Japan Geoscience Union Meeting 2013
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SCG61-P01 Room:Convention Hall Time:May 22 18:15-19:30

# Petrogenesis of incipient charnockite from Ihosy area in southern Madagascar

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Incipient charnockite (Pl+ Qtz + Kfs + Bt + Grt + Opx + Ilm + Mag) from Ihosy area in southern Madagascar occurs as patches of 20 to 50 cm in length within host orthopyroxene-free garnet-biotite gneiss (Pl + Qtz + Kfs + Bt + Grt + Ilm + Mag). The application of mineral equilibrium modeling on charnockite assemblage in NCKFMASHTO system to constrain the conditions of charnockitization defines a P-T range of 8-10.5 kbar and 820-880C, which is broadly consistent with the results from the conventional geothermobarometry (820-880C at 9 kbar) on Grt-Bt gneiss. The result of T versus mole $H_2O$ ($M(H_2O)$) modeling demonstrated that orthopyroxene-free assemblage in Grt-Bt gneiss is stable only at $M(H_2O) > 0.1$ mol.%, while orthopyroxene in charnockite occurs as a stable mineral at very low $M(H_2O)$ condition of $<0.1$ mol.%, which is consistent with the petrogenetic model of incipient charnockite related to the lowering of water activity and stabilization of orthopyroxene through dehydration reaction/melting of biotite. The dominant occurrences of $CO_2$-rich fluid inclusions in charnockite compared to host Grt-Bt gneiss indicate that the dehydration could have been caused by infiltration of $CO_2$-rich fluid possibly from external sources.

Keywords: charnockite, pseudosection, granulite, fluid

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# P-T evolution of eclogitic Grt-Cpx rocks from Vadugappatti within the Gondwana Suture Zone, southern India

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We report new petrological data of eclogitic garnet-clinopyroxene rocks from two new localities in Namakkal region within the Palghat-Cauvery suture zone, which corresponds to the Gondwana suture zone in southern India. The eclogitic rocks from Pavithram comprise garnet and clinopyroxene with accessory orthopyroxene, hornblende, plagioclase, and quartz. The peak mineral assemblage is garnet, clinopyroxene, orthopyroxene and quartz. The garnet is often surrounded by orthopyroxene + plagioclase + hornblende corona, suggesting the reaction: garnet + clinopyroxene + H2O => orthopyroxene + plagioclase + hornblende probably due to decompression from high-pressure stage possibly along a clockwise P-T path. This is a common reaction texture of mafic granulites in the region around Namakkal. The peak mineral assemblage of the eclogitic rocks from Vadugappatti is clinopyroxene, orthopyroxene and plagioclase. In contrast to Pavithram, clinopyroxene in the rocks is surrounded by garnet + quartz corona, suggesting the progress of reaction: clinopyroxene + plagioclase => garnet + quartz probably due to near-isobaric cooling or compression possibly along a counterclockwise P-T path. The two contrasting textures in garnet-clinopyroxene rocks from this region might indicate the occurrence of discrete metamorphic blocks with different P-T history within the suture.

Keywords: granulite, pseudosection, high-pressure metamorphism, Neoproterozoic

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# Internal textures and chemical composition of zircon from high grade metamorphic rocks of Southwest Group, Sir Lanka

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High-grade metamorphic terrene of Sri Lanka, consists of four major crustal units as, Highland Complex (HC), Wanni Comples (WC), Vijayan Complex (VC) and Kadugannawa Complex (KC). Western part of the HC is also regarded as Southwest Group (SWG). The SWG is dominated by garnet biotite gneiss, garnet biotite cordierite gneiss and charnockitic gneiss. In these rock types, zircon is identified as a major accessory mineral. During metamorphism, detrital zircon can be recrystallized. Thus, the preserved internal textures particularly, igneous oscillatory zoning can be progressively changed into: convoluted, blurred, and thickened. Then, the dominant texture is transgressive zircon patches and lobes. By introducing a chemical and internal textural classification of zircons, to SWG of Sri Lanka, it may helps to identify the relationships between chemical and internal textural domains, and petrological evolution of the rock. Basically, zircon occurred in matrix and as inclusions in garnet, biotite, and cordierite. Average chemical formulas of the studied zircons in these three different rock samples are $Zr_{0.939}Hf_{0.012}Si_{1.043}O_4$, $Zr_{0.945}Hf_{0.013}Si_{1.039}O_4$, $Zr_{0.936}Hf_{0.010}Si_{1.047}O_4$, respectively. Using backscattered electron (BSE) images from electron probe micro analyzer (EPMA), several types of internal textural domains were observed as detrital core, and overgrowth patterns. Overgrowth patterns are fir-tree texture, radial zoning, resorption, euhedral faces, and planner banded zoning. These textures may indicate the different geological and petrological events. According to the chemical analysis, Hf content may not contribute to the zoning of zircon. Then, further consideration should be based on the other trace elements and rare earth elements (REE). Zircon structure is available for the large radius atoms like REE, and especially, radiogenic elements may causes the damage of zircon structure. It is usual to observe that pleochroic halo around the zircon and fracture patterns during the long period of time. The damaged and fractured area allows the impurity elements (Ca, Al) to enter the zircon structure. Then, these impurities could be detected in considerable amount, in highly darker area of the zircon. The changes of internal textures of zircon, that is, oscillatory zoned zircons, gradually get faded and the chemical bands during the recrystallization may appear as new bands around rim area and sometimes in core area. Later, transgressive recrystallization patches developed with loss of trace elements (Pidgeon et al., 1998). In the case of high grade metamorphism finally, the all the banded pattern get disappeared. These transformations highly related to the metamorphic stages and the observed textures, in different grade of rocks and shows respective textural behavior.

Keywords: Sri Lanka, Zircon, Metamorphic rocks, Internal textures of zircon, Polymetamorphism

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# Phase equilibrium modelling of sapphirine-bearing metabasites from Akarui Point in the Lutzow-Holm Complex, Antarctica

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Phase equilibrium modelling of sapphirine bearing metabasites from Akarui Point in the Lutzou-Holm Complex, East Antarctica, in NCKFMASHO system indicates that ca-amphibole + plagioclase + orthopyroxene + garnet + biotite + sapphirine assemblage is stable at 860-890C and 6.5-8.5 kbar. The peak P-T condition, which is significantly gugher than that of surrounding rocks (770-790C), suggests that the sapphirine-bearing metabasites underwent local high-T event or minor components (such as B in sapphirine) might significantly decrease the stability temperature of the assemblage.

Keywords: sapphirine granulite, pseudosection, Gondwana, ultrahigh-temperature metamorphism

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# Heterogeneity of exsolution textures of ternary feldspars in felsic gneiss from Mt.Riiser-Larsen, East Antarctica

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Mt. Riiser-Larsen, East Antarctica is the one component of the Napier Complex. The Napier Complex consists of granulite-facies metamorphic rocks formed by multiple thermal events, including Late-Archean ultrahigh temperature metamorphism (Harley and Black, 1997). Based on ternary feldspar solvus models, the bulk compositions of ternary feldspars in felsic gneiss from Mt. Riiser-Larsen yield the minimum of metamorphic temperatures ranging from 1070 to 1110oC (Hokada, 2001). TH97012006 (hereafter shortend to 12006) is the garnet-porphyroblast-bearing portion of a garnet-bearing felsic gneiss from Mt. Riiser Larsen. This sample is almost composed of oligoclase($An_{29}Ab_{70}Or_1$; hereafter shortend to Olg), and mesoperthitic ternary feldspar(hereafter shortend to TF) composed of Olg lamellae and orthoclase($An_2Ab_8Or_{90}$; hereafter shortend to Or). Kodama et. al., (JAMS 2012 annual meeting) revealed that these unique exsolution textures in TF are results of combination of 2 types of exsolution textures; Type-A exsolution texture consist of coarse oligoclase lamellae and TF lamellae-like texture which contact with (010) plane; Type-B exsolution texture consist of fine oligoclase lamellae and fine orthoclase lamellae which contact with (-901) plane. However, problems that the mode of occurrence and textures of Olg grains and TF grains are heterogeneous are still remained.

In this study, to resolve the problems above, some high-resolution elemental maps of slab chips ($<$ 10 cm) of 12006 were obtained using by wavelength-dispersive X-ray spectroscopy (WDX), and comparison between the destribution of element and the occurrence of exsolution textures.

Petrographic characters of 12006 are devided into 4 types; (1)The area mainly consisted of Olg grains, (2)The area mainly consisted of Olg-rich TF grains, (3)The area mainly consisted of Or-rich TF grains, (4)The area mainly consisted of myrmekitic texture. Type(2) encloses type(3), Type(3) encloses type(4). Chemical compositions of type(2) to (3) are continuous, but chemical compositions of type(1) to (2) and type(3) to (4) are discontinuous. It is revealed that the difference of distribution of type-A and type-B exsolution texture corresponds to the difference of chemical compostions within 4 types above. The heterogeneous distribution of Olg grains and TF grains is result of change of local bulk chamical compositon of 12006.

Therefore, the following formation process of Olg grains and TF grains in 12006 was suggested; (1)Olg-rich crystals and TF melt were formed by partial melting (or something) (2) By fractional crystallization, Olg-rich to Olg-poor TFs were formed. Chemical composition of these feldspars is continuous. (3) Myrmekite-like textures were formed in contact with Or-rich TFs. (4) Type-A exsolution textures exsolved at Olg-rich TFs. (5) Type-B exsolution textures exsolved at all TFs by spinodal composition. The partial melting can cause coexistence of crystals and melt at (1), however, there are not enough evidence to make it clear that partial melting occurred. Further data about heterogeneity in 12006 are needed to reveal formation process of entire rocks.

Keywords: ternary feldspar, exsolution texture, Napier Complex, ultra high temperature metamorphism

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# Genetic link between basal lherzolites and gabbro of the northern Fitz massif, the Oman ophiolite

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Genetic link between basal lherzolites and up-section gabbro of the northern Fitz massif, the Oman ophiolite

Masako Yoshikawa, Python Marie, Eiichi Takazawa, Tomoyuki Shibata, Shoji Arai, Akira Ueda, Tsutomu Sato.

Ophiolite has been interpreted as a fragment of oceanic lithosphere emplaced onto the surface (e.g. Dietz, 1963, GSA Bul.). Numerous studies on ophiolites have been done to understand the structure and formation process of the oceanic lithosphere, because it is difficult to make direct observation on it in detail.

It is widely recognized that magmatism formed the oceanic crust, of which structure is different in accordance with the spreading rate of the axis. Our understanding about the oceanic lithosphere of fast spreading ridge origin has been built, however, mainly on the basis of data from Hess Deep, EPR (e.g. Miyashita and Maeda, 2003, J. Geol.). Therefore, some ophiolites, such as Oman ophiolite, considered to be a fragment of oceanic lithosphere from a fast spreading ridge provide valuable information on its structure and magmatic processes.

It was a simple and important question whether or not there is a genetic relationship between crustal rocks and underlying upper mantle peridotites in ophiolites. McCulloch et al. (1981, JGR) observed a genetic link between the crustal and upper mantle rocks based on the data of harzburgite that plotted on a mineral-whole rock Sm-Nd isochron of gabbroic rocks in the Ibra block, southern Oman. In the case of the Trinity ophiolite, accumulation of Sr-Nd isotopic and trace element data of clinopyroxenes required a more complex process; that is, the older lithospheric mantle was interacted with various melts at each block (e.g. Guruau et al., 1995, CMP). The accumulation of Nd isotopic compositions of peridotitic clinopyroxenes from the Oman ophiolite will help our more detailed understanding for magmatic processes at fast spreading ridges.

In this study, we obtained mineral compositions, and trace elements and Sr-Nd isotopic compositions of clinopyroxenes in the basal lherzolites form the Fitz block (Takazawa et al., 2003, G3) the northern Oman ophiolite. The chondrite-normalized rare earth element (REE) patterns of the clinopyroxenes display gentle to steep slopes from heavy REE to light REE. Nd isotopic compositions of the clinopyroxenes show an extremely wide range of variations. These features are compatible with an idea of interaction between residual peridotite and MORB-like melt. The Sm-Nd isotopic data of the clinopyroxenes are plotted on the mineral-whole rock isochron of a gabbroic rock from the Fitz massif (McCulloch et al., 1980, EPSL). We suggest that the gabbro and basal lherzolites were formed within the same magmatic regime.

Keywords: Oman ophiolite, Sm-Nd isotope systematics

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# Discernment technique of the granitoids by a chemical feature, Ryoke and Sanyo granites at Chubu district, central Japan

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## 1. Introduction

With the start of a fault movement, the surface environment of the hinterland also changes, and record of that change may be left behind to a downstream site. If the deposition age can be presumed at the depositing area of a downstream site, it will become possible to presume the time when the mountain land in a hinterland upheaved, and the starting time of the fault activity. In order to discuss change of a groundwater flow from the past to the present, it is necessary to restore the old geographical feature in consideration of time and spatial distribution of an analytic area or mountain land upheaval of the circumference of it.

In the hinterland analysis in old geographical feature restoration of the Kiso River and the Toki River area including the Kiso mountain land, and the Mino - Mikawa plateau, it is necessary to conduct hinterland analysis, also taking into consideration the petrographic feature and geochemical characteristics of a basement rock which constitute the mountain land of a hinterland, since the lithofacies to which the base geology which constitutes such mountain land was similar. In this research, in order to develop the hinterland analysis technique in the lithofacies which was similar in base geology, collection and analysis of the data about the geology and rock which is information required for hinterland analysis were conducted, paying attention to the Toki River valley over which several kinds of granites are distributed.

## 2. Examination by literature data

In order to specify the hinterland of the gravels of downstream site, it is necessary to identify gravels by the difference in the petrologic feature for each granitoids, quantity ratio of minerals, or chemical compositions. Although there are no restrictions in discernment of the granitoids of a hinterland, when being aimed at the gravels of downstream site, etc., there are restrictions by the quantity of a sample, change of the chemical constitution by weathering and deterioration. The techniques by small amount of samples, and considering the influence of weathering and deterioration are needed.

Petrological characteristics of these granitoids, Inagawa Granite usually contains basic inclusions and Naegi - Agematsu Granite dose not contains them (Suzuki and Ishihara, 1967), but it seems to be difficult the identification of these granitoids from the gravel ?size samples.

For geochemical characteristics, such as ratio of minerals and chemical composition of minerals, REE patterns of Ryoke and San-yo granitoids show that REE patterns of San-yo granitoids are accompanied by clear Eu anomalies, and those of Ryoke granitoids are usually accompanied by HREE depletion (Ishihara, 2003). Literature data of granitoids from these area (Ishihara and Murakami, 2006) show that REE patterns of Inagawa Granites contains the pattern with clear Eu anomalies, and are not clearly accompanied by HREE depletion compared with the case of Ishihara (2003). Hiraoka (1997) suggests the granitoids on hinterland using the chemical characteristics of biotite, considering depletion of several elements by weathering.

## 3. Examination by analytical data of granite samples

Petrological and geochemical approaches were adopted by samples of Inagawa Granite and Naegi ? Agematsu Granite, distributed along upper river basin of Toki River. And gravels from downstream site of Toki River were investigated for identification of granitic rock bodies.

Major element analysis of biotites by EPMA showed the samples from Naegi ? Agematsu Granite were rich in Fe and F relative to those from Inagawa Granite. We will report the result of identification of granitic rock bodies by using gravels from downstream site of the Toki River.

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# Change of whole-rock chemical and Sr isotopic compositions in the Soeda Granodiorite, northern Kyushu, Southwest Japan

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We investigated distributions of whole-rock chemical and Sr isotopic compositions in the Seoda Granodiorite, Cretaceous granitic rocks in northern Kyusyu.

The Soeda Granidiorite is divided into main and hornblende porphyritic facies (Yuhara and Masaki, 2013). The main facies mainly consists of medium-grained massive hornblende biotite granodiorite. The hornblende porphyritic facies includes hornblende phenocrysts (up to 1cm) in medium-grained hornblende biotite tonalite to granodiorite matrix. The hornblende porphyritic facies is distributed around synplutonic mafic rocks. The hornblende porphyritic facies is formed by mixing of mafic magma and main facies granodioritic magma.

The main facies is divided into two groups, high Sr and low Sr groups, based on Sr content. There is resemblance of modal and chemical compositions between the two groups. The hornblende porphyritic facies plots within range of chemical compositions of the low Sr group. The low Sr group is distributed around synplutonic mafic rocks and hornblende porphyritic facies, and in southwestern area of the Soeda Granodiorite. The distribution and chemical composition suggest that the low Sr group also is formed by mixing of mafic and granodioritic magmas.

The distribution pattern of each major and trace element depends on pattern of $SiO_2$ contents and behavior to $SiO_2$ content. There is no relation between the patterns and distribution of rock facies and groups. The distribution pattern of Sr content reflects partly distribution of low Sr group. The modal Sr initial isotopic ratio (SrI) calculated by 105Ma, 110Ma and 115Ma are high in central and northern parts of the body, and low in distribution area of the low Sr group and hornblende porphyritic facies. Thus, the rocks in the high SrI regions are not influenced by mixing of mafic magma. The low Sr group and hornblende porphyritic facies are influenced by mixing of mafic magma having low SrI.

Keywords: Soeda Granodiorite, whole-rock chemical composition, Sr isotopic composition

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# Petrogenesis of the Ao granite in the Ryoke belt, southwestern Japan.

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Granitic plutons of the Ryoke belt in the eastern part of Kinki area have been studied mainly by field research and petrography, however, geochemical research of these plutons has not been done enough. Among these plutons, the Ao granite is one of the large plutons and it extends 34 km from east to west and 10 km from north to south at the border between Nara and Mie prefectures. In this study, we have analyzed whole-rock chemical compositions of the Ao granite and discuss the petrogenesis of the pluton. The Ao granite is fine-grained biotite granite containing muscovite, and medium-grained biotite granodiorite containing muscovite distributes some part of the pluton. 15 samples were analyzed for major and minor chemical compositions by X-ray fluorescence spectrometer. $SiO_2$ content of the Ao granite range from 65.6 wt.% to 74.9 wt.%. It shows intermediate composition between I-type and S-type in the ASI (alumina saturation index). $SiO_2$ distribution within the pluton shows reverse zoning. Whole-rock geochemical characteristics of the Ao granite shows that the parental magma of the granite might have chemical relationships with surrounding migmatites of the Ryoke metamorphic belt.

Keywords: Ao, granite, Ryoke Belt

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# High-MgO and Low-MgO plagioclase phenocrysts in the 2011 eruption products of Shinmoedake, Kirishima volcano, Japan

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Plagioclase phenocrysts in the 2011 eruption products of Shinmoedake, Kirishima volcano is divided into high-MgO and low-MgO types, which may represent the two end components of mixing of magmas and may reflect the different temperatures of crystallization/annealing in the magma chamber. The MgO contents in plagioclase generally delineate increasing trends with decreasing Ca/(Ca+Na) ratio, and the MgO contents of the high-MgO plagioclase in the eruption products are 3 to 4 times higher than that of low-MgO type plagioclase. The high-MgO type generally have fairly homogeneous core with Ca/(Ca+Na) ratio of 0.82-0.92, whereas the Ca/(Ca+Na) ratio of the low-MgO type plagioclase ranges from 0.50-0.87. The high-MgO type plagioclase has voids in the core, whereas the low-MgO type plagioclase shows patchy or oscillatory zoned cores. The high-MgO type plagioclases generally have thin rim of lower Ca/(Ca+Na) ratio and high-MgO contents, whereas the low-MgO type may or may not have thin rim of high-MgO composition. The available experimental data suggest that three to four fold variation of the distribution coefficient of MgO between plagioclase and melt may be accounted for by differing temperature of crystallization and/or annealing. The distribution coefficient as defined by D(MgO)=(MgO)plagioclase/(MgO)melt varies from 0.05 at 1100-1200 degree C (Sato, 1989) to 0.021 at 950-1050 degree C (Sisson and Grove, 1993). The annealing temperature of the lower temperature dacitic magma is estimated from rare white pumices to be 850-900 degree C, whereas the high temperature end magma have 1000-1050 degree C from the pyroxene thermometry. We suggest that variable Ca/(Ca+Na) ratio of the core of low-MgO type plagioclase recorded previous intrusion events in the magma chamber, and Mg subsequently equilibrated in the low temperature dacitic magma in the magma chamber. The time scale of the diffusion annealing of Mg in the low-MgO plagioclase is more than 1000 years if we use the diffusion coefficient of Mg in plagioclase by LaTourrette and Wasserburg(1998). The thickness of the high-MgO rim in the low-MgO plagioclase is from 0 to 20 microns with sharp boundary against the core, suggesting short time duration between the mixing of magmas and the eruption.

Keywords: plagioclase, magma mixing, annealing time, Shinmoedake, Kirishima volcano

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# Possible collateral growth of columnar joints and groundmass crystals in an andesite lava, Iwanuma City, Miyagi PREF.

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Columnar joints occur due to the contraction and cracking during cooling of lavas. Their cross-sections typically shape hexagons. In general, their sizes depend on the cooling rate; small and large sizes indicate fast and slow cooling, respectively.

Peck and Minakami (1968) observed the surface cracks of Makaopuhi lava lake on March 1965 Kilauea eruption, when the cracks opened in the crust that still glowed red, and the measured crust temperature was about 900 degrees C. At this stage crystals still grow in the groundmass because lava does not completely solidified yet. Consequently, the formation of cracks may affect the crystal growth in the groundmass.

The middle Miocene (15-13 Ma) andesitic lavas occur in western Iwanuma City, 20 km south of Sendai City. A large quarry in the Kamigawara district, Iwanuma City, shows well-developed columnar joints of about 1m size. The aim of this study is to discuss the effect of columnar joint formation on crystal growth in the lava. To do this the properties of plagioclase in groundmass are compared between the central and peripheral parts of a column bounded by the joints, measuring their orientation, size, chemical composition and its zoning. In addition, magnetic susceptibility distribution is also mapped to show variation of magnetite crystallinity in a column.

In the center of a column, groundmass plagioclase grows larger (average length: 0.168 mm) than that in the periphery (0.130 mm), although there are some exceptions. Chemical composition of groundmass plagioclase in the periphery shows more diversity (An85.0-33.7) than in the center (An71.0-40.8). Magnetic susceptibility distribution in a column shows higher value (average 38 x $10^{-3}$SI unit) in the center than in the periphery(average 33 x $10^{-3}$SI unit), suggesting larger size of magnetite crystals in the center. These differences between the center and periphery of a column are thought to be mainly due to difference in cooling rate. Formation of joint cracks facilitated vaporization of volcanic gas and circulation of surface water through them, and rapidly cooled down the periphery of a column in comparison with its slowly cooling center, and this difference affected the ongoing crystal growth in the groundmass.

Keywords: columnar joint, plagioclase, magnetic susceptibility

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# Geochemistry of the Miocene volcanic rocks distributed around Utsunomiya, central Japan

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Two types of volcanic rocks were reported from Miocene formation distributed in Utsunomiya area, central Japan (Yoshikawa, 1998). Andesite and rhyolite are intercalated with the Kazamiyamada Formation, in the lower, and the Oya Formation, in the upper, respectively. K-Ar whole rock ages of the Kazamiyamada andesite and the Oya rhyolite are reported as 14.8-16.6 Ma and 14.2 Ma, respectively (Yoshikawa, 1998; Yoshikawa et al., 2001). These ages of igneous activity correspond to the opening event of Japan Sea.

The authors reported chemical characteristics of relatively biotite-rich rhyolite occurred in Mt. Haguro (Shimizu and Kawano, 2012), which was called the Haguro rhyolite discriminated from the Oya rhyolite.

This study revealed bulk chemical compositions of the Kazamiyamada andesite, the Oya rhyolite and the Haguro rhyolite. N-MORB normarized incompatible element patterns showed the characteristics of island arc volcanic rocks, that is more LIL elements and less HFS elements. In addition, the Oya rhyolite and the Haguro rhyolite are rich in LIL elements in comparison with the Kazamiyamada andesite. This suggests that both rhyolites were formed in advanced stage of magma differentiation. Also Y and Zr concentrations show lower value in the Haguro rhyolite than the Kazamiyamada andesite. The both volcanic rocks are the suggested to have been differentiated from discrete original magma.

Keywords: andesite, rhyolite, Miocene, Utsunomiya area

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# In-situ elemental analysis with laser-induced breakdown spectrometer (LIBS)

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Elemental and mineral composition of rocks is important information for classifying rocks and clarifying their origins. Elemental and mineral composition is usually measured in laboratories. In-situ elemental measurement, however, enables us to conduct a field research with gaining a better comprehension in real time. Furthermore LIBS would be a powerful tool for selecting appropriate samples to bring back to laboratories for more detailed analysis. Now we are developing a laser-induced breakdown spectrometer (LIBS), which is able to measure elemental composition of rocks in the field.

The measuring principle of LIBS is as follows: Samples are irradiated with pulsed laser beams in order to generate plasma plumes of a small amount of a sample. When atomic and ionic species excited in the plumes are deexcited, the emission of lights occurs according to the difference in energy levels before and after the deexcitation. These lights are measured with a spectrometer as emission lines on spectra. The wavelength of emission lines is unique to each element, and the intensity of emission lines is correlated with the elemental abundance. Both qualitative and quantitative analyses, such as elemental abundance determination and mineral classification, are carried out by analyzing the acquired spectra.

LIBS has several advantages such as (i) capability of remote analysis, (ii) rapid data acquisition, (iii) ability to analyze almost all elements including light elements, (iv) high spatial resolution, and (v) unnecessity of sample preprocessing.

On the other hand, LIBS have a weak point of slightly worse determination precision than other elemental analysis methods usually used. However, recent studies show that the use of multivariate analysis methods such as partial least squares regression (PLS) as a spectral analysis method improve the determination precision.

In this study we made a small portable LIBS, and carried out a field measurement test with it at Mount Mihara on Izu-Oshiam island. The LIBS we made is for a short range measurement and has a fifty-millimeter fixed focal length. Standard elemental-composition-known igneous rock samples have been measured with the LIBS in the laboratory in advance to make PLS regression models for quantitative elemental analysis. In the field we measured many samples such as bounding stones and lava flows under the Sun and obtained spectra with high signal-to-noise ratio. The elemental compositions determined with those spectra shows reasonable values for basalt.

We are going to improve the device in accordance with the intended use, such as extending the measurement distance to measure the samples at inaccessible places and mounting a micro imager to observe textures around the measuring point on the samples. We are also going to prepare more standard samples with various elemental compositions to determine elemental compositions with much higher precision.

Keywords: elemental composition, elemental analyzer, field research

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# The relationship of smectite crystal shape and growth rate

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To evaluate the volcanic glass alteration, smectite shapes were observed by SEM. Smectite was crystallized on volcanic glass surface. We recognized 5 criteria for the smectite morphological shape.

1, very young glass, erupted 100 year to 1000 year ago
- no smectite on glass surface.
2, 30000 to 40000 year
- scattered smectite-aggregation formed less than 1 micron dumpling sphere.
3, 90000 year
- smectite-aggregation connected each 1 ? 2 micron dumpling sphere.
4, 120000 year
- smectite-aggregation which developed the blade, formed 1 ? 2 micron sphere.
5, older
- smectite-aggregation with the blade, covered glass surface.

These morphological changes were found from pyroclastic rocks (pumice flow and fall deposit) collected from Hokkaido and Kyushu region. We hope to produce a good result to understand the time scale of the water ? rock interaction by the smectite morphological changes.

Keywords: smectite, pumice, morphology, alteration

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# Atomic columns in rock-forming mineral using Cs-corrected STEM

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A high angle annular dark field (HAADF) scanning transmission electron microscopy (STEM) has become widely used in the filed of materials sciences such as studies on ceramics, semi-conducting material and metals, because of high-resolustion capability and easily interpretable image contrast, which is roughly proportional to square of atomic number Z (Z^2). Howerver, the HAADF-STEM image sometimes gives lack of light element because the signal scales strongly with Z: when heavy elements are present, light elements are varely visible if at all. Recently, Okunishi et al (2009) & Findlay et al. (2009, 2010), presented a novel imaging mode for STEM which uses an annular detector spanning a range within the illumination cone of the focused electron beam. It was shown that the resultant images enable one to determine the location of columns containing light elements. This imaging mode was called annular bright field (ABF) imaging. The framework of most of rock forming minerals is composed from oxygen elements, and cation such as silicon, aluminum, magnesium, ..., is included in the framework. In this study, atomic columns in rock forming minerals were directly observed using Cs-corrected STEM. STEM specimens were made using focused ion beam (FIB, FEI Quanta 200 3DS) at Kyoto Univ. and HAADF- & ABF-STEM observation were performed using JEM-2400FCS (JEOL) at JFCC with an annular bright field and dark field detectors as well as a spherical aberration correction system for STEM. HAADF-STEM image of forsterite parallel to a-axis shows the magnesium atom columns and the columns which alternately formed of silicon and oxygen atoms. On the other hand, the ABF-STEM image shows the oxygen atom columns in addition.

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# Isotopic compositions of volatile elements trapped in fluid inclusions in hydrothermal ores

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Fluid inclusions are microscopic babbles of liquid and gas that are trapped within minerals. Fluid inclusions reflect the information of hydrothermal fluid during the formation of mineral. Therefore, we can know chemical compositions of hydrothermal fluids forming a hydrothermal ores by measuring compositions of fluid inclusions. Noble gases preserved in fluid inclusions reflect the composition of vent fluids and they are sensitive indicators of the source of hydrothermal fluids [1-3]. In this study, we measured the isotopic composition of noble gases contained in the fluid inclusions of hydrothermal ores to discuss the origin of the hydrothermal fluids. Further, in order to provide constraints on the formation process of hydrothermal ore, we also measured isotopic ratios of nitrogen in fluid inclusions of hydrothermal ores reported by only a few studies.

Hydrothermal ore samples were collected during NT11-20 expedition using ROV Hyper-Dolphin (JAMSTEC), from Okinawa Trough. Approximately 1 g of ore sample picked up and put it in a stainless-steel crusher with a stainless-steel ball. Each ore sample was baked at approximately 200 degree for 12 hours under vacuum to remove atmospheric components absorbed on the sample surface. When the crusher was shaken up and down, the minerals in samples were crushed by the stainless-steel ball movement. Then, gases in fluid inclusions were extracted and introduced into a vacuum line. These gases were purified, and $^{3}$He/$^{4}$He and $^{20}$Ne/$^{4}$He ratios were measured by a noble gas mass spectrometer(Helix), and a quadrupole mass spectrometer, respectively. In addition to noble gas, we measured d15N and $N_2$/$^{40}$Ar ratios by a nitrogen isotopic mass spectrometer (MicroMass 3600). At that time, we also measured $^{40}$Ar/$^{36}$Ar and $^{4}$He/$^{40}$Ar ratios by a quadrupole mass spectrometer.

Measured $^{3}$He/$^{4}$He ratios were 1.17 to 7.38Ra(Ra means atmospheric $^{3}$He/$^{4}$He =1.4x10$^{-6}$ [4]). These values display the mixing of atmospheric and MORB type helium(=8+-1Ra[4]), and suggest that hydrothermal fluids were originally derived from a upper mantle. From the results of $^{20}$Ne/$^{4}$He and $^{3}$He/$^{4}$He, helium and neon in fluid inclusion can be explained by a mixture of hydrothermal fluids and pore waters, and hydrothermal fluids were greatly affected by pore water. Considering MORB and pristine diamond data, d15N values of -3 to 7%o are expected in upper mantle[5]. On the other hand, all samples showed positive values of +2.47 to +4.16 %o in this study and these values are similar to sediments in the Okinawa Trough[6]. Measured $N_2$/$^{40}$Ar values of 54 to 112 are close to reported value of atmosphere(=85) and seawater(=55), and $^{40}$Ar/$^{36}$Ar values of (3.29 to 9.92)x10$^{2}$ displayed slightly higher than that of atmospheric ratio (=2.96x10$^{2}$) and obviously lower than that of MORB ratios(>40000)[7]. Then we estimated contribution of three nitrogen sources (mantle-derived, sedimentary and atmospheric nitrogen) using d15N, $N_2$/$^{36}$Ar and $N_2$/$^{3}$He values. As a result, 35 to 65% nitrogen was derived from sediment, and the contribution from the upper mantle was rarely seen. This result is in harmony with geological background that Okinawa Trough is covered with thick sediments and that observed helium and neon are greatly affected by the pore water. When estimating the origins of hydrothermal ores, d15N, $N_2$/$^{36}$Ar, $N_2$/$^{3}$He in fluid inclusions may be a useful tracers to understand contribution of sediment.

Keywords: fluid inclusion, noble gas isotope, nitrogen isotope, hydrothermal ore, Okinawa Trough

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# Geochemistry of the Kinshozan quartz diorite and associated pegmatite dykes, Ogawa-machi, Saitama Prefecture

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Quartz diorite and pegmatite occur around Kinshozan, Ogawa-machi, Saitama Prefecture (Ogachi et al.,1970; Makimoto & Takeuchi,1992).These rocks are called Kinshozan quartz dioritic body (Ogachi et al.,1970) and considered to be klippe lying on the Sambagawa Belt (Takagi et al.,1989; Takagi & Fujimori,1989). K-Ar hornblende age of 251+/-8 Ma (Ono, 1983) and FT zircon ages of 122 to 223 Ma for the quartz diorite (Watanabe & Suzuki, 1978; Suzuki and Watanabe, 1984), and K-Ar muscovite age of 252+/-8 Ma for pegmatite (Hayama et al, 1990) are obtained. These ages show that the Kinshozan body is Permian allochthonous granitic body. Sr initial isotopic ratios of the Kinshozan body are 0.70415 and 0.70406 (Shibata and Takagi, 1989).

Kinshozan body consists of three small masses, Fujiyama, Kinshozan and Kurumayama from east to west. Pegmatite dykes are not found out from Fujiyama mass, whereas some pegmatite dykes intrude in to the Kinshozan and Kurumayama masses. Constituent minerals of the quartz diorite are plagioclase, hornblende, quartz, potassium feldspar, biotite and opaque minerals. Pegmatite consists of quartz, plagioclase, potassium feldspar, white mica and garnet. SiO2 of the quartz diorite was 50 to 63 wt%, and that of pegmatite was 75 to 78 wt%. Thus, although a compositional gap is looked at in SiO2, pegmatite is plotted on extension of the changing trend of quartz diorite in many major compositions. However, changing trends in SiO2 vs. A.S.I. and SiO2 vs. FeO*/MgO diagrams are not necessarily conformable. In the trace element compositions, Zr and Zr/Nb show an upward tendency with increasing of SiO2 in the quartz diorite, those of pegmatite are very low. The quartz diorite is characterized by low K2O/Na2O and Rb/Ba ratios, and those ratios of pegmatite are large. In MORB normalized spidergrams, Nb vs. Y and (Y+Nb) vs. Rb diagrams, the quartz diorites and pegmatites suggest feature of an island arc igneous rocks.

If origin of pegmatite differs from that of the quartz diorite, it is thought that the pegmatite was originated by partial melting of crustal materials. If so, it can be considered that tectonic setting for the Kinshozan body was active continental margin.

Keywords: Kinshozan, Saitama Prefecture, geochemistry, quartz diorite, pegmatite