REPORT No. 153

GEOLOGICAL SURVEY OF JAPAN

Tomofusa MITSUCHI, Director

Albitite and Associated Jadeite Rock from Kotaki District, Japan: A Study in Ceramic Raw Material

By

Shūichi IWAO

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Abstract

The jadeite from the Kotaki district, Niigata Prefecture, which was first reported from Japan by Dr. Y. Kawano,(3) occurs occupying small marginal zones of albitite masses which outcrop either as considerably large intrusive-like bodies or as numerous boulders at many localities in serpentine area in this district.

Field and microscopic study revealed that the albitite might be regarded as a kind of leucocrate of peridotite from which the serpentine was derived, and that for the most part, it is brecciated, faulted or sheared. Along the fracture planes, as well as scattered through the albite crystals, the albitite is lined or speckled by secondary hydrous minerals such as zeolite, muscovite, phlogopite, prehnite and zoisite. Secondary development of actinolite or talc enveloping the albitite mass is also common.

Low temperature albite, quartz, jadeite or diopside are the main primary constituents of the rock, and the coexistence of quartz and jadeite is strikingly noteworthy.

The albitite ore is estimated by the writer at about ninety five thousand metric tons. It was found by B. Yoshiki(10) to be most adequate on an industrial scale for the principal raw material for the special low alkali glassware. The jadeite, however, does not yield high quality gem stone, because of its inferior in tone of green color. Its total reserves are almost nil.

Introduction

There is great interest among geologists in albitite, because of its important new use in ceramics as a principal raw material of low alkali glass, recently reported by Dr. B. Yoshiki,(10) Director of the Research Institute of the Asahi Glass Company, and also because of its use as glazing raw material of some porcelain ware. It was first in Japan that albitite is discovered in association with jadeite which was previously reported petrographically by Dr. Y. Kawano[3] who was formerly a member of the Geological Institute of Tōhoku University.

It is worthy of note that the mode of association of albite, jadeite, analcite, diopside and amphibole is similar to the Burmese[1] occurrence as well as to San Benito County[11] occurrence, with a main exception being the presence of quartz.

In this paper, the writer would like to give detailed information on the mode of occurrence of the rocks and also to investigate the mode of formation of the rocks.

Many suggestions were derived from the recent work of H. S. Yoder[7][11][12] and his collaborators on the problem of jadeite.

Localities and Outline of Geology

In the Kotaki District, Nishikubiki-gun, Niigata Prefecture, Japan, thirteen localities of albite rock were found. Among them are: (1) four exposures of bed rock, (2) three piles of large boulders not far removed from their initial position in the host rock, and (3) six deposits of acattered boulders of various sizes in streams. There are, most probably, some more. It is the second locality that the albitite is associated with jadeite. The albitite and jadeite rock are always surrounded by highly brecciated or sheared serpentine which is exposed

Fig. 1 Map showing of the location of the albite-jadeite deposits, Niigata Prefecture, Japan. Cross mark on the left top map indicates localities of the albitite rocks in Japan.

here and there over a considerable area in this district. The serpentine penetrates, along many fractured or thrust zones, a complex of chert, slate, sandstone and limestone of Permocarboniferous age as well as an alternation of sandstone and conglomerates of Jurassic age. Repeated dislocation of the

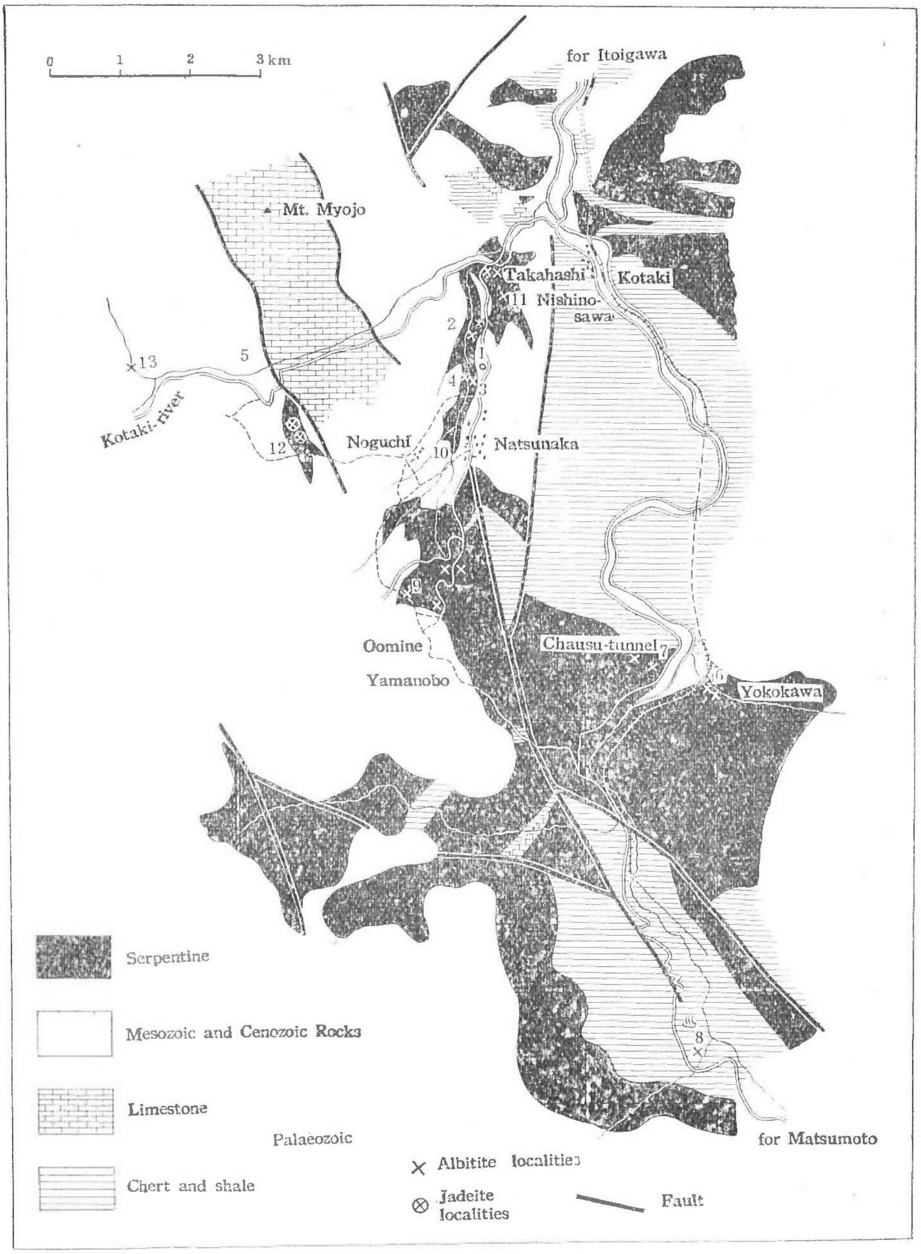


Fig. 2 Geological sketch map showing the localities of the albitite near Kotaki. (after K. Ishii, somewhat modified after M. Muraoka, etc.)

crust during the periods from post Jurassic to post Miocene has been believed to be characteristic of this area, and has been investigated by some Japanese geologists.[2] (Fig. 1, Fig. 2)

There is found no critical evidence in support of the contact metamorphic origin of the jadeite and the albite rocks as previously suggested by some Japanese petrologist,[3] who attached significance to the adjacent occurrence of the jadeite rock to serpentine and to the large mass of limestone of Mt. Myōjō.

In Table 1, the localities and mode of occurrences of the albitite and jadeite rocks are briefly summerized with short remarks.

Table 1. Localities and mode of occurrences of the albitite and jadeite rocks

Locality	Locality No.	Mode of occurrences	Size of exposures
Takahashi	1	Albitite, forming cliff on the bank of Kotaki-river, partly as boulders on the slope of a hill	max. 15m × 15m × 100m boulders 8m × 1m
Nishinosawa	11	Albitite, exposed on the bank, partly as boulders in the stream	boulders 10m × 1m
Primary school	2	Albitite, a pile of large blocks forming a small hill	blocks max. 7m
West of village	3	Albitite boulders in a rice field	ditto, 5m × 1m
Northwest of village	4	Ditto, in a stream	ditto, 4m × 1m
West of village	10	Ditto	ditto, 5m × 1m
Usagiiwa	9	Ditto, on a gentle slope of a hill	ditto, 5m × 4m
Chausu-tunnel	7	Large albitite mass in serpentine, and boulders on a hill	mass 13m × 10m × 10m boulders 5m × 1m
Yokokawa	6	Albitite, forming cliff on the bank of Yokokawa-river, and also as blocks and boulders	20m × 10m × 20m or more boulders 10m × 2m
West foot of Mt. Myōjō	5	Albitite, blocks and boulders nearly in situe, associated in part with jadeite	max. 14m × 8m × 7m others 10m × 1m

Slope of south side of the Ko-taki-river	12	Albitite, small blocks, partly associated with jadeite	blocks 1m × 0.3m
Tsuchikura-zawa	13	Jadeite-albitite boulders, said to be buried under the young boulder deposits in a valley	uncertain
Foot of Kuni-sakai-bridge	8	Albitite boulders in the valley of Kurohime-river	boulders 10m × 1m

The locality numbers refer to numbers on the map. (Fig. 2)

Fig. 2 is a locality map with a general sketch of geology after K. Ishii,[2] partly modified by using a data of M. Muraoka,[14] a geologist for the geological Survey of Japan, and incorporating data furnished by other geologists.

Typical mode of occurrences of the albitite and jadeite rocks

1. White and grey albitite with actinolite rim, from Takahashi.

The largest mass of albitite of all the localities was discovered near the edge of Takahashi-bridge where it forms a cliff of about thirty meters from the water level of the Kotaki river. The outcrop extends about 130 m × 50 m toward the gentle slope of the southwest bank of the river. Many large boulders, in addition, are scattered around this mass, some on the floor of the river.

The rock is massive, coarse grained, with well cleaved albite crystals, white, light grey, grey, or dark grey; it has a heterogeneous appearance. The white and light grey varieties are dominant. Distribution of quartz in the rock is uneven. (Fig. 3)

This mass, as proved by sketch mapping, is surrounded by serpentine on two sides, and seems to continue to depth. An albitite mass in Nishino-sawa valley, however, seems to be ball like in shape and is completely enclosed in a serpentine mass as shown in Fig. 4. (Fig. 4)

A narrow rim composed of actinolite aggregates partly surrounds the albitite at the contact with the host serpentine. In a few case, actinolite veinlets traverse albitite.

Serpentine is often converted into brown, or greyish rock, caused by remarkable carbonatization and silicification as commonly reported from some quicksilver fields.[13]

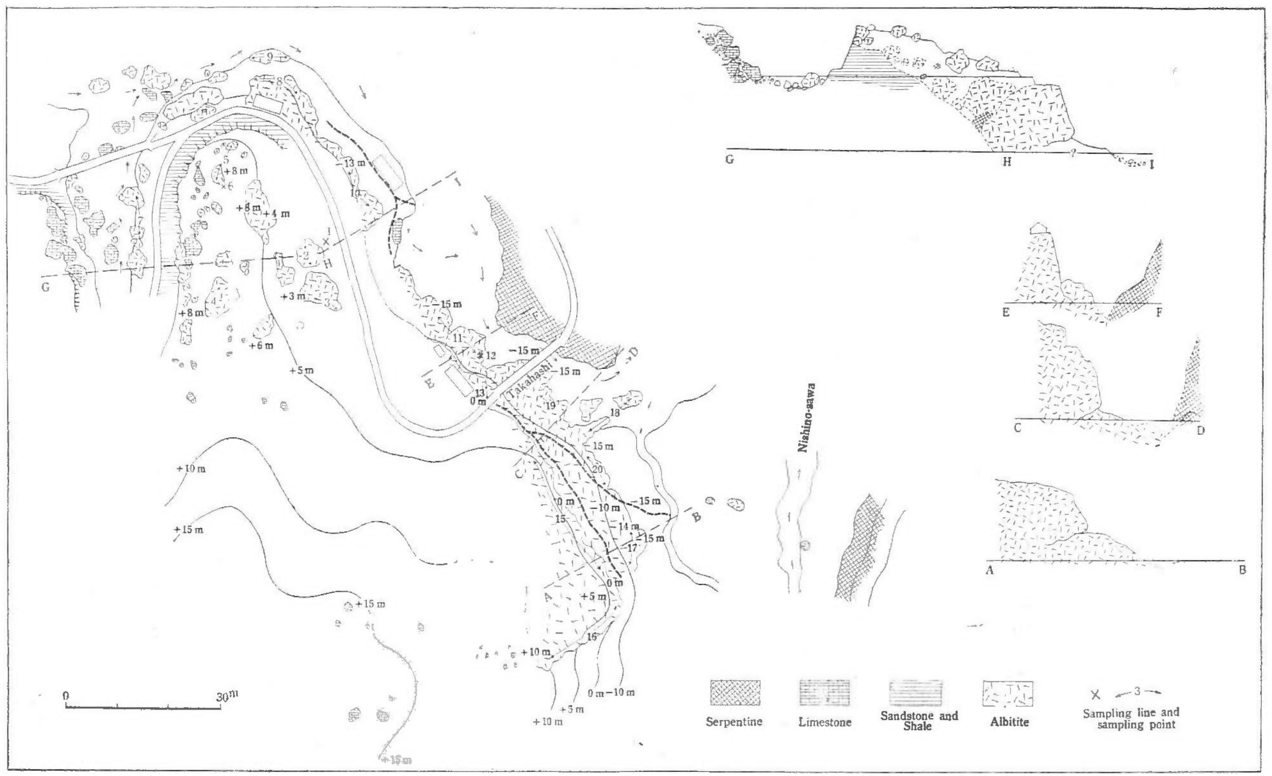
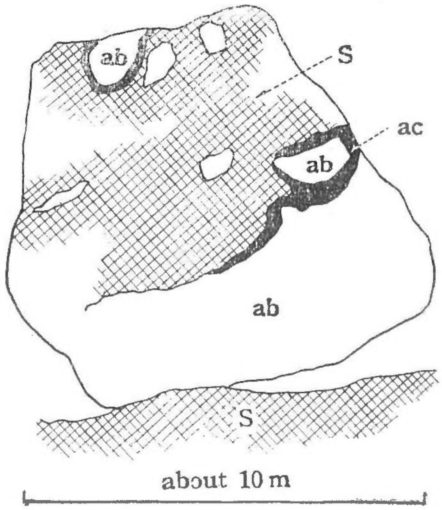


Fig. 3 Mode of occurrence of the albitite at Takahashi, Kotaki district. (after S. Iwao, 1952)



S : Serpentine
ab : Albitite
ac : Actinolite

Fig. 4 An example of exposure of albitite enclosed in serpentine and surrounded by actinolite rim. (after S. Iwao, 1952)

2. White albitite associated with jadeite, from the west foot of Mt. Myōjō.

A large number of white albitite boulders of various sizes are found spread in a narrow limited area on side and floor of the Kotaki-river at the west foot of Mt. Myōjō. That they are brought to the present position crossing a very short distance from the adjacent southern slope of the Kotaki-river, is verified by finding on the southern slope many boulbers of quite similar type of albitite in serpentine.

The albitite here is milky white, very compact, (Fig. 5) hard and not cleavable. Some of the boulders contain jadeite and actinolite, while others are associated either with diopside and anthophyllite, or with actinolite. Associations of jadeite-quartz and of jadeite-analcime are also found.

The most typical mode of occurrence of the jadeite is shown by concentric spherical zoning arranged in the order of albitite → white jadeite → green jadeite → green jadeite-

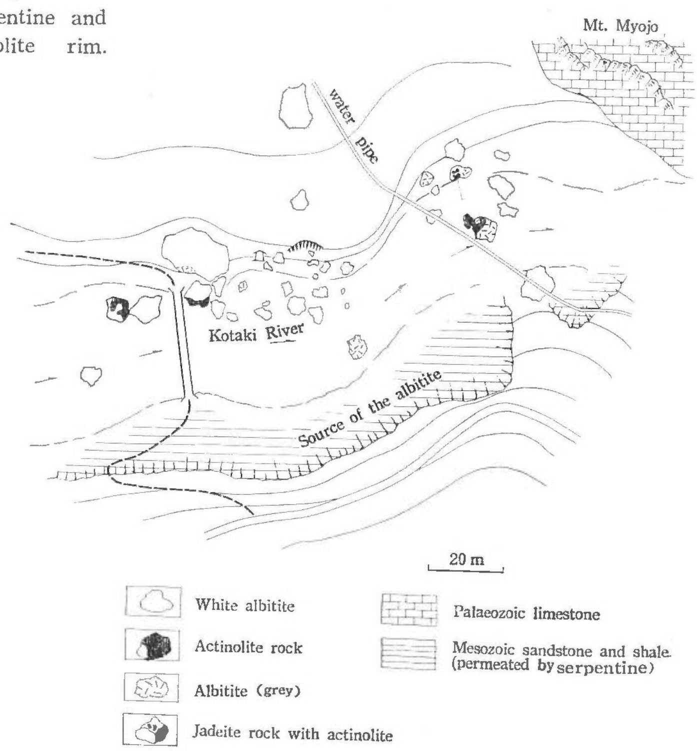


Fig. 5 Occurrence of jadeite and albitite at the west foot of Mt. Myojō. (after S. Iwao, 1952)

actiinolte → host serpentine from inner to outer. (Fig. 6) The albitite spherical core is much variable in diameter ranging from about 1 meter to 5 centimeters or less; the green jadeite shell rarely exceeds about 20 cm in thickness and rarely assumes a deep emerald green color. Quartz is usually confined to the albitite-core but exceptionally is mixed with jadeite crystals.

Some large albitite boulders have an onion-like structure, with repeated concentric thin layers of phlogopite or chlorite around the periphery of the boulder. (Fig. 7)

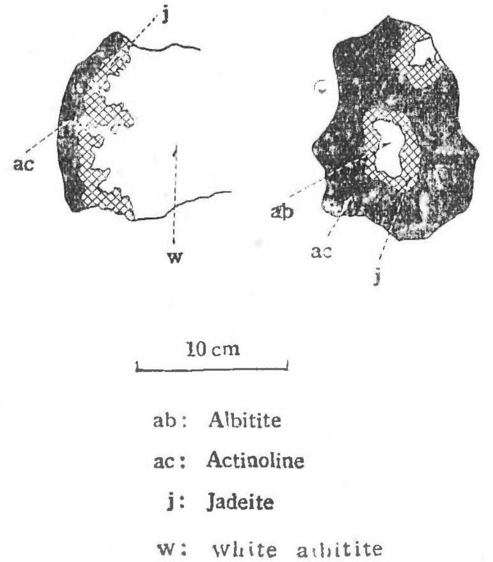


Fig. 6 Jadeite forming a part of ring ore. (after S. Iwao, 1952)

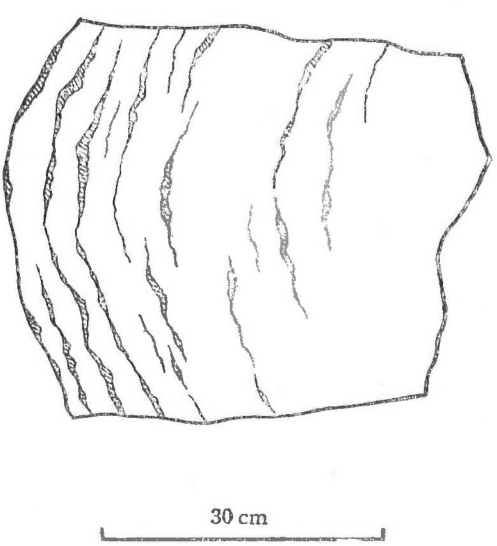


Fig. 7 Concentric thin layer of phlogopite or chlorite in albitite. (after S. Iwao, 1952)

Fig. 7 shows the manner of distribution of the various boulders, and their relations to the source of rock.

3. Albitite surrounded by talc schist near Chausu-tunnel.

About twenty meters south from Chausu-tunnel, fine-grained dark grey albitite containing a few diopside crystals occurs as a large spherical mass of about 15 m × 8 m × 10 m in size. A characteristic feature is that half of the mass is rimmed by talc schist about three meters thick at the contact with its host serpentine. Several small boulders of grey albitite are found nearby.

4. Albitite with alternating bands of grey and white layers at Yokokawa.

A part of the large mass of albitite which is exposed as a cliff of about sixty meters long along the southern bank of Yokokawa river, shows a beautiful banded structure of alternating white and greyish layers. The white layer consists of very compact albitite which is similar to that found at the foot of Mt. Myōjō, and the greyish layer is composed of coarse grained albitite with well cleavable albite crystals. Sometimes, a pale green diopsidic layer fringes the greyish albitite layer.

5. *Pile of albitite boulders in a valley to the west of Natsunaka village.*

About twenty-five boulders some larger than one cubic meter and many smaller ones are found within a short distance of one another along about two hundred meters of a small tributary of the Kotaki-river, which runs through the serpentine area. They are all white and grey, coarse grained albitite without association with jadeite and other mafic minerals. Maximum size of the boulders is about 9 m × 5 m × 4 m. It appears certain that they are derived by washing out of the weathered, brecciated serpentine mass on the river side. (Fig. 8)

6. *Sporadic occurrence of albitite boulders near Usagi-iwa.*

Scattered through out an area of about 250 m × 600 m on a very gentle slope of serpentine to the north of Usagi-iwa, there are found very many albitite boulders with maximum size about 10 m × 7 m × 5 m. Some large ones have settled on a top of domal hill, showing it to be in situe.

Many other occurrences are roughly similar to one or the other of the above mentioned six categories.

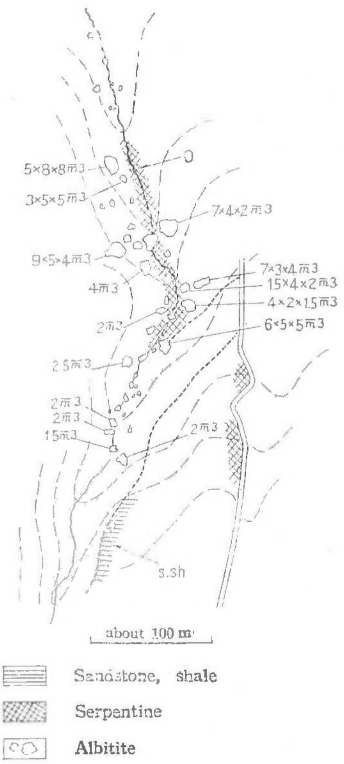


Fig. 8 Distribution of albitite boulders in the valley, southwest of Natsunaka village (after S. Iwao, 1952)

Petrography

1. *Albitite*

From the above occurrences, the following three types of albitite are recognized.

a. Coarse grained albitite (white, grey, dark grey)——normal type

b. Fine grained albitite

c. White, compact albitite

Coarse grained albitite is dominantly composed of large crystals of albite and associated with quartz. A minor content of zoisite and muscovite is common. The albite is usually very clear, nearly euhedral to subhedral, about 1.5 cm~0.2 cm in length, thick tabular or prismatic, coarsely twinned after albite law, well cleaved, and sometimes contains small scales of muscovite orientated along its cleavages. (Plate I) Radial micro-crystal aggregates of zoisite less than about three percent of the rock are not rare.

Actinolite is not common, but in some cases, it occurs, in accessory amount, as veinlets of small scaly crystal aggregates developed along slip planes of crushed albite crystals.

The difference between the white, grey and dark grey varieties could be recognized neither chemically nor microscopically. Dark dusty matter in albite crystals is chracteristic of the dark coloured variety, but it is too fine to be determined.

One noteworthy feature is the faulted or brecciated texture of the rock. Only a very few of the albitite masses are free of this texture and the others have suffered from brecciation, in varying degrees. (Plate II~VI) In the rocks of the most advanced stage of brecciation, albite is bent, faulted and detatched into small fragments; quartz displays a remarkable wavy extinction, flow or sutured texture; occasionally the intersticial matrix or veinlets is composed of recrysrallized aggregates of quartz and albite. Quartz is influenced by some minor liquor and seems to form veinlets more readily than albite. A bent film of muscovite or prehnite is newly formed sometimes.

Fine grained grey albitite from the neighbourhood of the Chausu-tunnel shows weak protoclastic texture, and consists of porphyroid albite, and scattered grains of diopside; the interstices are a fine grained matrix which is essentially composed of subidiomorphic albite grains. A subordinate amount of anthophyllite and mica is also present.

Albite is subidiomorphic with indented outline, up to about 4 mm in length, remarkably twinned after albite law, and very clear. The indented outline is due to veinlike penetration of fine crystal aggregates of albite, which are also very clear, xenomorphic, rounded in shape, about 0.2 mm in diameter, and penetrated by one or two twinning lamellae.

Diopside is stout short prismatic, about 0.5 mm in length and has the following optical properties.

$\alpha=1.680\sim1.679$ 2V (+) 55°~57° (core)~(margin)

$\gamma=1.701\sim1.702$ $c\wedge Z=35°$ dispersion in optic axes weak

Sometimes, it is partly rimmed by anthophyllite. Anthophyllite is also found as fine radial acicular crystal aggregates, associated with fine-grained albite veinlets.

Thin muscovite films traverse all other minerals.

Quartz is never found in the rock.

White compact albitite, under the microscope, is revealed to be different from the normal albitite by carrying a considerably greater amount of zoisite in the albite crystals. In other respects, however, it is almost like the normal type. The zoisite, for instance, in the rock from the foot of Mt. Myōjō, amounts up to about fifteen precent or more of the rock and is in the form of short prismatic crystals up to about 0.2 mm in length. The zoisite crystals are arranged in radial chain shaped aggregates orientated without regard to the outline of the host albite crystals, or to the relative orientation of the albite. (Plate VII)

Phlogopite is not rarely found, forming folded layers along the sheared plane of other minerals. It is pale brown with a golden luster, nearly colourless in thin section. The refractive indices are $\gamma \doteqdot \beta=1.597$, and the optic axial angle about X is 0°~5°. Muscovite is found in some cases either in parallel growth with phlogopite, or as small scaly inclusions in albite crystals. The phlogopite and muscovite seem to be of last minerals to form in the rock.

Actinolite-bearing albitite, from several localities, such as Usagi-iwa, Chausu-tunnel, and Mt. Myōjō also belongs to the common variety. In the rock, actinolite appears in two different manners, the one is prismatic presumably grown at the expense of earlier pyroxene, and the other is acicular or fibrous either grown on the pyroxene or along cracks of the earlier formed minerals, such as pyroxene, actinolite or albite.

Prehnite veinlets cutting all other minerals are sometimes found.

2. *Actinolite rock, a shell of the albitite mass.*

Under the microscope, the actinolite rock is almost essentially composed of stout long prismatic actinolite crystals, with a minor amount of prehnite which fills the interstices of the actinolite prisms together with newly formed actinolite. The optical properties of the actinolite are as follows:

$\alpha=1.620$ $n_1=1.628$ $c \wedge Z=22.8°$

$\beta=1.634$ $n_2=1.640$ $2V\ (-)=77°$

$\gamma=1.644$ $\rho > v$, around optic axis

The rock is free from cataclastic texture.

3. Jadeite actinolite rock.

The simplest mineral combination of all jadeite containing rocks in this area is represented by the actinolite-jadeite association. The rock occurs in association with jadeite rock near Mt. Myōjō. It consists of actinolite, jadeite, and Mg-chlorite, enumerated in the decreasing order. The actinolite crystals are stout prismatic, about 1∼3 mm in length, with an acicular variety of secondary growth on their terminal crystal surfaces. The jadeite grains are more or less long, prismatic, with an indefinite outline, about 0.5 mm∼1 mm in length, colourless in thin section. Chlorite fills up the interstices between the two minerals. Prehnite veinlets associated with small actinolite grains are sometimes found.

4. Quartz bearing albite-jadeite rock.

The quartz bearing jadeite rock is mainly composed of jadeite and albite with accompaning minerals such as actinolite, quartz, zoisite, and prehnite. The first three accessory minerals are present in considerably variable amounts. Although it shows various tones of emerald green and white to the naked eyes, chemical and optical properties of the jadeite are not so variable according to the report of Y. Kawano(3) and K. Omori.(4) Actinolite-rich jadeite rock is, however, usually somewhat dark green in colour.

Under the microscope the rock is commonly found to have a protoclastic texture with a network of veinlets of about 0.05 mm∼0.2 mm wide, which are composed of albite, albite-prehnite or of a prehnite-actinolite aggregate.

Crystals of jadeite, which were initially about 2 mm or 0.5 mm in length are brecciated into an aggregates of small fragments roughly arranged in a parallel orientation. The optical constants were determined as follows:

$\alpha=1.651\sim1.652$ $2V=74°\ (+)$

$\gamma=1.670\sim1.669$

Albite occurs as fine-grained mosaic crystal aggregates associated with a few quartz grains. It is clear, free from brecciated texture, rarely twinned, and about 0.2 mm in diameter.

Quartz is also clear, free from strain shadow, and about 0.1 mm in diameter. It is easily recognized by its refractive indices in thin section.

Zoisite is quite similar in appearance to that the white albitite.

It is worthy of special attention that some albite and quartz crystallized concurrently after brecciation of the already crystallized jadeite and albite.

5. Analcime bearing jadeite rock.

A few jadeite rock contain analcime filling the interstices between the jadeite crystals. On the terminal faces of the jadeite, slender acicular crystals of actinolite are attached and have grown into the analcime host. The specimen examined is free from cataclastic texture.

The jadeite has the following optical properties:

$\alpha=1.651$ $2V\ (+)=72^\circ$

$\gamma=1.670$

6. Serpentine.

Serpentine in the area is mostly antigorite serpentine, sometimes containing a small amount of chromite. At places, especially along a sheared zone, it is altered to schistose quartz-carbonate rock retaining in parts its original serpentine texture. The altered rock consists of imperfect alternation of carbonate and quartzose layers with scattered of fragments of chromite crystals. The carbonate layers are composed of calcite and siderite, the former being euhedral in crystallographic outline and mantled by a thin coat of aggregates of the latter. The quartz is rather intersticial against calcite, and less than about 0.1 mm in grain size.

The chromite is usually brecciated and surrounded by a shell of magnetite having the texture which is characteristic of some chromite ores in Japan.(6)

Judging from the crushed character of the chromite, the altered serpentine may be regarded as more or less crushed either before or during the alteration.

The serpentine also tends to grade into talc-serpentine schist, where it encloses the albitite. The schist, under the microscope, is found to contain, in some cases, beside talc, anthophyllite and albite spots.

Mode and chemical composition of the albitite and associated rocks

Because of very difficulty of accurate volumetric estimation of the minerals of the albitite and associated rocks caused by the considerable heterogeneity of the rocks, rough estimations under the microscope were carried out. The results are as follows:

Table 2. Rough modal percentage of the constituent minerals in the rocks.

Kind of rock	Normal coarse grained albitite											
Specimen No.	1 i	1 iv	1 ii	1 iii	26	31	49	55	59 ii	62	69 v	73
albite	68	60~70	60	70~74	68	84	95	70~60	95	80	90~80	96
quartz	30	30~40	40	29~25	28	14	—	30~40	—	18	—	—
mica	1~2	1	tr.	1~2	2	0.3	—	1	1	2	5~10	1
zoisite	0.5	1	tr.	0.5	—	—	—	tr.	3	—	—	2
actinolite	—	—	—	—	2	2	3	—	—	1	5~10	1
jadeite	—	—	—	—	—	—	2	—	—	—	—	—
diopside	—	—	—	—	—	—	—	—	—	—	—	—
others*	tr.	—	tr.	tr.	tr.	tr.	tr.	tr.	1**	tr.	tr.	tr.

Kind of rock	(a)	(b)	Jadeite rock			Actinolite rock		
Specimen No.	45	69 ii	70 iii	72	i	69 iv	70 i	70 iii
albite	85	80	26	—	—	20	—	4
quartz	—	—	3	—	—	—	—	1~2
mica	1	10	—	—	—	7>	—	—
zoisite	—	5	1	—	—	—	—	—
actinolite	—	3~5	10	1~2	20	70	98	70
jadeite	—	—	50	95	40	—	—	25
diopside	7	—	—	—	—	—	—	—
others*	5~7⚹	tr.	tr.	2~3[§]	40[×]	3	2[××]	—

(a) Diopside bearing fine grained albitite
(b) White compact albitite
* Carbonate, prehnite, tremolite, opaque minerals
** Opaque dusts, prehnite
⚹ Anthophyllite
1 i Grey albitite, from Takahashi
1 iv Dark grey albitite, from Takahashi
1 ii White albitite, from Takahashi
1 iii White albitite with phlogopite films, from the west foot of Mt. Myōjō
26 Light grey albitite, from Usagi-iwa
31 Albitite with remarkable brecciation, from Yokokawa

49 Light grey albitite, from Chausu-tunnel
55 Coarse grained grey albitite, from Natsunaka
59 ii Phlogopite bearing white albitite, from the west of Natsunaka
62 White albitite, Nishinosawa
69 v White albitite with phlogopite, from Kotakigawa
73 Light grey coarse albitite, from Kotakigawa
45 Fine grained dark grey albitite
69 ii White albitite with phlogopite
§ Analcime
× Mg-chlorite
× × Prehnite and others

Chemical analysis of the albitite from different exposures was performed by the analyst for the Research Institute of the Asahi Glass Company with the results as shown in the following table, in which the normative composition of its felsic minerals is also given.

Table 3. Chemical composition of the albitite and the normative composition of its felsic minerals (Analyst: Asahi Glass Company)

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	73.49	77.59	70.94	74.21	74.34	80.30	72.38	63.38	75.67	69.26	71.88	70.90
Al_2O_3	14.73	13.16	14.68	15.29	16.09	11.87	26.25	15.24	14.88	17.36	14.73	16.55
Fe_2O_3	0.22	0.17	0.22	0.20	0.22	0.01	0.20	0.21	0.11	0.13	0.78	0.01
FeO	0.08	0 09	0.53	0.08	0.08	0.17	0.07	0.20	0.07	0.30	0.01	0.55
TiO_2	0.19	0.18	0.19	0.19	0.14	0.18	0.15	0.23	0.18	0.12	0.25	0.24
CaO	1.63	1.30	2.57	1.04	1.15	1.07	0.50	3.83	0.85	1.75	1.75	2.00
MgO	tr.	tr.	2.81	tr.	0.50	tr.	tr.	0.55	0.52	0.79	0.50	0.75
Alkalies (diff.)	9.11	6.92	7.23	8.52	7.04	5.96	10.00	9.37	7.16	9.50	9.32	9.19
$+H_2O$	0.04	0.04	0.18	0.13	0.09	0.07	0.03	0.09	0.02	0.20	0.17	0.15
$-H_2O$	0.50	0.54	0.59	0.33	0.35	0.37	0.42	1.90	0.54	0.59	0.61	0.41
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ab	75	59	63	72	62	51	79	80	62	76	81	77
An	8	6	13	5	6	6	3	19	5	16	9	10
Q	17	35	24	23	32	43	18	1	33	8	10	13

1. Sample no. 18 White albitite from Takahashi
2. Sample no. 12 Dark grey and grey albitite, from Takahashi
3. Sample no. 20 White and grey albitite, from Takahashi
4. Sample no. 16 Ditto.
5. Sample no. 1 Light grey albitite from Takahashi
6. Ditto White albitite from Takahashi
7. Ditto Dark grey albitite from Takahashi
8. Sample no. 16 Grey albitite from Takahashi
9. Sample no. 10 White albitite from Takahashi
10. Sample no. 17 Pale grey albitite from Takahashi
11. Sample no. 8 White and pale grey albitite from Takahashi
12. Sample no. 4 Albitite of various colors, from the same locality.

Chemical composition of the albitite from several other localities in the area which was previously given by the Research Institute, is cited below for comparison.

Table 4. Chemical composition of the albitite from several other localities in the area.

	Kotaki	Takahashi	School	Natsunaka	Chausu*
SiO_2	63.68	72.40	69.92	68.37	67.14
Al_2O_3	21.94	15.03	17.50	21.19	16.65
Fe_2O_3	0.39	2.55	1.13	1.42	2.84
CaO	3.68	2.10	1.64	3.27	2·57
MgO	tr.	0.36	1.71	1.20	1.10
K_2O	0.44	none	tr.	none	tr.
Na_2O	10.21	8.40	3.69	10.00	10.65
Ig. loss	0.69	0.31	0.41	0.69	0.49
Total	100.97	101.45	101.34	101.98	101.44

(Analyst: Asahi Glass Company)

* Data given by Prof. S. Nagai of the Technical Faculty, Tōkōy University.

Fig. 9 in which the normative composition of the albitite is plotted in Ab-An-Q diagram indicates that the largest part of the albitite is characterized by the composition ranging from about An_{12} to An_4. (Table 5) Three albitites represented by numbers 3, 8, and 10 are exceptionally higher in normative content of anorthite molecule, evidently because of the higher content of zoisite in the rock.

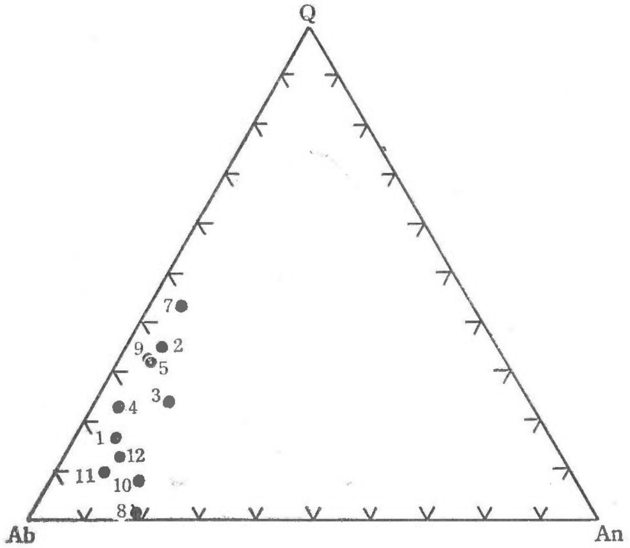


Fig. 9 Normative values of felsic components of the albitite from Kotaki District, as plotted in Q-Ab-An diagram.

The scarcity of zoisite which rarely exceeds one percent in volume, as well as of mica which seldom comprises more than two percent of the rock suggests that the normative feldspathic composition may be regarded to be practically coincident to the actual composition of the albite in the rock.

Table 5. The normative composition of the albite in the rock.

Nos.	1	2	3	4	5	6	7	8	9	10	11	12
Ab%	90	90	83	93	11	89	96	81	12	82	90	88
An%	10	10	17	7	9	11	4	19	8	18	10	12

The numbers 1~12 are the same as those of the Table 3.

The average content of anorthite molecule in the albite from three kinds of albitite of different colours is as follows:

	An%
White albitite	10
Grey albitite	9
Dark grey albitite	7

Albite and jadeite from the albitite

To see the critical character of the albite from the albitite, some optical constants of the mineral from several specimens were determined. The following results were obtained: (Table 6)

Table 6. Refractive indices and optical axial angle of albite.

	White albitite	Grey albitite	Diopside bearing grey albitite	Albite with dark veinlets
α	1.530	1.531	1.530	1.532
γ	1.547	1.544	1.541	1.545
2V	82°(+)	82°(+)	79°(+)	84°(+)

By plotting the optical data on the diagram given by F. Chayes,[9] O.F. Tuttle and N.L. Bowen,[8] who gave the relation of γ and 2V to chemical composition respectively, in low and high temperature plagioclase, it was revealed that the albite in the rock belongs to the low temperature form. (Fig. 10)

The optical data of the jadeite from the albitite was found to be similar to that from the jadeite rock formerly reported by Y. Kawano[3] and K. Omori,[4] as shown in the next table. Table 7)

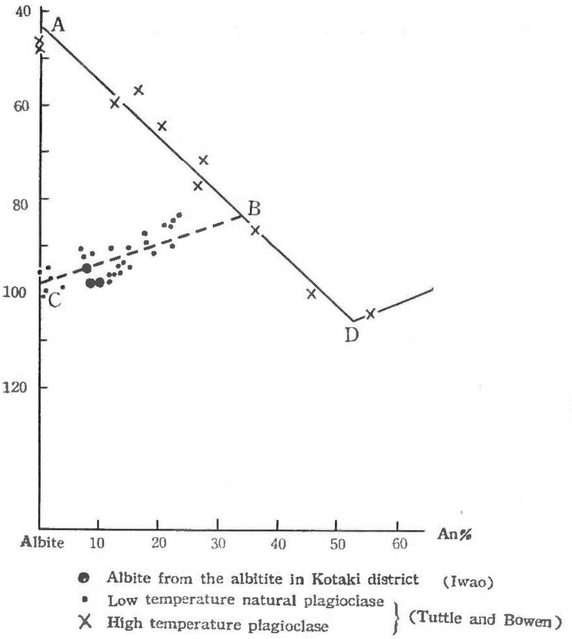


Fig. 10 Optic axial angle of albite from the analyzed albitite in Kotaki District, plotted in the digram given by O. F. Tuttle and N.L. Bowen.

Table 7. Chemical and optical properties of the jadeite from Kotaki district

	Jadeite from jadeite rock		Jadeite from albitite	
	green	white	associated with quartz	associated with analcime
SiO_2	58.02	58.35		
Al_2O_3	22.96	23.90		
Fe_2O_3	0.77	0.66		
FeO	0.18	0.08		
MgO	1.70	0.78		
CaO	1.58	0.98	n.d.	n.d.
Na_2O	12.38	12.55		
K_2O	0.16	0.12		
$+H_2O$	0.87	1.24		
$-H_2O$	0.61	0.67		
TiO_2	0.04	0.04		
MnO	0.01	0.00		
	99.28	99.37		
α	1.658		1.651～1.652	1.651
β	1.663		n.d.～n.d.	n.d.
γ	1.673		1.670～1.669	1.670
2V	—		74°(+)	72°(+)
$c \wedge Z$	33°		—	—

Genesis of the albitite and associated rocks

In discussing the genesis of the albitite and associated rocks including the jadeite bearing rocks in the area, the following are the most important to be brought to mind.

1. Geological occurrence of the host serpentine.
2. Cataclastic and protoclastic texture of the rocks including the host serpentine.
3. Outlined form of the albitite.
4. Mineral sequence in the rock.
5. Coexistence of albite, quartz, and jadeite as well as of analcite.

As above mentioned in this paper, the serpentine in this area which encloses the albitite and associated jadeite bearing rocks seems to have intruded the country rock during the Mesozoic along several thrust or sheared zones from a comparatively great depth in the earth's crust. There is no evidence of high temperature contact metamorphism around the serpentine mass, inspite of it being of peridotite origin. The mass had the form of having been squeezed out through the shattered and weak portions of the crust to be emplaced in the present position.

Prevalence of sheared or brecciated textures in the rock supports this consideration, which is suggested by many similar examples of chromite deposits in serpentine.

We can find no critical evidence to show that all of the albitite masses formed in their present positions.

Perhaps, some of the albitite might have been suspended following its solidification, in the upward flow of the mobilized peridotite with intersticial hydrous liquor which converted olivine to serpentine(15) and also anhydrous minerals to the hydrous minerals in the albitite.

Microscopic features of the albitite clearly suggest that the crystallization of albite, quartz, jadeite and diopside was followed by brecciation and forming of actinolite, phlogopite, muscovite, zoisite or analcite, plus crystallization of a small fraction of quartz and albite from the last residual solution.

Brecciation of albitite as well as of jadeite bearing rock took place during the course of their crystallization. That the brecciation of the rock was not of post complete consolidation is shown by the lack of cataclastic features in the wall rocks of serpentine.

Sequence of mineral formation as established from the microscopic relations as well as from the concentric manner of zonal arrangement in the jadeite-albitite, which is as follows:

$$\left.\begin{array}{l}\text{Albite}\\ \text{Jadeite}\\ \text{Diopside}\end{array}\right\}\rightarrow \text{quartz}\rightarrow\left\{\begin{array}{l}\text{actinolite}\\ \text{anthophyllite}\end{array}\right\}\rightarrow\left\{\begin{array}{l}\text{mica}\\ \text{zoisite}\\ \text{prehnite}\\ \text{analcite}\end{array}\right.$$

The diagram shows the general trend of crystallization shifting to the more hydrous and low temperature side.

In this sequence, the crystallization of albite, jadeite, diopside, and quartz seems to have taken place continuously without any remarkable time gap. The low temperature hydrous minerals were formed during the middle or later stage of shattering of the rock. This might be taken as indicating that the hydrous solution rose along the slip planes or cracks in the mostly solidified jadeite bearing quartz-albite rock.

Coexistence of albite, quartz, and jadeite in some specimens is worthy of special attention as pointed out by H. S. Yoder,[12] because such can not be the case under equilibrium conditions. It is well explained by the preliminary diagram of the system $CaMgSi_2O_6$–$NaAlSiO_4$–SiO_2 after Schairer, unpublished and cited by Yoder,[12] which shows the stability relations of the minerals. In some particular case, neverthless, that crystal of diopside-jadeite composition, in the course of its crystallization from a liquid of composition represented by point A is partly removed from the equilibrium system, and it may be possible that the composition of liquid is shifted to the SiO_2 side as represented by point B and jadeite is added to the albite-quartz association in the final solidified product. Another possible explanation is suggested by Fermor for the formation of jadeite from albite: albite=jadeite+quartz. The consistent increase of SiO_2 content in some jadeite bearing albitite from jadeitic margin to quartzose core, however, seems to support the idea of partial accumulation of jadeite in the homogeneous liquid of equilibrium of jadeite-albite composition, during the course of crystallization. (Fig. 11)

Analcime which is found as an intersticial substance between jadeite crystals along with actinolite fiber might be regarded either as a later product from the residual liquid in an environment sufficient in water with respect to analcite, or as a secondary product after jadeite.

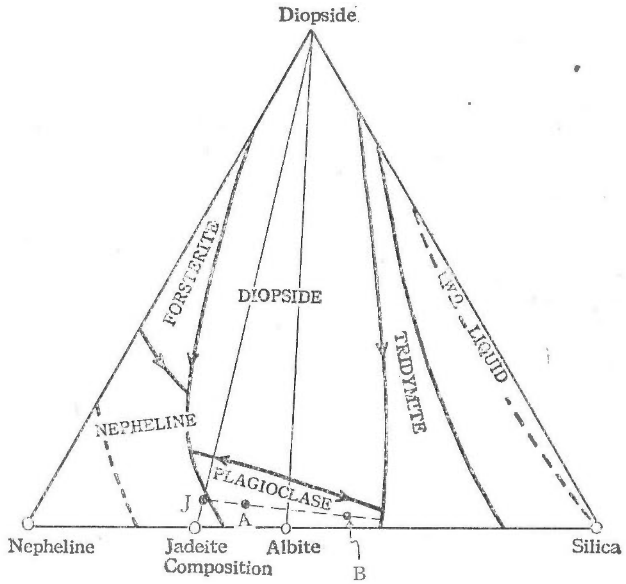


Fig. 11 The position of two different mineral associations in rocks represented by point A (jadeite-albite association) and B (jadeite-albite-quartz association) are shown respectively, in the diagram established by Schairer; the jadeite in the latter being regarded as removed away from the equilibrium in the course of crystallization.

This may be taken as consistent with the result of hydrothermal treatment of synthetic glass of jadeite composition performed by Yoder[12] and Schairer, in which either analcine, nephelite, analcite-nephelide-albite or nepheline-albite were formed.

With respect to grossularite and hydrous wollastonite which are found in albitite from Gamahara, we could find no additional petrographic evidence to be taken in consideration of genesis.

Occurrence of actinolite or talc schist surrounding the mass of albitite or jadeite-albite rock suggests the introduction of a hydrous siliceous solution along the contact of the hard albitite mass and the host serpentine along which the fracturing and shearing took place most intensely.

From the above, the following mode of formation of the albitite and associated rocks may be infered.

1. Serpentine is mostly of peridotide origin and probably intruded the earth's crust in a mobilized mush state, with hydrous liquor filling the interstices of the crystal aggregates of olivine.
2. The albitite mass comprising jadeite-albite blocks enclosed in the serpentine was formed as a residual representative of a certain

basic magma from which the peridotite was formed, and was brought to the present position from depth.

3. Brecciation and deformation of the albitite and its associated rocks happened either during the emplacement of serpentine or after the partial solidification of the rocks.
4. The most intense fracturing and shearing took place at the contact of the serpentine with the included albitite mass, along which hydrous fluids entered.
5. The hydrous fluids are considered to have formed minerals such as actinolite, phlogopite, muscovite, zoisite, prehnite and analcite lining the fractured or sheared planes in albitite as well as in jadeite-albitite, and also to have converted peridotite to serpentine and further to talc schist.

The above mentioned mode of formation of the rocks in the area shows some similarity to that in San Benito County, but there is no critical field evidence either to suggest that the jadeite was formed after the emplacement of serpentine was accomplished or to prove that all of the jadeite masses were carried upward from depth enclosed in the mobilized peridotite during its emplacement following the solidification of the albitite.

Economic Importance

The jadeite rock in this district will probably not yield excellent gem material, because it is not only very small in quantity, but also not deep in green colour.

The albitite, however, is of high-quality for two ceramic uses: i. e. (1) as raw material for special low-alkali glass, and (2) as raw material for glazing of porcelain wares.

With respect to the first use, the abstract cited from the paper written by B. Yoshiki and R. Yoshida[10] explains the reason for utilizing the albitite as follows: "The research was performed with a view to manufacturing of a new chemical ware glass with no boric oxide content, and has successfully obtained a glass composition which contains little alkali and nevertheless easily melts, by means of ternary melting diagram of albite-diopside-wollastonite. This low alkali glass shows little difference in practical melting and workability from ordinary borosilicate hard glass. Its water resistivity is even higher. Production of this glass on an industrial scale has been accomplished by utilizing natural rocks yet unexploited and no soda ash at all" The authors, in addition, pointed out that the albitite from the Kotaki district, one of many soda rich natural rocks in Japan, produces the most superior characteristics in the glass, because it contains much soda as its alkali components. It is also adequate for exploitation by reason of its large ore reserve.

In the next table, the chemical composition of the low alkali-glass with its physical properties given by B. Yoshiki[10] is cited, together with the chemical composition of the albitite which was used for making the glass.

	Albitite	Glass	Physical properties of the glass	
SiO_2	63.83	67.11	Devitrification temp.	950°C
Al_2O_3	21.94	12.62	Softening temp.	710°C
Fe_2O_3	0.34	0.14	Annealing temp.	560°C
CaO	3.63	9.61	Specific gravity	2.512
MgO	tr.	3.25	Expansion coeff. ($\times 10^{-6}$)	6.4
MnO	n.d.	—	Specific heat (mean)	0 256
K_2O	0.09	none	Thermal durability d= 5mm	160°C
Na_2O	10.21	7.63	Thermal durability d=10mm	141°C
Ig. loss	0.69	n.d.	Thermal durability d=15mm	134°C
Total	100.73	100.36		

(cited from Rept. Asahi Glass Comp. vol. 1, no. 1[10])

The ore reserves of the albitite deposits as estimated by the writer are as follows:

Table 8. The ore reserves of the albitite deposits from Kotaki district

Locality	Ore reserve (metric tons)
1. Takahashi	69,000
11. Nishino-sawa	1,300
2. Natsunaka primary school	24,000
3. West of Natsunaka village	500
4. In the valley, west of Natsunaka	300
6. Yokokawa	14,000
7. Chausu-tunnel	5,500
8. Gamahara	400
9. Usagi-iwa	2,700
10. In the valley, south-west of Natsunaka	2,600
5. Kotaki-gawa	150
Total	120,450 (about 120 thousand metric tons)

Above the level of river floor.

Of these deposits, about 95 thousand metric tons from Takahashi and Natsunaka seem to be adequate to exploitation. They are very accessible and could be exploited by open cut mining with monthly production of more than about 300～400 metric tons.

Acknowledgment

The writer expresses his cordial thanks to the staff of the Research Institute of the Asahi Glass Company, especially to Dr. B. Yoshiki, who gave him much useful advice during the course of his study and also through whose kindness, the writer could use the unpublished data of chemical analysis of the albitite carried out by the analyst for the Institute. He also wishes to acknowledge the encouragement given to him and the critical reviewing of his paper played by Mr. T. Mitsuchi, Director, and by Dr. Y. Kawano, Head of Areal Geology Division of the Geological Survey of Japan. He is also indebted to Mr. Charles G. Johnson of the Pacific Geological Surveys Section, U. S. Geological Survey, who kindly reviewed his paper in manuscript.

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PLATES

AND

EXPLANATIONS

Plate. I Muscovite flakes of secondary forming in albite crystals.
(crossed nicols, ×200) photo. by Y. Masai, 1952

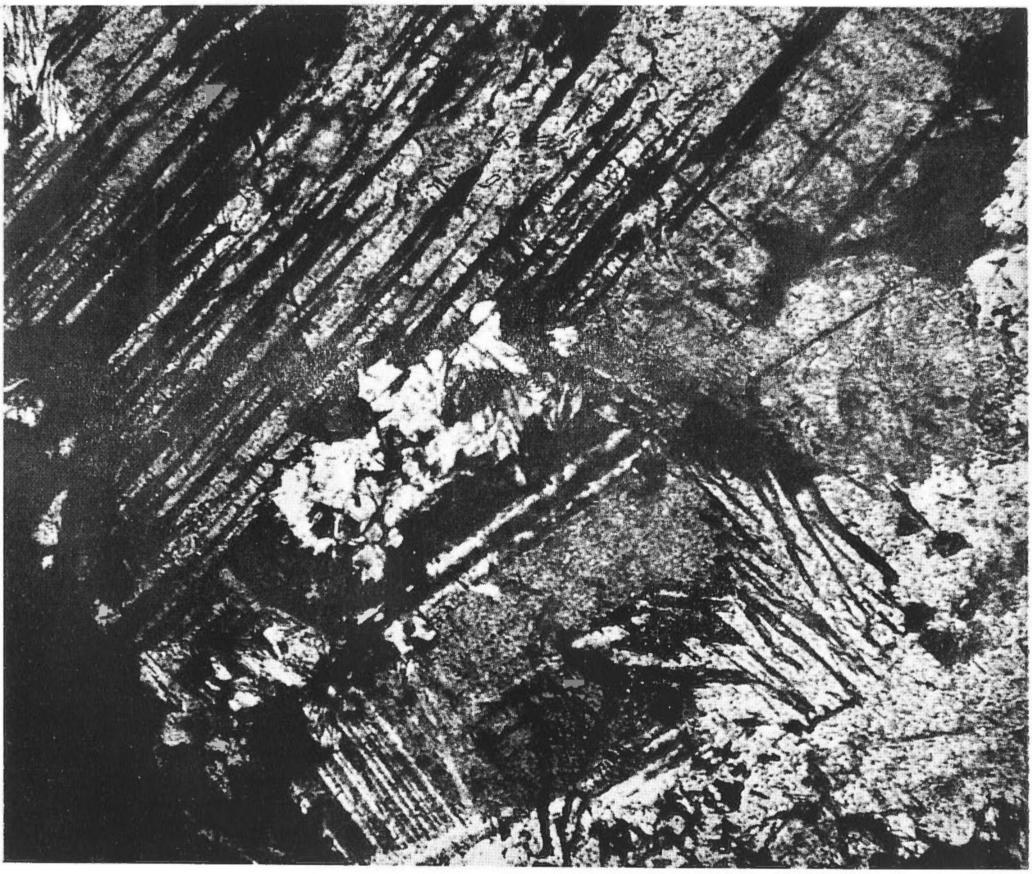

Plate. II Coarse grained albitite, free from cataclustic texture, showing distinct twinning lamellae after albite and pericline law; Central white area is muscovite. (crossed nicols, ×50) photo. by I. Sunagawa, 1952

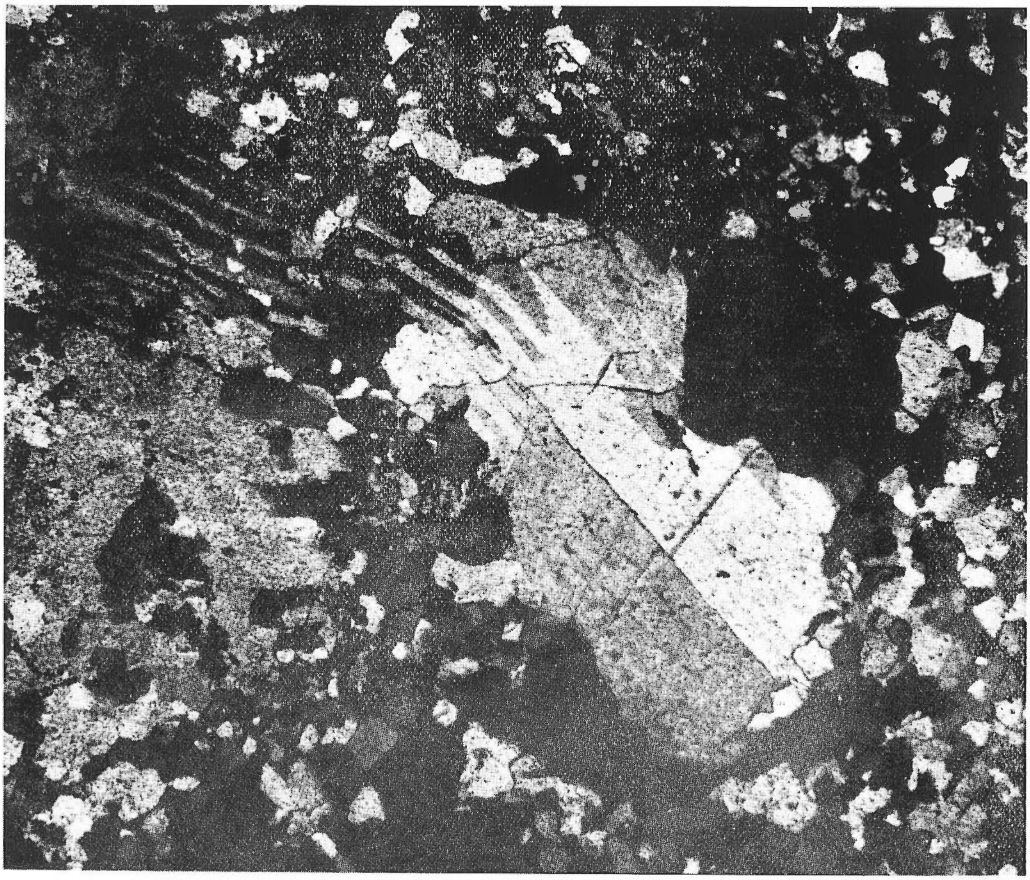

Plate. III Diopside bearing fine grained albitite (no. 45) nearly free from brecciation with minor faults in albite crystals. (crossed nicols, ×20) photo. by I. Sunagawa, 1952

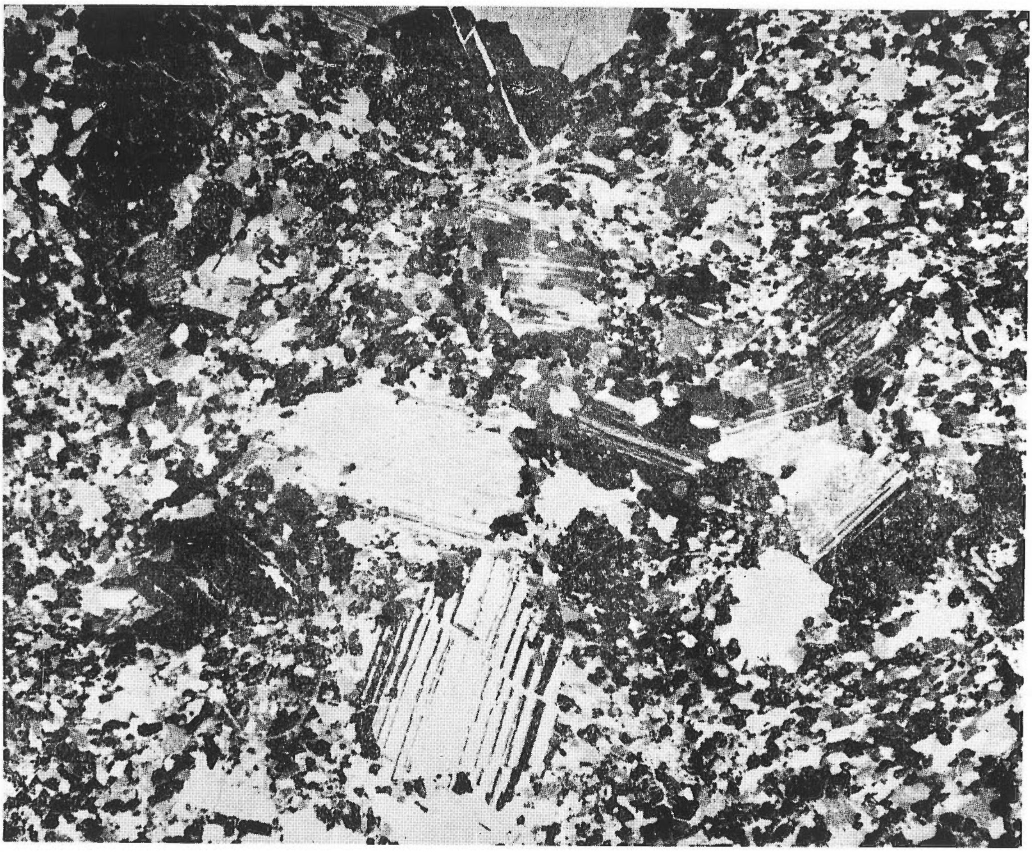

Plate. IV Modertely brecciated albitite, cemented by recrystallized matrix.
(crossed nicols, ×20) photo by I. Sunagawa, 1952

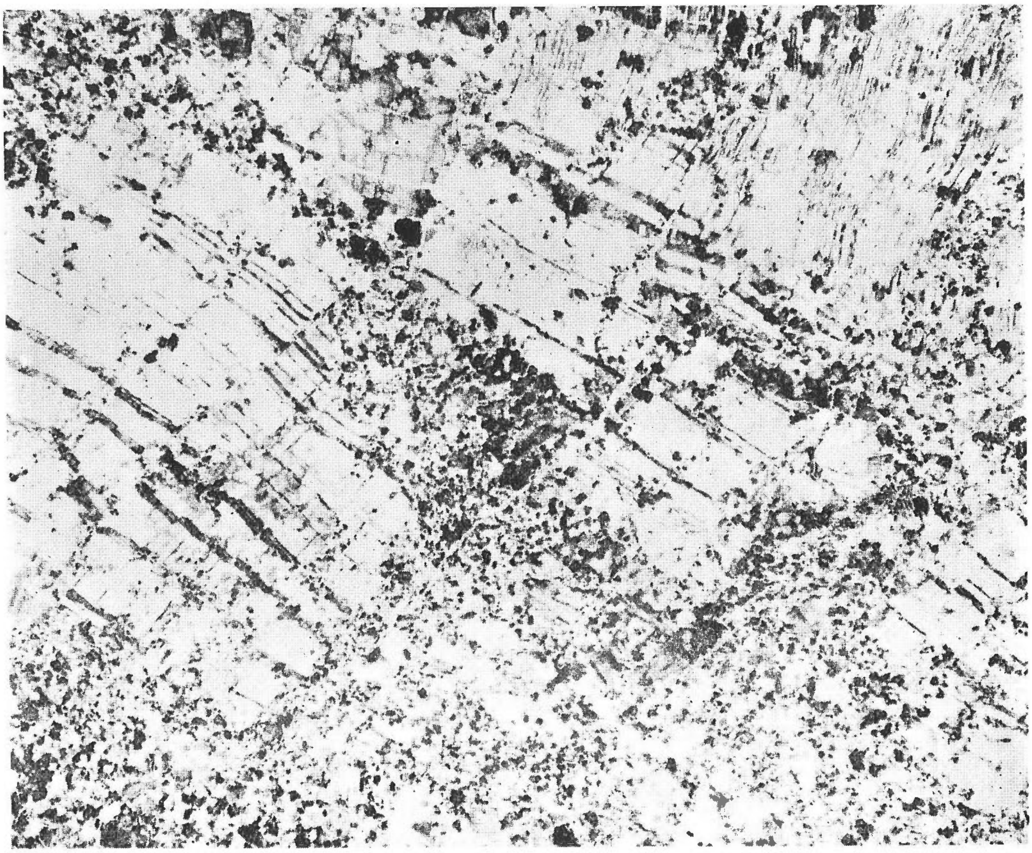

Plate. V Coarse grained albitite moderately brecciated, Notice the manner of deformation and brecciation of albite crystals. (crossed nicols, ×20) photo by I. Sunagawa, 1952

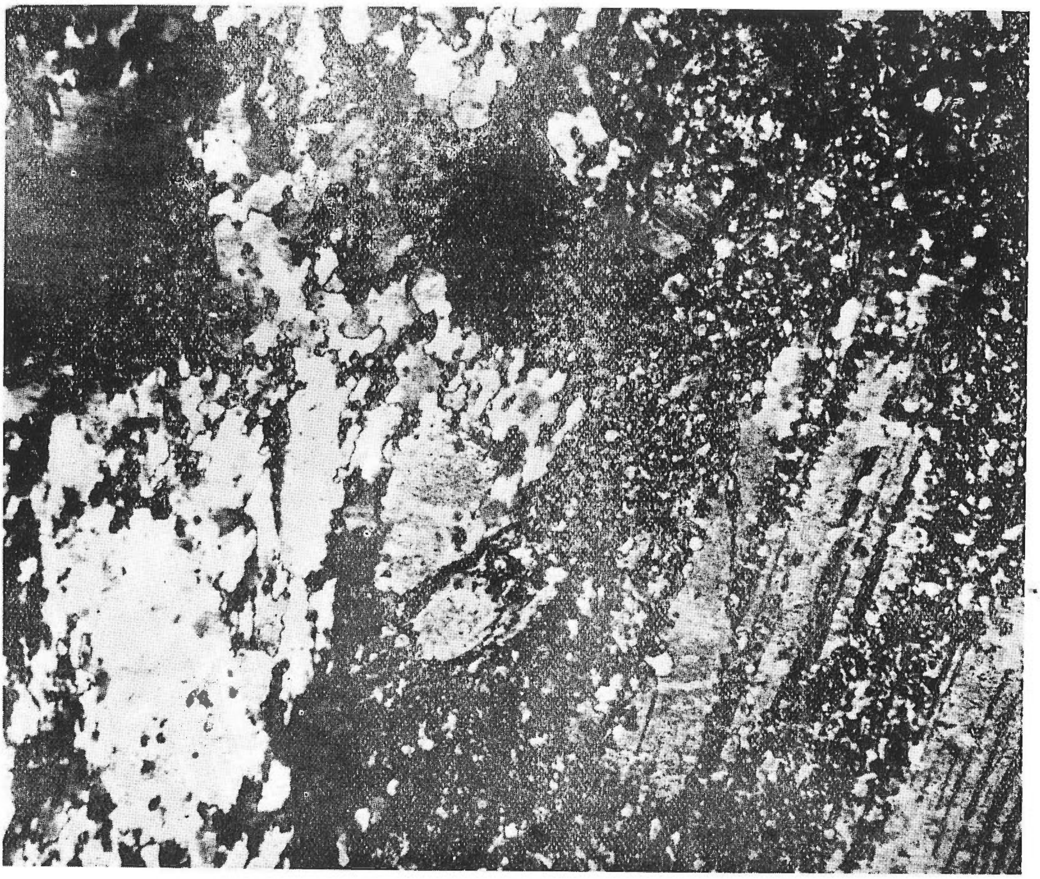

Plate. VI Extremely crushed coarse grained grey albitite from Usagi-iwa. Notice wavy extinction and flow texture of quartz, brecciated albite and partly recrystallized matrix. (crossed nicols, ×50) photo by I. Sunagawa, 1952

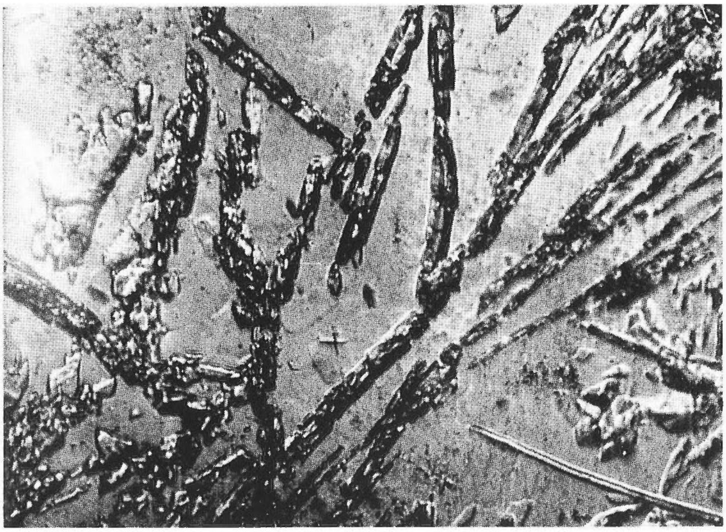

Plate. VII Radial crystal aggregates of zoisite, newly formed in albite crystals. (polarizer only, ×350) photo. by Y. Masai, 1952

要　　約

新潟県小滝産のアルビタイトおよびこれに伴うヒスイについて
——窯業原料の研究——

岩　生　周　一

小滝産アルビタイトは窯業原料として近時新しい用途が発見されており，その産出は特に注目されている。また，1939年河野義礼によつてわが国で初めて報告されたこの地産のヒスイは，従来その産状が余り詳らかでなかつたが，筆者の調査によつて蛇紋岩中のアルビタイトの周辺相として発達していることが明らかになつた。野外および顕微鏡下の観察によれば，このアルビタイトとヒスイとはともに蛇紋岩の原岩漿の残液に由来する産物であつて，少なくともそのある部分は固結後または固結しつつ，地殼変動に伴つて逆入して流動化された蛇紋岩に包まれて，もまれながら地下深所から現在の位置にもたらされたものと推定される。産状はおおむねビルマやカリフォルニヤのものに似ているが，ヒスイと石英とが共存することは特異な点である。

小滝産のヒスイは鉱量も少なく，色調も深みに乏しくそれ程有望なものとは思われないが，アルビタイトは鉱量12万tに達し，吉木文平等によつて考察された低アルカリガラスの原料などとして極めて適切な資源である。

なお，このアルビタイトの曹長石は低温型に属する。

The Geological Survey of Japan has published in the past several kinds of reports such as the Memoirs, the Bulletin, and the Report of the Geological Survey.

Hereafter all reports will be published exclusively in the Report of the Geological Survey of Japan. The Report will be consecutive to the numbers of the Report of the Imperial Geological Survey of Japan hitherto published. As a general rule each issue of the Report will have one number, and for convenience's sake, the following classification according to the field of interest will be indicated on each Report.

A. Geology & allied sciences
- a. Geology.
- b. Petrotology and Mineralogy.
- c. Palaeontology.
- d. Volcanololgy and Hotspaing.
- e. Geophysics.
- f. Geochemistry.

B. Applied geology
- a. Ore deposits.
- b. Coal.
- c. Petroleum and Natural Gas.
- d. Underground water.
- e. Agricultural geology. Engineering geology.
- f. Physical prospecting. Chemical prospecting & Boring.

C. Miscellaneous

D. Annual Report of Progress

Note: In addition to the regularly printed Reports, the Geological Suavey is newly going to circulate "Bulletin of the Geological Survey of Japan," which will be published monthly commencing in July 1950.

本所刊行の報文類の種目には従来地質要報・地質調査所報告等があつたが，今後はすべて刊行する報文は地質調査所報告に収めることとし，その番号は従来の地質調査所報告を追つて附けることにする。そして報告は1報文につき報告1冊を原則とし，その分類の便宜のために，次の如くアルファベットによる略号を附けることにする。

A 地質およびその基礎科学に関するもの
- a. 地　質
- b. 岩石・鉱物
- c. 古生物
- d. 火山・温泉
- e. 地球物理
- f. 地球化学

B 応用地質に関するもの
- a. 鉱　床
- b. 石　炭
- c. 石油・天然ガス
- d. 地下水
- e. 農林地質・土木地質
- f. 物理探鉱・化学探鉱および試錐

C その他

D 事業報告

なお刊行する報文以外に，当分の間報文を謄写して配布したものに地下資源調査所速報があつたが，今後は地質調査所月報として第1号より刊行する。

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