SMP43-01 Room:303 Time:May 24 09:00-09:15

Nano-granite and glass inclusions in zircon from the migmatite zone of the Aoyama area, Ryoke metamorphic belt, Japan

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Glass inclusions and nano-granite inclusions in Zrn are the important evidence of Zrn growth in the presence of melt. In this contribution, we report the first finding of the nano-granite inclusions [1] in Zrn from the migmatite of the Ryoke metamorphic belt at the Aoyama area, SW Japan.

In the Aoyama area, pelitic-psammitic metamorphic rocks of the upper amphibolite to granulite facies grade are widely exposed. Pelitic-psammitic schists dominate in the northern half (Sil-Kfs zone and low-T part of the Grt-Crd zone), and migmatites dominate in the southern half (mid- to high-T part of the Grt-Crd zone) [2].

The zircon in metatexites and diatexites from the mid-T to high-T parts of the Grt-Crd zone has a thin, bright annulus under BSE image along which tiny inclusions of several microns are aligned [3]. Some of the inclusions with the similar mode of occurrence are identified to be the glass that was included during the Ryoke metamorphism. The nano-granite inclusion is newly found from the same kind of annulus.

The nano-granite inclusions are about 2 um in diameter, which is the largest size among the inclusions found in the bright annulus under a BSE image. Based on the FE-SEM observation and EDS qualitative analysis, nano-granite consists of plagioclase, biotite and other several unidentified minerals or glass ([4] uses the term 'nano-granite' even if it contains some glass portions). In the zircon grains from the same metatexite sample, in addition to the totally glass inclusions, partially solidified glass inclusions with biotite-like mineral developed at the boundary between host zircon and glass are found. The fact that nano-granite and glass inclusions are found from the zircon rim developed at 90.3 +/- 2.2 Ma in metatexite [3] shows that partial melting took place during the Ryoke metamorphism. Composition of partial melts formed during the dehydration melting of micas is being determined using these glass inclusions [5]. It is difficult to quantitatively analyze the melt inclusions in zircon from the Aoyama area because they are too small in size as in the case of other areas [5]. However, the CIPW normative composition (Qtz-Ab-Or) of leucosomes segregated in the boudin necks that is found near the migmatite front of the Aoyama area [6] are plotted in between the compositions of melt inclusions from El Hoyazo and Kerala Khondalite Belt on the cotectic line between primary phase fields of Or and Qtz for P(H2O) = 0.5 GPa. This supports the idea that the leucosome in boudin necks are possible partial melts formed during the prograde metamorphism during Ryoke metamorphism [6].

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Keywords: zircon, nano-granite, migmatite, partial melting, glass inclusion

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SMP43-02 Room:303 Time:May 24 09:15-09:30

Behavior of REE-rich minerals during Cl-rich fluid activity under granulite facies metamorphism

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The importance of understanding the role of Cl-rich fluid in the crust is gradually recognized since metamorphic fluid in the granulite facies rocks has been long considered as CO_2-rich in most cases, and the *P-T-t* condition and the scale of its activity are still not clear. Cl-rich fluid and CO_2-rich fluid are possible candidates of low a_{H2O} fluids. Presence of such fluids shifts the wet solidus to the high-T side, and dehydration reactions to low-T (Newton et al., 1998). Cl-rich fluid can coexist with CO_2-rich fluid under high-T condition and is a powerful solvent (Heinrich et al., 2004; Newton and Manning, 2010). In order to understand the fluid-related geological process in the middle- to lower-crust of the continental collision zone, the *P-T-t* condition of Cl-rich fluid activity and the behaviour of REE-rich minerals during Cl-rich fluid infiltration are studied in detail at the Sor Rondane Mountains, East Antarctica where Late Proterozoic to Cambrian granulites are widely exposed.

Among 33 felsic gneiss samples, a Grt-Bt-Sil gneiss from Balchenfjella was selected, since it was best suited sample to constrain the *P-T-t* conditions of Cl-rich fluid activity. This gneiss contains Grt porphyroblasts that have a P-rich core with oscillatory zoning in P. The Grt core includes Cl-poor Bt and fluorapatite. The core of the Grt has been partially resorbed and discontinuously overgrown by a P-poor rim, in which Cl-rich Bt and chlorapatite are included. Coarse-grained, rounded Zrn grains are exclusively included in the rim of the Grt porphyroblast and are also present in the matrix. This mode of occurrence suggests that the Cl-rich Bt and chlorapatite, together with coarse-grained Zrn were formed almost simultaneously. The *P-T* condition of Cl-rich Bt entrapment in the Grt rim is estimated to be ca. 800 ^{o}C and 0.8 GPa. In comparison, peak metamorphic condition is estimated to be ca. 850 ^{o}C and 1.1 GPa. These pieces of observation suggest that Cl-rich fluid or melt infiltrated at the core-rim boundary of Grt. In the case of fluid infiltration, the $f_{HCl}/\ f_{H2O}$ ratio of the fluid in equilibrium with Cl-rich Bt and chlorapatite in the Grt rim are estimated to be ten times larger than that in equilibrium with Cl-poor Bt and fluorapatite in the matrix and the Grt core, because Cl concentration of the melt cannot be high enough to make Bt and apatite as Cl-rich as observed in this study (Higashino et al., 2012).

In this sample, there is a tendency that Mnz is included in the Grt core, and Zrn and Xtm are included in the Grt rim. This implies that Cl-rich fluid carried LREE away and brought HREE and Zr in, and that Zrn included in the Grt rim formed simultaneously with the Cl-rich fluid infiltration. The LA-ICP-MS U-Pb dating of the coarse-grained Zrn included in the Grt rim gave concordia age of 603 +/- 14 Ma. Therefore, Cl-rich fluid infiltrated under the near-metamorphic peak condition of ca. 800 ^{o}C and 0.8 GPa during the continental collision process. On the other hand, the rim of Zrn present in the matrix gave concordia age of 564 +/- 17 Ma. The field distribution of Cl-rich fluid activity is somewhat linear, located near the large scale ductile shear zones in the Sor Rondane Mountains. Regional distribution of high-grade Cl-rich fluid or melt activity in the Sor Rondane Mountains implies that it is one of the major phenomena in the continental collision processes. The *P-T-t* condition of Cl-rich fluid activity could be successfully determined because we successfully distinguished the Zrn grains formed by the Cl-rich fluid activity from the detailed microstructural study. Therefore, in addition to understanding the Cl-rich fluid activity itself, understanding the formation mechanism of datable accessory minerals is also important to correctly interpret the meaning of the age obtained.

Keywords: chlorine, fluid infiltration, granulite facies, Sor Rondane Mountains, REE

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SMP43-03 Room:303 Time:May 24 09:30-09:45

Thermal anomaly map in low P/T type metamorphic belt -Case study of the Ryoke metamorphic belt in the eastern Yamaguchi

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Low P/T type metamorphic belts show that the slope of their field P-T curves is higher (60-150^{0}C/km) than any steady-state geothermal gradients of continental crust (De yoreo et al., 1991). This suggests that excess heat was supplied by any transport proses to form the low P/T type metamorphic belts. The traditionally proposed process is heat conduction from granitic melts (Hunson and Barton, 1989). Recently, Miyazaki (2007) proposed pervasive melt migration as a heat transport proses. In contrast, Hoisch (1987) proposed hot fluid as source of high geothermal gradient in the crust.

A thermal anomaly map would help evaluate the validity these models. In this study, we provide thermal anomaly map of low P/T type metamorphic belt by using petrological method in the Ryoke metamorphic belt in the eastern Yamaguchi Prefecture.

[Method 1]

We estimated pressure-temperature conditions of one sample from K-feldspar-cordierite zone, seven samples from the sillimanite-K-feldspar zone and four samples from the garnet-cordierite zone by using the garnet-biotite thermometer of Hodges and Spear (1982) and the relative geothermobarometry of Ikeda (2004). Addition of result of Ikeda (2004) enables us to reveal the thermobaric structure of this area. Isotherms are oblique to isobaric lines, suggesting that the crust has thermally heterogeneous at the same depth. We constructed thermal anomaly map that shows difference between metamorphic temperature and steady-state temperature at the depth (dT).

[Result 1]

We divide the study area into two domains where T is larger than 500^{0}C and smaller than 500^{0}C. The former domain contains garnet-cordierite zone, low temperature and pressure part of sillimanite-K-feldspar zone and K-feldspar-cordierite zone.

[Method 2]

We measured areal fraction of the Older Ryoke Granite (ORG) based on the geological map of Nishimura, et al., (1995).

[Result 2]

The areal fraction of ORG is larger in the domain of dT $<$500^{0}C than that of dT $>$500^{0}C. The domain of T $>$500^{0}C elongates subparallel to the gneissosity.

[Discussion]

The areal fraction of ORG being larger in domain of dT$>$500^{0}C suggesting that ORG could not be a heat source of Ryoke metamorphism. We proposed three alternative models.

1: Infiltration of high temperature H2O fluid that is not controlled regionally by the distribution of ORG (Hoisch, 1987).

2: Advection of the small amount of melt has slow flow velocity or long duration (Miyazaki, 2007).

3: Spatially dense injection of thin granitic melts.

The gneissosity subparallel to the long axis of the domain of dT $>$500^{0}C may support the model3.

Keywords: metamorphic rock, Low P/T metamorphic belt, Ryoke belt, Thermobaric structure, Thermal anomaly map

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SMP43-04 Room:303 Time:May 24 09:45-10:00

Structure and growth of the lower crust beneath SW Japan: constraints from xenoliths in Cenozoic alkaline basalts

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Felsic continental crust is thought to be unique to the Earth and is important to constrain material circulation of the crust-mantle system throughout its history. The continental crust is estimated to be chemically stratified; the upper crust is considered to be felsic and the lower crust to be mafic. The crustal materials may interact with the mantle via subduction of crustal materials and/or delamination of the lower crustal rocks. However, lack of a direct evidence of such processes, in particular the latter for the lower crust, prevents us from understanding evolution of the crust-mantle system even in a qualitative sense. The purpose of this study is to constrain a timing of formation and growth mechanism of the lower crust, which will provide fundamental information to discuss evolution of the continental crust and the mantle.

Subduction zones are thought to be a site of continental growth and differentiation. We have conducted detailed analyses of various types of xenoliths in alkali basalt from the Gongen volcano in the Kibi plateau, SW Japan. As we particularly concern the formation and growth timing of it, zircon U-Pb age dating has been conducted, as well as petrology of the xenoliths.

We have collected total 40 xenoliths and observed them using optical microscope and electron probe micro analysis (EPMA). The xenoliths consist of various rock types; peridotite, gabbro, pyroxenite, anorthosite and quartzite. Based on the petrological analysis including EPMA and phase relation study, gabbro, anorthosite and quartzite are likely to have derived from the lower crust. Among the xenoliths, pyroxenite may represent a dense igneous cumulative materials located around the Moho beneath the area. Temperature of the pyroxene cumulate is estimated to be 810 degree C based on olivine-spinel geothermometry [Fabries, 1979]. Anorthosite, in which corundum is observed, exhibits Al-rich bulk compositions. Kyanite and garnet are observed in quartzite xenoliths. The kyanite-bearing quartzite xenoliths, which is estimated to have been formed in granulite facies, exhibits silica-rich and CaO-poor bulk compositions, indicating that sedimentary materials are incorporated into the lower crust of the SW Japan.

To constrain the formation age and the underplating process of sedimentary rocks, we have measured U-Pb ages of zircon crystals in the lower crustal xenoliths. Based on the zircon U-Pb age and petrological analyses, structure and growth process of the lower crust beneath SW Japan is discussed.

Keywords: lower crust, xenolith, south west Japan, zircon U-Pb age

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SMP43-05 Room:303 Time:May 24 10:00-10:15

Development of olivine crystal-fabrics in the southern Marian forearc mantle wedge: insights from S. Chamorro Seamount.

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Large serpentinite mud volcanoes form on the overriding plate of the Mariana subduction zone, which extends for approximately 2,500 km in the N-S direction parallel to the Mariana Trench axis. Fluids from the descending plate serpentinize the forearc mantle and enable serpentine muds to rise along faults to the seafloor (Fryer, 2012 Ann. Rev. Marine. Sci.). The seamounts are direct windows into subduction processes at depths far too deep to be accessed by any known technology (Fryer, 2012 Ann. Rev. Marine. Sci.). In this study, we focused on serpentinized peridotites obtained from South Chamorro Seamount in order to understand the forearc mantle wedge structure of southern Mariana forearc. The South Chamorro Seamount is located at 100 km east of Guam island and 85 km west of the Mariana Trench axis. The peridotite samples consist mainly of harzburgites with a few dunite samples. We analyzed olivine crystallographic fabrics and chemical compositions of olivine and spinel grains. As a result, two types of olivine crystal fabrics were obtained: [010]-fiber type (or AG-type) and [100]{0kl} type (or D-type). The chemical compositions show that Cr# (Cr3+/Al3++Cr3+) of spinel is 0.4 to 0.8 and Mg# (Mg2+/Mg2++Fe2+) of olivine is 89 to 92, which are in the range of Olivine-Spinel Mantle Array (OSMA) of Arai (1994 Chem. Geol.). However, no other seamounts have been found to have as wide a range of Cr# in spinel composition as those of South Chamorro Seamount. The equilibrium temperatures induced by olivine and spinel compositions are 700 C for the [100]{0kl} type peridotites and 800 to 850 C for the [010]-fiber type peridotites. Since [010]-fiber olivine fabrics could be developed under melt-bearing high-temperature conditions, such as in the subsolidus regime (e.g., Kohlstedt & Holtzman, 2009 Ann. Rev. Earth Planet.), it is unlikely that they have been developed in the forearc region. Alternatively, the [010]-fiber type peridotites may be derived from the older lithospheric mantle before the formation of the Mariana arc system, whereas the {100}{0kl} type could be related to supra-subduction tectonics or the development of serpentine mud volcanoes.

Keywords: peridtite, serpentinite, crystal fabric, [010]-fiber type, [100]{0kl} type, subduction

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SMP43-06 Room:303 Time:May 24 10:15-10:30

Development of an ultramylonite zone within the mafic rocks in the Moho Transition Zone, Oman Ophiolite

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The purpose of this study is to reveal the process of structural development of a ductile shear zone across the crust-mantle boundary in Oman ophiolite. The ductile shear zone has been developed within the mafic rocks in the Moho Transition Zone, Fizh massif. Ultramylonites are widely distributed, whereas mylonitie does not occur in the shear zone. Weakly and moderately deformed rocks observed in the outside of the ductile shear zone have igneous equigranular textures and partly contain domains of dynamically recrystallized fine grains consisting of plagioclase and minor amphibole. The mean grain sizes of fine-grained plagioclase matrix within ultramylonites are 5-6 microns which are nearly steady state. Plagioclase crystal-preferred orientations (CPO) show (010) [100] pattern and (001) [100] pattern in the weakly and moderately deformed rocks, respectively, and random in the ultramylonites. The change of the CPO patterns suggests a transition from dislocation creep to grain-size-sensitive creep. The modal composition of amphibole is higher in each ultramylonite than those in weakly and moderately deformed rocks. Combined with the whole rock chemical compositions, it suggested that the shear zone has been infiltrated by water, by which element mobilization could occur. As the grain sizes of plagioclase decreased along with the amphibole formation, intense strain localization in the shear zone could take place accommodated with strain softening.

Keywords: ultramylonite, gabbro, mafic rock, shear zone

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SMP43-07 Room:303 Time:May 24 10:30-10:45

Microstructural development of coarse granular peridotite derived from Kaapvaal cratonic lithosphere, South Africa

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Kimberlite was generated in deep upper mantle (70-250km) beneath craton and subsequently ascended to surface rapidly. Peridotite xenoliths, which were entrained by kimberlite, record composition and texture formed in upper mantle beneath the craton. Peridotite xenoliths from Kimberley pipe, Southern Africa, are divided into two groups: granular type and foliated type. The granular type peridotite has difficulty in identifying any foliation, whereas the foliated type shows distinct foliations. The granular type peridotite has a few studies in terms of microstructural development, presumably because of very coarse grain. In this study, five large samples have been selected among thirty-five samples and several thin sections for three orthogonal planes in each sample have been made after lineation and foliation were identified visually. We performed microstructural analyses and measured major mineral compositions and water contents in minerals in order to reveal microstructural and petrological characteristics of peridotite xenoliths in kimberlite and to interpret cratonic lithosphere. All five samples are garnet harzburgites. They were divided into two groups: Group1 includes two samples containing no clinopyroxene and Group2 includes three samples containing minor amounts of clinopyroxene. The crystallization of clinopyroxene appears to be associated with metasomatism. Rounded garnets were observed in Group1 peridotites, whereas elongated garnets occur in Group2 peridotites. Olivine and orthopyroxene Mg# in Group2 are lower than those in Group1 peridotite. Olivine and orthopyroxene have different compositions between Group1 and Group2 peridotites. Equilibrium temperature and pressure are similar (1000 degree C, 40kbar) among all five samples regardless of the group. With respect to CPO analyses, Group1 olivine fabrics were characterized by a point maximum of [010] and girdle distribution of [100] and [001]. Orthopyroxene fabrics were characterized by a point maximum of [001] and girdle distribution of [100] and [001]. Group2 olivine and orthopyroxene fabrics did not show any dominant concentration. Water contents in garnet are different between two types. Rounded garnet in Group1 had relatively low water contents (10ppm), whereas elongate garnet in Group2 presents high water contents (50ppm). Although both Group1 and Group2 peridotites have similar equilibrated P-T conditions, they showed different mineral compositions of olivine and orthopyroxene. It appears that Group2 peridotite has been affected by metasomatism process. The change of mineral compositions from Group1 to Group2 is attributed to melt infiltration, possibly resulting in different fabrics of olivine and orthopyroxene. With respect to garnet shapes, rounded garnet in Group1 might be facilitated to strain and be transformed elongate garnet in Group2 by water added with melt during metasomatic event. It is generally considered that granular type peridotite represents the steady state mantle process in the cratonic lithosphere. However, this study suggested that granular type peridotites show a variation, resulting from melt infiltration in the cratonic mantle.

Keywords: Kaapvaal craton, Kimberlite xenolith, olivine fabrics, metasomatism, seismic anisotropy

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Thermal alteration of the R1 parameter of carbonaceous matters

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Burnham and Sweeney (1989) concluded that the vitrinite (VTN) maturation during heating could be treated most simply by considering the following four independent parallel reactions: VTN -> VTN + H2O, VTN -> VTN + CO2, VTN -> VTN + CHn and VTN -> VTN + CH4. Huang (1996) proposed the empirical power law rate model for the evolutions of VTN reflectance controlled more by temperature than time based on his heating experiments of lignite.

The thermal maturity of carbonaceous matters (CMs) may also be represented by the R1 ratio (measured commonly as D/G peak intensity ratio) of the Raman spectra. Muirhead et al. (2012) estimated the kinetic rate of the thermal maturity of CMs indicated by the R1 ratio as R1 = B + 0.441557 $*$ exp(-402/T) $*$ t$\hat{}$(6.04E-5$*$T+0.011304), where t is the duration of heating in seconds, T is the temperature in Kelvin and B the initial ratio of R1 (=0.23 in his study), from his flash pyrolysis experiments of CMs for 5 to 80 seconds heating. However, the CMs taken in his experiments were collected from Murchison meteorite and show quite different Raman spectra from those of CMs in non-metamorphosed pelitic rocks. Also, it should be noted that his R1 ratios may be D/G peak area ratios.

Therefore, we have made heating experiments of CMs in pelitic rocks collected from the Kanoashi Group of Jurassic complex, SW Japan and measured the R1 (D/G peak intensity) ratios before and after the experiments. Reflectances of the CMs indicate their diagenetic temperatures as around 284C. The initial R1 ratios before heating are about 0.5.

Polished rock chips were kept in an Ar purged capsule, and then taken into an electric oven. Unfortunately, the oven is not available for quick heating, it took, for example, 14 minutes to achieve 800C. The experiments have been done under 290, 500 and 800C with different durations. Note that the both 500 and 800C experiments, the same rock chips were used, that is, repeatedly heated, to follow the evolution of the R1 ratios of the individual CMs.

Small peaks between the D and G bands of the Raman spectra appeared in some CMs after short heating (< 10 minutes at 500C and (1) of 800C). However, they disappeared after longer and higher heating experiments. Other two types of the thermal evolution of the R1 ratios could be observed during 500C experiments. The one is that the R1 ratios systematically increased with increasing heating durations (i.e., repeating times), while the other is that the ratios increased after a short time heating and then decreased to the initial ratios and again increased by further heating. On the other hand, the R1 ratios after 800C heating experiments show two types of their evolutions. The one is that the ratios did not exceed 1.5 after heating, while the other did. The latter showed various R1 ratios irrespective of heating durations. Those characteristics of the thermal evolution of the R1 ratio may depend on the difference of the precursors of CMs.

Therefore, it can be concluded that the large grained CMs of which R1 ratios do not exceed 1.5 should be taken to estimate a kinetic rate for the thermal maturation of CMs. The power term on time of a preliminarily estimated kinetic rate of the thermal evolution of the R1 ratios estimated by the present experiments is one order of magnitude higher than that of Muirhead et al. (2012), implying that the rate depends not only on temperature and time but also on the initial R1 ratio. Also, it should be investigated in a future study that there may be maximum value(s) of the R1 ratios as shown by Beyssac et al. (2002), which in turn may also affect the kinetic rate.

Keywords: carbonaceous matters, R1 ratio, Raman

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Trace-element analyses of clinopyroxene megacryst in garnet lherzolites from the Bohemian Massif

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High-pressure and ultrahigh-pressure metamorphic rocks in the continetal collision zone contain a number of garnet-bearing ultramafic rocks within the metamorphic rocks of upper crustal compositions. Two different hypotheses has been proposed to incorporate the peridotites in the crustal metamorphic rocks: (1)a high-temperature mantle wedge peridotite was dropped into the subducting crust, and (2)the dry mantle peridotite was entrained in the low-P-T crustal rocks and was transformed to serpentinite/chlorite peridotites that are transformed into garnet peridotite by the subsequent subduction.

To reconcile this controversy, we study garnet peridotites from the two localities in the Bohemian massif (Variscan orogeny), Lom pod Libidem (LPL) and Plesovice quarry (PQ). In both localities, garnet peridotites are enclosed in the high-pressure acidic granulite. The previous researches demonstrated that these garnet peridotite have equilibrated at 1020 C/2.5 GPa and 940 C/2.9 GPa during the UHP metamorphism. The subsequent exhumation partially transformed garnet peridotite into spinel peridotite at 770C/1.5 GPa.

We find clinopyroxene megacrysts, with size up to 3 cm, surrounded by the fine-grained matrix of garnet peridotite assemblages which are variably retrogressed to spinel peridotite ones. The clinopyroxene megacryst contains numerous amphibole inclusion (bleb/lamella) along with phlogopite, olivine, orthopyroxene, apatite,ferrit chromite, and rare huttonite.

The 3 cm-size clinopyroxene from the LPL locality are strongly zoned. Chemical mapping demonstrated it consists of three zones: (1)the core poor in Al2O3 (~1.0 wt. %) and Na2O (0.8 wt. %), (2)the mantle contains highern Al2O3 (~2.0 wt. %) and Na2O (1.2 wt.%) and (3) the rim with higher Al2O3 (~3.0 wt. %) and lower Na2O (0.8 wt.%). The CaO content slightly decreases from the core to the mantle (from 22.0 to 20.5). The trace element analyses of clinopyroxene showed positive anomalies of Pb, Sr, LREE and negative HFSE anamalies, suggesting an involvement of fluid. Rare earth element concentration is very low in the core with moderate LREE/HREE slop with (Yb/Gd)N=9+-5 normalized by CI chondrite. Such an Al-Na-REE poor clinopyroxene are typically observed in the chlorite-bearing peridotite. The mantle REE pattern have a steeper slope of LREE/HREE with (Yb/Gd)N=17+-4 suggesting a coexistence with garnet. The REE contents at the rim become higher in concentration with a slope of (Yb/Gd)N=7+-2, reflecting a re-equilibration in the spinel-lherzolite facies.

The clinopyroxene megacryst at the PQ locality show a similar zoning with the core and the rim. (1)The core is poor in Al2O3, Cr2O3 and Na2O (2.0, 0.5 and 1.2 wt.% respectively), and (2)the rim is rich in them (3.6, 0.8 and 1.9 wt.% respectively). The CaO content decreases from the core toward the rim (from 22 to 20 wt. %).The trace element analyses for the megacryst rim showed enrichment in Pb, Sr. LREE and depletion in HFSE. The rim contain high concentration of REE with a steep LREE/HREE {(Yb/Gd)N~20+-6}, suggesting a coexistence with garnet. The coexistence of clinopyroxene rim with garnet suggest a week retrogression that is consistent with the week kelyphitization of garnet.

Based on the above information, we propose a following thermal history for the Bohemian garnet peridotites. Both the LPL and PQ peridotites were stable at chlorite-stability field at the initial thermal history. The alumina-poor composition in clinopyroxene suggests the rocks were originally chlorite-bearing peridotites at T<700C (or very low-T spinel peridotite), and the increse of Al, Na and the decrease of Ca toward the rim suggests a heating during the subduction history, which finally transformed chlorite peridotite into garnet peridotites. Both peridotite were partially transformed to spinel peridotite, but the retrogression is more severe in LPL peridotite while PQ peridotite preserve the garnet-peridotite even at the rim of clinopyroxene.

Keywords: orogenic peridotite, continental collision, Bohemian massif, subduction, clinopyroxene megacryst

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SMP43-10 Room:303 Time:May 24 11:30-11:45

Evolution of Archean high-pressure granulites from the Namakkal Block,southern India

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The Namakkal Block of Southern Granulite Terrain is bounded by Salem- Attur Shear Zone to its North and Cauvery Shear Zone to its South. Major litho-units are meta-gabbro, charnockites, granites, hornblende-gneiss, pyroxene granulites, ultramafics and iron formations. Here we describe the high-pressure granulites /retrogressed eclogites (meta-gabbro) from three key localities which are found along the verge of shear zones.

The meta-gabbros exposed in the Devannur-Mahadevi area are located in the southern part of Namakkal Block.They are associated mainly with iron formations, two-pyroxene granulites and websterites. Mg-rich garnet porphyroblasts coexist with the magnesium rich clinopyroxenes porphyroblasts, changing partially to amphiboles and plagioclase along the grain boundaries and fractures. Garnet contains clinopyroxene and quartz inclusions. On the other hand, garnet inclusions in clinopyroxene are not observed. Both garnet and clinopyroxene have exsolution lamellae of rutile or Ilmenite, which formed during retrogression and exhumation. Rutile is also present in the matrix assemblage. It is noted that orthopyroxene is totally absent. The pressure and temperature condition of the peak mineral assemblage (Grt+Cpx+Qtz) are about21 kbars 900oC, respectively that are determined through isochemical phase diagram.

Retrogressed eclogites/high-pressure granulites are also reported from the Sittampundi area located in the southwest of Namakkal Block, where the opx free meta-gabbroic rocks are associated amphibolites and layered anorthosite. Sajeev et al. (2009) found relict omphacite inclusions in garnet porphyroblasts and described the eclogite facies conditions (about 25 kbar and 1020oC). Amphibole and plagioclase are the retrograde phases in these samples. The U-Pb zircon age from the high-pressure granulites gives 2490 Ma (Sajeev et al., unpublished). The high-pressure granulites are also found in several places towards the North of Namakkal Block. The most notable occurrence is at Kanjamalai near Salem town. The U-Pb zircon ages from the associated rocks also yield 2490 Ma (Anderson et al., 2012, George et al., unpublished). These rocks with geological and textural similarity in the southern localities contain orthopyroxene. Moreover, these samples also have significant variation in the mineral chemistry with high iron content. The pressure and temperature of meta-gabbros are estimated to be about 19Kbar and 800oC, respectively.

Thus, the mineral chemistry and geochronological studies of the high-pressure granulites in a traverse from North to South suggest that the Namakkal block had undergone late Archean metamorphism. Hence, the region possibly represents various levels of a subducted basaltic oceanic crust, with the lower crust to the South and the middlecrust to the North. A comprehensive geochemical study, including Rb-Sr and Sm-Nd isotopes as well as zircon SHRIMP age dating are underway, which will be significant in discussing the geotectonic architecture of Namakkal Block of Southern Granulite Terrain in late Archean.

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Keywords: High-pressure granulite, Namakkal Block, Subduction zone metamorphism, Late Archean, Oceanic crust

SMP43-11 Room:303 Time:May 24 11:45-12:00

Metamorphic age of the eclogites from the Lake Zone, SW Mongolia

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The Alag Khadny metamorphic complex in the Lake Zone, SW Mongolia, which is located in the central part of the Central Asian Orogenic Belt, consists mainly of orthogneisses and minor micaschists interleaving marbles including lenses of garnet-chloritoid schists of the Maykhan Tsakhir Formation. Eclogites occur as lenses and boudins in the matrix of orthogneisses and minor micaschists. The peak metamorphic conditions for the eclogites were estimated to be high *P/T* conditions of T=590-610^{o}C and P=20-22.5 kbar (Stipska *et al*., 2010), in contrast the pressure conditions of the garnet-chloritoid schists (P=10-11 kbar) are distinctly lower than those of the eclogites, whereas temperature conditions (T=575-585^{o}C) are similar (Otgonkhuu *et al*., 2012).

We discovered the amphibole-rich veins (up to 5 mm in width) are developed in the eclogite bodies. Two types of amphibole-rich veins are distinguished based on the mineral assemblage, i.e. amphibole-sodic plagioclase-phengite (Amp-NaPl-Ph) vein and amphibole-quartz (Amp-Qz) vein. Amp-NaPl-Ph vein consists mainly of amphibole (barroisite), sodic plagioclase, phengite with minor amounts of titanite and quartz. Amp-Qz vein consists of quartz and amphibole (tremolite).

Amphiboles in the Amp-NaPl-Ph vein occur as subhedral prismatic crystals and they are up to 0.5 mm long. They show compositional zoning from barroisite (Si=6.97-7.20 pfu, Na_B=0.52-0.68 pfu, K_2O=0.37-0.46) cores to Mg-hornblende and/or edenite (Si=6.56-7.41 pfu, Na_B=0.22-0.48 pfu, K_2O=0.18-0.74) rims with rarely actinolite (Si=7.50-7.57 pfu, Na_B=0.07-0.35 pfu, K_2O=0.10-0.26) outer-most rims. Whereas the amphiboles in the Amp-Qz vein occur as subhedral prismatic crystals, up to 3 mm long in the matrix of quartz. They show compositional zoning from tremolite (Si=7.58-7.62 pfu, Na_B=0.31-0.42 pfu, K_2O=0.09-0.14) cores to Mg-hornblende rims (Si=7.27-7.49 pfu, Na_B=0.17-0.44 pfu, K_2O=0.04-0.19) with rare actinolite (Si=7.50-7.67 pfu, Na_B=0.09-0.42 pfu, K_2O=0.06-0.16) outer-most rims. Sodic plagioclases (An=1-14) in the Amp-NaPl-Ph vein are of anhedral grain, intercalated with amphiboles and phengites. Phengites (Si=6.64-6.92) in the Amp-NaPl-Ph vein occur as subhedral crystal, up to 0.5 mm across.

The geothermometer of amphibole-plagioclase (Holland and Blundy, 1994) and the geobarometer of Si content of phengite (Massonne and Scherer, 1987) have been applied for the approximate *P-T* conditions of Amp-NaPl-Ph vein developed in the eclogites. The cores of barroisite and intercalated plagioclase with highest anorthite component (An=14) suggest temperature conditions of 540-580^{o}C. Si contents of phengite (6.64-6.92 pfu) suggest pressure conditions of $>$10 kbar.

We obtained K-Ar ages of the Amp-NaPl-Ph vein [603 +/-15 Ma (amphibole) and 612 +/-15 Ma (phengite)] and Amp-Qz vein [602 +/-15 Ma (amphibole)], and we interpret the ages of c. 600 Ma as exhumation age of the eclogite bodies. The obtained ages of the eclogites are distinctly older than $^{40}Ar/^{39}Ar$ phengite ages of c. 540 Ma from the eclogites and garnet-chloritoid schists (Stipska *et al*., 2010), which are located about 2 km east from the present localities of the veins. These suggest that the eclogites were once exhumed at c. 600 Ma from the high-P conditions and juxtaposed with the garnet-chloritoid schists, and the amalgamated sequence of metamorphic rocks was then exhumed together to shallower crustal levels at c. 540 Ma.

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Keywords: K-Ar age, Amphibole-rich veins, Eclogite, Lake Zone, Mongolia

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SMP43-12 Room:303 Time:May 24 14:15-14:30

Jadeite-bearing garnet glaucophane schists from the Sambagawa metamorphic belt in the Bizan area, eastern Shikoku, Japan

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Discovery of jadeite-bearing garnet glaucophane schists from the Bizan area offers a new locality of eclogite facies metamorphic rocks and extension of the distribution of eclogites to the easternmost part of the Shikoku Island. The Bizan area of the Sambagawa metamorphic belt is located in the Tokushima Prefecture of eastern Shikoku, Japan and it is mainly composed of pelitic schists, basic schists and siliceous schists with minor garnet glaucophane schists. Faure (1983) suggested that a melange zone containing tectonic blocks of serpentinite, metagabbro and garnet-amphibolite (garnet-glaucophane schist) occurs within a ductile shear zone between spotted and non-spotted schist zones. Jadeite-bearing garnet glaucophane schists are newly found in the melange zone.

Jadeite-bearing garnet glaucophane schists consist mainly of garnet, jadeite, amphibole (glaucophane and barroisite), epidote, phengite, paragonite, chlorite, albite, rutile, titanite, calcite and quartz. The porphyroblastic garnets are almandine-rich composition and display prograde growth zoning with decreasing X_{Sps} (0.23-0.02), increasing X_{Alm} (0.47-0.66) and slightly increasing X_{Prp} (0.01-0.03) from core to rim. The cores of the garnets contain inclusions of barroisite, epidote, muscovite (Si 6.04-6.15 pfu), chlorite, calcite, titanite and quartz and polyphase inclusions of barroisite +/- epidote +/- chlorite + titanite + quartz assemblage. The rims of garnet contain inclusions of glaucophane, epidote, phengite (Si 6.49-6.73 pfu), paragonite, chlorite, rutile and quartz and polyphase inclusions of jadeite +/- glaucophane +/- epidote + chlorite + titanite + quartz. Impure jadeite inclusions are present throughout garnet grain (X_{Jd} 0.49-0.75, X_{Aeg} 0.19-0.47). Glaucophanes in the matrix contain inclusions of phengite, epidote, chlorite, titanite and quartz and they are partly replaced by barroisite. Phengites (Si 6.61-6.67 pfu) in the matrix contain inclusions of glaucophane, epidote and chlorite. Some large grains of epidotes and chlorites contain inclusions of matrix minerals such as glaucophane, phengite, epidote, titanite and quartz.

The metamorphism of the garnet glaucophane schists is divided into three events based on petrography and chemistry of constituent minerals, i.e. (i) precursor metamorphic event (muscovite inclusions in the garnet cores), (ii) first high-pressure metamorphic event of eclogite facies, and (iii) second high-pressure metamorphic event (large epidote and chlorite in the matrix).

Chloritoid-bearing garnet glaucophane schists lack of jadeite represent multy-stage metamorphic evolution (Kabir *et al*., 2012; Takasu *et al*., 2012; Kabir *et al*., 2013). *P-T* conditions of prograde stage are estimated as 450-500^{o}C and 9-11 kbar (epidote-blueschist facies metamorphic conditions) using inclusion mineral assemblage in garnet core. The peak metamorphic conditions of eclogite facies (550-600^{o}C and 17-19 kbar) are obtained from inclusions minerals in the rims of the porphyroblastic garnets and schistosity-forming matrix minerals. *P-T* pseudosection in the MnNCKFMASH model system and garnet compositional isopleths also consistent with the obtained prograde and the peak metamorphic conditions. Prograde and peak metamorphic conditions of the garnet glaucophane schists are similar to those of newly found lawsonite eclogites in the Kotsu area, eastern Shikoku (Tsuchiya and Hirajima, 2012), probably suggesting both of them have similar metamorphic evolution. Large grains of epidotes and chloretes in the matrix, which contain minerals of the peak metamorphic stage suggest another high-pressure prograde metamorphism occurred and the metamorphism is correlated with the Sambagawa metamorphism in the Besshi area, central Shikoku (Aoya, 2001; Kabir and Takasu, 2010a, b). Both jadeite-bearing and chloritoid-bearing garnet glaucophane schists are considered to experience similar high-pressure metamorphic history.

Keywords: Sambagawa metamorphic belt, Bizan area, garnet-glaucophane schist, eclogite, jadeite

SMP43-13 Room:303 Time:May 24 14:30-14:45

Two stages of orthopyroxenite formation in the slab-mantle wedge interface

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The slab-mantle wedge interface is a site of intensive chemical-mechanical interactions between mantle and crustal rocks in the presence of a slab-derived agent (fluid/melt). Mantle rocks that suffered from Si-metasomatism probably play important roles in subduction interface processes such as mechanical coupling and recycling of volatile and incompatible elements, although the detailed petrological structure of the subduction interface and its spatial-temporal evolution are not well-understood.

We focus on the two important processes of orthopyroxenite formation along the slab-wedge mantle interface. One is metasomatic replacement of peridotite via the reaction Ol + SiO_2 (slab partial melt or solute-rich fluid) = Opx (R1). This process can occur at high-T conditions such as seen at forearc depths of infant subduction zones or subarc depths of matured subduction zones. The other is dehydration of Si-enriched serpentinite via the reaction Tlc + Atg = Opx + H_2O (R2). This reaction takes place at low-T eclogite facies conditions and may be responsible for the maximum depth of decoupled slab-forearc mantle interface.

Natural records of these reactions have been discovered in the Western Iratsu body of the Sanbagawa belt, which consists of metabasaltic and minor ultramafic domains. This mafic-ultramafic complex represents an important natural laboratory to study slab-mantle interactions in an evolving subduction zone environment. Dunite is the major rock type of the ultramafic domain and grades into Opx-rich rocks (orthopyroxenite with a harzburgitic zone at the contact with dunite) at the mafic-ultramafic boundary. In addition, Opx-rich veins crosscut the whole sequence.

The earlier orthopyroxenite is mainly composed of coarse-grained orthopyroxene (Opx1: up to 1.3 wt% Al_2O_3) that include rounded olivine crystals and texturally primary multiphase solid inclusions (MSI). Olivine enclosed in Opx1 in the orthopyroxenite is enriched in Ni (up to 1.1 wt% NiO, Fo88-89) with respect to this mineral in adjacent dunite (up to 0.35 wt% NiO, Fo88-89), suggesting the progress of R1. Cores of Cr-spinel in the Opx1-bearing rocks and dunite show identical compositions (Cr#=0.83-0.87, Mg#=0.20-0.29, $TiO_2<0.4$ wt%) that are indicative of a highly depleted forearc mantle origin. These observations, in conjunction with previously constrained P-T-t history of the body, suggest that the Opx1-bearing rocks were formed by reactions between a slab-derived melt and the dunitic mantle wedge during the earliest stage of the subduction zone development. MSI in Opx1 probably represent remnants of residual melt/fluid after the progress of R1. LA-ICPMS analyses of MSI and the host Opx1 reveal that the residual melt/fluid (and also metasomatic agent) is rich in LILE, U, Th and LREE and only minor fraction of them resides in Opx1. Therefore, the metasomatic formation of orthopyroxenite permits transportation of the reactive slab-derived agent into the mantle wedge and recycling of the slab-derived incompatible elements.

The later orthopyroxene-rich vein consists of euhedral prismatic Al-poor orthopyroxene (Opx2: $Al_2O_3<0.04$ wt%) in association with antigorite, chlorite and tremolite. The mineral assemblage and the composition and morphology of Opx2 suggest Opx2-bearing veins were formed via R2 in the eclogite facies conditions. Before the dehydration veining, dunite and/or Opx1-bearing rocks must have suffered from hydration to form antigorite and talc by influx of H_2O-rich fluid. Opx2 is significantly lower in HFSE (Nb, Ta, Zr, Hf, Ti) and higher in fluid mobile elements (Li, B, Cs and Rb) than Opx1, supporting this interpretation.

Keywords: orthopyroxenite, metasomatism, mantle wedge, Sanbagawa belt

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SMP43-14 Room:303 Time:May 24 14:45-15:00

The importance of slab-mantle coupling at 80 km depth in subduction zones

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Subduction zones are complicated regions with fluid flow, earthquakes, melting and metamorphism, and ductile deformation, all interacting. One of the major controls on these processes is temperature. Thermal modeling suggests that the temperature of subduction zones is largely determined by the balance between cooling due to inflow of cold lithosphere and heating due to the flow of hot mantle towards the slab due to induced convection in the wedge mantle. Understanding this flow in the mantle wedge has been a major topic of research in the geodynamics of subduction zones.

Direct evidence for solid-state flow in the mantle wedge is provided by heat flow patterns across convergent margins. Few margins are very well characterized and the arc region is associated with local heat sources such as magmatic intrusions that are a cause of large scatter in the data. Nevertheless, the available data suggest mantle convection occurs at depths greater than around 70 to 90 km irrespective of the age of the slab.

Flow in the mantle wedge is thought to be restricted to regions where there is strong coupling between the downgoing slab and overlying mantle. Shallow levels in subduction zones are more weakly coupled. As a result of the decoupling, the corner of the wedge mantle undergoes cooling and hydration to form a cold nose.

Thermal modeling predicts a kink should exist in the thermal structure along the subduction boundary corresponding to the depth at which strong coupling between the mantle and slab become effective. The study of subduction-type metamorphism provides information on the P-T conditions close to the subduction boundary and can potentially be used to identify this type of kink in the thermal structure and, hence, to constrain the depth of strong coupling in ancient subduction settings. The Sanbagawa belt is a rare example of where this has been proposed and suggests induced flow at a depth of around 65 km.

The available evidence suggests the depth of coupling is roughly the same in all subduction zones. This common depth of coupling can help explain the common depth to the slab beneath volcanic arcs. The mechanism responsible for a change from weak to strong coupling is, however, not well known. Dehydration of antigorite and other weak hydrous phases may play a role. However, the temperature at the onset of the thermal kink is different for different subduction zones and so such a mechanism cannot explain the common depth.

The Sanbagawa belt preserves a series of peridotite bodies derived from the mantle wedge, which have experienced metamorphism at depths from 30 to greater than 100 km. The boundaries of these bodies are, therefore, fossil examples of the subduction boundary. This area is ideal for studying the controls on the coupling.

Keywords: subduction zone, wedge mantle, coupling, slab

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SMP43-15 Room:303 Time:May 24 15:00-15:15

Metamorphism of the Eastern Iratsu mass in the Sambagawa metamorphic belt, Besshi district, central Shikoku, Japan

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Based on petrography and chemistry of the constituent minerals metamorphic P-T pass is revised as 1)granulite facies met (amphibolite-epidote amphibolite facies), 2) high T eclogite facies met, 3)low-T eclogite facies met, 4) epidote amphibolite met (Sambagawa met).

Keywords: Sambagawa metamorphic belt, Iratsu, granulite, eclogite

SMP43-16 Room:303 Time:May 24 15:15-15:30

Hydrofracturing, fluid flow, and rhythmic precipitation of carbonates in marble: An example of orbicular marble

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The Hirao Limestone at Hirao-dai, Kita-kyushu City, is considered to be a Paleozoic limestone bed metamorphosed by Cretaceous granites, and now consists of completely re-crystallized limestone (marble) with little fossil evidence (Fukuyama et al., 2004, 2006; Urata, 2009). We newly found a peculiar zone with orbicular structure in the marble, and refer it as an orbicular marble hereafter. The orbicular marble occurs as a narrow zone of about 1 meter width, extending about 20m straight from north to south. In parallel to the zone occurs several veins of dolomite with various width ranging from several millimeters to 5 centimeters in the marble. The zone contains a lot of angular fragments of marble, several centimeters to 10 centimeters in size, surrounded by alternating thin layers of dolomite and calcite. The resulting structure looks concentric orbicules. The number of alternating layers is typically more than 10. The thickness of each thin layer is variable, ranging from 1 mm to 6 mm. The interstices between orbicular marbles are filled with dolomite. The angular fragments sometimes show jig-saw puzzled structure with neither clay nor fine-grained crushed materials between the fragments. The contact between the zone of orbicular marble and the country rock (massive marble) is sharp and shows no obvious displacement.

The occurrence of the orbicular marble zone suggests that the zone was originated as a tensile fracture caused by hydrofacturing and that fluid flew through the fractured zone and precipitated dolomite and calcite around the fragments formed by fracturing. The absence of clay and gouge strongly supports hydrofracturing rather than faulting for the origin of tensile fracture.

We will present here a qualitative model to explain alternate precipitation of dolomite and calcite. The precipitation reaction of calcite is written as (e.g. Fein and Walther, 1989)

Ca2+ + CO2(aq) + H2O = CaCO3 + 2H+ (1)

Assuming similar reaction for dolomite, we get

0.5Ca2+ + 0.5Mg2+ + CO2(aq) + H2O = Ca0.5Mg0.5CO3 + 2H+ (2)

In the fluid, the following two reactions occur together with the above two reactions(Fein and Walther, 1989):

H2O + CO2(aq) = HCO3- + H+ (3)

H2O = H+ + OH- (4)

The charge balance equation holds for these reactions:

2mCa2+ + 2mMg2+ + mH+ = mHCO3- + mOH- (5)

Here m stands for molality. Reaction rates for the formation of calcite and dolomite can be modelled as:

dnCc/dt = k1[KCcaCa2+aCO2(aq)aH2O - aH+]A/V (7)

dnDo/dt = k2 [KDoaCa2+aMg2+aCO2(aq)aH2O - aH+]A/V (8)

All the reactions are assumed to be 1st order. KCc and KDo represents equilibrium constant for calcite and dolomite, respectively, and k1 and k2 are rate constants. A/V stands for specific area(area / solution volume). Assuming ideal dilute solution, activity is equal to molality.

Equation (5) gives

aMg2+ = - aCa2+ + K (9)

We assume K = (aHCO3- + aOH- - aH+)/2 is a positive constant. Then equation (8) becomes

dnDo/dt = k2 [KDoaCa2+(- aCa2+ + K)aCO2(aq)aH2O - aH+]A/V (10)

Antivity of H2O is almost unity in the dilute solution, then qualitative behavior of the solutions can be discussed in an aCa2+ vs. aH+ plane under constant aCO2(aq), by using nullclines of (7) and (10). The two nullclines intersect at a certain point with positive values of aCa2+ and aH+, which represents an equilibrium point. Precipitation of dolomite and calcite occurs interchangeably while the solution changes its composition around the equilibrium point.

Keywords: periodic precipitation, hydrofracturing, fluid flow, dolomite, calcite, orbicular marble

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SMP43-17 Room:303 Time:May 24 15:30-15:45

Viscous flow and thermal evolution of metamorphic belt

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Evolution of internal structure of metamorphic belt under viscous flow and thermal diffusion was evaluated using a virtual metamorphic belt. The virtual metamorphic belt consists of two phases viscous fluids. Thickness of the virtual metamorphic belt is set at 3 km and periodic boundary condition (9 km long) is adopted. Two phases viscous fluids is sandwiched by top and bottom solid plates. Viscosity of two phases fluids is set at 10ˆ23 and 10ˆ21 Pa s, respectively. Simple shear deformation is induced by the top and bottom moving-plates. Shear velocities of these plates are 1 cm/y and -1 cm/y, respectively. Thermal boundary conditions are given by constant temperatures at both plates (600 and 800 ?C). Heat conductivity of the both viscous fluids is set at 2.5 W/m/K.

Thermal structure within the virtual metamorphic belt shows a simple vertical thermal gradient during deformation. Thermal structure will be steady-state under the given thermal boundary conditions during 0.1 M yr.

When residential time is shorter than sufficient progress of diffusional relaxation and hydration reaction at lower temperatures, metamorphic rocks record peak metamorphic temperature. Therefore, thermal structures of metamorphic belt may represent spatial distribution of peak temperature. Spatial distribution of peak temperature of each element of the virtual metamorphic belt is mapped. The result shows that thin layers of which peak temperature is higher or lower than surrounding area were formed. Very large apparent thermal gradient is observed in the virtual metamorphic belt. These thermal structures are not formed without viscosity contrast between two phases. Therefore, the thin layers are formed by selective elongation of low viscosity phase under shear deformation.

Large thermal gradient perpendicular to schistosity is observed in many metamorphic belts. The above-mentioned selective-elongation of low viscosity phase is one of explanation for the large thermal gradient observed in the metamorphic belt.

Keywords: Metamorphic belt, viscous flow, thermal structure

SMP43-18 Room:303 Time:May 24 15:45-16:00

metamoprhic banding-moving Liesegang patterns in the plate boundary

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Recent studies of parallel metamorphic bands in plate boundary rocks revealed that the band front advances accompanied with metasomatic instability by Toriumi and Fukuyama (2012) during the large scale hydration metamorphism of the plate boundary rocks, judging from waveform interface between band and matrix. The chemical reactions at the front are dissolution of matrix minerals and precipitation of metasomatic minerals together with grain boundary fluid lens partially connected and networked together with neighboring fluid lenses. Advancing fronts of the bands should be controlled also by diffusion of ionic species of constituent minerals through the network of the fluid lenses.

In the plate boundary metamorphic rocks of Sanbagawa and Alpine and also Franciscan have abundant albite bands and spots. These bands and spots of albite contain commonly inclusion trails of matrix mineral grains, indicating replacement of albite after matrix.

Considering these evidences, it is confirmed that the metamorphic band is just the precipitation band behind the diffusion front of solution penetrating the network of fluid lenses of the rock. In this case, we will propose the simple band formation model by albite replacement after chlorite in the basic metamorphic schists in the greenschist facies and low pH conditions as follows:

Mg2Al3Si3O10(OH)5 + 13H+ = 2Mg2+ + 3Al3+ + 3H4SiO4 + 3H2O

Na+ + Al3+ + 3H4SiO4 = NaAlSi3O8,aq + 4H+ + 8H2O

NaAlSi3O8,aq = NaAlSi3O8,s (albite)

In this system, ionic concentrations of every species are governed by the following reaction-diffusion equations;

Ci,t = Di Ci.xx + Ri(Cj) (i,j = Na+, Mg2+, Al3+, H+, NaAlSi3O8,aq)

where Di and Ri are the diffusion constant and reaction term, respectively. These reactions comprise the system of inhibitor (H+) and activator (Na+) of ionic solutes with respect to precipitation of albite and dissolution of chlorite. Thus, it should have precipitation pattern like general Liesegang patterns (Izak and Lagzi, 2005). In this presentation, we would like to propose the dynamic Liesegang type metasomatism in plate boundary hydration metamorphism in the wide range of spatio-temporal scales.

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Keywords: metamorphic band, reaction-diffusion equation, Liesegang, plate boundary