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Mineralogical and Chemical Studies of Clay Veins in Granitic Rocks of Chugoku District, Southwest Japan

By

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with 27 Figures

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Abstract:This paper deals with the chemical composition of clay veins found in granitic rocks distributed in Chugoku district with special reference to constituent clay mineral and chemical composition. Clay minerals were collected from clay veins developed in granitic rocks in Rokko , Hiroshima , Mitoya , Izuha and Kumogi districts. Granitic rocks distributed in Rokko and Hiroshima districts belong to the ilmenite-series, whereas those in Mitoya, Izuha and Kumogi districts belong to magnetite-series. The constituent clay minerals of clay veins were identified by means of X-ray powder diffraction. The element contents of clay minerals were investigated by means of atomic absorption spectrophotometry, and the values obtained were examined from mineralogical view points. The results obtained are as follows.

1) Clay veins are generally composed of mainly mica clay mineral, smectite and kaolin minerals with a small amount of interstratified mineral of mica clay mineral and smectite. A few veins are composed of zeolite, especially laumontite.

2) Clay veins of Rokko and Hiroshima districts are rich in kaolin minerals and smectite, and those of Mitoya, Izuha and Kumogi districts are rich in mica clay mineral. 3) Among the major elements, content of Mn in clay veins is high in Izuha and Kumogi districts.

4) Na ,Ca and K contents depend on the constituent clay minerals. That is, content of K depends on the amount of mica clay mineral, whereas content of Ca depends on that of smectite.

5) Contents of minor elements such as Li, Cu and Pb, vary with respective districts. Li content is high in clay veins of Rokko and Hiroshima districts. In Mitoya, Izuha and Kumogi districts, Li content is very low. This fact may represent the difference of the host granite, ilmenite-series and magnetite-series. Cu and Pb are abundant in clay veins of Hiroshima and Izuha districts.

Based on the above results, chemical characteristics of clay veins in respective district and mineralogical and chemical characteristics of constituent clay minerals were discussed in relation to the origin of hydrothermal activities of the respective post granitic activities.

CONTENTS

I. INTRODUCTION

In the inner zone of southwest Japan, granitic rocks of Cretaceous to Palaeogene age are distributed widely. These granitoids were divided into two series by Ishihara(1975,1977). According to Ishihara(1977), the one is ilmenite-series distributed characteristically in Sanyo province, and the other is magnetite-series in Sanin province. The former granitic rocks are intruded from late Cretaceous to early Palaeogene age, whereas the latter intruded relatively younger age than those of the former.

In these granitic rocks, numerous clay veins are commonly observed. The width of veins varies from one millimeter to one meter. These veins are formed along nearly perpendicular faults, fissures and joints with variable directions. With regard to these veins, the mode of occurrence, constituent minerals, genesis of fractures and formation age of these clay veins are studied in detail by Kitagawa and Kakitani(1978, 1979), Kitagawa et al.(1981, 1982) Kitagawa and Okuno(1983), and Kitagawa(1985, 1986).

Kitagawa (1986) concluded the clay veins developed in the granitic rocks were formed by hydrothermal solutions during the post granitic activities based on his examination of the mode of occurrence, formation ages of clay minerals constituted clay veins and hose of granitic rocks as well as on the investigation of clay minerals from the stand point of crystal growth.

On the other hand, it is experientally established that clay minerals adsorb various cations in considerable amount (e.g. Takeno et al.,1981). This fact suggests that clay minerals play an most important role on dispersion process of metallic elements derived from hydrothermal solutions related to the post granitic activities. Therefore, it can be expected that metallic elements contained in clay minerals reflect the chemical characteristics of the hydrothermal solution of the respective post granitic activity. Thus, examination of metallic element contents of clay minerals will be useful to clarify the granitic activity. However, few chemical analyses of clay minerals constituted clay veins, especially concerning minor elements, have been done before (e.g., Kitagawa, 1987).

In this paper, first, mineralogical characteristics of clay minerals collected from clay veins developed in granitic rocks are clarified. Then, detailed chemical composition of the clay minerals were examined on the major elements as well as on the minor elements.

Based on the mineralogical and chemical properties of clay veins, chemical characteristics of the hydrothermal activities of respective post granitic activity will be discussed.

II. OUTLINE OF GEOLOGY

The five localities, Rokko, Hiroshima, Mitoya, Izuha and Kumogi districts were chosen for this investigation (Figure 1). Granitic rocks distributed in Rokko and Hiroshima districts belong to the ilmenite-series granite, whereas those of Mitoya, Izuha and Kumogi districts to the magnetite-series granite (Ishihara, 1977).

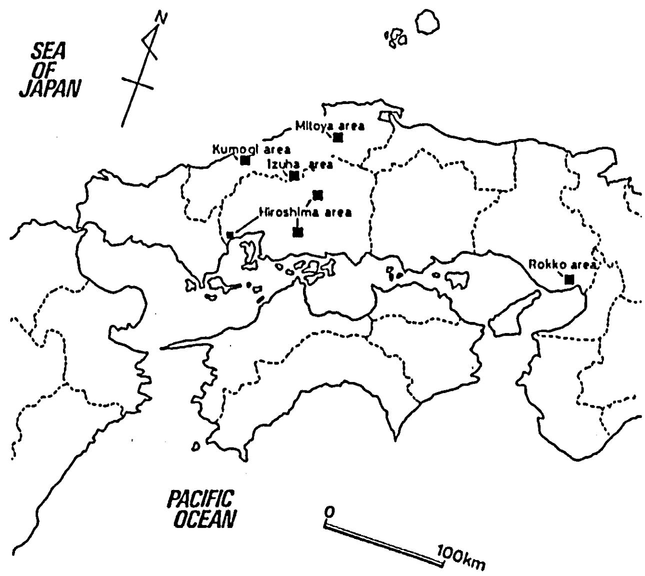


Fig.1. Locality map of the investigated area.

1. Rokko district

Figure 2 shows geological map of the Rokko area. The geology of the district is studied in detail by Kasama (1968) and Huzita and Kasama (1982,1983). According to Huzita and Kasama (1983), the basement of the geology of the district is composed of Paleozoic-Mesozoic sedimentary rocks and the granitic rocks. These basement rocks are sporadically covered by Cenozoic sediments. According to Kasama (1968), the granitic rocks forming the Rokko blocks divided into three types on the basis of their petrographical features, i.e., Nunobiki granodiorite, Dobashi quartz diorite and Rokko granite.

The Nunobiki granodiorite is medium-grained hornblende-biotite granodiorite and often includes dark-colored basic xenolith. The Dobashi quartz diorite is fine-grained and dark-colored and composed of quartz, feldspar, biotite and needle crystals of hornblende. The Rokko granite is medium to fine-grained and light-colored biotite granite characterized by pinkish potassium feldspar and constituting the major part of the Rokko massif.

K-Ar dating on the biotite of the Rokko granite ranges from 75 to 72Ma (Kawano and Ueda,1966). Clay veins developed in these granitic rocks were examined.

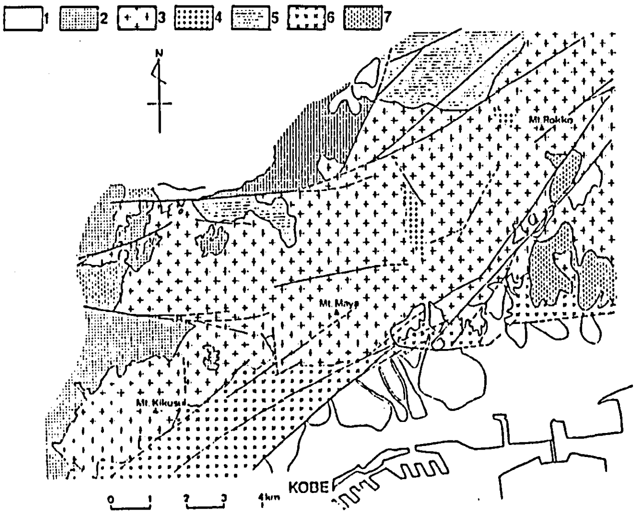


Fig.2. Geological map of the Rokko district. 1:Quarternary sediments, 2:Kobe group(Miocene), 3:Rokko granite, 4:Dobashi quartz diorite 5:Arima group(Cretaceous), 6:Nunobiki granodiorite, 7:Paleozoic rocks.

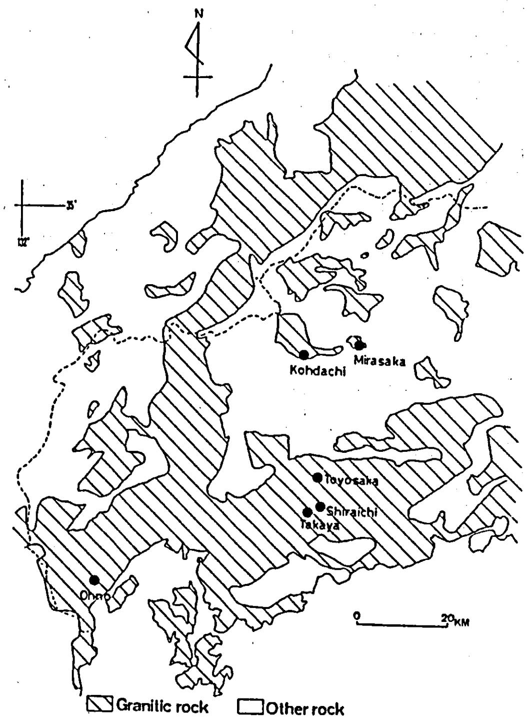


Fig.3. Locality map of the investigated area in the Hiroshima district.

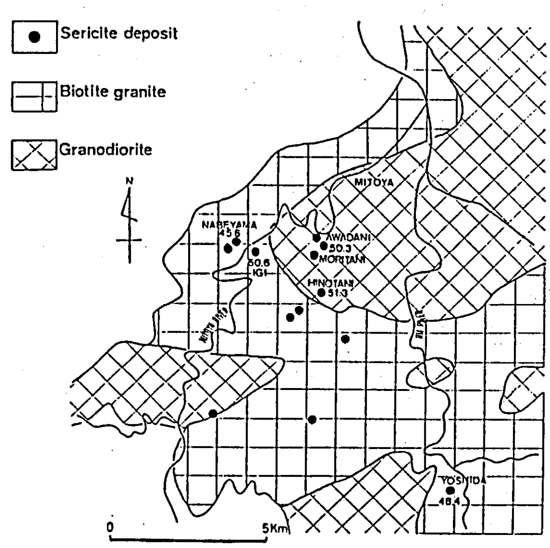


Fig.4. Geological map of the Mitoya district together with localities of sericite deposits (after Ito, 1985).

2. Hiroshima district

Figure 3 shows the sampling localities of Hiroshima district. Six localities (Mirasaka, Kohtachi, Toyosaka, Shiraichi, Takaya and Ohno) were chosen for the present study. Granitic rocks distributed in these areas are coarse-grained biotite granite composed mainly of quartz, feldspar and biotite.

The ages of these granite obtained by K-Ar method on biotite are 87-72Ma (Kawano and Ueda,1966; Shibata and Ishihara,1974). Clay veins developed in granitic rocks distributed in these six localities were examined

3. Mitoya district

Figure 4 shows simplified geological map of the Mitoya district. The granitic rocks distributed in this area can be divided into two types on the basis of petrographical features. One is coarse to medium-grained biotite granite which appear in the southern and northern part, and the other is coarse to medium-grained hornblende biotite granodiorite which distributed in the central part of the area. Both granitic rocks are correspond to early-Paleogene ages. That is, K-Ar dating made on biotite ranges from 51 to 48Ma (Kawano and Ueda,1966; Shibata and Ishihara 1974).

It should be mentioned that many sericite deposits formed by hydrothermal metasomatism are developed in this granitic rocks. (Kitagawa et al.1981).

4. Izuha district

Figure 5 shows geological map of the investigated area of the Izuha district. This area consists of rhyolitic and dacite pyroclastics, granitic rocks and a small amounts of Cenozoic sediments. Rhyolitic rocks in the northern part are rhyolite and dacite tuff corresponding to Hikimi group. Cenozoic sediments are distributed in the northern part, which is consists of sandstone and conglomelate corresponding to Kuri-Kawai formation. The granitic rocks in the central part are porphylitic aplite granite correlated to the Tamagawa group of Eocene-Oligocene age. This granite are called Tadokoro Granite by Higashimoto (1975). The K-Ar ages of this granite are 40-34Ma (Shibata and Ishihara,1974).

Sericite deposits are also found in this granite, which was formed in open fractures by direct precipitation from hydrothermal solution (Kitagawa et al.,1988).

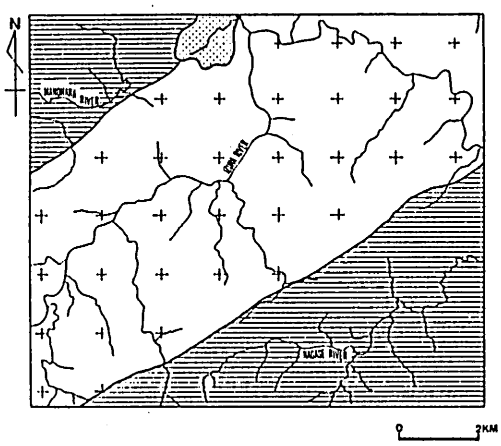


Fig.5. Geological map of the Izuha district. 1:Miocene sediments, 2:Tadokoro granite, 3:Rhyolitic rocks(Cretaceous).

5. Kumogi district

Figure 6 shows the geological map of the Kumogi district. The geology of this area is studied in detail by Imaoka et al.(1977) and Imaoka(1986). According to Imaoka(1986), the Kumogi granite mass distributed in this area is about 13km in length(N-S direction) and about 5km in width(E-W direction). This granite intruded along the boundary between Hamada group and the basement rocks which are composed of Sungun metamorphic rocks and Cretaceous volcanic rocks. The Kumogi granite is characterized by semi porphyritic texture. The mineral constituents of the rocks are mainly quartz, feldspars and biotite.

Fission-Track dating of the granitic rocks indicate 33-30Ma (Matsuda,1983).

6. Formation ages

Figure 7 shows the results of K-Ar age determinations published up to the present. In the figure, K-Ar ages of clay minerals together with those of the host granitic rocks are arranged in chronorogical order. The ages of the sericite deposits are also presented. The determined age of 36.4Ma for mica clay mineral collected from Iwaya sericite deposit in Izuha district is consistent with those of the host granite, whose age ranges from 34Ma to 40Ma (Kawano and Ueda,1966; Shibata and

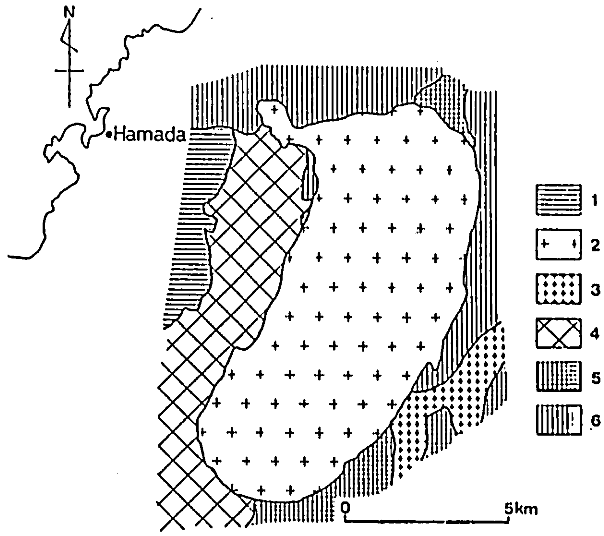


Fig.6. Geological map of the Kumogi district(After Imaoka, 1985). 1:Kokubo group(Miocene), 2:Kumogi granite, 3:Jokoji-dani granite porphyry, 4:Hamada group(Oligocene), 5:Felsic volcanic rocks (Cretaceous), 6:Sangun metamorphic rocks.

Ishihara,1974; Kitagawa et al.,1988). K-Ar ages of mica clay mineral from sericite deposits (Nabeyama, Yoshida, Unnan, Igi,Hinotani) in Mitoya district range from 45.6 to 51.3Ma (Ishihara et al.,1980; Kitagawa et al.,1988). Whereas, the ages of biotite granite and granodiorite distributed in Mitoya district range from 49 to 51Ma (Kawano and Ueda,1966; Geological Survey of Japan, 1982). Thus, the formation ages of mica clay mineral constituted clay veins in Mitoya district are very close to those of the host granite. Kohtachi, Toyosaka and Takaya are dated to be 76.5Ma, 79.5Ma and 86Ma, respectively (Ishihara et al.,1980; Kitagawa et al.,1988). The K-Ar age of biotite granite which corresponds to the Hiroshima granitic rocks ranges 72 to 87Ma (Shibata and Ishihara, 1974). Therefore, the formation age of clay minerals in Hiroshima district is included in range of that of the host granite.

In all districts, the formation ages of clay minerals are almost coincide with those of the host granitic rocks. In other words, Clay veins were seemed to be formed during the hydrothermal stages of granitic activities.

III. EXPERIMENTAL METHODS

1. X-ray diffraction analysis

In order to obtain pure clay minerals, the samples were treated by wet sieving and sedimentation method. Thus the less than 2micron-size fraction of pure clay minerals were analyzed to clarify the constituent clay minerals by X-ray powder diffraction method. The relative amount of clay minerals was estimated semi-quentitatively on the basis of the relative intensities of basal reflections.

2. Chemical analysis

About 100mg of pure clay minerals was dissolved in mixed hydrofluoric and hydrochloric acids and 50ml solutions were obtained. The concentrations of elements were determined by atomic absorption using Model AA-646 atomic absorption spectrophotometer. Measured elements are Al, Fe, Mn, Mg, Ca, Na, K, Li, Co, Ni, Cu, Zn, Rb and Pb. Among the measured 14 elements, it is generally accepted that the 4 elements such as Ca, Na, K and Rb occupy the interlayer position and the rest belong to the octahedral position (e.g. Deer et al.,1962; Newman, 1987).

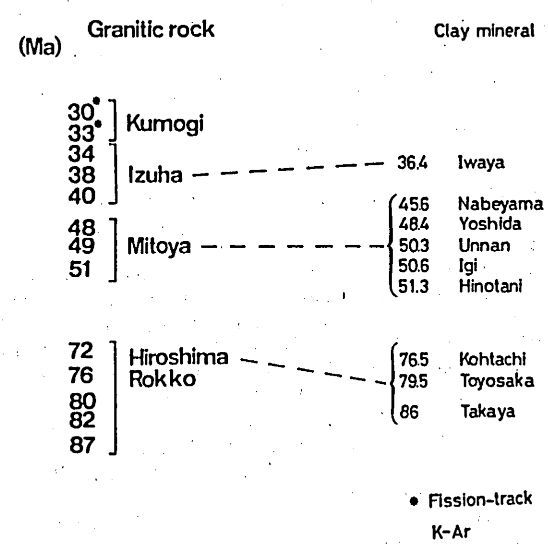


Fig.7. Formation ages of the granitic rocks and clay minerals(Data taken from Kawano & Ueda, 1966; Shibata & Ishihara, 1974; Geological survey of Japan, 1982; Ishihara et al.,1980; Matsuda, 1983, Kitagawa et al.,1988).

IV. RESULTS

1. Constituent clay minerals

X-ray powder diffraction patterns for typical specimens of each districts are shown in Figures 8 to 11. The powder patterns generally reveal the reflections of several clay minerals at about 15Å, 10Å and 7Å. In rare cases, weak reflections of interstratified mineral whose basal reflection appear about 25Å and that of zeolite at 9.2Å. All of the 15Å reflection expands by ethylene glycol treatment to 17Å. Therefore, the 15Å reflection is ascribed to smectite. The 10Å and 7Å spacing are identified to mica clay mineral and kaolin minerals, respectively. As is seen in the powder patterns indicate that clay veins are composed of more than two kinds of clay minerals in all districts.

The regional variation of the constituent clay mineral in Rokko, Mitoya, and Izuha districts are summarized in Figure 12, 13 and 14, respectively. As is seen in these figures, mica clay mineral, smectite and kaolin minerals are distributed randomly, and no special development of certain clay minerals are observed. However, zeolite appear at a part of Rokko district(Figure 12). Chlorite rarely distribute in Izuha district(Figure 14).

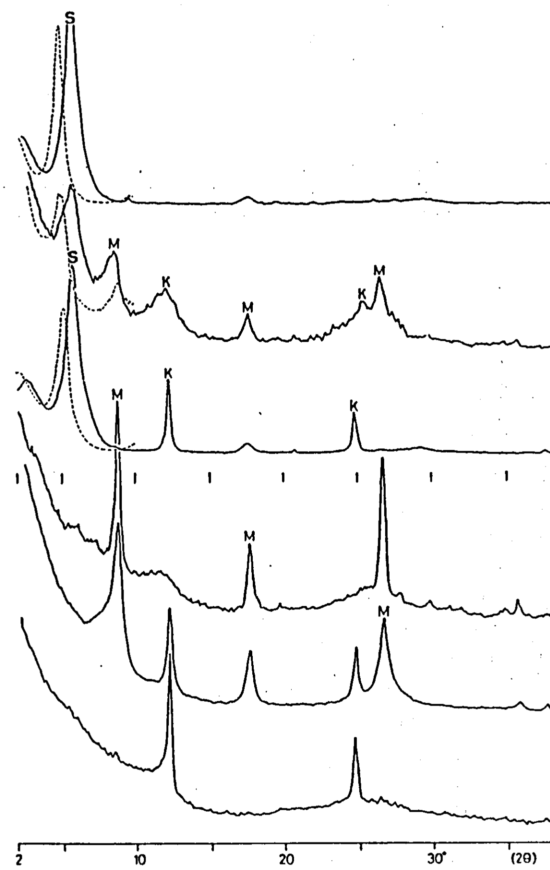


Fig.8. X-ray powder diffraction patterns of clay minerals found in clay veins in the Rokko district. S:Smectite, M:Mica clay mineral, K:Kaolin mineral. —— :Untreated, -----:Ethylen glycol treated.

2. Chemical composition

The concentration histogram of aluminium, iron, manganese and magnesium content in the five districts are shown in figure 15. In Rokko and Hiroshima districts, Al shows a symmetrical dis-

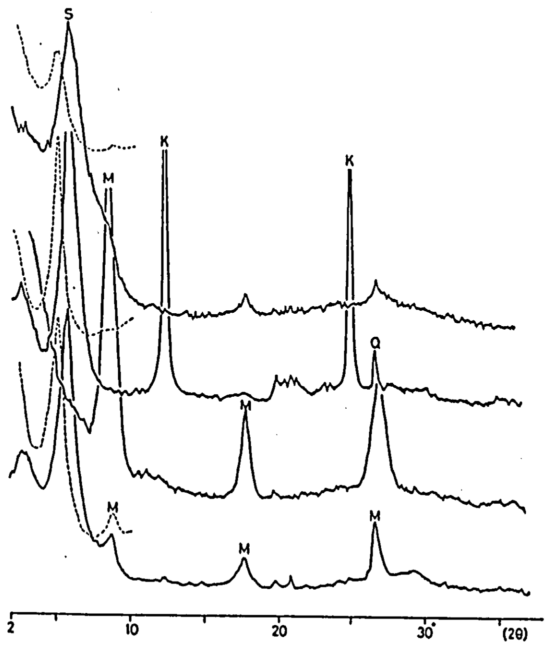


Fig.9. X-ray powder d patterns of clay minerals found in clay veins in the Hiroshima district.

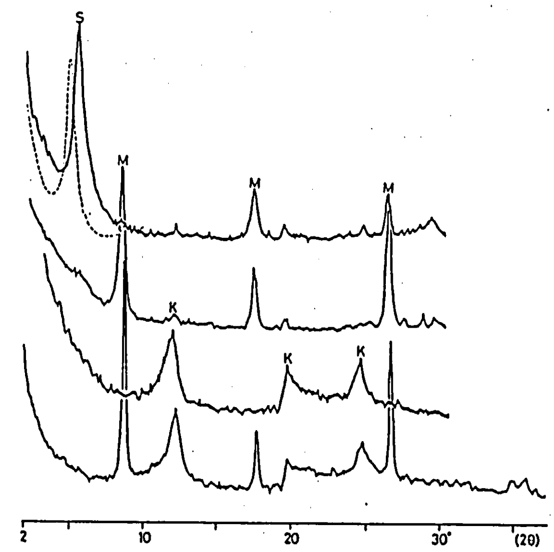


Fig.11.X-ray powder diffraction patterns of clay minerals found in clay veins in the Kumogi district. S:Smectite, M:Mica clay mineral, K:Kaolin mineral. ——— :Untreated, -----:Ethylen glycol treated.

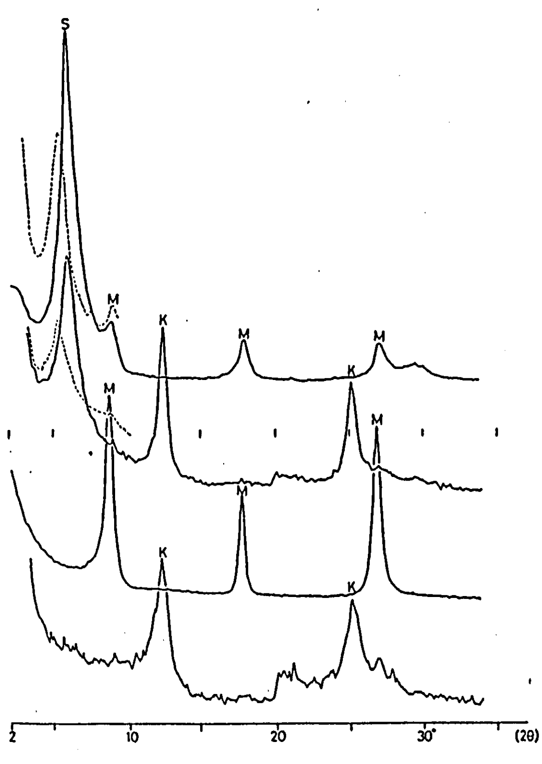


Fig.10.X-ray powder diffraction patterns of clay minerals found in clay veins in the Izuha district. S:Smectite, M:Mica clay mineral, K:Kaolin mineral. ——— :Untreated, -----:Ethylen glycol treated.

tribution, whose maximum ranges from 8wt% to 20wt%. In Mitoya and Kumogi districts, the distribution of Al show some skewness due to concentration in the range from 15wt% to 18wt%. Histogram of Fe in Rokko, Hiroshima and Izuha districts show a symmetrical distribution, but in Mitoya district, bimodal distribution with high concentration portion at about 0.5wt% and 2.0wt%. In Kumogi district, low content than 1wt% is remarkable. Mn content in Rokko, Hiroshima and Mitoya districts shows the concentration less than 500ppm. In Izuha and Kumogi, the variation range of Mn content are relatively large between 0 and 2500ppm compared with that of other districts. Mg content in Rokko and Izuha district is clustered on lower contents less than 0.5wt%. In Hiroshima, Mitoya and Kumogi districts Mg content distributes almost symmetrically.

Among major elements, Ca, Na and K are assumed to be interlayer cations. Distribution of these cation contents are shown in Figure 16. As is seen in the figure, Ca content in Rokko and Hiroshima districts are characteristically uneven, In Mitoya, Izuha and Kumogi districts, low content of Ca less than 0.1wt% are recognized. Histograms of Na in Rokko district are characteristically uneven and the range from 0 to 2wt%. In other four districts, the distribution patterns show similar tendency concentrated from 0 to 0.3wt%. As is evident in the histogram of K, in all districts, the variation range of K are relatively large in the range between 0 and 8wt%.

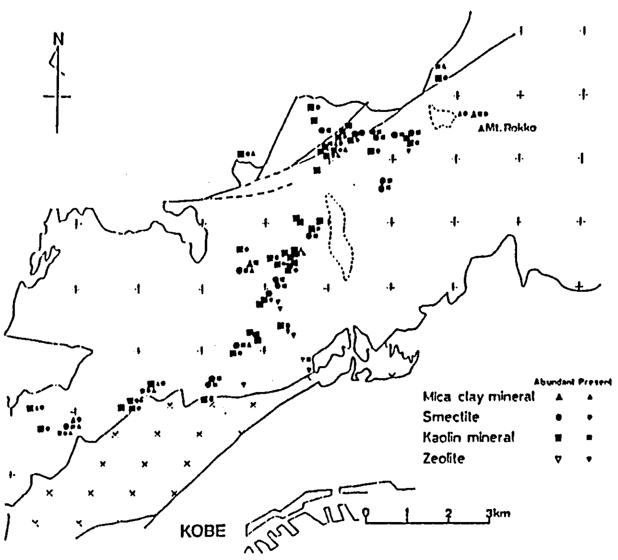


Fig.12. Distribution of clay minerals found in clay veins in the Rokko district.

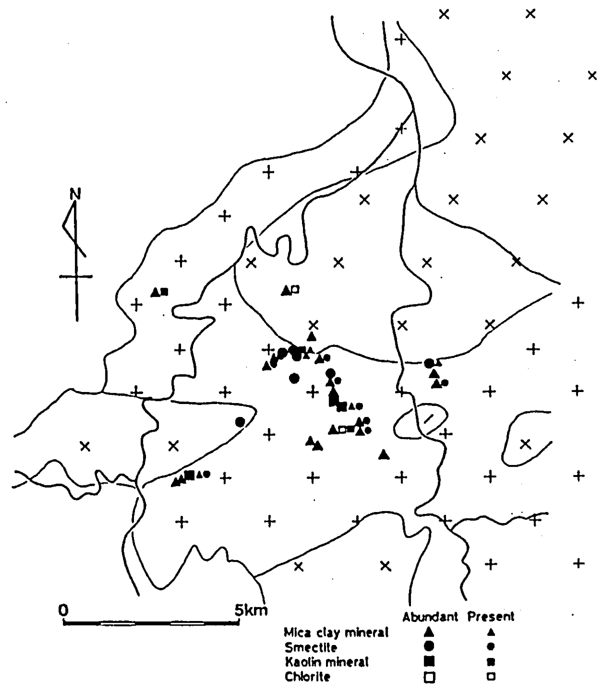


Fig.13. Distribution of clay minerals found in clay veins in the Mitoya district.

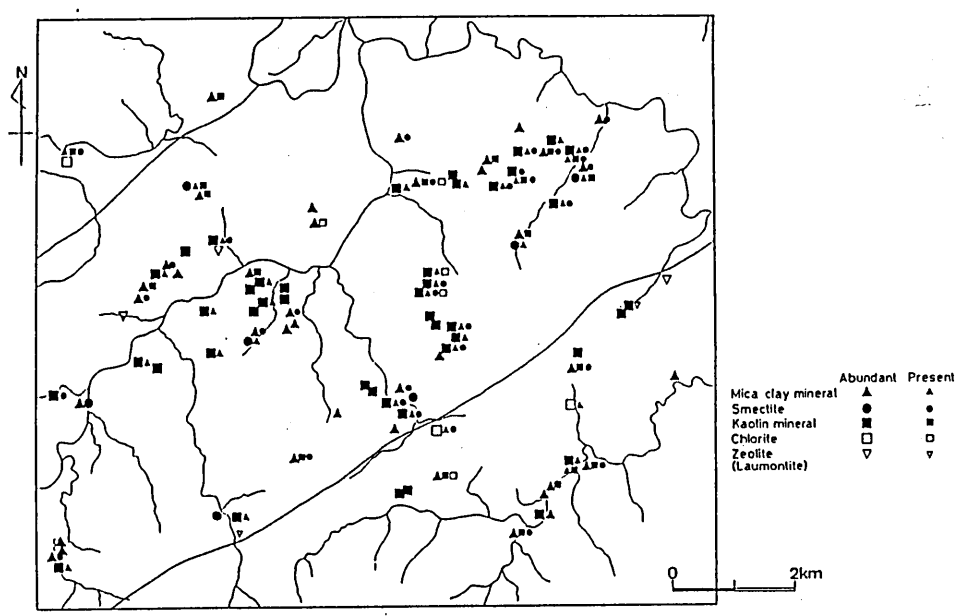


Fig.14. Distribution of clay minerals found in clay veins in the Izuha district.

Figures 17 and 18 show variation of minor element contents of clay minerals in the five districts. Li content in Rokko and Hiroshima districts is variable in the range from 0 to 100ppm. In the other districts, high distribution of concentration is recognized between 10 and 20ppm. The concentration distribution of Co and Ni show the same tendency in all districts. Co contents are usually less than 25ppm and Ni contents are less than 30ppm. Cu contents in all districts show the concentration in the range less than 10ppm. Zn show the sharp distribution in all district, i.e. high distribution is observed in less than 100ppm. Variation of Rb content is variable in the range from 0 to 500ppm in all district. Pb contents varies from 0ppm to 300ppm in all district.

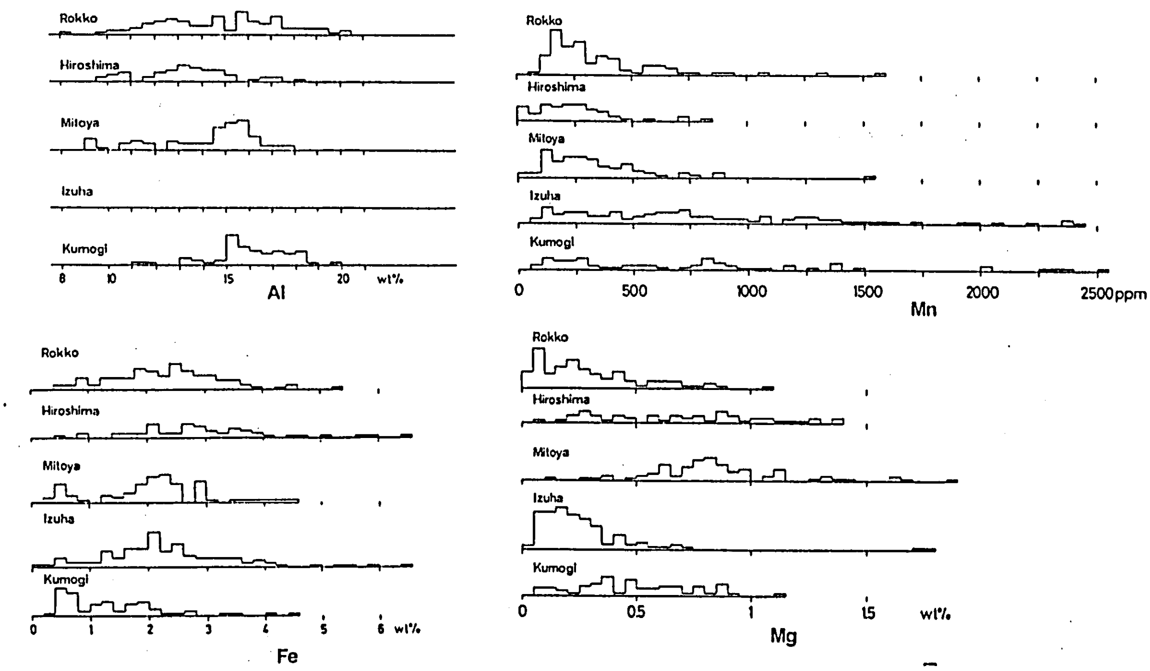


Fig.15. Variation of metal contents (Al, Fe, Mn and Mg) of clay veins in the five districts.

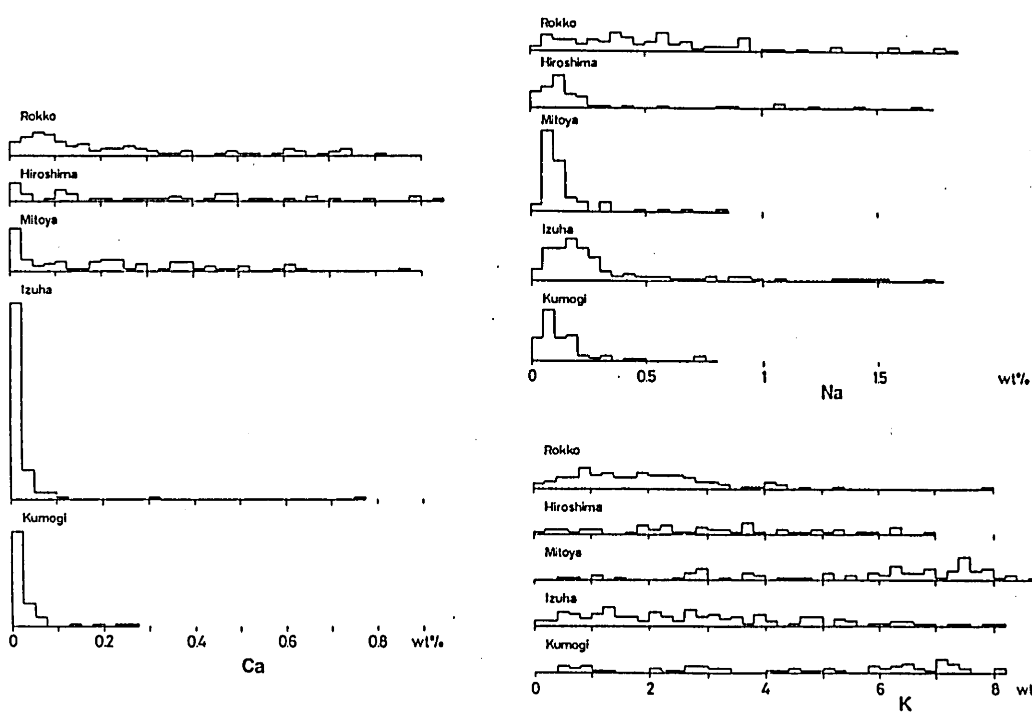


Fig.16. Variation of metal contents (Ca, Na and K) of clay veins in the five districts.

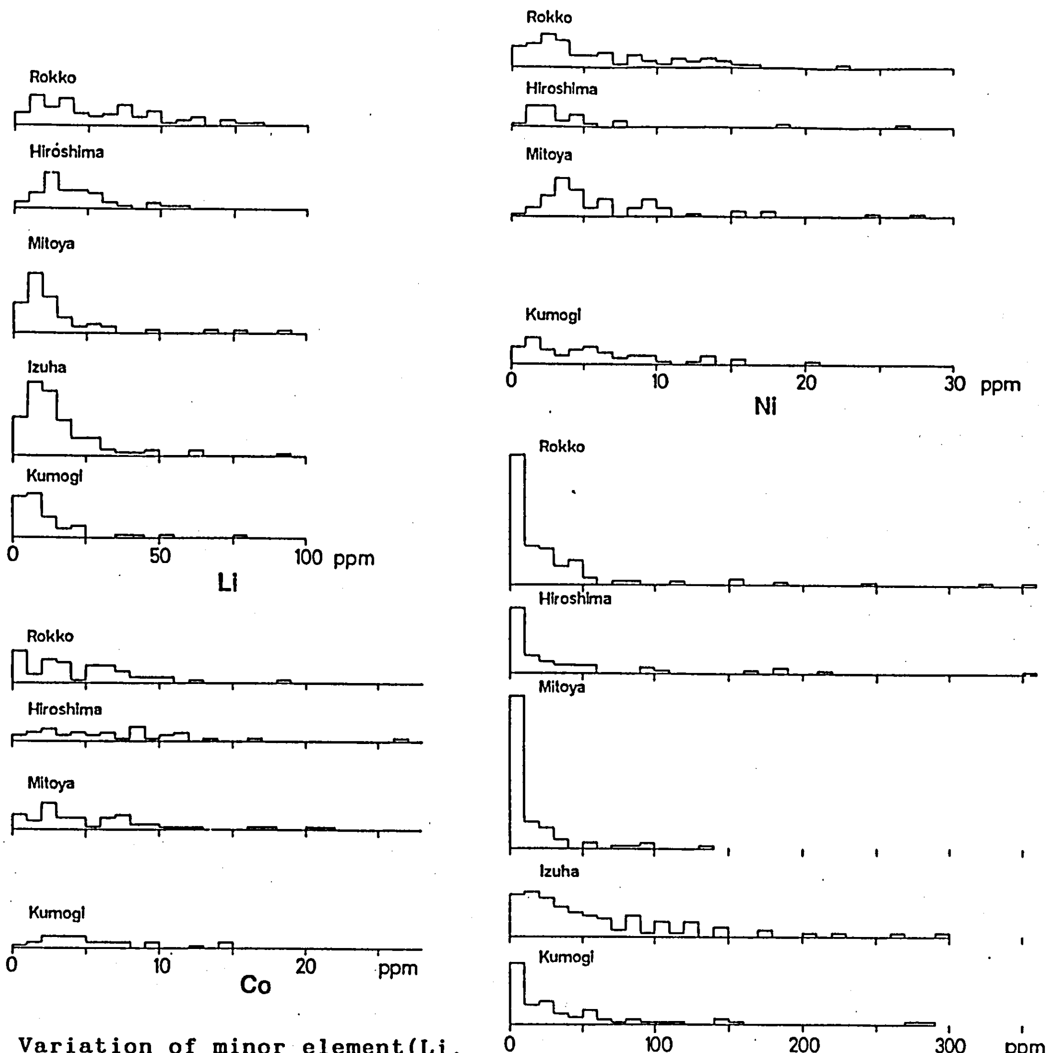
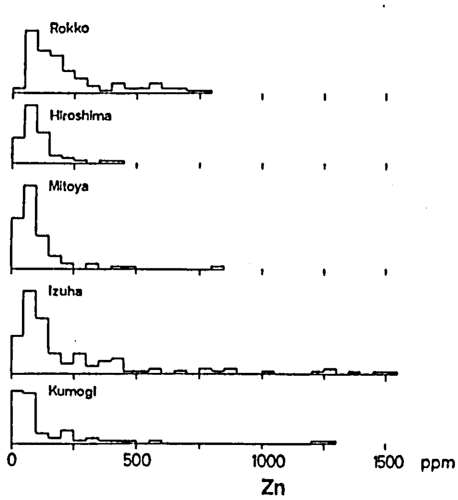


Fig.17. Variation of minor element(Li, Co, Ni and Cu) contents of clay veins in the five district.



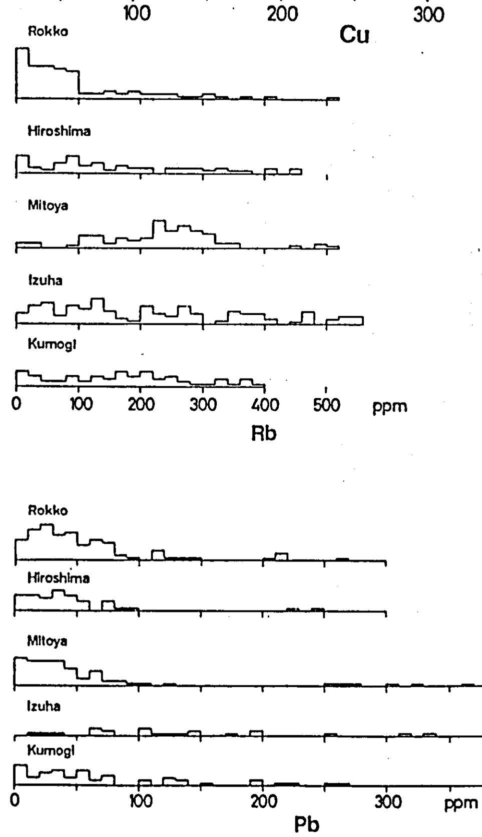


Fig.18. Variation of minor element (Zn, Rb and Pb) contents of clay veins in the five districts.

V. DISCUSSION

1. Constituent clay minerals

Regional variation of the constituent clay minerals of clay veins in the investigated five districts is shown Figure 19. Relative abundance of clay minerals were determined by the X-ray powder diffraction method. As is evident in the figure, each district has its own characteristic assemblage of clay minerals. First, predominant distribution of kaolin minerals in Rokko district should be pointed out. In Hiroshima district, mica clay mineral, smectite and kaolin minerals are almost equally distributed. Mitoya and Kumogi districts are characterized by dominant mica clay mineral. Mica clay mineral and kaolin minerals equally prevail in Izuha district, where chlorite is developed more than in the other districts.

Figure 20 shows distribution of the

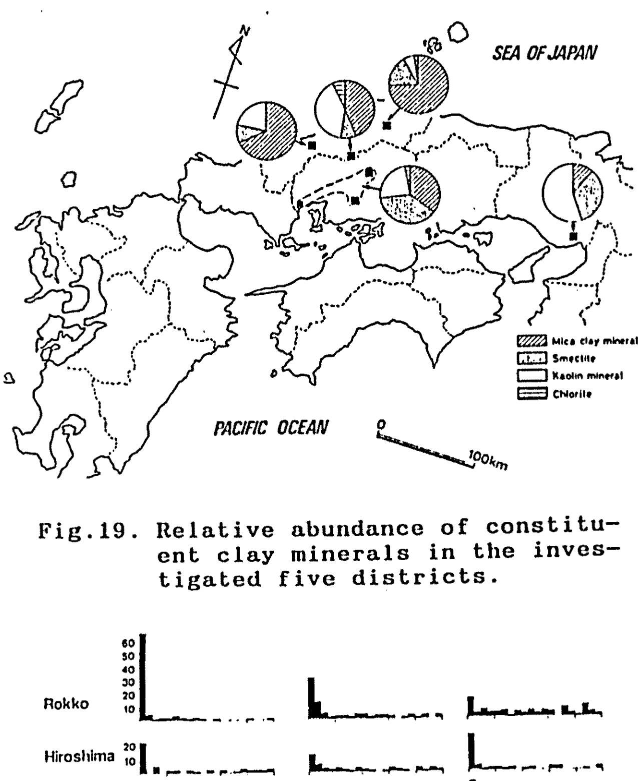


Fig.19. Relative abundance of constituent clay minerals in the investigated five districts.

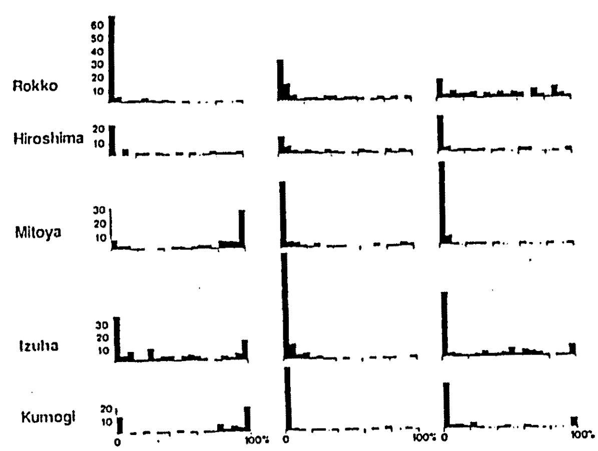


Fig.20. Histogram of three main clay minerals showing their relative abundance in wt.%.

constituent clay minerals. As is obvious in the figure, mica clay mineral is very rare in Rokko and Hiroshima districts, whereas very abundant in Mitoya and Kumogi districts. That is, most of clay veins consist mainly of mica clay mineral in the both districts. In Izuha district, bimodal distribution of the mineral at zero and 100% is observable. It should be noted that many veins contain no smectite in the five districts. Kaolin minerals are characterized almost even distribution in Rokko and Hiroshima districts. In other districts, on the other hand, clay veins contain small amount of kaolin minerals.

As was described above, clay veins in Rokko and Hiroshima districts have almost similar tendency. That is, in the two districts, kaolin minerals and smectite are contained in various amounts showing equal distribution (Figure 20). In addition, mica clay mineral is contained in very small amount. In Mitoya, Izuha and Kumogi districts, on the other hand, clay veins are characterized by mica clay mineral. In other words, clay veins in these districts are occurred in two ways, one is predominant in mica clay mineral and the other is very poor. Kaolin minerals and smectite are contained in small amount. However, in Izuha district, clay veins free from mica clay mineral are more common than those of other two districts. Therefore, Izuha district represents intermediate character between ilmenite-series and magnetite-series with respect to the constituent minerals of clay veins.

Concerning the constituent clay minerals of clay veins, the five districts can be divided into two groups, one is Rokko and Hiroshima districts and the other is Mitoya, Izuha and Kumogi districts. It is to be noted that host granitic rocks of the former districts belong to ilmenite-series granite while those of the latter magnetite-series granite.

2. Chemical characteristics of clay veins

Range of major element contents of clay veins of the five districts together with average value are shown in Figure 21.

As is seen in this figure, general tendency of Al, Fe and Mg contents of the respective district is almost similar with each other. Mn content is rich in Izuha and Kumogi districts. Average value of the two districts is about 0.1wt% which is higher than those of other districts, i.e., 400ppm. Ca content is relatively rich in Rokko district (ave. about 1.0wt%) than those of the other. In Izuha and Kumogi districts, Ca content is very low with value of about 0.1wt%. Na content is also higher in Rokko district than those of the other districts. K content are relatively high in Mitoya and Kumogi districts with average value of about 5wt%. Variation of Mn and Ca content among the five district is completely different. In similar way, Na and K contents show different distribution.

The relation between chemical composition and constituent clay minerals will be examined in the following.

Mn and Ca contents do not depend on the constituent minerals. That is, constituent clay minerals in Rokko and Hiroshima districts are poor in mica clay mineral whereas those of Mitoya district are rich in mica clay mineral. However, regardless the constituent clay minerals, Mn is poor and Ca is rich in these three districts. The K-Ar ages of granite in Izuha and Kumogi districts are younger than the others. Therefore, it is considered that Mn is rich in hydrothermal solutions which formed the clay veins. On the other hand, Na and K contents vary with amount of mica clay mineral. As the content of mica clay mineral increased, K content increases and Na decreases vice versa.

Figure 22 shows minor element contents with values of average and standard deviation. As is seen in this figure, Co and Ni contents are almost similar in respective districts. That is, average Co content is about 7ppm in all districts and that of Ni content about 5ppm. In addition, Rb content are about 200ppm in all districts. Local enrichments of Li, Cu and Pb are remarkably recognizable.

Li is rich in Rokko and Hiroshima districts with average value of about 60ppm whereas that of the other districts is distinctly low, 20ppm. Cu content is relatively high in Hiroshima and Izuha districts than that of the other districts. Pb content shows similar tendency as that of Cu.

Cu and Pb contents are high in Hiroshima and Izuha districts. However, clay veins in Hiroshima district are different from those of Izuha district in the constituent clay minerals, formation ages of host granitic rocks. Thus, Cu and Pb contents may characterize hydrothermal activities of the respective granitic rocks. Thus, it may be concluded that Li content is high in the ilmenite-series granite, whereas in magnetite-series granite Li is poor.

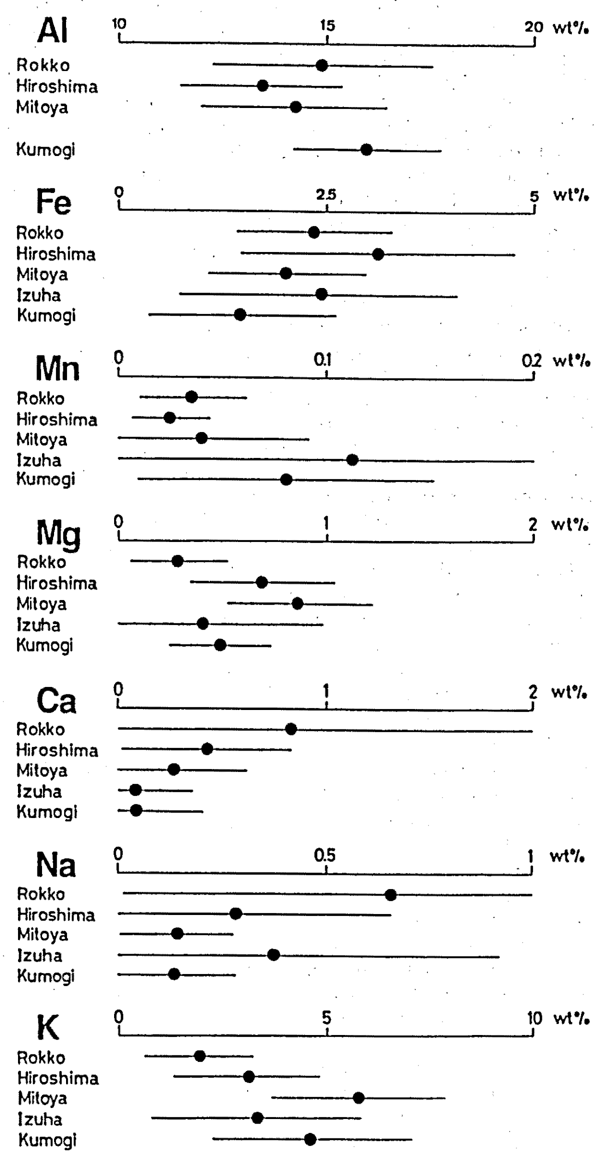


Fig.21. Range of major element (Al, Fe, Mn, Mg, Ca, Na and K) contents of clay veins in the five districts with average value.

3. Chemical characteristics of clay mineral

Bulk chemical composition of clay veins which are generally composed of several clay minerals has been described before. In this section, chemical characteristics of main constituent clay mineral will be examined, mica clay mineral, smectite and kaolin minerals. The results are summarized in Figure 23.

Concerning mica clay mineral, Mn content is higher than that of the other minerals. High content of K in mica clay mineral is reasonably explained since K is fixed in interlayer site. High contents of Mg and Ca in smectite indicate that these elements are contained in interlayer site as exchangeable cations. Average Al content obtained in kaolin minerals (33wt% of Al_2O_3) is less than that of ideal one (39%). On the other hand, ideal kaolin mineral should not contain iron but kaolin mineral in the clay vein always contains several wt% and the average Fe content is about 2.1wt%. The fact suggests that a part of Al in kaolin mineral is substituted by Fe.

Li content is high in smectite and kaolin minerals, whereas Li content of mica clay mineral is very low. Regardless to the constituent clay mineral species, Co, Ni and Zn contents are almost constant. Rb content is higher in mica clay mineral than in the others. Pb content is also high in mica clay mineral. Average Pb content in mica clay mineral is about 150ppm, whereas those of smectite and kaolin minerals are 60ppm and 75ppm, respectively. As is evident in Figure 23, the behavior of K is almost similar to that of Rb and that of Pb. The intimate geochemical relations between K and Rb were pointed out already by Mason (1966). Thus, Rb should occupy the interlayer position of mica clay mineral replacing K. In the similar way, Pb replaces partly the interlayer cation, especially K, since Pb has a relative large ionic radius(1.2A) which is similar to that of K (1.33A). On the other hand, the distribution tendency of K is reverse to that of Li. In general, Li included in mica clay mineral replacing the octahedral cations, especially Al. This fact has been established in the case of Lithium-mica. However, Li content of the present experiment is very low, and it may be considered that Li is adsorbed on crystal surface.

Taking all results into consideration, regardless to constituent clay minerals, Mn content is high in Izuha and Kumogi districts where relative younger granitic rocks are distributed. Ca content depends on amount of smectite. Na and K contents may reflect amount of mica clay mineral. Li content is low in mica clay mineral, that is, Li content is higher in clay veins of ilmenite-series granite. Regardless to the mineral species of clay mineral, Cu content is high in Hiroshima and Izuha districts, that is , Cu also characterizes the district as well as Pb.

4. Interlayer and octahedral cations

The crystal structure of clay minerals, i.e., layer structure, can easily allow to adsorb various cations. Thus, the elements can occupy the interlayer position and/or octahedral position. It is to be considered that the interlayer position of mica clay mineral are generally occupied by K, Na and Ca, and those of smectite are assigned to exchangeable cations such as K, Na, Ca and Mg. Further, in kaolin minerals, K, Na and Ca are also assumed to be adsorbed cations. The other elements are in general considered to occupy the octahedral site. Concentration histogram of the interlayer cations such as K, Na, Ca and Rb are shown in Figures 24 and 25. Figure 24 shows total amount of Na,Ca and Rb , whereas Figure 25 shows relative abundance of possible interlayer cation(Na+Ca+Rb) against most representative interlayer cation, K. As is seen in Figure 24, total amount of the possible interlayer cation in Rokko and Hiroshima districts vary in the range from 0.1 to 2wt%, whereas those of Mitoya, Izuha and Kumogi districts tend to more smaller concentration from 0 to 0.5wt%. Moreover, as is obvious in Figure 25, ratio of the possible interlayer cations against K in Rokko and

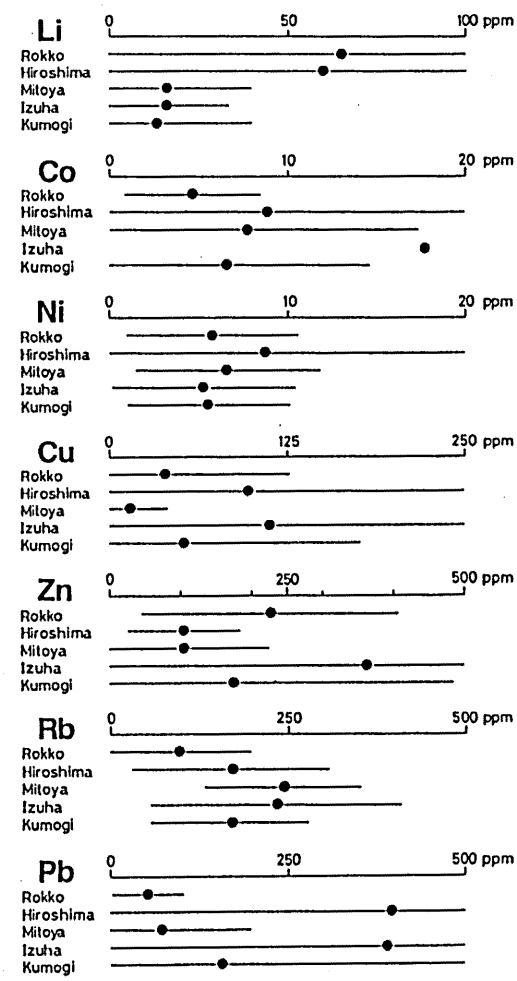


Fig.22. Range of minor element (Li, Co, Ni,Cu, Zn, Rb and Pb) contents of clay veins in five districts with average value.

Hiroshima districts ranges from 0 to 2. In Mitoya, Izuha and Kumogi districts, the ratio is significantly small, i.e., less than 0.2. In similar way, concentration of possible octahedral cations and the ratio against Fe are represented in Figures 26 and 27, respectively. Figure 26 shows the total amount of minor elements. In all districts, the distribution pattern shows similar tendency in the range from 200 to 2500ppm. As is also seen in Figure 27, the distribution patterns do not indicate noticeable difference between the districts. In regard to constituent clay minerals, it may be considered that the interlayer cations play a more important role than the octahedral cations.

VI. CONCLUSION

Mineralogical and chemical characteristics of clay minerals found in clay veins developed in the granitic rocks in

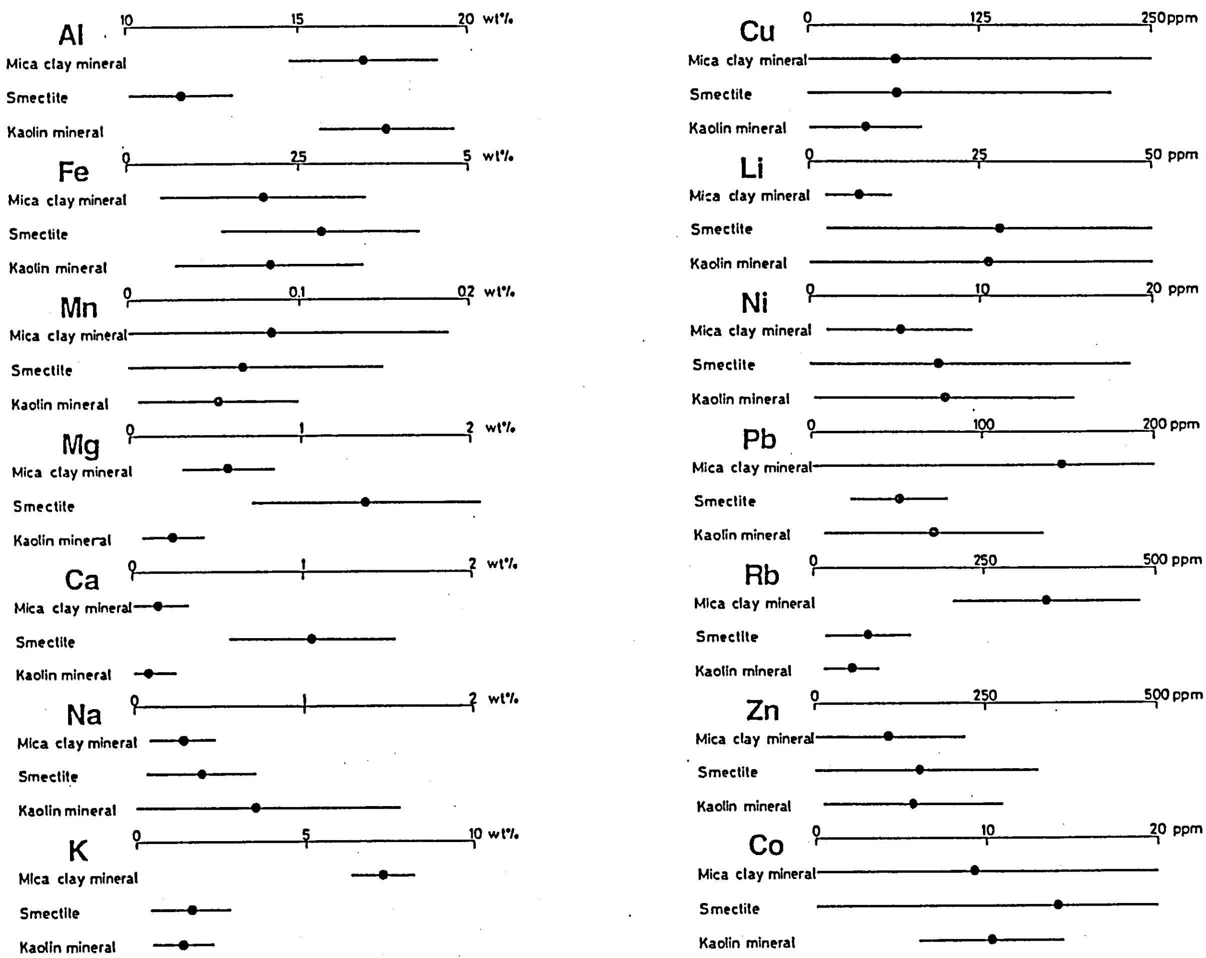


Fig.23. Average metal contents of mica clay mineral, smectite and kaolin mineral. Length of bars indicate standard deviations of the respective metals.

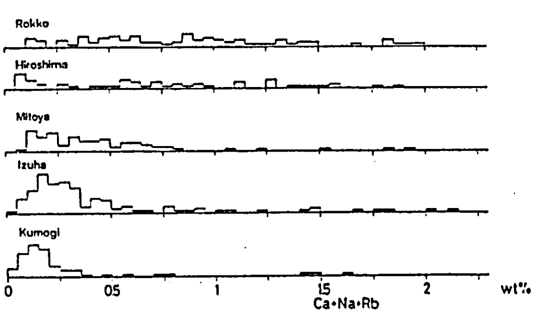


Fig.24. Relative abundance of possible interlayer cations in the five districts.

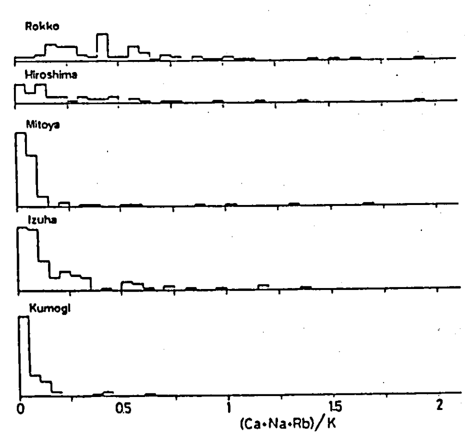


Fig.25. Relative abundance of possible interlayer cations against potassium content.

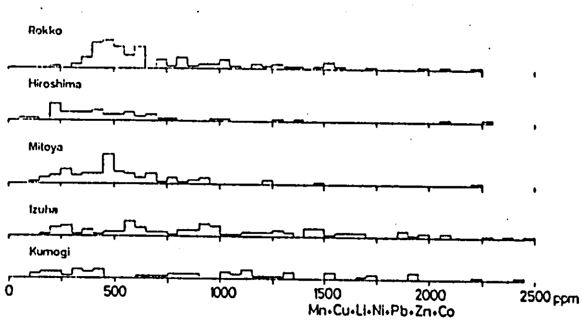


Fig.26. Relative abundance of possible octahedral cations in the five districts.

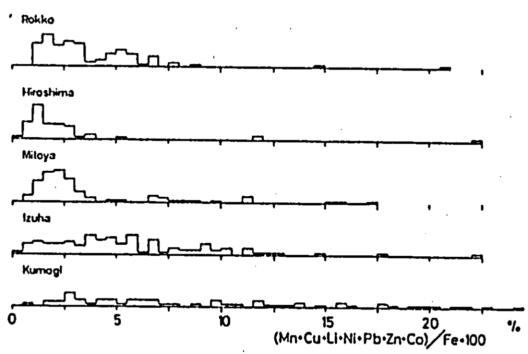


Fig.27. Relative abundance of possible octahedral cations against total iron content.

the Chugoku district are summarized as follows:

In regard to constituent clay minerals, significant difference is recognized between ilmenite-series granite and magnetite-series granite. That is, clay veins developed in the ilmenite-series granite are rich in smectite and kaolin minerals, whereas those in the magnetite-series granite are rich in mica clay mineral.

Content of trace elements such as Li, Mn, Cu and Pb are characteristically vary in each district. Typical example is Mn which is rich in Izuha and Kumogi districts. Cu and Pb are rich in Hiroshima and Izuha districts. The most representative difference is Li content, i.e., Li content is high in ilmenite-series granite and low in magnetite-series granite. This fact is caused by the difference of the main constituent minerals between the two series.

Possible interlayer cations such as K, Ca, Na and Rb clearly vary between ilmenite-series granite and magnetite-series granite. Clay veins developed in magnetite-series granite are predominated in potassium content occupying the interlayer positions.

These chemical characteristics of clay veins may probably indicate the difference of hydrothermal activities related to the respective granitic rocks. Thus, it may be concluded that the post hydrothermal characteristics of ilmenite-series granite are different from those of magnetite- series and the fact is clearly shown in clay veins developed commonly in both series granites.

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