pb ages at the meeting. FT dating was also carried out for the schist clasts from Eocene Oyamamisaki Formation in the Shimanto Belt where K-Ar ages (78.2-71.4 Ma) of the clasts have been already reported by Yoshikura et al (1991). The FT ages were 67.3 +/- 9.0 Ma and 68.4 +/- 8.2 Ma. From the results of K-Ar phengite ages and FT zircon ages for schist clasts (Table 1), it is suggested that the exhumation rate of the schist eroded at Eocene time is faster than that eroded at Miocene time.

References :

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Keywords: Sanbagawa belt, schist, radiometric dating

Table1. Phengite K-Ar and zircon fission track ages of schist clasts from the Miocene and Eocene strata in Shikoku.

Series	Formation Name		Sample	Phengite K-Ar age (Ma)	Zircon FT age (Ma)
Miocene	Kuma Group	Furuiwaya Formation	32204-2 psamm.sch.	81.5 ± 1.3	68.7 ± 6.0
			112101-2 pel.sch.	83.5 ± 1.3	64.9 ± 5.8
Eocene	Hiwadatoge Formation		2003-8 psamm.sch.	86.8 ± 1.3	85.2 ± 7.7
	Oyamamisaki Formation		1-B psamm.sch.	78.2 ~ 71.4 (Yoshikura et al., 1991)	67.3 ± 9.0
			1-F psamm.sch.		68.4 ± 8.2

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SMP46-P09 Room:Poster Time:April 28 18:15-19:30

The metamorphic evolution from PrP to LBS facies in a late Paleozoic cold subduction system in Kurosegawa belt

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Introduction: Recent progress of thermal modeling and thermodynamic calculation can help the general understanding of the thermal structure of subducting plate and the total movement of H2O stored in high-pressure type metamorphic rocks from the trench to the upper mantle depth in various subduction settings (e.g., Peacock & Wang, 1999; Hacker et al., 2003). For example, Peacock (2009) indicated that the oceanic plate in the Philippine Sea plate subducting below the Kii Peninsula would suffer the cold HP/LT type metamorphism represented by zeolite facies, prehnite-pumpellyite facies, pumpellyite-actinolite facies, lawsonite-blueschist facies to jadeite-lawsonite-blueschist to 2GPa. However, the natural example recording abovementioned progressive metamorphic evolution has not been recognized yet.

Recently prehnite-pumpellyite facies and lawsonite-blueschist facies units have been recognized in the Otao unit of Kurosegawa belt in Yatsushiro area, Kyushu, Japan (Kamimura et al., 2012). However, the relationship of two metamorphic units has not been verified yet.

In this paper, we propose the progressive change of metamorphic grade from the prehnite-pumpellyite facies to lawsonite-blueschist facies based on petrography and thermodynamic phase analysis in metabasite system.

Petrography and Mineralogy: We confirmed that the prehnite-pumpellyite facies assemblage is predominant in the Tobiishi subunit of (Kamimura et al., 2012), but we newly found pumpellyite-actinolite facies from the western end of this subunit.

In the lawsonite-blueschist facies unit, Hakoishi-subunit of (Kamimura et al., 2012), located to the west of the Tobiishi-subunit, following mineral assemblage with excess chlorite, quartz, albite and phengite are systematically distributed from the east to the west in the subunit:

lawsonite + pumpellyite + aegirine-augite,pumpellyite + Na-amphibole,lawsonite + pumpellyite + Na-amphibole, lawsonite + Na-amphibole + aegirine-augite.

The compositions of sodic pyroxene, pumpellyite and Na-amphibole also show the following systematic trend westwards in the subunit; jadeite component of sodic pyroxene generally increases from XJd=0.12 to XJd=0.50 with XAeg= up to 0.5. Al content of pumpellyite increases from 3.7 to 4.6 p.f.u. for O=24.5 Fe3+/(Al+Fe3+) in Na-amphibole decreases from 0.8 (riebeckite) to 0.15 (glaucophane).

Thermodynamic phase analysis: To evaluate stability relationship among abovementioned mineral assemblages, the phase diagram was construct-ed in the NCFMASH system with PERPLE_X soft-ware package (Connolly, 2005) for 1-10 kbar and 100-400 C. The considered minerals are stilbite, laumontite, prehnite, pumpellyite, ferro pumpellyite, tremolite, ferro tremolite, diopside, hednbargite, clinochlore, daphnite, lawsonite, glaucophane, ferro graucophane, clinozoisite and albite with excess, quartz and water. As the first order approximation, solid solution in each mineral was ignored. The new-ly constructed phase diagram predicts following representative mineral assemblages appear with the increase of the pressure along the high HP/LT path.

lawsonite + pumpellyite + clinopyroxene,pumpellyite + glaucophane,lawsonite + pumpellyite + glaucophane,lawsonite + glaucophane + clinopyroxene.

This metamorphic evolution in the model system is coincident well with the natural observation in the Hakoishi subunits.

Conclusion: Mineral assemblages observed in metabasites of the Tobiishi and Hakoishi subunits and the newly constructed petrogenetic grid suggest the metamorphic grade increases from prehnite-pumpellyite facies to lawsonite-blueschist facies westward ca. 20km in the Otao unit of Kurosegawa belt. The westward increase of Al content in pumpellyite, Na-amphibole, and Na- clinopyroxene also suggest the metamorphic grade increases westward. Thus, this area would become a type locality of a cold subduction system as proposed by the Peacock (2009)s thermal modeling.

Keywords: lawsonite, blueschist, HP/LT type metamorphic rocks, Kurosegawa belt, petrogenetic grid, cold subduction system

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SMP46-P10 Room:Poster Time:April 28 18:15-19:30

Morphological change of zircon under high temperature metamorphism: Example of the Kiso Ryoke metamorphic rocks

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Zircon is an important key mineral to obtain the age of rocks, however zircon newly grew at each metamorphic cycle and its timing of crystallization should have been recorded as U-Pb age. It is not always fully understood how zircon crystal grows at different metamorphic grade. Williams (2001) demonstrated that the behavior of zircon has been changed accompanying with metamorphic grade in Cooma complex, SE Australia. In low grade, there are detrital zircons but in high grade, overgrown or newly formed zircons are observed. Kawakami et al (2013) reported the behavior of zircon in the upper-amphibolite to granulite facies schist/migmatite transition, Aoyama area, Ryoke metamorphic belt. They concluded that the recrystallization of zircon has been controlled by partial melt. Thus, crystal morphology is quite important for understanding the U-Pb age of zircon.

This study reports morphological change of zircon crystal at different metamorphic grades in the Kiso area, Ryoke metamorphic belt in Central Japan, where metamorphic grade continuously increases from non-metamorphic (Mino belt) to migmatite facies, similar with Cooma complex. The district is located in northeastern part of Mt. Kisokomagatake and the study area is about 43km from north to south, and about 22km west to east. In this district, regional metamorphic rocks (metasediments, quartz schist, basic schist, and carbonate rocks, etc.) and non-metamorphic rocks widely occur. Morikiyo (1984) classified the district into nine mineral zones (I to VII) based on the mineral assemblages.

We have studied total 46 samples from all zones. Mineral assembles of the studied samples indicate the following characteristics features: biotite appears in zone II, albite disappears in zone IIIa, chlorite disappears in zone IIIb and sillimanite appears in zone VIa.

On the basis of the optical microscope and SEM observations, morphology of zircon is divided into 3 groups, such as zones I-II, zones IIIa-V and zones VIa-VII.

Zones I-II: Under the optical microscope, each zircon grain shows different color (purple, pale-pink and colourless). Zircon grains are essentially euhedral, and show variable range of grain size (40-220 um). In SEM observation, the abrasion and cracks are notable in zircon crystal surface. The above observations are consistent that the zircons in these zones are detrital origin that were derived from a variety of different source rocks.

Zones IIIa-V: Surface of zircon in these zones are irregular and rough with small holes which are likely to reflect resorption during the metamorphism. In contrast with the zircons from zones I-II, zircon crystal surface is relatively rough and shows no abrasion and cracks. But, even in the same zircon grain, both resorption surface and non-resorption surface can also be observed. Non-resorption surface is considered to preserve detrital surface (same with zone I-II), and resorption surface possibly reflects metamorphic dissolution or recrystallization (similar to zone VIa-VII). According to BSE images, no obvious new growth zone can be observed in many of zircon grains, but a few grains show sign of new overgrowth zone. Grain size of newly growing zircon is relatively small about 30um.

Zones VIa-VII: Surface of zircon in these zones is relatively smooth, which differs from rough crystal surface in zones IIIa-V. It is assumed that the irregular surface of zone IIIa-V zircons are overgrown and filled by smooth surface as temperature increases to zones VIa-VII. In the highest-grade zone VII, the rough surface is disappeared, and smooth zircon grains are dominated.

Thus in the Ryoke metamorphic rocks from Kiso area, crystal morphology of zircons changes from the dominant detrital signature in the lowest-grade zone through irregular and rough resorption and recrystallization features in the middle-grade zone to the more smooth overgrowth recrystallization in the higher-grade. New zircon grain growth can be found in the middle to higher-grade zone.

Keywords: zircon morphology, regional metamorphism, Ryoke belt

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SMP46-P11 Room:Poster Time:April 28 18:15-19:30

P-T estimates of a metapelite containig garnet zoning from Mefjell, Sr Rondane Mountain, East Antarctica

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The Sør Rondane Mountains, East Antarctica have been considered to be situated in the Gondwana suture zones. Therefore the mountains have attracted interest as a key area for understanding amalgamation process of the supercontinent. The mountains consist of amphibolite- to granulite-facies metamorphic rocks with granitic intrusions, and the timings of the main metamorphism are interpreted as *c*. 640-600 Ma and *c*. 550-500 Ma. Metamorphic rocks from northern and eastern part of the mountains (Balchenfjella and northern part of Austkampane) record a clockwise *P-T* path, on the other hand, metamorphic rocks from central part of the mountains (Brattnipene and eastern Menipa) record anti-clockwise *P-T* path. This suggests each area records a different *P-T* path. However, pre-peak *P-T* conditions of southwestern part of the mountain such as Mefjell have been still not clear.

In this study, we report a garnet porphyroblast with a prograde zoning in a metapelite from Mefjell. The St-bearing Grt-Sil-Bt gneiss mainly consists of garnet, biotite, sillimanite, quartz and plagioclase, with minor K-feldspar, staurolite, apatite, monazite, ilmenite and magnetite. The garnet grain is 12 mm in diameter, with the change of color from reddish in the core to transparent in the rim. The garnet has core-rim boundary defined by Mn-zoning. The garnet is typically almandine-rich, and shows compositional zoning with decrease in spessartine content from the core ($Alm_{63}Sps_{24}Prp_{14}Grs_6$) to the rim ($Alm_{74}Sps_2Prp_{20}Grs_4$), and spessartine content increase again towards the outer-rim ($Alm_{73}Sps_{11}Prp_{20}Grs_6$). The garnet includes staurolite, sillimanite, biotite, chlorite, plagioclase, K-feldspar, quartz, apatite and ilmenite. Garnet-ilmenite and staurolite-garnet geothermometers yield a temperature increase towards rim from 350-400 to 630-700 ℃. Garnet-Al_2SiO_5-quartz-plagioclase geobarometer applied to rim inclusions yields 7.2kbar$\pm$0.9kbar for an assumed temperature of 650 ℃.

Keywords: East Antarctica, Sør Rondane Mountain, pressure and temperature conditions

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SMP46-P12 Room:Poster Time:April 28 18:15-19:30

Syn-metamorphic fluid infiltration and petrogenesis of leucogranites in the MCT zone in Eastern Nepal

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Syn-metamorphic fluid activity in the continental collision zone is of great importance especially for the petrogenesis of leucogranites and mass transfer through the fluid/melt extraction. Tourmaline (Tur) is a common accessory mineral in the crust having a wide stability field [1]. It is the most important sink of B in metapelites [2, 3, 4]. Although B behaves incompatibly under the absence of its sink minerals and is transported in fluid, once the *P-T-X* condition permits, it can be precipitated as Tur and other borosilicates in the site of fluid/rock interaction. Therefore, Tur can be a good tracer of B-bearing fluid [4]. Since Tur is a polar mineral, different concentrations of cations are incorporated at opposite poles of the crystal as a function of temperature up to 650^{o}C, and this interpolar element partitioning in Tur can be used as a geothermometer [2, 5].

We have investigated the mode of occurrence of Qtz veins and Tur-rich veins in the MCT zone around Dhankuta, Eastern Nepal. In this area, pelitic schists are widely exposed and subordinate amounts of metamorphosed dolostone, quartzite and mafic rocks are intercalated with them. The metamorphic grade decreases from the Ky zone through the St zone to the Grt zone as the distance from the MCT increases toward the south.

Qtz veins are abundant in metapelites of this area. They are mostly deformed by the ductile deformation with top-to-S sense of shear during the activity of the MCT, and are found as lenses. In the Ky zone, Qtz veins contain mm- to cm-sized crystals of Ky and minor Pl. Grt and Ky are coarse-grained only at the vicinity of the Qtz veins, and Ky tends to be formed exclusively around the Qtz veins. This suggests that the fluid activity that formed the Qtz veins took place around the peak metamorphism of the Ky zone, and Si, Al, Na and Ca were mobile in the fluid. Preliminary *P-T* estimate of this fluid activity using Grt-Ky-Pl-Bt-Qtz assemblage gave ca. 8kbar and ca. 600^{o}C. In the St and Grt zones as well, Grt tends to be coarser grained around the Qtz veins. Therefore, these veins are the evidence for the externally derived fluid that infiltrated during the prograde to peak metamorphism of each zone.

Unusually abundant Tur is locally found in metapelites of the MCT zone. It is localized in aluminous, Ms-rich layers and can be formed through the input of external B into the appropriate whole-rock composition for Tur growth. Such a B-bearing fluid infiltration continued from the prograde stage because Grt with prograde chemical zoning includes abundant Tur crystals. B-bearing fluid infiltration continued in the post-peak stage as suggested by the presence of Tur-rich vein cross-cutting the schistosity. Interpolar Ca/Na partitioning of Tur [5] gives 530-590^{o}C for the temperature of the Tur-rich vein formation. A potential source of external fluid could be lower grade metasediments underlying these metamorphic zones, because syn-metamorphic dehydration reactions of hydrous minerals can supply not only H_2O but also B in the fluid.

B-bearing fluid infiltration during the prograde to post-peak metamorphism in the MCT zone is important for the petrogenesis of the Higher Himalayan (HH) and North Himalayan leucogranites whose source region and petrogenesis remain highly controversial [6]. Observation in this study supports the fluid-fluxed melting of the MCT zone or Higher Himalayan Crystallines (HHC) [7]. Tur-bearing leucogranite veins in the HHC just above the MCT could be a potential product of such a fluid fluxed partial melting that took place near the MCT.

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Keywords: fluid, tourmaline, boron, inverted metamorphism, partial melting, continental collision zone

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SMP46-P13 Room:Poster Time:April 28 18:15-19:30

Geochronology of the metamorphic rocks from the Masora, Antananarivo and Betsimisaraka domains, east-central Madagascar

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In a previous reconstruction of Gondwana supercontinent, Madagascar is located within the interior of the supercontinent (e.g. Jacobs and Thomas, 2004). Therefore, Madagascar is one of the most significant areas to understand the process of Gondwana supercontinent formation. However, it is still controversial whether the central part of Gondwana supercontinent was formed by young arc-arc collision and amalgamation (Stern, 1994), or was reworked of old continent (e.g. Collins and Pisarevsky, 2005; Tucker et al., 2012). In this study we estimated the age of protolith formation by applying LA-ICP-MS zircon dating method to metaigneous rocks and the age of metamorphism by applying EPMA monazite dating method to metasedimentary rocks, to understand the geochronological characteristics of the composed domains in east-central Madagascar.

East-central Madagascar is divided into Masora, Betsimisaraka and Antananarivo domains from east to west based on the geology and geochronology (Tucker et al., 2011). The Masora domain is mainly composed of the felsic metamorphic rocks with subordinate amounts of the metasedimentary rocks. Two metasedimentary rocks gave ages ranging from ca. 520 to 510 Ma. This age range is consistent with the age obtained from the meta-granitoid (ca. 530 to 510 Ma, Smith et al., 2008) and from quartzite (ca. 540 to 520 Ma, De Waele et al., 2011) by U-Pb zircon dating method. The felsic metamorphic rock gave igneous age at ca. 3300 Ma. This age is consistent with the age obtained from the migmatized gneiss (Tucker et al., 2011).

The Antananarivo domain is mainly composed of the felsic metamorphic rocks with subordinate amounts of the metasedimentary rocks. This domain is divided into east and west on the basis of the metamorphic condition and structural geology. The east and west areas are bounded by the low-angle ductile shear zone of top-to-west sense. Monazites from the metasedimentary rock in the east gave ages ranging from ca. 500 to 480 Ma. In the west monazites from the two types of the metasedimentary rocks gave ages ranging from ca. 540 to 500 Ma (Martelat et al., 2000) and ca. 630 to 540 Ma (Jöns and Schenk, 2011) and from the meta-granitoid gave age ranging from ca. 560 to 540 Ma (Grégoire et al., 2009). Therefore, the metamorphic age in the east is relatively younger than in the west. The felsic metamorphic rocks are geochemically classified into two types, which gave individual igneous ages of ca. 2700 Ma in the east and ca. 760 Ma in the west, respectively. The intermediate metamorphic rocks are exposed in the west and gave igneous age at ca. 550 Ma.

The Betsimisaraka domain is mainly composed of the metasedimentary rocks. Monazites from the metasedimentary rocks gave ages of ca. 500 Ma. This age is younger than the ages reported from the quartzite at ca. 550-520 Ma (Tucker et al., 2011) and rim ages from the metasedimentary rock at ca. 550 Ma (Collins et al., 2003) by U-Pb zircon dating method.

As a consequence east-central Madagascar was metamorphosed between ca. 550 and 500 Ma. Both the east of the Antananarivo and Betsimisaraka domains was metamorphosed at the youngest age around ca. 500 Ma. In previously reported geochronological results the oldest igneous activity was at ca. 2500 Ma in the Antananarivo domain (e.g. Kröner et al., 2000) Therefore the ca. 2700 Ma igneous age is new and the oldest igneous age in this domain. The east of the Antananarivo domain was older than the west and the oldest part of this domain. The age transition zone was possibly exposed between the Masora, Betsimisaraka and the west of the Antananarivo domains. The age and geological relationship in Archean domain was recently reported from the Dhawar Craton in southern India (Peucat et al., 2013). The existence of the ca. 2700 Ma igneous activity in the east of the Antananarivo domain could be the significant evidence of the continuity between India and Madagascar since Archean.

Keywords: Gondwana supercontinent, east-central Madagascar, LA-ICP-MS U-Pb zircon dating, EPMA monazite dating

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SMP46-P14 Room:Poster Time:April 28 18:15-19:30

Deformation microstructures of a Kamila amphibolite mylonite and their formative temperatures

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The Kohistan complex and the Kamila amphibolite belt in the northern Pakistan are considered to represent a Cretaceous island arc crust and a part of its lower crust, respectively. Here we report deformation microstructures of a Kamila amphibolite mylonite sample and their formative temperatures.

The amphibolite mylonite sample studied is composed of 100 μm to 1 mm thick alternating layers of hornblende + pyroxene, plagioclase, and hornblende + plagioclase + quartz, intercalating a 3 mm thick layer of garnet + quartz + plagioclase. Composite planar fabrics of a top-to-south sense of shear are developed in this sample; C plane defined by compositional layering (= foliation), S plane defined by lenticular domains of plagioclase aggregate clockwise oblique to the C plane, and C′ plane anticlockwise oblique to the C plane.

Hornblende + pyroxene layers contain pyroxene porphyroclasts of grain sizes ≈ 200 μm scattered in matrix mainly composed of hornblende grains with grain sizes ≈ 30 μm. Hornblende exhibits a strong crystallographic preferred orientation with (100) and [001] subparallel to foliation and lineation, respectively. Orthopyroxene porphyroclasts are elongated subparallel to foliation, and are accompanied by asymmetric tails mainly composed of hornblende indicating a top-to-south sense of shear. In addition, pyroxene porphyroclasts are surrounded by fine-grained (≈ 10 μm) hornblende and quartz, suggesting a breakdown reaction of pyroxenes (orthopyroxene + clinopyroxene + H2O = hornblende + quartz), which is a retrograde reaction from granulite facies to amphibolite facies.

Plagioclase layers are composed of dynamically recrystallized plagioclase grains of An_{47-54} in composition. Lenticular domains of plagioclase are likely porphyroclasts in origin. Plagioclase grains are polygonal in shape, and weakly aligned clockwise oblique to foliation, which also suggests a top-to-south sense of shear. Plagioclase exhibits a distinct crystallographic preferred orientation with {131} and <1-12>clockwise oblique to foliation and lineation, respectively by ≈ 20 degrees. But {131} and <1-12>are aligned subparallel to the S plane, suggesting the dominance of {131}<1-12>during the dynamic recrystallization of plagioclase.

We applied three pyroxene geothermometers to the chemical compositions of orthopyroxene and clinopyroxene porphyroclasts, which yielded temperatures around 850 degrees C. We also applied a hornblende-plagioclase geothermometer to the average chemical compositions of hornblende and plagioclase in hornblende + plagioclase + quartz layers, and obtained a temperature of ≈ 610 degrees C. Thus, the amphibolite mylonite studied likely experienced a peak metamorphism of granulite facies at ≈ 850 degrees C, and subsequently a retrograde metamorphism of amphibolite facies at ≈ 610 degrees C, during which it was sheared by top-to-south thrusting.

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SMP46-P15 Room:Poster Time:April 28 18:15-19:30

The tectonics evolution of metamorphic and igneous rocks embedded in the serpentinite melange from the Kurosegawa Tecton

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This study focuses petrology of the Kurosegawa Tectonic Zone, which is characterized by serpentinite melange in the Jurassic Chichibu Belt, in SW Japan. The serpentinite melange contains several blocks including high-pressure/low-temperature metamorphic rocks, high-temperature metamorphic rocks and granites. A small amount of age data obtained in previous study suggests that all rock types were formed before the Jurassic. However, detailed petrological and geochronological works on the blocks have been never performed so far. In this study, we carried out regional-scale geological, geochemical and geochronological analyses on the blocks in serpentinite from the western part of Kyushu to the eastern part of Kii peninsula.

Keywords: Kurosegawa Tectonic Zone, U-Pb zre age

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Metamorphism of the NE side of the Seba eclogitic basic schist in the Sambagawa metamorphic belt, central Shikoku, Japan

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The Sebadani area belongs to the albite-biotite zone and is located in the central part of the Besshi district. The Sebadani area is composed of the Sebadani metagabbro mass and surrounding Seba basic schists, pelitic and siliceous schists occur as intercalation within the Seba basic schists (Takasu and Makino, 1980; Takasu, 1984). Eclogitic mineral assemblages are sporadically preserved in both the Sebadani metagabbro and the Seba basic schists (Seba eclogitic basic schists) (e.g. Takasu, 1984; Naohara and Aoya, 1997; Aoya, 2001). The Onodani eclogites preserved within the Seba basic schists have a complex metamorphic history, undergoing three different metamorphic episodes (Kabir and Takasu, 2010). The first and second eclogite facies metamorphism is estimated as 530-590 ℃ and 19-21 kbar and 630-680 ℃ and 20-22 kbar, respectively. The second metamorphic event is similar to that of the Seba eclogitic basic schist of Aoya (2001) (610-640 ℃ and 12-24 kbar). The pelitic schists intercalated within the Seba eclogitic basic schists also underwent eclogite facies metamorphism of 520-550 ℃ and *c*. 18 kbar (Zaw Win Ko *et al*., 2005; Kouketsu *et al*., 2010).

The eclogite in the northeastern part of the Seba eclogitic basic schists consist mainly of garnet, epidote, amphibole (glaucophane, barroisite, taramite, Mg-taramite, Mg-katophorite, edinite), omphacite (X_{Jd} 0.27-0.41), phengite (Si 6.5-6.9 pfu). Minor amounts of albite, dolomite, rutile, titanite, biotite, chlorite and quartz. The schistsity is defined by preferred orientation of phengite, amphibole and epidote. Garnets are almandine-rich in composition, increasing almandine (X_{Alm} 0.54-0.60), pyrope (X_{Prp} 0.07-0.13) and decreasing spessartine (X_{Sps} 0.10-0.03) from core to the rim and contain inclusions of epidote, omphacite (X_{Jd} 0.27-0.41), dolomite, quartz and titanite. They also contain inclusions of barroisite/Mg-katophorite and albite symprectite. Amphibole in the matrix are zoned, barroisite/Mg-katophorite cores to edinite rims. Some other amphiboles in the matrix are parallel to the schistosity and occasionally occur as randomly oriented. The cores of these amphiboles are resorbed barroisite, glaucophane in the mantle and barroisite/edenite in the rim.

Based on the mineral paragenesis of the eclogites the metamorphism is divided into three events. The first eclogitic metamorphic event is deduced from symprectites of barroisite/ Mg-katophorite and albite after omphacite inclusions in garnet. The prograde stage of the second eclogitic metamorphic event is represented by the inclusions minerals within the mantle and rim of garnets consisting of epidote, barrosite and dolomite. The peak eclogite facies stage is defined by garnet rim and omphacite inclusins within the garnets with schistosity forming minerals of barroisite, omphacite and phengite. Garnet and omphacite rim-rim pairs yielded 530-570 ℃ and >11-14 kbar, and garnet and omphacite inclusion within garnet yields 520-560 ℃, >11-12 kbar (Ellis & Green, 1979 ; Bannno, 1986). THEMOCALC (Holland & Powell, 1998) average *P-T* calculation for garnet + omphacite + barroisite + phengite assemblage obtained 590-610 ℃ and 19-20 kbar. The retrograde stage is defined by symprectite of barrosite and albite after omphacite. The third metamorphic event is defined by zoned amphibole in the matrix.

The estimated matamorphic temperatures of the eclogites are lower than that of the second high-pressure metamorphic event of the Onodani eclogite and similar to that of the omphacite-bearing metapelites from the NW part of the Seba eclogitic basic schists (Kouketsu *et al*., 2010). This suggests a metamorphic thermal gradient existed within the Seba eclogitic basic schists.

Keywords: Sambagawa (Sanbagawa) metamorphic belt, Seba basic schist, eclogite, glaucophane, P-T path, thermal gradient

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SMP46-P17 Room:Poster Time:April 28 18:15-19:30

Metamorphic history of garnet amphibolite from the Neldy Formation, Makbal district in the Kyrgyz Northern Tien-Shan

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The Kyrgyz Tien-Shan Mountains extend from east to west, separating the Kazakhstan plate to the north and the Tarim plate to the south. They are divided into three tectonic units; the Northern Tien-Shan, the Central (or Middle) Tien-Shan and the Southern Tien-Shan. In the Northern Tien-Shan there are two HP and UHP metamorphic complexes, Makbal HP and UHP in the western part, and Aktyuz HP in the eastern part of the complexes. The Makbal complex in the Kyrgyz Northern Tien-Shan is located in the western segment of the CAOB.

The metamorphic rocks exposed in the Makbal district are divided into the Akdzhon and the Scharkyrak Groups based on their metamorphic conditions. The Akdzhon Group contains rocks of the HP and UHP metamorphic conditions, whereas the Scharkyrak Group underwent greenschists facies metamorphism. The Akdzhon Group is divided into two contrasting metamorphic formations, the structurally lower Makbal Formation and the upper Neldy Formation.

The Neldy Formation is mainly composed of garnet-phengite schists and chlorite-carbonate rocks, along with minor metaquartzites and marbles. Amphibolites and garnet amphibolites occur in the garnet-phengite schists as lenses or blocks up to 50 m across. Eclogites preserved in the cores of the garnet amphibolite bodies. Garnet amphibolite consists mainly of amphibole (magnesiohornblende, ferropargasite, ferrotschermakite, tschermakite, barroisite, actinolite), garnet and chlorite, with minor amounts of quartz, epidote and albite. Accessory minerals are paragonite, titanite and calcite. A schistosity is defined by preferred orientation of amphibole.

Garnets in the garnet amphibolite are rich in almandine (X_{Alm} 0.35-0.64), with variable amounts of spessartine (X_{Sps} 0.00-0.20), grossular (X_{Grs} 0.27-0.61) and pyrope (X_{Prp} 0.01-0.07) compositions. Garnet displays a compositional zoning, in which decrease X_{Sps} (0.20-0.04), increases X_{Alm} (0.35-0.60), X_{Grs} (0.31-0.62) and slightly increase X_{Prp} (0.01-0.03) from the core to the rim and contain inclusion of paragonite, titanite, chlorite, epidote and amphibole (actinolite, magnesiohornblende). The garnets are partly replaced by chlorite and aggregates of amphibole (ferrotschermakite, barroisite), chlorite and quartz along the cracks. Amphiboles in the matrix are zoned with magnesiohornblende and barroisite cores to ferrotschermakite and tschermakite rims and contain inclusions of titanite and quartz.

Based on the texture and mineral composition, we consider that the prograde stage probably stable in the epidote-amphibolite facies condition due to the existing of barroisitic amphibole and epidote along with garnet, paragonite, albite and chlorite. The tschermakitic rim of matrix amphibole suggests that the peak stage probably stable in the amphibolite facies conditions. The expecting metamorphic condition of the garnet amphibolite from the Neldy Formation corresponding with peak *P-T* conditions of 610-620 ℃ and 14-16 kbar for the garnet amphibolite from the Makbal complex (Rojas-Agramonte *et al*., 2013).

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Keywords: Garnet amphibolite, metamorphic history, amphibolite facies, Makbal complex, Neldy Formation, Kyrgyz Tien-Shan

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SMP46-P18 Room:Poster Time:April 28 18:15-19:30

The stress-strain history of metamorphic sole: the case study of Greece, Turkey, Oman and Andaman islands

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Metamorphic sole is formed by intra-oceanic thrusting and is found in some locations around the world. Greece, Turkey, Oman and Andaman islands are Tethys type ophiolite exposured area. The microboudin method, which is palaeostress analysis, is based on the proportion of boudinaged mineral grains with respect to applied differential stress. In this study, we used columnar minerals bearing metacherts from four areas and examined the value of palaeodifferential stress. The microboudin method revealed the value of palaeodifferential stress is 3.3˜24.8 MPa and we got stress-strain curve by using strain reversal method. The stress-strain curve indicate the stress history. Palaeodifferencial stress increased until the end of deformation in all samples. This result show that peak P-T condition and peak differencial stress are not simultaneous.

Keywords: microboudin, metamorphic sole, palaeodifferential stress, Tethys, stress-strain history

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SMP46-P19 Room:Poster Time:April 28 18:15-19:30

Late Cretaceous and Paleogene nappe tectonics in the forearc regions of Southwest Japan

ONO, Akira[1]*

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Nappe tectonics occurred at many times in the Paleogene and late Cretaceous forearcs of Southwest Japan. Upper parts of the crust moved toward trench by the nappe tectonics (Figures A and B). Actually the Atokura and Ryoke Nappes are observed in the northern margin of the Kanto Mountains although most of the nappes were eroded. The Atokura Nappe is mainly composed of Permian granites, mid-Cretaceous granitic and metamorphic rocks, late Cretaceous Atokura Formation, early Paleogene Yorii Formation and late Cretaceous pyroclastic rocks. The Ryoke Nappe mainly consists of late Cretaceous granitic and metamorphic rocks. The Permian granitoids are geological bodies of the Kinshozan-South Kitakami Belt. The mid-Cretaceous granitic and metamorphic rocks were geological members of the Higo-Abukuma Belt. The late Cretaceous granitic and metamorphic rocks were distributed in or near the Ryoke Belt. These various rocks were located in the early Paleogene forearc (Figure B) and were removed by nappe tectonics (Ono, 2011, Abs. Geol. Soc. Japan, Meeting, p. 196).

It is important to reveal the tectonics of the lower crust when the upper crust of about 5km in thickness was moved as a nappe toward trench. The author postulates that the lower crust moved toward mantle. The surface layer of the crust moves as a nappe and the lower crust flows towards the mantle. A thrust is assumed near the base of the lower crust. Figure C shows directions of the movements of crustal materials. Tectonics like this has been repeated in late Cretaceous and Paleogene and almost all the mid-Cretaceous Higo-Abukuma metamorphic rocks were eliminated. The Ryoke Belt was also partly removed after the nappe tectonics.

The tectonics described above is consistent with the geological structure near the Median tectonic Line where the Ryoke Belt is directly in contact with the Shimanto Belt in the central part of the Kii Mountains. In this context, Ryoke granitic and metamorphic rocks are in contact with Sanbagawa metamorphic rocks from surface to lower crust according to the crustal section of Southwest Japan (Ito and Sato, 2010, Journal of Geography, 119, p.235). It is difficult to find a crustal layer which was situated in the deep parts of the Higo-Abukuma and Kinshozan-South Kitakami Belts in the crustal section.

Keywords: Southwest Japan, Forearc, Late Cretaceous and Paleogene, Nappe tectonics, Lower crust