TOPOGRAPHICAL EXAMINATION AND GENESIS OF CLAY VEINS FOUND IN THE KUMOGI GRANITE MASS IN SHIMANE PREFECTURE, SOUTHWEST JAPAN

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On clay minerals found in veins developed in the Kumogi granite mass in the vicinity of Hamada city, Shimane Prefecture, the modes of occurrence and mineralogy such as polytypes and crystal forms were investigated. The clay veins are distinctly divided into three types (types I, II and III) based on the mode of occurrence. The clay veins of type I are formed along nearly vertical faults or fissures, type II occurs as replacement products in vein-form and type III are formed along small fissures or joints. The clay veins of types I and II are composed of mainly mica clay mineral and type III are composed of mainly kaolin minerals. The polytypes of mica clay mineral of type I are identified to be 1Md, 1M and 2M, while that of type II is only 2M. The modes of occurrence and mineralogy of the clay minerals of types I and III show almost the same mineralogical characteristics to those of clay veins found in Hiroshima granitic rocks (Kitagawa and Kakitani, 1978a, b, c), while the type II is characteristic in the Kumogi granite mass.

Topographical examinations of mica clay (type I) and kaolin (type III) veins show that mica clay veins are mainly distributed in the margin of the granite mass which is situated at the lower level, while kaolin veins in the middle part of the mass is situated at relatively higher level. More detail examination of type I indicates that 2M mica clay minerals are found in the margin of the mass and relatively in the lower than 1Md mica clay minerals.

It may be indicated from these results and study of Imaoka et al. (1977) and Ishihara et al. (1980), mica clay minerals in type I veins were formed by hydrothermal solution which interacted with meteoric ground water which intruded from the margin of the granite mass.

INTRODUCTION

Numerous clay veins named “Seam” in the field of civil engineering are observed at many outcrops of granitic rocks, and also found in the caves of dam-sites and tunnels. They are formed along nearly vertical joints, small fissures and faults. Their width are generally in the range of about 0.1 mm to 30 cm and they are green, pale-green, dark-green, white or gray in colour.

Kitagawa and Kakitani (1978a, b, c) reported the mode of occurrence of these clay veins and mineralogy of the clay minerals found in granitic rocks of Hiroshima and Shimane Prefectures. According to them, clay veins are distinctly divided into two types based on modes of occurrence and mineralogy of the clay mineral, i.e. one is greenish vein and the other is white.

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Vein. The greenish clay veins, formed along small faults or fissures, consist mainly of mica clay mineral, the interstratified mineral of mica clay mineral & montmorillonite, and montmorillonite mineral. The white clay veins consisting of kaolinite and/or halloysite formed along small fissures or joints, or often developed as networks. They also considered that mica clay minerals were converted to montmorillonite minerals through the interstratified minerals by weathering. On the other word, the greenish clay veins are corresponded to mica clay veins, while white clay veins are corresponded to kaolin veins. The detail mechanism of formation of mica clay and kaolin veins, however, remain to be solved.

In this paper, clay veins found in a small granite mass, the Kumogi granite, were investigated in detail with special attentions on the modes of occurrence and the topographical distributions of mica clay and kaolin veins in the mass and we tried to clarify the genesis of both mica clay and kaolin minerals.

**GEOLOGY AND TOPOGRAPHY OF THE MASS**

The Kumogi granite mass which is inferred to be early Tertiary, is located at about 10 km southeast from Hamada city, Shimane Prefecture (Fig. 1). The granite mass is about 13 km in length (N-S direction) and about 5 km in width (E-W direction). The Kumogi granite is characterized by semiporphyritic texture. The mineral constituents of the rock are mainly alkali-feldspar, quartz, plagioclase and biotite accompanied with a small amount of chlorite, epidote, illumenite, apatite, zircon and pyrite (Imaoka et al. 1977; Imaoka, 1978).

The Kumogi granite mass appears in
the topographical range of 150–667 m level. The contour map of the mass, which is drawn at every 200, 300, 400, 500 and 600 m, is shown in Fig. 2. The highest point in accordance at about 667 m corresponds to the summit of Mt. Kumogi which is located at south part of the mass. In general, the margin of the mass is situated at the lower level than the middle part.

**Mode of Occurrence**

The mode of occurrence of clay veins can be distinctly divided into three types (types I, II and III). The veins of type I are 1–50 cm in width and pale-green, white or gray in colour. They are formed along nearly vertical small fissures or faults. The mode of occurrence of this type veins is illustrated schematically in Fig. 3.

The veins of type II are ca. 5 cm–5 m in width and white or brown in colour. The microscopic observation indicates that feldspar and biotite are generally altered to mica clay mineral aggregates, loosing their original euhedral forms. These veins seem to occur as replacement products in vein-form (Fig. 4).

The veins of type III are formed along joints or small fissures. Some of them are developed as network patterns. These veins range 1 mm–10 mm in width and are white in colour. Some veins of this type are cut by those of type II. The mode of occurrence is shown schematically in Fig. 5.
CLAY MINERAL CONSTITUENT

Constituent clay minerals of the clay veins of three types were identified using X-ray powder diffractometer and transmission electron microscope.

Type I: The specimens which give 10 Å basal reflection are inferred to be mica clay mineral (Fig. 6, A). Some specimens show 14-15Å reflection accompanied with 10Å reflection (Fig. 6, B). Some other specimens have 7Å reflection with 10Å reflection (Fig. 6, C). The 15Å peak expands to 17Å with ethylen glycol treatment, and reduces to 10Å with heating at 500°C for one hour. Therefore, some specimens have montmorillonite mineral. On the other hand, the 14Å reflection shows no change by heating at 500°C for one hour, neither by ethylen glycol treatment, indicating existence of chlorite. The 7Å reflection, disappearing by heating at 500°C for one hour, is inferred to be kaolin minerals. From these, it can be said that clay veins of this type consist mainly of mica clay mineral with small amount of montmorillonite mineral, chlorite and kaolin minerals.

The polytypes of mica clay mineral were identified as 1Md, 1M and 2M polytypes. Some of 1Md mica clay minerals are associated with montmorillonite mineral and kaolinite, and some of 2M polytype mica clay minerals are rarely accompanied by montmorillonite mineral.

Type II: The specimens showing 10Å...
basal reflection is inferred to be mica clay mineral. The X-ray powder diffraction patterns of specimens of this type veins are also shown in Fig. 6-D.

The 2M mica clay mineral is common in all veins of type II. No 1Md and 1M polytypes are found in the veins.

The crystal forms of mica clay minerals of types are similar with each other (Fig. 7). The bright-field images of mica clay minerals are shown in Fig. 7. The minerals in the veins are aggregated of well-developed elongated plates or irregularly particles. The size of elongated crystals measured parallel to the basal plane is in the range from 1 μ to 5 μ at the longest direction and 0.3-0.8 μ in width. The size of irregular and hexagonal particles is in the range of 1-2 μ.

Type III: The X-ray powder diffraction patterns are given in Fig. 8. Two types of patterns are recognized, i.e. one is characterized by 15 Å and 7 Å reflections (Fig. 8, A) and the other is 10 Å and 7 Å reflections (Fig. 8, B, C, D). Because the 10 Å basal reflection disappears with heating at 110°C for one hour, the 7 Å peak is inferred to be that of both kaolinite and/or halloysite (Fig. 8, B, C, D). The 15 Å reflection expands to 17 Å with ethylen glycol treatment. Therefore, it corresponds to the peak of montmorillonite mineral (Fig. 8, A). A few specimens have weak 10 Å reflection which is inferred to be the peaks of

**Fig. 8. X-ray powder diffraction patterns of clay minerals in veins of type III.**

![X-ray powder diffraction patterns of clay minerals in veins of type III.](image)

**Kaolinite & Halloysite**

**Halloysite**

**Fig. 9. Transmission electron micrographs of kaolin minerals in the veins of type III.**
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mica clay mineral overlapping with those of halloysite.

From the bright field images of TEM (Fig. 9), it is known that almost specimens are halloysite showing tubular form and a few specimens are kaolinite showing irregular of hexagonal forms. The diameter and length of halloysite particle are generally in the range of 0.03-0.1 µ and 0.1-3 µ respectively. The size of irregularly sharped plates ranges from 0.5 to 2 µ.

Thus, it can be concluded that specimens of type I consist of mainly mica clay mineral accompanied with small amount of montmorillonite mineral, chlorite and kaolin minerals, those of type II of mica clay mineral only, and those of type III mainly of kaolin minerals (kaolinite and halloysite) accompanied with a small amount of montmorillonite mineral or mica clay mineral.

**TOPOGRAPHICAL DISTRIBUTION OF CLAY VEINS**

Topographical distribution of clay veins in the mass based on differences of mode of occurrence of veins, constituent clay minerals in veins and polytypes of mica clay mineral are as follows:

**Mode of occurrence**

The topographical distribution of clay veins of the three types were plotted on the ground plane of the mass (Fig. 10). As shown in Fig. 10, the veins of type I are mainly distributed in margin of the mass which is situated at relatively lower level. On the other hand, types II and III of clay veins are mainly distributed in the middle part which is situated at relatively higher level (Fig. 11).

The frequency of the three types in the vertical direction of the mass is represented in Fig. 11. At the lowest level (below 200 m), type I veins (99.4%) prevail mostly with small amount of veins of type II (5.6%), and type III veins are not observed. At 200-250 m level, percentages of type I, II and III are 49.1, 10.9 and 40.0%, at 250-
300 m, 27.1, 30.0 and 42.9%, and at the highest level, 13.2, 31.6 and 55.2%, respectively. This shows that the type I prevails at the lowest level (below 200 m), while the types II and III develop at the highest level. Especially, veins of type III are found only at the higher level, about 200 m.
Clay mineral constituent

Two minerals, mica clay mineral and kaolin minerals, are distributed characteristically in the mass (Figs. 12 and 13). Mica clay veins are common throughout the granite mass, whereas kaolin veins are prevail in the middle part of the mass (Fig. 13). The frequency of mica clay and kaolin veins in the vertical direction of the mass is shown in Figs. 14 and 15. These figures show that kaolin veins are restricted to the higher level (about 200 m), though mica clay veins are found at all levels. Below 200 m level, only mica clay veins are observed.

Fig. 16. The distribution of mica clay veins (type I) of three polytypes.

Polype type of mica clay mineral in the veins of type I

The veins of type I consist mainly of mica clay mineral of 2M, 1M and 1Md polytypes. The clay is divided into three types based on the difference of polytype of mica clay mineral, i.e. 2M, 1M and 1Md. The distribution of the three types are plotted in the ground plane of the granite mass (Fig. 16). The 2M mica clay is mainly distributed in the north and south parts of the mass which are situated at relatively lower level, while 1M and 1Md mica clay veins at middle part of the mass locating at relatively higher level.

The frequency of the veins of three kinds is represented in four levels (below 200 m, 200-250 m, 250-300 m and above
300 m) (Fig. 17). Clay veins of 2M mica clay mineral prevail at the low level, while clay veins of 1Md and 1M mica clay mineral prevail at the high level of the mass.

**DISCUSSION**

The clay veins are distinctly divided into three types (types I, II and III). Namely, the veins of type I and III formed along small faults or fissures, while type II veins occur in vein-form as replacement products. The clay veins of both types I and II are mainly composed of mica clay mineral consisting of irregularly plate and elongated tabular forms, and type III veins are mainly composed of kaolin minerals (kaolinite and halloysite). The veins of types I and III are remarkably similar to those in granitic rocks of Hiroshima and Shimane Prefectures (Kitagawa and Kakitani, 1978a, b) with respect to the mode of occurrence of veins and mineralogy of clay minerals in veins, i.e. type I corresponds to mica clay vein (greenish vein) and type III corresponds to kaolin vein (white vein) which are found generally in granitic rocks of Hiroshima and Shimane Prefectures. However, the veins of type II is characteristic in the Kumogi granite mass.

It became clear that the close relation are observed between the distributions of clays (types I and III) and their topographical situation. Namely, mica clay veins are mainly distributed in the margin of the mass which is situated at relatively lower level, though they are widely distributed throughout the mass. On the other hand, the kaolin veins are only distributed in the middle part which is situated at higher level, about 200 m.

The mica clay minerals of type I are mainly 2M and 1Md with a small amount of 1M. The 2M mica clay veins are mainly found in the margin of the mass which is situated at relatively lower level, while the 1M and 1Md mica clay veins are distributed at relatively higher level and especially 1Md mica clay veins are not found at below 200 m (Figs. 16 and 17). As is well known, polytypes of mica clay minerals are disordered one layer monoclinic (1Md), ordered one layer monoclinic (1M), two layer monoclinic (2M) and three layer trigonal (3T) structures. Both the 1M and 1Md polytypes are metastable forms and 2M is only stable polytype of mica clay mineral (Velde, 1965). The 2M is more stable than the 1M and 1Md at higher temperature and/or pressure, and with increasing temperature and pressure, 1M structure changes to that of the 2M structure (Smith and Yoder, 1956; Yoder and Eugster, 1955). According to this, mica clay minerals in the lower level or the margin of the mass may be formed under higher temperature and/or higher pressure than those in the higher level or the middle part of the mass, or metastable mica clay minerals (1Md and 1M) may be produced because of rapid fluctuations in equilibrium.

The mica clay veins of type I with 2M polytype are mainly distributed in the margin of the mass. From study of oxygen isotopic composition of the Kumogi granite, Imaoka et al. (1977) clarified that meteoric ground water interacted with the Kumogi granite mass from the margin to the inside during their cooling process. Ishihara et al. (1980) dated mica clay mineral corresponding to type I in granitic rock of Hiroshima Prefecture by K-Ar method, and suggested that genesis of mica clay mineral is related to the post granitic activity, i.e. hydrothermal activity. These results may suggest that mica clay minerals in type I veins were formed by hydrothermal solu-
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... which interacted with meteoric ground water intruded from the margin of the mass.

Kitagawa and Kakitani (1978c) reported from observation of the clay vein that mica clay mineral transformed to kaolin mineral through montmorillonite mineral by weathering. However, the mica clay veins differ clearly from kaolin veins in the mode of occurrence and topographical distribution in this mass. The observation does not show that mica clay mineral transformed to kaolin mineral, or mica clay vein transformed to kaolin vein.

The mode of occurrence and mineralogy of veins of type II differ from those of type I and III. It is necessary for clay veins of type II and III to examine in more detail and using different approaches to clarify the mechanism of their formation, e.g. trace element composition (Wilke et al., 1978).

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島根県の雲城花崗岩体中にみられる粘土細脈の地形的分布と成因

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島根県浜田市近くに分布している雲城花崗岩体中にみられる粘土細脈を構成している粘土礦物について、その産状、鉱物学的特徴を検討した。粘土細脈は、産状の違いにより3種類（Type I, II, III）に分類される。Type Iの脈は、ほぼ垂直な断層、割れ目を粘土鉱物がうって形成され、Type IIでは、花崗岩が脈状に粘土鉱物により交代されて形成されている。Type IIIの脈は、小さな割れ目や節理に沿って形成されている。Type IとIIは主に雲母粘土鉱物よりなり、Type IIIは、主にカオリノ粘土鉱物より構成されている。また、Type Iの脈において雲母粘土鉱物のポリタイプは、2M, 1M, 1Mdで、Type IIは、2Mのみである。Type IとIIIの脈は、北川・柿谷 (1978 a, b, c) すでに報告している広島県下の花崗岩中にみられる粘土細脈の産状や構成鉱物の特徴とはほとんど同じであるが、Type IIの脈は、他にあまり見られず、この岩体中に特徴的である。

雲母粘土鉱物脈（Type I）とカオリノ粘土鉱物脈（Type III）の岩体中における分布状態を調べた結果、雲母粘土鉱物脈（Type I）は主に地理的に高度の低い位置にあたる岩体周縁部に、一方、カオリノ粘土鉱物脈（Type III）は、高度の比較的高い場所にあたる岩体中央部に集中して分布していることがわかった。さらにType Iの脈において雲母粘土鉱物のポリタイプの違いによる分布状態を調べた結果、2Mは岩体周縁部で、さらに1Mdよりも高度の低い位置に主に認められる。

これらの結果と今岡ら (1977), 石原ら (1980) の研究より、Type Iの雲母粘土鉱物は、岩体周辺部から侵入した地下水と相互作用した熱水溶液により形成されたものと推定される。

Kumogi 雲城