

SCG067-01

Room:105

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## Chromite and uvarovite in rodingite from the lowermost crust of Oman ophiolite: Cr mobility in hydrothermal condition

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Uvarovite-rich garnets have been commonly reported as a secondary mineral from chromitites. We found rodingites that contain uvarovite-rich garnets from layered gabbros, located about 50 m above the gabbro/peridotite boundary (= possible Moho) along Wadi Fizh of the northern Oman ophiolite. The rodingite from Wadi Fizh contains relic cpx gabbro clasts, and is mainly composed of Ca-rich plagioclase (An, 97-100), diopside (Mg#, 0.87-0.97), uvarovite, chromite and titanite. Both chromite and uvarovite are euhedral and fine-grained (<0.1 mm across); they are concentrically zoned and partly skeletal. Unlike the frequent occurrence of uvarovites, which overgrow on chromite documented from chromite-bearing rocks, some uvarovite and chromite occur as discrete grains in the Fizh rodingite. Chromite has a high Cr# ( $\text{Cr}/(\text{Cr} + \text{Al})$  atomic ratio; around 0.8), which is one of the highest Cr# chromian spinels reported from Oman.  $\text{Fe}^{3+}/(\text{Cr} + \text{Al} + \text{Fe}^{3+})$  (= YFe) increases from the core (<0.1) to the rim (0.2) in chromite. MnO and TiO<sub>2</sub> contents (wt%) of the chromite are 0.5-0.6 and 0.2-0.3, respectively. Cr/(Cr + Al + Fe<sup>3+</sup>) atomic ratio of uvarovite ranges from 0.5 to 0.6. The YFe of uvarovite is from 0.05 to 0.2.

It is noteworthy that chromite appears authigenic together with other minerals in this rodingite. Chromites or chromian spinels are totally absent in relic cpx gabbro clasts or in neighboring layered gabbros. The euhedral and partly skeletal chromite contains inclusions of pumpellyite. These indicate that Cr was transported with a hydrothermal aqueous solution, which metasomatized the layered gabbro to rodingite. A highly oxidation condition was possible for such high Cr mobility.

Keywords: uvarovite, rodingite, Oman ophiolite, hydrothermal alteration, chrome mobility

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## Phase equilibria and mineral paragenesis on crustal materials under ultrahigh-pressure metamorphic conditions

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We carried out the ultrahigh-pressure experiments at 8.0 GPa under dry condition on the pelitic granulite from Hidaka metamorphic belt, Hokkaido to clarify the phase changes.

We found the assemblage of the Al<sub>2</sub>O<sub>3</sub>-deficient garnet with pyroxene components, significantly SiO<sub>2</sub>-oversaturated clinopyroxene containing a large amount of jadeite, kyanite and coesite in the charges. We obtained the following results from chemical and microscopic analyses of these minerals:

1. Contents of Na<sub>2</sub>O and K<sub>2</sub>O in clinopyroxene at UHP conditions should be constrained by the bulk composition of the system.
2. The amount of clinopyroxene increases with increasing SiO<sub>2</sub>, simultaneously with decreasing Na<sub>2</sub>O and K<sub>2</sub>O.
3. The tschermak content in clinopyroxene depends on the amount of kyanite in the system.
4. Coesite and kyanite buffer the solubility of Na<sub>2</sub>O and K<sub>2</sub>O in clinopyroxene at ultrahighpressure metamorphic conditions.

Keywords: ultrahigh-pressure metamorphism, garnet-clinopyroxene-kyanite-coesite coexistence, Al<sub>2</sub>O<sub>3</sub>-deficient garnet, SiO<sub>2</sub>-oversaturated clinopyroxene

## A kelyphite produced by isochemical breakdown of garnet in a garnet peridotite from the Czech Moldanubian Zone

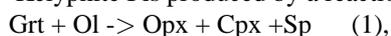
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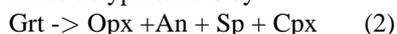
Kelyphite, a symplectitic mineral intergrowth of Opx, Cpx and spinel that developed around garnet in peridotite, is not a simple breakdown product of garnet but a reaction product between garnet and olivine. It is typical that such kelyphite has a bulk chemical composition show higher Mg and lower Al than garnet (e.g. Obata, Spengler, 2010 JpGU). We report a different kind of kelyphite (kelyphite II) that appeared to have formed by an isochemical breakdown of garnet inside of an ordinary kelyphite (kelyphite I) from a garnet peridotite of Czech Moldanubian Zone (Plesovice peridotite, Naemura et al 2009). The garnet peridotite once equilibrated at 2.3-3.5 GPa, 850-1030C intruded into lower continental crust and got partially equilibrated in spinel lherzolites facies. The temperature of the kelyphite formation has been estimated to be 730-770C (at 0.8-1.5 GPa). Kelyphite II occurs inside the ordinary kelyphite I adjacent to a relict garnet. It is revealed that the kelyphite II has nearly the same composition as the garnet by EPMA X-ray mapping. The kelyphite consists of Opx, Sp and anorthite (An). It has very well-defined lamellar structure that consists of Opx lamella containing very small spinel lamella (less than 0.2 micrometer) and plagioclase lamella that lack spinel lamella. There is a transitional zone of tens of micron width between the kelyphite I and kelyphite II domains.

The mineral assemblage Opx-Sp-An has been known to occur in kelyphite in mafic granulites and garnet pyroxenites that lack olivine (e.g. Obata, 1995) but have previously never been found in kelyphites in garnet peridotites.

Kelyphite I is produced by a reaction



while kelyphite II is by



(Kushiro & Yoder, 1966).

Reaction (2) occurs at lower pressures than reaction (1). Considering the textural relationship and phase equilibrium constraints, following scenario may be drawn. Upon decompression of garnet peridotite, kelyphite I is first developed by reaction (1). At further decompression, if garnet is still remained, it is converted to kelyphite II. This scenario assumes a time gap between kelyphite I and kelyphite II formations. But we cannot rule out a possibility that reaction (2) started before reaction (1) ceased.

### References:

Kushiro, I. and Yoder, H. S. Jr. (1966) *J. Petrol.*, 7, 337-362.

Naemura, K. et al. (2009) *J. Petrology*, 10, 1795-1827.

Obata, M. (1994) *J. Petrology*, 35, 271-287.

Keywords: kelyphite, symplectite, garnet peridotite, isochemical breakdown, Czech

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## Primary structures in Archean metamorphosed BIF: the SXAM analyses

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Precambrian banded iron formations (BIFs) are characterized by alternating Fe-rich and Si-rich layers and have been assumed to preserve primary structures formed on seafloor; physical sedimentation and chemical precipitation from seawater or from submarine hydrothermal fluids, and microbial activity have been generally considered as genetic processes of BIFs. Banded structures in the BIFs exhibit several different scales, from sub-millimeters to several tens of meters. Some of these hierarchy structures have been considered to periodic phenomena in different time scales, corresponding to seasonal cycles, tidal or solar cycles, and Milankovitch cycles. However, most BIFs have undergone various grades of metamorphism. To decode environmental changes in the Precambrian era recorded in BIFs, it is necessary to distinguish primary structures from secondary ones (compositional banding), which were formed after burial of the BIFs. We analyze the banded structures in the BIF samples in the Yellowknife greenstone belt, NWT, Canada. In this study, we investigated the influence of metamorphic reactions on the banded structures in an Archean BIF (2.9-2.8 Ga) comprised in the Bell Lake Group.

In the Bell Lake BIF, there are centimeter-scale alternating Fe-rich and Si-rich bands. Under a microscope, this BIF is now completely recrystallized into medium-grained metamorphic minerals. The Fe-rich band is mainly composed of magnetite, green hornblende, and colorless Fe-Mg-amphibole (grunerite). The Si-rich band constitutes of quartz, magnetite, and a small amount of actinolite. The schistosity defined by orientation of amphiboles is almost parallel to the Fe-rich and Si-rich bands, but an intrafolial fold is locally developed, where the schistosity plane clearly intersects the banded structures. These observations indicate that the alternation of Fe-rich and Si-rich bands already existed at the time of metamorphism.

X-ray fluorescence (XRF) element mappings of the BIF samples were conducted with a Horiba XGT-2000V scanning X-ray analytical microscope (SXAM). The SXAM makes possible acquisition of XRF intensity maps of samples up to 20\*20 cm<sup>2</sup>. The SXAM analyses found over the entire sequence that Ca concentrate at the middle parts of the Fe-rich bands and are sandwiched with Fe and Mg. These element distributions correspond that hornblende is observed at the center of Fe-rich band and is sandwiched with magnetite layers and Fe-Mg amphibole layers. As no exsolution lamellae are found in these co-existing amphiboles and the hornblendes have larger grain size compared with the Fe-Mg amphiboles, we consider that such sandwich structures were formed via nucleation-growth during prograde metamorphism. An incompatible element of Mn is considered to have diffused out to the margin of Fe-rich band and finally recrystallized as grunerite. On the other hand, Ti-spots are uniformly distributed in Fe-rich band. The SEM-EDS and XANES analyses appeared that Ti-spots are locally hosted in hornblende. Since titanium is generally known to be immobile in in metasomatic and metamorphic processes, primary structure of Fe-rich and Si-rich bands may be defined by the Ti-spots distribution.

The Si-rich bands are intercalated with thin magnetite-rich layers with the thickness of sub-millimeters, each of which contains several to tens of magnetite-rich layers. Laminations of this scale (microbands) are commonly observed in low-metamorphic grade Hamersley BIF (Western Australia). It is likely that these laminations record primary structures formed during the sedimentation and precipitation processes. In the Bell Lake BIFs, grain size of magnetite-rich layers is much larger than that in quartz-rich matrix, suggesting the role of Ostwald ripening in their development.

Keywords: banded iron formation, banded structure, metamorphic differentiation, primary structure, Scanning X-ray Analytical Microscope, element mapping

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## Magnetically-induced free motions of dia- & para-magnetic mineral grain and a novel method of its mineral identification

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The origin of minor mineral phases (including biological remnants) contained in various semimetal and igneous rocks has become one of the major interests in various fields of earth science. The development of a simple and nondestructive method to identify the material of a single fine particle is desired in various research fields that are concerned with micro- and nano-materials. Here, a new method of material identification is proposed which is based on magnetization data; the data is obtained from magnetically induced motions of the single grain that is observed in micro-G condition. Specifically, diamagnetic susceptibility is obtained from translation of the single mineral grain caused by field-gradient force; anisotropy of susceptibility can be obtained from period of rotational oscillation of magnetically stable axis with respect to field direction. According to a data book that compiles published susceptibility values [1], an intrinsic diamagnetic susceptibility and its anisotropy are assigned to almost all the rock forming mineral. Hence identification of a mineral (or material) is possible from the measured values of susceptibility and anisotropy. This attempt does not appear in previous literatures.

Free translation due to field-gradient force was previously reported for various diamagnetic and paramagnetic crystals [2][3]. Rotational oscillation was observed as well for a number of diamagnetic crystals in a homogeneous field located in micro-gravity [4]. The susceptibility and its anisotropy obtained from the above motions agreed well with their published values.

The terminal velocity of the above-mentioned translation at zero field area is observed in the present work. Through these measurements, the field-induced potential at initial position was completely converted to kinetic energy out-side the magnetic field. The mass independent property of terminal velocity, deduced from the above-mentioned energy conservation, is examined in wide range of sample size between 1.0 and 0.005cm in diameter. A compact microgravity system, which is introduced in an ordinary laboratory, was newly developed. This was because the conventional facilities of microgravity were not suitable for a routine analysis such as the present magnetization measurement; a large facility system requires a long machine time, and their running costs are high. In the compact system, length of the drop shaft is 1.5m, and micro-G duration was below 0.7 seconds. The experimental setup was contained in a wooden box (30cm in diameter), which was dropped from the sealing of our laboratory. The micron-sized samples were released in the area of field-gradient; the field was produced by a by a small NdFeB magnetic-circuit (maximum field 0.7 T). The introduction of the small circuit enabled the development of the compact drop system.

The above-mentioned free motion is expected to be a breakthrough to detect susceptibility (& material identification) of limitlessly small particles, because the method is free of both sample holder and mass measurement. Magnetization is measured on any sample irrespective of its size, provided that motion of the sample is observable.

At the first stage of analyzing geological materials, the sample should be separated to a single grain size. Secondly, the material of individual grain will be identified nondestructively by the above-mentioned free motions; then it can be put to various refined analysis based on chemical, isotopic or optical probes, etc. The method is applicable to search biological remnants as well as micro-meteorites from semimetal rocks. It may be effective to identify a new type of exotic grain from primitive meteorites.

[1] R. Guputa: Landort Bornstei, New Series II (1983) 445.

[2] K. Hisayoshi et al: J.Phys.: Conf. Ser., in press.

[3] C.Uyeda et al.J.Phys.Soc.Jpn. 79 (2010) 064709 .

[4]C.Uyeda et al.: Appl. Phys. Lett. (1983) 445.

Keywords: material identification, magnetic ejection, diamagnetic susceptibility, paramagnetic susceptibility, micro-gravity, nano-science

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## Mineral chemistry of pyroxene megacrysts from Japanese island arc: Contribution of Mn-pyroxene end-member to Island arc

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The chemical compositions of both augite (4 to 8 mm long) and enstatite (4 mm in size) megacrysts from the pyroxene-andesites, south-Yatsugatake volcano, central Japan, were determined by electron microprobe analysis (EMPA). This determination led to accurate expression of the pyroxene end-members obtained by calculation based on the assumption of charge equilibrium and the site occupancy as full as possible, represented as follows:  $\text{MgSiO}_3$  (enstatite),  $\text{Fe}^{2+}\text{SiO}_3$  (ferrosilite),  $\text{MnMgSi}_2\text{O}_6$  (kanoite),  $\text{CaTiAl}_2\text{O}_6$ ,  $\text{CaFe}^{3+}\text{AlSiO}_6$  (esseneite),  $\text{CaSiO}_3$  (wollastonite),  $\text{CaAl}_2\text{SiO}_6$  (Ca-Tschermak's molecule) or  $\text{Ca}_{0.5}\text{Al}_{0.5}\text{Si}_2\text{O}_6$  (Ca-eskolite),  $\text{NaAlSi}_2\text{O}_6$  (jadeite),  $\text{NaCr}^{3+}\text{Si}_2\text{O}_6$  (kosmochlor) and  $\text{Mg}_{1/2}\text{Al}_{1/2}\text{Mg}_{1/2}\text{Si}_{1/2}\text{Si}_2\text{O}_6$  (a new end-member). Furthermore, calculation of the above end-members is also applicable to the chemical compositions of common pyroxenes, resulting in the determination of  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  contents in the analyzed pyroxenes.

Encompassment of the end-members by the pyroxene has yielded two significances in pyroxene chemistry: (1) pyroxene megacrysts from Japanese island arc are always richer in  $\text{MnMgSi}_2\text{O}_6$  content than those from all the other world, and (2) a negative correlation between  $\text{NaAlSi}_2\text{O}_6$  (jadeite) and  $\text{Mg}_{1/2}\text{Al}_{1/2}\text{Mg}_{1/2}\text{Si}_{1/2}\text{Si}_2\text{O}_6$  contents (a new end-member) implies that the presence of the latter in pyroxene requires high-pressure conditions for the formation. Stability of jadeite at high pressure, the silicon coordinated by six oxygens contributing to its genetic environment of high-pressure (Larry et al., 1991), and the success in synthesizing high-pressure pyroxene with octahedrally coordinated silicon,  $\text{Na}(\text{Mg}_{0.5}\text{Si}_{0.5})\text{Si}_2\text{O}_6$  at 1873 K and 15 GPa (Angel et al., 1988), all support the utility behavior of a new end-member of pyroxene at high-pressure.

Most significantly, as the allanites in granitic rocks from Japanese island arc are always more enriched in Mn compared to those in the other worldwide granites, so the present pyroxene megacryst containing  $\text{MnMgSi}_2\text{O}_6$  end-member is an eloquent example of "Island arc mineralogy".

Keywords: Pyroxene megacrysts, end-member expression,  $\text{MnMgSi}_2\text{O}_6$ , "island arc mineralogy", new end-member

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## Geochemical characteristics of Nanzaki Basanite, Izu peninsula, Japan

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We report results of detailed petrological and geochemical analyses carried out for Nanzaki basanite in the southern most part of the Izu peninsula, which locates 50km toward back-arc from the present volcanic front of Izu-Bonin volcanic arc.

Nanzaki volcano erupted 0.43 Ma (Kaneoka et al.,1982). We identified two types of basanitic rock (Massive Lava; Scoria and Layered Lava) based on, composition of phenocryst (Cpx+Olivine) and bulk rock chemistry. Massive lava contains more or less differentiated olivine (Fo=77-90), nepheline micro-phenocryst, and higher Ba/Sr values. FeO\*/MgO value is 0.96-1.08. Scoria and layered lava have primitive composition of olivine (up to Fo=0.91), lower FeO\*/MgO values (0.81-1.01), and lower Ba/Sr values. Other major elements composition shows no clear differences between both magmas (SiO<sub>2</sub>=42.1-44.5 wt.%, CaO=12.1-13.4 wt.%). Chemical characteristics of scoria and layered lava may indicate character of primary (undifferentiated) magmas generated in the upper mantle.

We also found xenolith in layered lava, which contains clino-pyroxene (>95%), olivine (<5%) and chromian micro-phenocrysts. 0.1-2mm Vugs are observed dominantly. Composition of phenocryst does not distinguishes xenolith from host rock. Although the origin of this xenolith is still unspecified, it was thought to have captured during the upward movement of layered basanite lava.

Both types of rock have same patterns of REE and trace element. Nanzaki basanite is abundant in REE, especially in LREE. It has approximately same value of La/Yb with basanites in SW Japan (e.g. Iwamori, 1992; Tatsumi et al., 1999) and in Hawaii (e.g. T. W. Sisson et al., 2009; 2002). Aoki et al. (1986) suggested that Nanzaki basanite is resemble to alkali basalts in oceanic island tectonic setting. However, there is a significant differences in some elements concentration, such as anomaly in Ba, Sr, Pb and negative anomaly in Rb, K, Zr) recognizable. Such unique magmas could be generated from carbonate-metasomatized mantle in subducting slab tectonic setting.

Keywords: Basanite, Izu-Bonin volcanic arc, major and trace element geochemistry, back-arc rift, ocean island basalt, Sr isotopes

SCG067-08

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## There is sea uranium for 1000 years to 1.8 billion years

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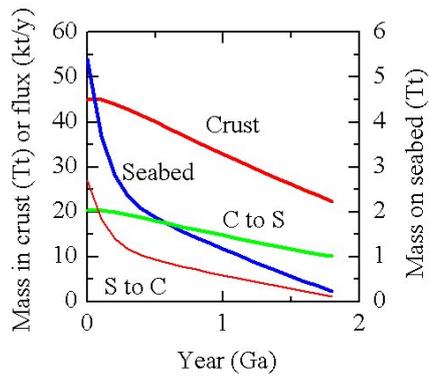
Proven reserves of energy resources will be exhausted in 74 years if primary energy consumption is kept constant. This is a very rough estimation because the exhaustion of reserves does not mean exhaustion of resources and R/P ratio varies with price, discovery of new reservoirs, development of new technology, population increase, economic growth etc. This R/P ratio does not seem to be enough, however, it will increase to 153 years by including probable reserves of oil shale, shale gas and methane hydrate (Ishimoto, 2011 in Japanese). Dependency on gas energy will dominate in several ten years because R/P ratio of petroleum is just 43 years. R/P ratio of uranium is 744 years if only fast breeder reactors are employed instead of light water reactors.

It might be meaningless to worry about human society more than 100 years from now considering the human society 100 years ago and the above energy seems enough. The current author, however, would like to mention that there are a large quantity of thorium and sea uranium.

Thorium is a nuclear fuel and can be smelted from monazite with rare earths. It has been not widely used because it does not produce plutonium which can be used for nuclear weapons. It is found in Turkey, Australia, India (already using), Norway, US, Canada etc. and its proven reserves are 1.58 Mt (MacKay, 2010). The reserves are for 58 years supplying primary energy for the whole world. Thorium has such advantages as most parts fission so that nuclear waste is much less than uranium, fuel has to be changed just once a 30-year period and serious accidents are not expected by its fission mechanisms although the smelting cost is higher than uranium. Thallium in nuclear waste radiates intense Gamma-ray and the half-life is 30 years. It is impossible to significantly increase R/P ratio by the mechanism which is similar to fast breeder reactors because most parts fission.

There is uranium of 4.2 Gt as uranyl carbonate,  $\text{UO}_2(\text{CO}_3)_3^{4-}$ , at 3.34 ppb in sea water (Davies et al., 1964). Blade type-extracting system using tannin collectors and installed on continental shelves with warm current is under development and the cost is 3 times the uranium from ore (Tamada et al., 2006 in Japanese). The cost for power generation will increase by only 20% if the cost for uranium is 3 times because cost for uranium is just 10% the cost for power generation for light water reactors. Assuming that one quarter of the resources can be collected, probable reserves would be 1 Gt and this is for all primary energy for the whole world of 1000 years. Continental shelves along Indonesia, Philippines, Taiwan, Okinawa-Tosa bay, East coast of Australia, Florida, East coast of Africa would be suitable for collection. However, 110,000 km<sup>2</sup> wide system is necessary and this does not seem practical.

Assuming that only fast breeder reactors are used, all primary energy for the whole world can be supplied by uranium of 10 kt and the necessary area is just 1100 km<sup>2</sup>. The cost can be several 100 times the ordinary uranium. Sea uranium is flowed from rivers and dissolve in sea water and precipitate on sea bed. The inflow rate is 27 kt/y (Davies et al., 1964). Apparently, precipitated uranium is subducting to mantle at 27 kt/y. Uranium amount in continental crusts is roughly estimated as 45 Tt based on the volume of continental crust and average concentration (3 ppm). Assuming that a constant portion of uranium in continental crust inflows into sea, a constant portion of uranium in sediments on sea bed subducts to mantle and is supplied to continental crust as magma, plate will stop in 6 Gy at a constant deceleration, sea uranium of 10 kt/y is extracted and considering the half-life time of <sup>238</sup>U (4.5 Gy), sea uranium can be extracted for 1.8 Gy. It is supposed that human cannot survive till the time because of the predicted extreme climate change and water shortage at that time if the morph and function of the human is similar to present ones.



Keywords: energy resources, thorium, sea uranium