Riebeckite-bearing Soretite-trachyandesite and Its Allied Glassy Variety (Monchiquite) from Kozaki, Prov. Bungo, Japan.

BY

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With Pl. XIII (I).

INTRODUCTION.

There is a volcanic belt stretching from WSW to ENE through the Inland Sea or Setouchi.[1] It is characterized by the occurrence[2] of bronzite-andesites (Tonalose[3]), which are easily distinguishable in appearance from other volcanic rocks in the district, being black in color, compact and fine in texture. Of those rocks one special glassy variety has been described as "Sanukite" by Professor WEINSCHENK.[4] Along the southern border[5] of the bronzite-andesite region, the occurrences of other special kinds of

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1) The Inland Sea is the name given to a body of water lying between the main Island of Japan on the north and the islands of Shikoku and Kyūshū on the south. Through the Inland Sea there are scattered many islands and rocks. These consist mainly of granite and the paleozoic formation through which volcanic rocks (chiefly bronzite-andesites) were erupted.

2) See IDDINGS' Igneous Rocks Vol. II. p. 611.

3) Two chemical analyses of the bronzite-andesites are given below:

	I	II	Norm.	I	II
SiO_2	57.42	57.13	Quartz	13.1	15.8
Al_2O_3	18.53	14.40	Orthoclase	12.8	8.3
Fe_2O_3	1.55	6.03	Albite	22.0	25.7
FeO	5.08	5.45	Anorthite	24.5	21.4
MgO	4.72	3.17	Corundum	3.0	—
CaO	4.90	6.81	Diopside	—	9.4
Na_2O	2.59	3.04	Hypersthene	18.8	7.0
K_2O	2.15	1.41	Magnetite	2.3	8.8
H_2O	2.59	1.76	Ilmenite	1.2	1.5
TiO_2	0.60	0.80	Apatite	—	0.3
P_2O_5	trace	0.18			
MnO	0.07	0.14			
Sum	100.20	100.32			

I. Bronzite-andesite, Takahama, Prov. Iyo. C. SUGIURA, analyst.
II. Olivine-bronzite-andesite, Kashima, Prov. Iyo. T. Ohashi, analyst.

	I	II
$\frac{Sal}{Fem}$	$\frac{75.4}{22.3} = 3.38$	$\frac{71.2}{27.0} = 2.64$
$\frac{Q}{F}$	$\frac{13.1}{59.3} = 0.22$	$\frac{15.8}{55.4} = 0.29$
$\frac{K_2O' + Na_2O'}{CaO'}$	$\frac{65}{88} = 0.74$	$\frac{64}{77} = 0.83$
$\frac{K_2O'}{Na_2O'}$	$\frac{23}{42} = 0.55$	$\frac{15}{49} = 0.30$
	(Tonalose)	(Tonalose).

4) E. WEINSCHENK: "Beitrage zur Petrographie Japans." N. J. BBd. VIII. 1890.

5) This border region runs along the boundary of the granite mass on the north and the crystalline schist on the south, and its direction is made more conspicuous by a geotectonic line along the narrow belt of the Cretaceous formation.

minor extrusives or intrusives have already been noticed. So far as know to the writer, the oligoclase rhyolitic rock from Tsuruha, Prov. Sanuki, and that of Shihida, Prov. Iyo, the mica dacitic rock from Shiroyama, Prov. Sanuki, the garnet-bearing glassy rhyolitic rocks occurring on Nagashima, Prov. Iyo, and the hornblende andesitic and rhyolitic rocks from Himeshima,[1] Prov. Bungo, may be given as instances of such rocks, although their details are not yet worked out. The riebeckite-bearing soretite trachyandesite dealt with in the present paper is also a variety which occurs in the outer border, that is, the southwestern margin of the bronzite-andesite belt.

At the close of 1911, Professor B. KOTÔ called my attention to two interesting pieces of holocrystalline and glassy rocks in a collection made by him during his trip in southern Japan in the course of the previous summer, and he kindly placed these specimens at my disposal.

He found them in the form of blocks in a rivulet called "Otsurumidzu" near Kozaki, a small village in the province of Bungo, Kyûshû. I visited Kozaki last summer with the object of collecting more specimens of those rocks and of observing their mode of occurrence. But unfortunately, owing to the limited area of exposure, and on account of the many bushes and trees, I had some difficulty in locating the rocks. It was only by digging about a metre down in the soil that I discovered them. Under such conditions, I could not clearly learn their geological relations, but I did ascertain that they formed a dyke cutting through the metamorphic rocks, formed of clayslate, chlorite and graphite schists, of which the region was mainly composed, and that a glassy variety was the peripheral facies of the holocrystalline soretite trachyandesite.

My thanks are due to DR. FRED. E. WRIGHT and DR. H. E. MERWIN, under whose guidance my optical work was undertaken.

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1) Two chemical analyses of the rocks from Himeshima are as follows:

	I	II	Norm	I	II
SiO_2	74.98	69.69	Quartz	33.8	28.0
Al_2O_3	13.63	14.51	Orthoclase	21.7	17.2
Fe_2O_3	0.31	1.17	Albite	36.7	36.2
FeO	0.87	1.47	Anorthite	1.7	8.9
MgO	0.38	0.85	Corundum	1.9	1.0
CaO	0.52	2.13	Hypersthene	2.3	3.6
Na_2O	4.32	4.26	Magnetite	0.5	1.6
K_2O	3.66	2.90	Ilmenite	—	0.6
H_2O	0.74	2.19	Apatite	0.3	0.6
TiO_2	trace	0.33		97.7	97.7
P_2O_5	0.07	0.25		2.2	2.6
MnO	0.08	0.17		99.9	100.3
Sum	99.56	99.92			

I. Obsidian. T. OHASHI, analyst.

II. Hornblende Andesite (Dacite). K. YOKOYAMA, analyst.

$\frac{Sal}{Fem}$ .... $\frac{95.8}{3.1} = 30.90$ $\frac{91.3}{6.4} = 14.25$

$\frac{Q}{F}$ .... $\frac{33.8}{60.1} = 0.56$ $\frac{28.0}{62.3} = 0.45$

$\frac{K_2O' + Na_2O'}{CaO'}$ .... $\frac{109}{6} = 18.16$ $\frac{100}{32} = 3.13$

$\frac{K_2O'}{Na_2O'}$ .... $\frac{39}{70} = 0.56$ $\frac{31}{69} = 0.45$

(Kallerudose) (Lassenose)

Petrographical Character.

Riebeckite-bearing soretite-trachyandesite.

Megascopically, the trachyandesite is almost non-porphyritic, due to the small size of all the constituent minerals. It is light gray in color, more or less decomposed, and appears holocrystalline, but the individual crystals are scarcely recognizable; save that abundant, black and slender hornblende crystals are clearly seen, by close observation, in the light gray groundmass. Their average size is 1 mm. by 0.2 mm., with larger crystals of different habit (short prisms about 2 mm. by 1 mm.) evenly scattered through the rock in small quantity. The general mass is almost compact, though there are a few cavities of irregular form and varied in size. Their walls, in the decomposed specimen, are stained brown by ferric oxide.

Microscopically, the constituent minerals are hornblende, plagioclase, alkali feldspar, magnetite, and apatite, with pale colored augite and olivine in small quantity. Among them the most conspicuous mineral is hornblende in mega- and microphenocrysts, abundantly scattered through the feldspathic groundmass.

The hornblende is of three kinds; brown, blue and green varieties. The majority of the mineral belongs to the brown variety. The blue one usually occurs in association with the former, as a fringe or border on the terminal faces of the host crystal and sometimes as inclusions. The relation of the two hornblendes to each other are shown in the accompanying figures (Pl. XIII (1), Fig. 1-5). The way of fringing of the blue kind appears to be very similar to the blue hornblende in the dyke rock from Custer County, Colorado, described by DR. CROSS[1] and in the syenite from Tripyramid, described by Prof. PIRSSON.[2] The green variety forms the inner part of the brown hornblende, the boundary being indistinet and the transition gradual. The brown hornblende is generally well bounded by crystal faces, even by the terminal ones. It has two habits; one an extremely elongated prism and the other a stout one, which frequently grows in larger crystals, but does not exceed 3 mm. in length. The twinning parallel to *b* (010) is frequent. The zonal structure appears commonly; in some cases, the kernel is blue or green, as noted above, while in the others, the whole material is brown, but the inner part is lighter in color, (Pl. XIII (I), Figs. 3 and 4). This zonal growth is repeated in some crystals, as seen in figure 3 of the Plate XIII (I). The optical measurements of the brown hornblende, given below, were made on the inner part of the mineral as this is the prevailing mass of the crystal. It is strongly pleochroic, $\mathfrak{a}$ = pale yellow, $\mathfrak{b}$ = dark brown, and $\mathfrak{c}$=brown; and the absorption is $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$. The extinction angle ($\dot{c} \wedge \mathfrak{c}$) on a face considered as (010) in the thin section is 16° in the obtuse angle β and that on (110) is 13°, the latter section being made from an isolated crystal. The maximum and minimum indices of refraction, measured by the total refractometer, are as cited below. The measurement of β did not give a satisfactory result, as the comparatively large crystals which otherwise might have been used for the direct measurement had abundant inclusions which disturbed the reflected ray. The value given below is the result of calculation from the axial angle measured by an indirect method.

$\alpha = 1.655$ $\beta = 1.667$ $\gamma = 1.675$ $\gamma - \alpha = 0.020$

The birefringence ($\gamma' - \alpha'$) measured by the quartz compensator is 0.019. The axial angles measured on three thin sections by the method described by DR. WRIGHT in the " Methods of Petrographic-microscopic Research (pp. 155—163)" are $2v = 73°$, 75°, and 78°; and the optical character is negative. For comparison, these optical properties are tabulated with those from other localities which show a close relation.

1) W. CROSS: Note on some Secondary Minerals of the Amphibole and Pyroxene Groups. Am. J. Sci. 39, 1890, p. 359.

2) L. V. PIRSSON: Contribution to the Geology of New Hampshire, No. V; Petrography of Tripyramid Mountain. Am. J. Sci. May, 1911, p. 406.

	α	β	γ	$\gamma-\alpha$	2v	$\acute{c}\wedge c$	opt. character
Common hornblende	1.629	1.642	1.652	0.024	53°–85°		−
Common hornblende	1.640	1.643	1.656	0.016	54°–84°		
Brown hornblende from Kozaki	1.655	1.667	1.675	0.020	{73°, 75° 78°	16°	−
Soretite	1.659	1.670	1.681	0.022	78° 24′	17°	+
Soretite	1.663	1.677	1.686	0.022	89°	17°30′	+
Basaltic hornblende	1.677	1.695	1.708	0.061			
Basaltic hornblende	1.680	1.725	1.752	0.072	67°–80°	0–10°	−

As will be seen in the above table, the brown hornblende from Kozaki has a close relation to the brown soretite in the beerbachite dyke cutting the koswite at Koświnsky Kamen, Urals, described by DUPARC and PEARCE;[1] and shows a character transitional from soretite to common hornblende.

The blue hornblende is identified as riebeckite, though an identification in detail can not be made, owing to its scarcity in quantity and smallness in size. It is markedly pleochroic, $\mathfrak{a}$ = deep blue, $\mathfrak{b}$ = somewhat lighter than $\mathfrak{a}$, $\mathfrak{c}$ = pale yellowish green; the extinction angle ($\acute{c}\wedge\mathfrak{a}$) is very small. The maximum and minimum indices measured by the refractive liquid method lie between 1.675 and 1.670; and so the double refraction is very low. The green hornblende has higher birefringence than the blue and its maximum and minimum indices are nearly equal to 1.675 and 1.665 respectively.

The feldspar, which occurs essentially as an ingredient of the groundmass, is of three kinds, viz., orthoclase, oligoclase, and calcic andesine. Well defined, polysynthetically twinned, and lath-shaped crystals, with average size of 0.2 mm. by 0.03 mm. belong to oligoclase with a kernel of calcic andesine. Their mean indices of refraction are $n=1.533-1.543$ ($Ab_{94}\,An_{6}$—$Ab_{80}\,An_{20}$) and $n=1.550-1.560$ ($Ab_{44}\,An_{56}$—$Ab_{35}\,An_{65}$) respectively. The orthoclase occurs as the border of the plagioclase laths. These feldspars show intersertal arrangement and their interstitial spaces are filled up by a little residual glass, sometimes by a secondary sodalite-like mineral. The feldspar encloses abundant granules and minute apatite needles.

The apatite appearing conspicuously in the groundmass is in well-defined, elongated prisms. It is fairly abundant and its size is frequently comparable to that of the labradoritelaths. Magnetite crystals are scattered through the groundmass and also associated with the brown hornblende. Pale colored augite is seen in the groundmass in minute prisms and olivine is met with in rare instances.

The chemical analyşis of the rock, which was kindly undertaken by MR. K. YOKOYAMA at the chemical laboratory of the Geological Survey of Japan, is given below. For comparison, the chemical analysis of the orthoclase-gabbro-diorite from Yellowstone Park, which is similar to that of the rock from Kozaki, is cited in a parallel column.

	A	B	A_1
SiO_2	53.91	56.21	899
Al_2O_3	15.65	18.24	153
Fe_2O_3	3.75	3.26	23
FeO	2.82	3.69	39
MgO	4.81	3.38	120
CaO	7.09	5.91	127
Na_2O	4.12	4.15	67
K_2O	2.47	3.02	26
H_2O	2.05*	0.78	—
TiO_2	2.00	0.88	25

1) L. DUPARC et F. PEARCE: Sur la soretite, une amphibole nouvelle du groupe des hornblendes communes.

P_2O_5	1.28	0.64	9
MnO	trace	0.17	—
	—	—	—
Sum	99.95	99 87	

* Loss on ignition.

A. Soretite-trachyandesite, Otsurumizu, near Kozaki. K. YOKOYAMA, analyst.

B. Orthoclase-gabbro-diorite (andose), Hurricane Ridge, Crandal Basin, Yellowstone Park. L. G. EAKINS, analyst.

A_1. Molecular proportion of A.

The norms are:

	A	B
Quartz	3.7	3.8
Orthoclase	14.5	17.8
Albite	35.1	35.1
Anorthite	16.7	22.5
Diopside	8.6	3.0
Hypersthene	8.0	9.7
Magnetite	3.3	4.6
Hematite	1.4	—
Ilmenite	3.8	1.7
Apatite	2.8	1.3
	97.9	
	2.1	
	100.0	

The ratios, calculated from the norms, are as below:

$$\frac{Sal}{Fem} \cdots\cdots \frac{70.0}{27.9} = 2.51 \qquad \text{Class II}$$

$$\frac{Q}{F} \cdots\cdots \frac{3.7}{66.3} = 0.056 \qquad \text{Order 5.}$$

$$\frac{K_2O' + Na_2O'}{CaO'} \cdots\cdots \frac{9.3}{6.0} = 1.55 \qquad \text{Rang 3.}$$

$$\frac{K_2O'}{Na_2O'} \cdots\cdots \frac{26}{67} = 0.39 \qquad \text{Subrang 4.}$$

According to the Quantitative System, the trachyandesite is classified as andose near akerose (II, 5, '3, 4).

Classification. The rock from Kozaki consists essentially of plagioclase, occurring in parallel growths of sodic oligoclase and calcic andesine, and soretite. Besides these, there occur subordinately orthoclase, riebeckite, etc. The rock therefore, is mineralogically classified as an andesitic variety with alkaline affinity, that is, a variety of trachyandesite. This character can also be observed in the chemical analysis given above, 51.8 per cent. of the normative sodic andesine (Ab_{70} An_{30}) and 14.5 per cent. of the normative orthoclase exist in the rock. This quantitative relation, considered with the femic minerals of the norm, characterizes the rock as a transitional variety between andose and akerose.

Glassy Variety (Monchiquite).

As already mentioned, the outcrop of the rock mass, from which the mode of the transition between the crystalline part and the glassy variety might be studied, could not be well observed, but it is evident, from the hand specimens which were dug out, that the variety is a peripheral facies of the holocrystalline trachyandesite.

The rock is black and compact. Yellow olivine and black mica are magniphyric phenocrysts in fairly plentiful quantities. Under the microscope, the residual glass (brown or pale brown) in the rock from which the thin section was prepared and the chemical analysis was made, is comparatively smaller in quantity than was expected by the appearance of the rock. But the minerals appearing in the groundmass well show the individuality in their shape, which is characteristic of glassy rocks. The constituent minerals are olivine, brown mica, brown hornblende, pale colored augite, apatite, and magnetite. Feldspar is almost absent. The lack or scarcity of the mineral in this rock is similar to that of sanukite or boninite and limburgite, regarded as the glassy varieties of bronzite-andesite and alkalic basalt respectively.

Phenocrysts are essentially of olivine and brown mica with a few crystals of pyroxene and hornblende. The olivine is euhedral to subhedral and its material is quite fresh, though a greenish alteration product can be seen along its characteristic cracks in some instances. The maximnm refractive index (1.690) is almost the same as that from Koswinsky, Ural. There are two kinds of brown mica. One shows very small axial angle, while the other exhibits the large angle ($2E=24°$) with the anomite orientation. The refractive indices (γ and β) of the anomite lie between 1.615 and 1.620, while those of another mica are between 1.505 and 1.610. The pleochroism of the anomite is $\mathfrak{a}$=light brown, $\mathfrak{b}$=dark yellowish brown, $\mathfrak{c}$=yellowish brown with a greenish tinge; and the absorption is $\mathfrak{a} < \mathfrak{c} < \mathfrak{b}$.

The minerals in the groundmass are long prisms of pale colered augite and brown hornblende (soretite), magnetite and apatite with beautifully defined outline. The brown hornblende is less than the augite and its character is the same as that of the trachyandesite. No blue and green hornblende can be seen in this glassy variety.

The chemical analysis of the rock, made by MR. K. YOKOYAMA, is given below.

	A	B	C	D	A_1
SiO_2	45.58	47.82	46.48	44.63	0.760
Al_2O_3	11.60	13.56	16.16	13.77	0.114
Fe_2O_3	3.12	4.73	6.17	7.30	0.019
FeO	7.31	4.54	6.09	5.60	0.101
MgO	8.71	7.49	4.02	4.47	0.218
CaO	7.98	8.91	7.35	7.96	0.143
Na_2O	4.02	4.37	5.85	4.20	0.065
K_2O	2.67	3.23	3.08	2.65	0.029
H_2O	4 39*	3.37	4.27	4.04	——
TiO_2	2.97	0.67	0.99	4.25	0.038
CO_2	n. d.	——	0.45	1.34	——
P_2O_5	1.98	1.10	——	0.09	0.014
MnO	0.04	trace	——	0.08	0.000
BaO	——	0.50	——	——	——
Incl.	——	0.18	——	0.05	——
Total	100.37	100.20	100.91	100.43	

* Loss on ignition.

A. Monchiquite, Otsurumizu near Kozaki. K. YOKOYAMA, analyst.

B. Monchiquite, Highwood Gap, Highwood Mts., Montana. FOOTE, analyst.

C. Monchiquite, Santa Cruz, Cabo Frio, Brazil. HUNTER, analyst.

D. Foyaite, Banatette River, Kupang Bay, Timor. O. PUFAHL, analyst.

A_1. Molecular proportion of A.

The norms derived from the above figures are:

	A	B	C	D
Orthoclase	16.1	18.9	18.3	16.1
Albite	21.5	17.8	14.1	19.4
Anorthite	5.6	7.8	8.6	10.6
Nepheline	6.8	10.5	19.0	8.8
Diopside	17.9	23.9	22.3	22.6
Olivine	13.6	7.4	2.9	0.5
Magnetite	4.4	8.0	9.0	6.0
Hematite	—	—	—	3.0
Ilmenite	5.8	1.2	1.8	8.2
Apatite	4.3	2.5	—	—

The ratios of the monchiquite from Otsurumizu near Kozaki are as follows:

$\frac{Sal}{Fem}$ .... $\frac{50.0}{46.0} = 1.09$ Class III

$\frac{L}{F}$ .... $\frac{6.8}{43.2} = 0.15$ Order 6

$\frac{K_2O' + Na_2O'}{CaO'}$ .... $\frac{94}{20} = 4.7$ Rang 2.

$\frac{K_2O'}{Na_2O'}$ .... $\frac{29}{65} = 0.45$ Subrang 4.

According to the Quantitative System the rock is classified as monchiquose (III, 6 (7), '2, 4).

Classification. The rock is a glassy variety, being almost devoid of feldspar and containing the crystallized ingredients of olivine, augite, hornblende, biotite, magnetite, and apatite. No modal, feldspathoid mineral was observed. That mineralogical property places the rock in the group either of monchiquite or limburgite, and this final classification is determined by the character of the glass-base.

According to the chemical analysis, the glass may be taken as amorphous analcime and so the rock belongs to the group of monchiquite.

For the sake of comparison, the two chemical analyses of the monchiquite from Brazil and Montana and one of a foyaite from Timor, are given in the above table. As will be seen they show close similarity to each other. Through these, high alkali content in proportion to those of alumina and silica is a characteristic of the alkalic nature of the rock group and this relation causes, on the one hand, the existence of the nepheline component and, on the other, the presence of smaller quantity of the anorthite molecule, even though there is fairly large percentage of lime. The high content of water is also a characteristic of the monchiquite.

Explanation of Plate.

Fig. 1. is the microphotograph of riebeckite-bearing soretite-trachyte. × 56.

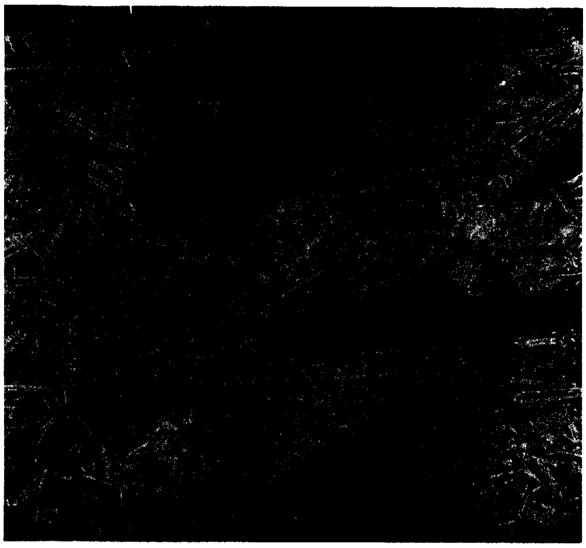
Fig. 2. is the microphotograph of the same rock, showing the riebeckite-fringe on the terminal face of soretite. × 60.

Fig. 3. is the microphotograph of the same rock, showing the zonal structure of soretite on a cross section. × 100.

Fig. 4. is the microphotograph of the same rock, showing the zonal structure of soretite on a longitudinal section. × 95.

Fig. 5. is the microphotograph of monchiquite, showing olivine phenocrysts. × 60.

Fig. 6. is the microphotograph of monchiquite, showing phenocrysts of biotite, olivine, augite, and hornblende, and well bounded apatite crystals.



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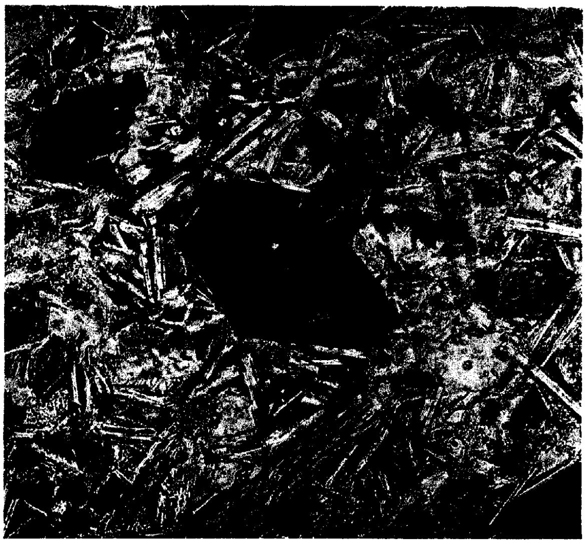

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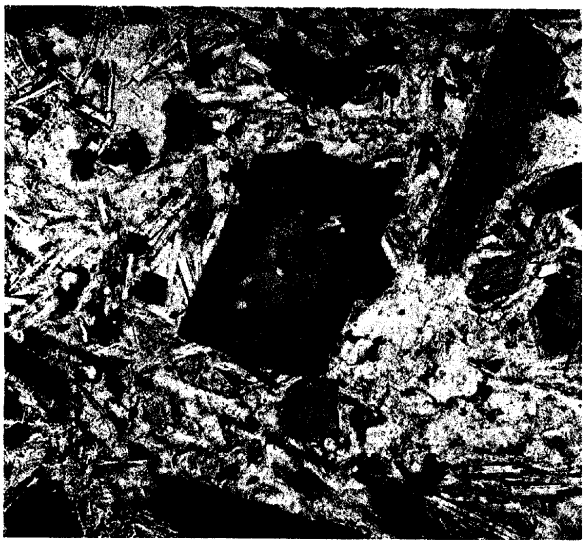

4.

Tamura Photo.

5.

6.