

Metamorphic P-T evolution and fluid inclusion study of Bodonch, Zereg, Sharga and Altai areas, Southwestern Mongolia Metamorphic P-T evolution and fluid inclusion study of Bodonch, Zereg, Sharga and Altai areas, Southwestern Mongolia

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The Altai Orogen in the southwestern margin of the Central Asian Orogenic Belt (one of the largest accretionary and collisional orogen in the world) extends from Russia and East Kazakhstan to the west, through Northern China, to southwestern Mongolia to the east. It contains various volcano-sedimentary rocks that were deformed and metamorphosed under various pressure-temperature (P-T) conditions from greenschist to amphibolite and partly granulite facies. We report first detailed petrological and fluid inclusion data of pelitic schists and mafic rocks from Bodonch, Zereg, Sharga, and Altai areas, southwestern Mongolia, which occupy a significant part of the Paleozoic history of the Altai Orogen in the southwestern margin of the Central Asian Orogenic Belt (or Altaids), and discuss P-T evolution of the area.

Zereg, Sharga, and Altai areas contains mafic to ultramafic rocks and pelitic schists with various mineral assemblages such as amphibole + plagioclase + muscovite + chlorite + calcite, serpentine + olivine + chromium spinel + iron oxide, serpentine + olivine + clinopyroxene + talc, chlorite + muscovite + plagioclase + quartz + ilmenite. In the context of traditional terrain tectonics (Badarch et al., 2002) the belt belongs to the Hovd and Dariv terrains and classified as accretionary wedge and metamorphic belt with uncertain tectonic affinity.

Bodonch area contains pelitic schists and amphibolites with various mineral assemblages such as garnet + kyanite + staurolite + biotite + plagioclase, garnet + biotite + staurolite + cordierite, and amphibole + quartz + plagioclase + garnet + ilmenite.

We performed detailed petrologic, geothermobarometric and mineral equilibrium modelling studies on the rocks from Bodonch area and obtained peak P-T condition of 640-690°C /6.3-10.7 kbar and clockwise path from the area. The peak high-pressure amphibolite-facies condition and clockwise P-T evolution of the area estimated for the first time in this study is consistent with available reports of other localities in the Altai Orogen outside Mongolia. Three categories of fluid inclusions have been observed in quartz: dominant primary and secondary inclusions, and least dominant pseudosecondary inclusions. As quartz in the samples are texturally associated with biotite, kyanite, and staurolite, which were probably formed during peak metamorphism, we regard that the primary fluid inclusions trapped in the quartz grains probably preserve peak metamorphic fluids. The melting temperatures of all the categories of inclusions lie in the narrow range of -57.5 to -56.6°C, close to the triple point of pure CO₂. Homogenization of fluids occurs into liquid phase at temperature range between -33.3 to +19.4°C, which convert into densities in the range of 0.78 to 1.09 g/cm³. The results of this study, together with the primary and pseudosecondary nature of the inclusions, indicate CO₂ was the dominant fluid component during the peak amphibolite-facies metamorphism of the study area. Therefore, this is a rare example of CO₂ -rich fluid inclusions trapped in amphibolite-facies rocks.

キーワード: fluid inclusion, mineral equilibrium modeling, Altai Orogeny, Central Asian Orogenic Belt, Mongolia

Keywords: fluid inclusion, mineral equilibrium modeling, Altai Orogeny, Central Asian Orogenic Belt, Mongolia

Fluid and cooling-driven reaction exsolution in garnet porphyroblasts: near-peak history of UHT granulites, EGB, India

Fluid and cooling-driven reaction exsolution in garnet porphyroblasts: near-peak history of UHT granulites, EGB, India

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Intergrowth textures in porphyroblastic assemblages of granulites are extremely important to decipher the near-peak evolutionary history of deep continental crust undergoing several pulses of orogenic cycles. Eastern Ghats granulite belt of India evolved through Proterozoic orogenic events has occurrences of aluminous granulites and associated quartzofeldspathic gneisses where garnet porphyroblasts contain nanometer- to micrometer-thick ilmenite needles oriented crystallographically. Such garnet porphyroblasts are presumably a product of dehydration melting reaction(s) of Ti-rich phlogopite during the pre-peak metamorphic stage leading to the UHT peak condition. The high oxygen fugacity condition during this stage promoted the enrichment of possible Ti-bearing andradite component in garnet porphyroblasts in appropriate bulk chemistry. In the subsequent post-peak cooling-dominated history with lowered oxygen fugacity, Ti-bearing components of garnet porphyroblasts decomposed to rhombohedral oxide solid solution (ilmenite-hematite). Transmission electron microscopic study of the garnet porphyroblasts and needle-shaped monomineralic ilmenite solid solution indicates that though there is an overall parallelism of [011]* of host garnet and [011]* of ilmenite, structural coherence between the two phases is progressively lost during growth from thin to thick needles. We argue that cooling from high-temperature peak metamorphic condition promoted growth of ilmenite solid solution through reaction-exsolution process within garnet porphyroblasts. Integrated temperature and fO₂ information during deep crustal evolution can thus be retrieved from the detailed petrographic, SEM, EPMA and TEM studies of high-grade granulites.

キーワード: Oriented ilmenite needles, Garnet porphyroblasts, UHT granulites, Reaction-exsolution, EGB, India
Keywords: Oriented ilmenite needles, Garnet porphyroblasts, UHT granulites, Reaction-exsolution, EGB, India

伊豆衝突帯に分布する新第三紀花崗岩質岩体の地球化学的多様性とその解釈 Interpretation for geochemical diversity of the Neogene granitoid plutons in the Izu Collision Zone

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Neogene granitoid plutons are widely exposed in the Izu Collision Zone in central Japan, where the northern tip of the Izu-Bonin arc (juvenile oceanic arc) has been colliding with the Honshu arc (mature island arc) since middle Miocene. Three main granitoid plutons are distributed in this area: Tanzawa Plutonic Complex (TPC), Kofu Granitic Complex (KGC), and Kaikomaga-take pluton (KP). The TPC and southern part of the KGC were intruded in submarine volcanic piles of the Izu-Bonin arc, while the KP and the northern and central parts of the KGC were intruded in Shimanto metasedimentary rocks of the Honshu arc. In this study, I compile geochemical data of these three plutons (Kawate and Arima 1998; Saito et al. 2004; Saito et al. 2007a,b; Saito et al. in press), and propose a petrogenetic model explaining the geochemical diversity of granitoid plutons in the Izu Collision Zone.

The TPC consists of tonalite and trondhjemite and characterized by low K₂O contents (< 2.5 wt %), whereas the KP is characterized by relatively high K₂O contents (3-5 wt %) and composed of granodiorite and monzogranite. The rocks of KGC range from tonalite, trondhjemite, granodiorite to granite, and show wide variation of K₂O contents (0.5-7 wt %). Previous petrogenetic studies on the plutons have been suggested that (1) the TPC formed by lower crustal anatexis of juvenile basaltic rocks occurring in the Izu-Bonin arc (Kawate and Arima 1998), (2) the KGC formed by anatexis of hybrid lower crustal sources comprising of both basaltic rocks of the Izu-Bonin arc and metasedimentary rocks of the Honshu arc (Saito et al. 2007b), and (3) the KP formed by anatexis of hybrid lower crust consisting of K-rich rear-arc crust of the Izu-Bonin arc and metasedimentary rocks of the Honshu arc (Saito et al. in press). These studies collectively suggest that the chemical diversity within the Izu Collision Zone granitoid plutons reflects the chemical variation of basaltic sources (i.e., across-arc chemical variation in the Izu-Bonin arc) as well as variable contribution of the metasedimentary component in the source region.

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Keywords: Izu Collision Zone, Granite, Kofu Granitic Complex, Tanzawa Plutonic Complex, Kaikomaga-take pluton

東北日本弧に産する第四紀火山岩類のHf同位体比組成の空間分布 Spatial variations in Hf isotopic compositions of Quaternary volcanic rocks in North-eastern Japan Arc

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The dual Quaternary volcanic chains of the North-eastern Japan (NEJ) Arc sit 100 km and 150-170 km above the top of the subducting Pacific Plate. We focus on a particular variation in the isotopic compositions of Quaternary volcanic rocks in the NEJ Arc because isotope data are useful for estimating the influence of subducting components on mantle wedges. In general, slab-derived materials from subducting plates add to mantle wedges, and these materials induce the generation of island arc magma.

In this study, we report a new spatial variation of Hf isotopic compositions in combination with Sr-Nd-Pb isotopes and trace element compositions. Although a high-field-strength elements (HFSE), Hf is one of them, rare earth elements (REE), and large-ion lithophile element (LILE) behave as incompatible elements during mantle-melting processes, they distinctively separate from each other into preferentially partitioned aqueous fluids due to the increased solubility from LILE, REE to HFSE. Therefore, Hf isotopes in combination with other geochemical signatures serve as identification of metasomatic agents in subduction-related magma generation.

On the rear arc (RA) side, we collected samples from the Chokai, Sannome-gata, Moriyoshi, and Kampu volcanoes. On the volcanic front (VF) side, we collected samples from the north area (the Iwate and Akita-koma-ga-take volcanoes), the central area (the Zao and Azuma volcanoes), and the south area (the Nasu and Takahara volcanoes).

The RA volcanic rocks have limited and slightly enriched Sr-Nd-Pb isotopic ratios and trace element compositions as compared to those of mid-ocean ridge basalts (MORB) from the Japan Sea. In contrast, the compositions of the VF samples tend to be more enriched with wide variations. The Sr-Nd-Hf isotopes in the VF rocks tend to be more enriched as one goes from north to south, and the sample with the most enriched isotopic compositions is from the Takahara volcano. In the correlation diagrams of the Sr-Nd isotopic compositions, the trend from the RA to the VF samples appears as a mix of depleted MORB mantle (DMM) and enriched oceanic sediments or continental crust materials. However, the variation in the Hf-Nd isotopes in the VF samples could not be explained by a model of bulk-mixing between DMM and subducted oceanic sediments. Moreover, these isotopic ratios decrease with increasing SiO₂ content. These observations indicate that the variations in the VF samples were formed during processes of magmatic evolution, such as assimilation-fractional crystallization (AFC) or mixing with silicic magma, thus resulting in enriched isotopic compositions. Furthermore, the VF rocks have different Pb isotopic compositions in different area, which indicates that such a varied trend was probably caused by a variety of contaminated crust compositions. In contrast, the Sr-Nd-Hf-Pb isotopic ratios for the RA rocks suggest that their enriched isotopic compositions as compared to MORBs were most likely influenced by the enriched subducting components, and not the crustal material, because the values of the isotopic ratios become constant when their SiO₂ content increases.

キーワード: 東北日本弧, 第四紀火山岩, 同位体組成の空間分布, Hf 同位体比組成

Keywords: NE Japan arc, Quaternary volcanic rocks, Spatial variations in isotopic compositions, Hf isotopes

“ 黒色かんらん石 ” の成因 Origin of “black olivines”

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Rocks of SDW (spinel-rich dunite-wehrlite) suite of the Horoman peridotite complex are characterized by fresh black-colored olivines. The black color is caused by numerous minute inclusions in olivine. The inclusions are homogeneously distributed in olivine grains of the SDW. They are different from the secondary inclusions of magnetite associated with hydrous minerals aligned in olivine both in the SDW dunite and in the MHL harzburgite. The inclusions are abundant in dunites from the central part of the SDW layer, whereas they are scarcely observed in olivines near the contact with the MHL harzburgite. The MHL harzburgite do not contain olivines with such inclusions.

Raman spectroscopy revealed that the numerous minute inclusions consist of magnetite and orthopyroxene. It is very difficult to form such magnetite inclusions by secondary oxidation of olivines. They are possibly subsolidus exsolution products from OH-bearing olivines, precipitated from a hydrous magma. The “black olivine” in dunite can be an indicator for involvement of hydrous melt. Fresh olivines with black colors are frequently found in coarse-grained dunites.

北部オマーンオフィオライト、Wadi Hilti 地域における調和性クロミタイト周囲のダ ナイト中の高 NiO かんらん石 High-NiO olivine in the dunite enveloping the concordant chromitite from the Wadi Hilti, northern Oman ophiolite

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Two types of podiform chromitite, concordant and discordant, are exposed on the same cliff in the mantle section of Wadi Hilti, northern Oman ophiolite. Chromian spinel grains only from the concordant chromitite contain thin lamellae of diopside and enstatite. This indicates that the concordant chromitite has experienced cooling, and probably decompression, for a longer prolonged period than the discordant one. Olivines in the dunite enveloping the concordant chromitite is sometimes extraordinarily high in NiO (up to >0.5wt%), suggesting subsolidus Ni diffusion from the chromitite. This is not the case for the dunite envelope around the discordant chromitite. Ni has moved over about 10cm from the boundary between the concordant chromitite and dunite, which is consistent with the appearance of pyroxenes lamellae in spinel of the concordant chromitite. According to the well-known Ni diffusion coefficient in olivine, the high-NiO olivine in the dunite envelope can constrain the cooling duration of the concordant chromitite. Podiform chromitites are enigmatic in origin, and their origins should be systematically classified to understand concerning mantle processes. Their temporal relationship is a clue to solve this problem.

キーワード: かんらん石, Ni の拡散, ポディフォーム・クロミタイト, オマーンオフィオライト

Keywords: Olivine, Ni diffusion, Podiform chromitite, Oman ophiolite

隠岐の島大久地域産レルゾライトゼノリスにおける高温酸化の影響： High temperature oxidation of lherzolite xenolith from Oku district, Oki-Dogo Island, Japan: evidence in olivine

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Ejima et al. (2011) は、隠岐の島大久地域に産するレルゾライトゼノリス中のかんらん石に少量の Fe^{3+} (0.02 apfu) が存在することを報告し、 Fe^{3+} がマントル条件下で生成した可能性と、ゼノリスが玄武岩マグマに取り込まれて上昇する過程で高温酸化を受けたことにより生成した可能性を指摘した。本研究では、ゼノリスが玄武岩マグマの熱による高温酸化の影響を検討するために、ゼノリスのホスト玄武岩との接触部におけるかんらん石のリムに見られる幅 0.3 mm の褐色部を詳細に観察・分析した。

ゼノリスの玄武岩との接触部におけるかんらん石のリムにみられる褐色部は、Fo 含有量が 69 mol% のかんらん石であった。これはゼノリス中心部分のかんらん石 (Fo₈₁ mol%) に比べて Fe 含有量が高い。褐色部のラマン分光分析の結果、赤鉄鉱及び磁鉄鉱の Fe-O 振動が検出された。褐色部の高分解能透過型電子顕微鏡 (HRTEM) 観察では、かんらん石の (001) 面に平行に転位芯が発達していることが確認された。また電子線回折では、c 軸方向にストリークが観察された。しかし、HRTEM 観察では、ラマン分光分析結果から予想された赤鉄鉱、磁鉄鉱、あるいは存在する可能性のあるライフーナイトは認められなかった。この結果は、褐色部の電子線微小部分分析ではかんらん石の組成のみであり、不純物相が検出されなかったことと調和的である。したがって、ラマン分光分析で認められた褐色部の赤鉄鉱および磁鉄鉱の Fe-O 振動ピークは赤鉄鉱および磁鉄鉱の相の存在を示すものではなく、かんらん石構造中に赤鉄鉱および磁鉄鉱の構造に相当する部分が存在することを示すと考えられる。

褐色部がゼノリスの玄武岩との接触部におけるかんらん石にのみ存在する産状と上記の観察・分析結果から、ゼノリスの溶岩接触部におけるかんらん石では、1) 高温酸化のために、リムの部分で Fe^{2+} の一部が Fe^{3+} に変化し、それに伴って 6 配位席に空席が生じた； 2) 高温酸化の進行に伴い Fe^{3+} が増加し、かんらん石構造中に磁鉄鉱もしくは赤鉄鉱構造のクラスターが生じた； 3) 赤鉄鉱構造クラスターが形成された部分では (001) 面に平行に空席の層が生じ、転位芯が形成された。

このモデルによれば、さらに高温酸化が進むと転位芯に磁鉄鉱、赤鉄鉱が晶出し、析出物として成長することになる。かんらん石の加熱実験による従来の酸化プロセスモデルでは、加熱温度の上昇に伴って、ライフーナイト 赤鉄鉱 磁鉄鉱の順に析出する。他方、大久産レルゾライトゼノリス中のかんらん石では、かんらん石構造中に磁鉄鉱構造および赤鉄鉱構造クラスターが形成されていることは、冷却過程におけるかんらん石の高温酸化プロセスを示すものである。かんらん石の加熱実験の結果と合わせると、加熱温度の低下に伴う析出物の生成順は、磁鉄鉱 赤鉄鉱 ラーフーナイトとなるが、磁鉄鉱、赤鉄鉱が初めに生成するとかんらん石構造を持つライフーナイトの形成は難しくなると考えられる。実際に、かんらん石の褐色部にはライフーナイトは認められない。

Ejima et al. (2011) が報告した隠岐の島大久産レルゾライトゼノリスのかんらん石中の Fe^{3+} は、ゼノリスが玄武岩マグマに取り込まれ、上昇する過程で生成したと考えられる。

キーワード: かんらん石, レルゾライトゼノリス, 鉄の酸化数, 高温酸化

Keywords: olivine, lherzolite xenolith, oxidation state of Fe, high temperature oxidation

岩石薄片中の層状珪酸塩から電子後方散乱回折 (EBSD) を得るための試料作製法と lepidolite の多型決定

A technique for EBSD analyses of phyllosilicates in petrographic sections and determination of polytypes in lepidolite

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Applications of Electron backscatter diffraction (EBSD) to obtain crystallographic information of minerals in petrographic thin sections are increasing in mineralogy and petrology. However, platy phyllosilicates that mostly appear with their silicate layers terminated by the surface of the thin section generally do not show sharp EBSD patterns in spite of gentle mechanical polishing using colloidal silica. Transmission electron microscopy (TEM) examination indicated that this is due to crystal bending of phyllosilicates from the surface to a few micrometers in depth, caused by the polishing process (Fig. a). Ion beam etching commonly used to prepare TEM specimens was found to be applicable to remove the surface region with crystal bending (Fig. b and c). As a result, clear and sharp EBSD patterns were acquired from the phyllosilicates (micas, chlorite, etc.) in petrographic thin sections, by which their crystal orientations and polytypes were unambiguously determined. This technique was applied to the determination of polytypes of lepidolite, a lithium-rich aluminous mica whose general composition is expressed as $K(Li, Al)_{2-3}(Si, Al)_4O_{10}(OH, F)_2$.

The mica structure generates six standard polytypes expressed as $1M$, $2M_1$, $2M_2$, $2O$, $3T$ and $6R$. They are divided into two subfamilies: *subfamilies* A and B. $1M$, $2M_1$ and $3T$ are classified into *subfamilies* A, and $2M_2$, $2O$ and $6R$ are classified into *subfamilies* B (Backhaus and Durovic 1984). Using EBSD pattern, it is possible to distinguish the two *subfamilies* (Kogure 2002). We investigated lepidolite from a lithium pegmatite in Myoken-san, Ibaraki, where various polytypes have been reported (Kogure and Bunno 2004). EBSD analyses of lepidolite crystals in petrographic thin sections showed that polytypes with different subfamilies coexist within a single crystal: The outside was $1M$ (*subfamilies* A) and inside was $2M_2$ (*subfamilies* B).

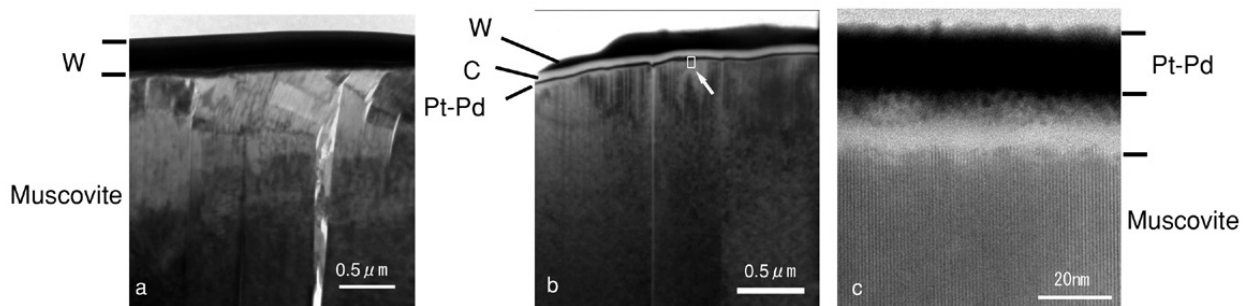
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Keywords: EBSD, phyllosilicates, ion milling, petrographic thin section, polytype, lepidolite



Ca₂MgSi₂O₇-Ca₂Fe₃+AlSiO₇系合成メリライトの二つの四配位席における陽イオン分布と変調構造の関係について Distribution of cations at two tetrahedral sites in Ca₂MgSi₂O₇-Ca₂Fe₃+AlSiO₇ series synthetic melilite and its relation

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Synthetic melilites, W₂T₁T₂O₇, were analyzed to determine the distribution of Fe³⁺ between two different tetrahedral sites (T1 and T2), and the relationship between ionic substitution and incommensurate structure in melilite. Melilites on the join Ca₂MgSi₂O₇ ("<a>kermanite: Ak)-Ca₂Fe³⁺+AlSiO₇ (ferrialuminium gehlenite: FAGeh) system were synthesized from starting materials with compositions of Ak₁₀₀ (100Ak), Ak₈₀FAGeh₂₀ (80Ak), Ak₇₀FAGeh₃₀ (70Ak) and Ak₅₀FAGeh₅₀ (by sintering at 1200-1250 °C and 1 atm. The synthetic melilites were analyzed using X-ray powder diffraction, ⁵⁷Fe Mossbauer, and high-resolution transmission electron microscopic methods. The average chemical compositions and end-member components, Ak, FAGeh and Geh (Ca₂Al₂SiO₇), of the synthetic melilites were Ca_{2.015}Mg_{1.023}Si_{1.981}O₇ (100Ak), Ca_{2.017}Mg_{0.788}Fe³⁺_{0.187}Al_{0.221}Si_{1.791}O₇ (80Ak), Ca_{1.995}Mg_{0.695}Fe³⁺_{0.258}Al_{0.318}Si_{1.723}O₇ (70Ak) and Ca_{1.982}Mg_{0.495}Fe³⁺_{0.449}Al_{0.519}Si_{1.535}O₇ (50Ak), respectively.

The site populations at the T1 and T2 sites were [0.788Mg+0.054Fe³⁺+0.158Al]T1[0.056Fe³⁺+0.153Al+1.791Si]T2 for 80Ak, [0.695Mg+0.105Fe³⁺+0.200Al]T1[0.112Fe³⁺+0.165Al+1.723Si]T2 for 70Ak and [0.495Mg+0.173Fe³⁺+0.332Al]T1[0.281Fe³⁺+0.332Al+1.535Si]T2 for 50Ak (apfu: atoms per formula unit), respectively. The results indicate that Fe³⁺ is distributed at both the T1 and the T2 sites. The mean T1-O distance decreases with the substitution of Fe³⁺+Al³⁺ for Mg²⁺ at the T1 site, whereas the mean T2-O distance increases with substitution of Fe³⁺+Al³⁺ for Si⁴⁺ at the T2 site, causing decrease in the a dimension and increase of the c dimension.

The existence of incommensurate structure in all synthetic melilites at room temperature was confirmed by Mossbauer and CuK_{alpha}1 X-ray line profile analyses. The Mossbauer spectra of the melilites consist of two doublets assigned to Fe³⁺ at the T1 site and two or three doublets to Fe³⁺ at the T2 site, which imply the existence of multiple T1 and T2 sites with different site distortions, respectively. The existence of two T1 sites is not influenced by ionic substitution. Conversely, the splitting of T2 sites becomes more remarkable with the substitution of Fe³⁺+Al³⁺ for Si⁴⁺ which results in the increase of volume and site distortion of the T2O₄-tetrahedra.

Incommensurate structure in melilite has been interpreted rather statically, based on the crystal structure of "a}kermanite, that the incommensurate structure is caused by the misfit between the tetrahedral sheet and the polyhedral sheet. However, as found in this study, effect of ionic substitution at the T1 and T2 sites on the formation of incommensurate structure is also significant. The first factor is the site distortion arising from the distribution of cations with different ionic radii in the T1 and T2 sites. Even though the cation sites are symmetrically equivalent in the average structure, each tetrahedron which is occupied by different cation(s) has variant volume. The second factor is the site distortions caused by the difference of adjacent coordination polyhedra around tetrahedra. Therefore, in Ak-FAGeh melilite solid solutions, the site distortions caused by the ionic substitution at the tetrahedral sites play important role on the formation of the incommensurate structure.

キーワード: 合成メリライト, 変調構造, 粉末 X 線回折, 電子線回折, メスバウアー分光分析

Keywords: synthetic melilite, incommensurate structure, X-ray powder diffraction method, Electron diffraction, Mossbauer spectroscopy

地球における衝突構造の分類と衝突性炭素元素等の濃縮保存の研究 Study on classification of terrestrial impact structures and concentration of impact-related carbon light elements

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地球における表面活動の跡である衝突構造は次のように大きく分類できる。

1) タイプ1 衝突構造: 大きな大陸地殻の結晶質岩石 (火成・堆積岩等) に衝突してできる衝突孔 (クレーター) 構造で、現在の地球惑星の大陸に残されたほとんどの衝突孔構造はこのタイプである。放出物はすべてターゲット岩石から放出され、放出物は衝突の反対方向に飛散する。

2) タイプ2 衝突構造: 海水の基盤岩 (堆積岩・石灰岩等) に衝突してできる衝突孔構造で、現在はプレート等の大陸移動で埋没または破壊され、掘削や物理探査をしないと正確に把握できないタイプである。このタイプは、衝突構造物の残存場所で、さらに、海底と陸地に分けられる。海底は比較的新しく残存して探査できるが、陸地では低地に埋没破壊または、高地に地殻運動で上昇して残存していることが多い。後者の陸地残存タイプとして、比較的低位残存 (秋吉、高松など) と高地山頂残存 (米国 Santa Fe など) がある。

米国 Santa Fe 衝突構造は、昨年秋 Univ. New Mexico 大学研究滞在中にその大学の研究スタッフらと現地調査をして、現地でこれまで報告のない石灰破碎岩や衝突時の炭素含有物 (ミクロ、各種) を筆者の FE-ASEM 分析研究ではじめて確認し、高地であるがタイプ2と分類できる。

地球の元素濃縮 (鉱床形成) は高温時に起るのでこれまでの地下火成マグマ以外に、衝突高温時に元素濃縮 (炭素や希土類元素) が生じていることが、衝突構造の破碎岩などで確認できた。

この考えは、地球以外の天体表面、例えば月面アポロ試料の破碎岩でも同じような元素濃縮 (資源形成) 生じており、他の惑星・小惑星天体への応用が可能な新資源・岩石鉱物探査になる重要なことである。

キーワード: 衝突構造, 分類, 衝突性炭素含有物, 海水衝突, 濃縮保存, 破碎石灰岩

Keywords: impact structure, classification, impact carbon-bearing materials, ocean impact, concentration reservoir, limestone breccias