研究報文

PETROGRAPHY AND PETROCHEMISTRY OF
KIRIGAMINE VOLCANO, CENTRAL JAPAN (I)

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Abstract: The rocks from the Kirigamine volcano are andesites and dacites, which are in the calc-alkalic rock series (hypersthene rock series) in mineralogy. The rocks which belong to alkalic or tholeiitic rock series have not been erupted. From the characters of alkali-lime indices, K_2O enrichment at the later stage and others, the parental magma of this volcano may not have relation with tholeiitic magma. The phenocrystal hornblende has crystallized at middle stage of fractionation at this volcano. There is no chemical discontinuity between the hornblende free and the hornblende bearing rocks. The contamination is negligible at this volcano. Having no connection with the presence or the absence of phenocrystal hornblende, the differentiated veinlets are often present with ground-mass hornblende. From the mineralogical and chemical differences between the host rock and the veinlets, these veinlets may be produced by gas transformation. The enrichment of volatile components are very effective to the crystallization of hornblende.

INTRODUCTION

The Kirigamine is a volcano in Central Japan. It is in the 'Fossa Magna' and situated on the cross point of the Itoigawa-Sizuoka tectonic line and the Median line. For the presence of the garnet bearing rhyolite in the basements, many authors have been interested in the volcano. S. Kawachi and Y. Kawachi (1963), in their recent paper, expressed their opinions on the volcano. K. Momose et al. (1959) studied the volcano and the surrounding area on the view point of paleomagnetism. S. Hori (1959) has reported pollen analytical studies on the bogs of the Yasimagahara, which is situated near the summit of the volcano, and gave a suggestion on the age,

when the activity of the volcano came to an end.

Although we have now many reports on the volcano, no one reports petrography or petrology of the volcano, and we cannot know to which volcanic zone the volcano belongs. In this paper, the present author gives the petrographic descriptions and discusses the petrochemical characters and the crystallization of hornblende in the andesite magma of this volcano.

GEOLOGY

Geological setting

In the east of the volcano, the Yatugatake mountains extend from the north to the south, drawing convex to the eastward. There is the Asama volcano about 45 km. to the north by east of the Kirigamine volcano. S. Aramaki (1963), in his recent paper, reports that the volcanic rocks from the Asama volcano are for the most part andesites and dacites of calc-alkalic rock series, which are derived from the tholeiitic magma contaminated with sialic materials. S. Kawachi (1961), in his studies of the Yatugatake mountains, divides this province into three zones, and sets the Kirigamine volcano in the inner most zone. Attending to the presence of the garnet bearing rhyolite, S. Kawachi and Y. Kawachi (1963) maintains that the Setouti volcanic province extends northwards along the Median line and reaches the Kirigamine volcano.

At Nisimotiya, about 2 km. to the southwest of the Wada-toge, there is a small dike of alkaline olivine basalt. But it is hard to comprehend what relation is in this alkaline olivine basalt magma and the magma of the Kirigamine volcano. As described in the later chapters, the rocks of this volcano are andesites and dacites of calc-alkaline rock series.

H. Kuno (1954) sets the volcano in the northern subzone of the Fuji volcanic zone.

Pre-Kirigamine igneous activities

The geological map is shown in Fig. 1. In this region, at early Miocene age, there were some volcanic activities and relatively large amounts of tuff breccias were erupted around the Lake Suwa. One of these tuff breccias crops out typically at Asakura-yama, and named Asakura-yama tuff breccia. This tuff breccia may belong to the upper part of the Moriya formation, which develops widely around the Lake Suwa and covers unconformably the metamorphosed

Fig. 1. Geological map of the Kirigamine volcano. 1 ; Alluvial deposits, 2 ; Kita-Osio-Toge pumice fall deposits, 3 ; Sawatari mudd flow, 4 ; Kuruma-yama lava flow, 5 ; Yasima lava flow, 6 ; Tonosiro-yama lava dome, 7 ; Kowasimizu lava flow, 8 ; Omekuragoe lava dome, 9 ; Wasigamine lava dome, 10 ; Kasigari-yama lava flow, 11 ; Wasigamine lava flow, 12 ; Siozawa lava flow, 13 ; Osasamine lava flow II, 14 ; Kasiwabara lava flow, 16 ; Kannon-zawa lava flow, 17 ; Osasamine lava flow I, 18 ; Fukuzawa-yama lava flow, 19 ; Omekura-goe lava flow, 20 ; Kamagaike lava flow, 21 ; Wada-toge rhyolites, 22 ; Enrei formation, 23 ; Fumonji granodiorites, 24 ; Asakura-yama tuff breccia, 25 ; fault.

Fig. 2. Geological profile of the Kirigamine volcano. Symbols are same as Fig. 1.

Mesozoic formations. At late Miocene age or early Pliocene age, many stocks or bosses of granodiorites intruded in this region, and metamorphosed the tuff breccias into low grade hornfelses.

At the early Pliocene age, a gigantic volcanism began its activity and erupted a number of pyroclastic deposits around the Lake Suwa. These deposits are named Enrei formation by the Fossa Magna research group (1958). Within the pyroclastic deposits there are several lake deposits and lava flows of pyroxene andesites and basalts. The total thickness of the Enrei formation reaches several hundred meters. At the northern part of the Suwa city, the lake deposits are not disturbed and show strike N 20 W and dip 25 S.

After this volcanism at the late Pliocene age, the garnet bearing rhyolites and related rocks erupted around the Wada-toge. The age of this activity was determined by the K-A method, and professor Kawano and Dr. Ueda calculated about 4 million years before. The Kirigamine volcano began its activity when the eruption of the rhyolites came to an end.

K. Momose et al. (1959) studied andesites and basalts in the Enrei formation on the stand point of paleomagnetism and concluded that the volcanic activity of Mt. Kirigamine had been one of the gigantic volcanisms which had extruded many pyroclastic deposits and built up the Enrei formation.

The Kirigamine volcano has never erupted pyroclastic deposits. It spouted successively very fluent lava flows and built up many little shield volcanoes. Considering these characters of volcanism and the presence of the eruptions of the garnet bearing rhyolites between the Kirigamine volcanism and the volcanic activities of the Enrei formation, it is suitable to cut off the former from the later.

Foundation of the Kirigamine volcano

The scheme of the development of the Kirigamine volcano may be grasped from a block diagram as shown in Fig. 3. As described in the last chapter the Kirigamine volcano began its activity when the eruption of the garnet bearing rhyolites quieted down, at late Pliocene.

The Kirigamine volcano is divided into two parts in topography by Kannon-zawa, which is a branch of To-gawa and streams to westward from the northern shoulder of the Kuruma-yama. The southern part of this volcano consists of several lava flows, which run out from the highest part of this volcano and built up main portion of it. The lava flows of this part are a large quantity and very fluidal. The topography shows that the lava flows run down on a gentle slope of the basements from north to south. On the northern part, several lava domes and small shield volcanoes were formed intermittently as it were parasitic cones.

The volcanic activity of this volcano is divided, as shown in the Fig. 3, into six stages by the characters of the erupted rocks. The first stage is that the Kamagaike lava flow and Omekura-goe lava flow are erupted at the northern part. These lava flows are consisted of the hornblende and biotite bearing dacites. These dacites show distinct fluidal textures. The volume of these flows is relatively small. There may not be a significant time gap between the end of the rhyolite activity at Wada-toge and the eruption of these dacites.

On the second stage, relatively basic rocks were erupted. At the southern part a great deal of pyroxene andesites i.e. Fukuzawa-yama lava flow, Kannon-zawa lava flow, and Narita lava flow were erupted from near the summit of the Kuruma-yama, and run down southwards on the gentle slope of the basements. These lava flows are relatively fluidal. For the instance, the Fukuzawa-yama lava flow, about thirty meters thick, runs down southwards about 7.5 km. to reach the Fumonji granodiolite and turns the flow eastwards. These lava flows, show well development of platy joints. The Fukuzawa-yama lava flow, which shows typical platy joints, is used as buildingstone from old age, and famous as Teppai-seki or Hira-isi. The Osasamine lava flow I is pyroxene andesite erupted in the northern part at this stage. This flow runs down from Osasamine to the north, and does not show so remarkable platy joints.

The third stage is the eruption of the Siozawa lava flow, the Kasiwabara lava flow at the southern part and the Osasamine lava flow II at the northern part. The rocks of this stage are similar to

Fig. 3. Block diagram showing the history of development of Kirigamine volcano. The rocks 1, 3 and 5 are hornblende bearing rocks and of stages 2 and 3 are hornblende free rocks.

that of the first stage, i.e. hornblende bearing dacites or andesites. The platy joints are not recognizable.

The fourth is relatively calm stage. Only one flow, the Kasigari-yama lava flow runs out near the summit of the Kasigari-yama and flows down to southwards. The volume of this flow is relatively small. This rocks shows the earliest stage of differentiation in this volcano.

At the fifth, the activity of this volcano is most violent. In the southern part, Kowasimizu lava flow, and Kuruma-yama lava flow are erupted. These flows are consisted of hornblende bearing dacites or andesites. They are very fluidal and floods over a half of the southern part. It is thought that the fluidity of these lavas may come from abundance of the volatile components. They show many volatile enriched parts in the groundmass. On the northern part at this stage, lava domes and small shield like volcanoes, i.e. Wasigamine, Tonosiro-yama and Tutujigaoka and others are built up. The rocks of this stage are hornblende bearing dacites or andesites, too.

The six stage is the final. The small mudd flow run down at the northern part and dammed up a branch of the Kannon-zawa to make a little dammed lake, which develops now to the Yasima Bog. S. Hori (1959) studied some bogs of Central Japan and calculated the average growth rate of peat. From his study, there is about 805 cm. thick peat in the Yasima Bog, and the time, necessary for the growth, is about ten thousand years.

As summaries, the Kirigamine volcano began its activity about 4 million years ago and came to an end about ten thousand years ago. One of the important characters of the activity of this volcano is alternative eruptions of hornblende bearing and hornblende free rock types.

PETROGRAPHY

Olivine hypersthene augite andesite

Megascopically, it is black in colour, and compact. Relatively small plagioclase and black pyroxenes are recognizable with the naked eye. The modal analysis of this rock is given in the Table 1.

Phenocryst; Plagioclase is usually prismatic. There are two types in microscopically. The first is the crystal showing distinct honeycomb texture. It has no zonal pattern and many dusty inclusions in the core. At the periphery, it may take narrow zonal pattern, but sometimes discordant with the crystal outline. The second type is automorphic, with slightly zoned crustal part. In this case, the zonal pattern is concordant with the crystal outline. The composition of plagioclase is An 61-90.

Augite takes usually good crystal surface. Twinning on (100) is common, being often repeated. Some crystals take irregular form, as if suffered magmatic corrosion, and distinct zonal patterns at the periphery. Plagioclase, magnetite and olivine lie scattered as in-

Table 1. The modal compositions of rocks. Vol. %

	1	2	3	4	5
Pl	37.1	25.0	10.0	22.9	22.9
Ol	tr.	0.6			
Au.	6.3	5.9	0.2	2.3	0.8
Hy.	3.8	3.5	0.3	0.7	1.0
Ho.			3.5	2.9	0.5
Mt.	2.0	2.2	0.8	1.6	1.2
Ground.	50.8	63.2	85.2	69.6	73.6

1. Olivine bearing hypersthene augite andesite, Kannon-zawa lava flow.
2. Olivine hypersthene augite andesite, Osasamine lava flow II.
3. Augite hypersthene bearing hornblende dacite, Wasigamine lava dome.
4. Hypersthene augite hornblende andesite, Kuruma-yama lava flow.
5. Hornblende augite hypersthene dacite, Yasima lava flow.

clusions. Optical axial angle $2V(+)$ is 52–56 and index β is 1.692–1.697.

Hypersthene is rather small grained and usually round form. The zonal pattern is recognizable at the periphery. Optical axial angle $2V(-)$ is 75° .

Olivine is usually round form and coated by mafic groundmass minerals. Sometimes it is enveloped in myrmekitic intergrowth of hypersthene and magnetite. Magnetite inclusion is rarely present.

Apatite is very rarely present, forming slightly round prisms. It carries characteristic inclusions of fine rods or dusts of brownish materials, so that it shows faint pleochroism, Z' =pale blue and X' =pale brown, and biaxial negative with large $2V$.

Quartz is very rarely present with round form. It may be xenocryst. It is surrounded by groundmass augite, but in general, there is glassy materials with many dusts between quartz and augite.

Opaque mineral is magnetite. Ilmenite exsolution lamellae is not recognizable under the reflection microscope.

Groundmass; Groundmass is mainly composed of microcrystalline materials and glass. The relatively coarse grained belts are found here and there in the groundmass. These belts are composed of plagioclase, augite, hypersthene, magnetite, ilmenite and interstitial silica minerals. The boundaries of the belt and matrix are not distinctive but gradual.

Olivine bearing hypersthene augite andesite

Megascopically, it is gray in colour, with phenocrysts of plagioclase, up to 2 mm. in length, and some black pyroxenes of

smaller grained. The porphyritic pyroxenes often form grouping. The modal analysis of this rock is given in the Table 1.

Phenocryst; Plagioclase is prismatic, usually 2 mm. in length. There are two types in microscopically. In the first, it is usually large, with unzoned, honeycombed core and distinct narrow zonal pattern at the periphery. The inclusions in the honeycomb core are plagioclase, pyroxenes, and or glassy materials. Around these inclusions the host crystals show wavy extinction. In some cases, the core shows distinct narrow zonal pattern, which is discordant with the crystal surface. The second type is rather small grained with faint zonal pattern. The inclusions are usually not present. The composition of plagioclase is An 44-76.

Augite is usually round form. Twinning on (100) is common, being often repeated. The zonal pattern, which is concordant with the crystal surface, is recognizable at the periphery. If the crystals take irregular surface, which seem to be suffered magmatic corrosion, the zonal pattern is concordant with it. Frequently, it shows parallel intergrowth with hypersthene. In this case, augite usually twins on (100) and envelops hypersthene. $2V(+)$ is 50-54, and β is 1.689-1.695. Plagioclase, apatite, magnetite are present as inclusions.

Hypersthene is usually round form and rather small grained. Relatively small grained aggregate phenocrysts, showing myrmekitic intergrowth with magnetite, are very common. There is a little crystal which seems to be suffered magmatic corrosion along cleavages or cracks. The zonal pattern is not recognizable. The optical axial angle $2V(-)$ is 65-72.

Olivine is round form, usually surrounded by myrmekitic intergrowth of hypersthene and magnetite. Inclusion is absent.

Apatite is short prismatic and usually round form. It includes numerous fine dots or dusts of brownish materials which are arranged parallel to the c-axis of apatite. It has weak pleochroism which seems to be derived from the inclusion; Z' =pale blue, X' =pale brown.

Opaque minerals are not determined, but may be magnetite and ilmenite.

Groundmass; Groundmass is fine grained. It carries, as essential constituents, euhedral lath shape plagioclase, hypersthene, augite, brown mica, opaque minerals, and as matrix, quartz, cristobalite and brown glass with many opaque dots. Alkali-feldspar, apatite and hornblende are the accessory minerals. Alkali-feldspar adheres usually to the phenocrystal and groundmass plagioclase. Green hornblende is in the characteristic part, where biotite and

alkali-feldspar are concentrated and pyroxenes are very poor. In these parts, alkali-feldspar and quartz are hypautomorphic and granitic-like texture. Cristobalite and opaque minerals are present as accessories, too. The grain size of these parts is larger than the others. It may be said that, these parts take lenticular outline in thin section. But there is no clear boundaries between these hornblende bearing parts and the others.

Olivine bearing hornblende augite hypersthene andesite

Phenocryst; Plagioclase is usually prismatic. There are two types in microscopically, as in the other rocks, i.e. the honeycomb type and the other type. In this rock, the nonhoneycomb type is predominant, but small grained. The composition is An 44-62.

Hypersthene is usually prismatic. The relatively small crystal takes good crystal face, but the larger the crystal it takes more round. Zonal pattern is recognizable at the periphery of the large crystal. Sometimes there are liquid inclusions in large crystals, and biotite is recognizable in them. $2V(-)$ is 60-76.

Augite is usually short prismatic. As hypersthene, the smaller crystal takes better crystal face. Twinning on (100) is very common, often repeated. Zonal pattern is recognizable at the periphery. In small crystal, it is concordant with the crystal surface, but in large one, which takes often irregular form, it is discordant with the outline. $2V(+)$ is 50-56, and the index is β 1.691-1.698.

Hornblende is usually oxidized and changed into oxyhornblende. Pleochroism is very strong, X' =yellow and Z' =reddish brown to red. The extinction angle is very small. The optical axial angle $2V(-)$ is large and the dispersion is $r < v$ strong on one axis. Oxyhornblende is generally enveloped in the so called opacite margin, which is composed of opaque dots and cryptocrystalline materials. The opacite margin is inclined to effect an entrance into the crystal along the cleavages, and the opaque dots are often arranged along them. In some sections, hornblende is exchanged completely into the aggregate of plagioclase, hypersthene, magnetite and augite. Though these minerals grow larger than the groundmass minerals, the outline of hornblende is remained.

Olivine is round form and usually small grained. It is generally wrapped in the intergrowth of hypersthene and magnetite.

Apatite is as minor constituent.

Opaque minerals are magnetite and ilmenite. Magnetite takes exsolution lamellae of ilmenite, which may be oxidation products of

ulvospinel component in magnetite.

Groundmass; Groundmass is very fine grained, carrying, as essential constituents, plagioclase, hypersthene, magnetite, ilmenite. Augite, apatite, biotite and alkali-feldspar are as accessory minerals. Cristobalite and glass with many dusts are interstitially.

In some sections, there are differentiated schlierens, which are usually 0.06 mm. in width and one or two cm. in length, composed of quartz, alkali-feldspar and biotite. They often traverse phenocrystal plagioclase. If they traverse the honeycomb type crystals, plagioclase is remarkably decomposed, but in the nonhoneycomb type crystals, the decomposition is not recognizable. Biotite in the schlieren is inclined to enriched where the schlieren contacts with mafic minerals.

Hypersthene augite hornblende andesite

Megascopically, it is black in colour and is compact. The modal analysis of this rock is given in the Table 1.

Phenocryst; Plagioclase is usually prismatic. There are two types in microscopically, as in the other rocks. The honeycomb type crystals show generally intense zoning pattern, which is discordant with the crystal outline. Biotite and silica minerals are often present in the honeycomb part. The composition is An 48–68.

Hornblende is usually oxidized, with thin opacite margin. There is a little resolved crystal. The twinning on (100) is very common.

Augite is usually prismatic. Twinning on (100) is common, often repeated. The larger the crystal, it takes more round. It takes often parallel intergrowth with hypersthene. The optical axial angle $2V$ (+) is 50–54, and the index β is 1.692–1.700.

Hypersthene is generally round form. In some cases, it is seemed to be suffered magmatic corrosion. The optical axial angle $2V$ (–) is 69°.

Apatite and opaque minerals are as accessory constituents.

Groundmass; Groundmass is very fine grained. It carries, as essential constituents, plagioclase, hypersthene, opaque minerals, and as accessory or interstitially, apatite, biotite, alkali-feldspar and silica minerals, showing flow texture. Alkali-feldspar adheres often to plagioclase.

Olivine bearing hornblende augite hypersthene dacite

Megascopically, it is gray in colour, carrying abundant phenocrysts of plagioclase, usually 2 mm. in length, and black pyroxenes of smaller

size. Many lenticular cavities are arranged parallel to the well developed platy joints. But no druse minerals are recognizable.

Phenocryst; Plagioclase is prismatic, usually 2 mm. in length. There are three types in microscopically. In the first, zonal pattern is distinct in the outer part, but imperceptible in the core. The inner part shows irregular outline, as suffered magmatic corrosion, and is discordant with the crystal face. Honeycomb texture develops in the inner part, carrying colourless, low refractive isotopic substance along the cleavage. Inclusions are present as small opaque dots. Second type is extremely honeycombed and has many inclusions as augite, hypersthene, opaque minerals, and glassy substance, but no crustal part. The third is rarely present, and fragmental crystal.

Hypersthene is usually round form and coated by brown materials. Optical axial angle $2V (+)$ is 67° , and the dispersion is $r > v$ weak. Occasionally, hypersthene shows magmatic corrosion, and coated by colorless, low refractive, isotopic substance and light colour amphibole.

Augite is rather large, usually with good crystal outline. Twinning on (100) is common, being often repeated. Zonal pattern is not recognizable. Optical axial angle $2V (+)$ is 55° and the dispersion is $r > v$. Opaque inclusions, probably magnetite, is present.

Hornblende is changed into oxyhornblende, being sometimes dissociated along cleavages from periphery to core. When the dissociation develops, the segregated minerals, hypersthene, plagioclase, magnetite and sometimes augite, grow larger than the groundmass minerals. The optical axial angle $2V (-)$ of oxyhornblende is large and the dispersion is $r < v$ strong at one axis. Pleochroism is distinct, showing pale yellowish green to red. It takes nearly parallel extinction. Zonal pattern is faintly recognizable at periphery. Twinning on (100) is very common and the mineral is usually with good crystal outline.

Olivine is rarely present, being rounded in outline and sometimes altered to iddingsitic minerals along cracks. It seems to be remnant or xenocryst.

Apatite is rarely present with dark streations parallel to the c-axis. These streations are made of small dark dots.

Ore minerals are present, but not determined.

Groundmass; Groundmass is very fine grained. It carries, as essential constituents, euhedral lath shape plagioclase, acicular hypersthene, prismatic augite and opaque minerals, and as matrix,

silica minerals and cryptocrystalline materials. Apatite, brown hornblende, biotite, alkali-feldspar are the accessory minerals. There are small veinlet schlierens which are composed of alkali-feldspar and silica minerals. These schlierens are too small to be determined with the naked eye, i.e. 0.05 mm. in width and 1 cm. in length, in general. Hornblende is rarely present in the part where biotite is relatively concentrated and pyroxenes are almost absent.

Biotite olivine bearing hornblende augite hypersthene dacite

Megascopically, it is gray in colour, carrying relatively little phenocrysts. It is comparatively heterogeneous with the naked eye, carrying many small brown coloured veinlets and xenoliths.

Phenocrysts; Plagioclase is usually prismatic. There are two types in microscopically. The one is large, and the other is small. The large one does not take crystal face, as if it suffered magmatic corrosion. The colourless, low refractive, isotropic materials, perhaps glass, are very abundant along the cleavages, carrying many dusty substances. Zoning pattern is not recognizable. The smaller one is idiomorphic, and zoning pattern is distinct at the periphery.

Hypersthene is usually small grained, with good crystal outline. Zoning pattern is not recognizable. Relatively large crystals are present a little. They are crushed and show distinct wavy extinction.

Augite is present as microphenocryst. Twinning on (100) is common, being often repeated. Relatively large crystals are present a little, too. They are crushed and show hourglass structure with wavy extinction.

Hornblende is oxidized and changed to oxyhornblende. It is surrounded by thick so called opacite margin, which is composed of very fine grained dark dots.

Olivine is rarely present. It is small grained and round form, being surrounded by iddingsitic minerals.

Biotite is rarely present. It is oxidized and dissociated to small dark dots along the cleavages from periphery to core.

Ore minerals are present, but not identified.

Groundmass; Groundmass is very fine grained. It consists of two distinct areas differing from one another in the mineral assemblage. In one area, it is mainly composed of brown glass and opaque small materials, while in another, of plagioclase, cristobalite and ore minerals. In the former case, plagioclase and hypersthene are present, but small in volume and relatively small

grained. In the latter, crystals are generally larger than the former, and glass is less. Hypersthene is rarely present with acicular form. These two areas are mixed complicatedly. The boundary is not clear and continuously changed one another.

Hornblende augite hypersthene dacite

Megascopically, it is brownish gray in colour, and porous rock. The modal analysis of this rock is given in the Table 1.

Phenocryst ; Plagioclase is usually prismatic, with distinct zonal pattern. The honeycomb type crystal is not present. The composition is An 44-74.

Hypersthene is usually round form. The larger the crystal, it takes more round form. The optical axial angle $2V$ (-) is 64-73.

Augite is usually prismatic. Twinning on (100) is common, often repeated. The zonal pattern is recognizable at periphery. The optical axial angle $2V$ (+) is 52, and the index β is 1.693-1.697.

Hornblende is usually oxidized, with thin opacite margin. The small dots are arranged parallel to the cleavage from periphery to core. Twinning on (100) is common.

Opaque minerals are magnetite and ilmenite. Magnetite takes exsolution lamellae of ilmenite. Hematite adheres often to the magnetite, which is seemed to be duteric origin.

Apatite is accessory constituent.

Groundmass; Groundmass is very fine grained. Plagioclase, hypersthene, augite, magnetite, ilmenite, biotite and a little apatite are scattered in the interstitial cryptocrystalline materials and silica minerals. There are small veinlets which are faintly recognizable on the microscope, which may be composed of silica minerals and biotite.

Augite hypersthene bearing hornblende dacite

Phenocryst; Plagioclase is usually prismatic. There are two types in microscopically, as in the other rocks. The composition is An 44-64.

Hornblende is oxidized and sometimes resolved. In this rock, biotite joins in the resolved aggregate. Plagioclase in the resolved aggregate, if it has been as the inclusion of hornblende, takes honeycomb texture. The optical axial angle $2V$ (-) of hornblende is 73°.

Hypersthene is usually round form. The zonal pattern is recognizable at periphery. The optical axial angle $2V$ (-) is 67°-

73°.

Augite is prismatic in general. Twinning on (100) is common, often repeated. The zonal pattern is recognizable at periphery. The optical axial angle $2V$ (+) is 50° – 56° , and the index β is 1.689–1.697.

Opaque minerals are magnetite and ilmenite. Magnetite takes exsolution lamellae of ilmenite, which may be produced by the oxidation of ulvöspinel component in magnetite.

Apatite and quartz are as accessories.

Groundmass; Groundmass is fine grained. It carries, as essentials, plagioclase, hypersthene, augite magnetite, and as accessories, biotite apatite, ilmenite and alkali-feldspar. Silica minerals and glass are present interstitially. The optical axial angle $2V$ (–) of hypersthene is 63° – 68° . In some section, hypersthene in the resolved aggregate of hornblende has $2V$ (–) 65° , while in groundmass has 63° .

Augite hypersthene bearing hornblende dacite

Megascopically it is gray in colour with distinct flow texture. There are some brown belts, usually 5 mm. in width, parallel to the texture. The gray host part and the belt are separated and chemically analyzed. As lately shown there is no remarkable difference between them. The brown belt has slightly larger ratios in Fe_2O_3/FeO and K_2O/Na_2O than host part.

Phenocryst; Plagioclase is usually altered to low refractive glassy materials. But the outline of the crystal remains often as thin crust.

Hornblende is changed to oxyhornblende with thin opacite margin. When it is contact with drusy part, it is often resolved into aggregate of plagioclase, magnetite, and pyroxenes.

Augite and hypersthene are as accessories.

Groundmass; Groundmass is mainly glass. Cryptocrystalline materials are present, a little showing flow textures. There are some crystallized belt, which are seen brown colour in the naked eye. In these belts, the mineral assemblage of phenocryst is not different from the host, but the phenocrystal pyroxenes are oxidized with hematite like minerals around them. The groundmass of the belt is composed of plagioclase, alkali-feldspar, cristobalite, augite and hypersthene. Hornblende is present, but oxidized. Relatively large groundmass pyroxenes are oxidized, but the smaller ones are not oxidized.

Olivine hypersthene augite bearing hornblende dacite

Phenocryst; Plagioclase is usually prismatic. There are two types in microscopically, as in the other rocks, i.e. the honeycomb type and the nonhoneycomb type. The honeycombing is inclined to spread into all over the crystal along cleavages. In some crystal it is confined within a zone which has higher index than other parts. When augite and hypersthene are present as inclusion, plagioclase is inclined to change into low refractive materials, perhaps glass, around them.

Biotite is usually oxidized. It has distinct pleochroism i.e. $X' =$ pale yellowish brown $Z' =$ dark brown. Optical axial angle $2V(-)$ is small and the dispersion is very strong, $r < v$. Many opaque dots or dusts are arranged parallel to the cleavage, and in some cases they spread all over the crystal. It is often resolved into the aggregates of magnetite, augite and alkali-feldspar, which take parallel elongation with the cleavage of biotite.

Hornblende is changed into oxyhornblende. It is often wrapped up in the so called opacite margin or changed to the aggregates of plagioclase, magnetite and pyroxenes. Twinning on (100) is very common. Optical axial angle $2V(-)$ is $73^{\circ} - 84^{\circ}$. The dispersion is $r < v$ strong on one axis.

Augite is usually round form. Twinning on (100) is common, being often repeated. Zoning is recognizable at the periphery. It takes often hourglass texture.

Hypersthene and olivine are present subordinately. Hypersthene takes often parallel intergrowth with augite.

Ore minerals, quartz, apatite and sphene are accessory minerals.

Groundmass; Groundmass is consisted of two distinct areas. One is relatively mafic enriched part and the other is salic part. The former carries, as essential minerals, plagioclase, hypersthene, augite, magnetite, ilmenite and as accessoires, biotite and apatite. Cristobalite and glass are present interstitially. The salic part carries as essentials, plagioclase, alkali-feldspar, cristobalite, and as accessories, magnetite, ilmenite, apatite and hypersthene. These two areas have no clear boundaries, but are gradual.

(to be continued)