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WOLLASTONITE AND ASSOCIATED MINERALS FROM MOJI, KITA-KYUSHU CITY

by

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(with 5 text-figures)

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Abstract

Recently wollastonite was found in the crystalline limestone pebbles in the thermally metamorphosed conglomerate near Moji. It is associated with salite, vesuvianite, prehnite, and calcite. Optical properties, cell constants, X-ray diffraction data and chemical compositions of wollastonite and salite are given. Brief consideration on the genesis is also mentioned.

Introduction

During the course of the field study in the Kiku Peninsula near Moji, Kita-Kyushu City, the authors found a new occurrence of wollastonite in the crystalline limestone pebbles in the conglomerate of the Cretaceous formation. Mode of occurrence and mineralogical description of the wollastonite and the associated minerals are given in the present paper.

Geological sketch

The locality of the wollastonite is situated in the northern part of the Kiku Peninsula. The geology of this area was first studied by Takehara (1937), and later by Hase (1960) and Oota (1960). The specimen for the present study was collected from the basal conglomerate of the lower part of the Kwanmon Group (Inkstone Series) (Matsumoto, 1951), correlated to the Wakino Subgroup (Oota, 1960) of the lower Cretaceous formation. The strata are unconformably underlain by the Paleozoic formation, composed of shale, sandstone (grey-wacke), chert, schalstein and limestone. Of these *Heterocrinidae*-bearing schalstein from Aohama has been well-known as "Baika-seki" (plum-blossom stone) because of the presence in the dark-colored matrix of radial aggregates of calcite crystals replacing the fossils (Okamoto, 1956). Red

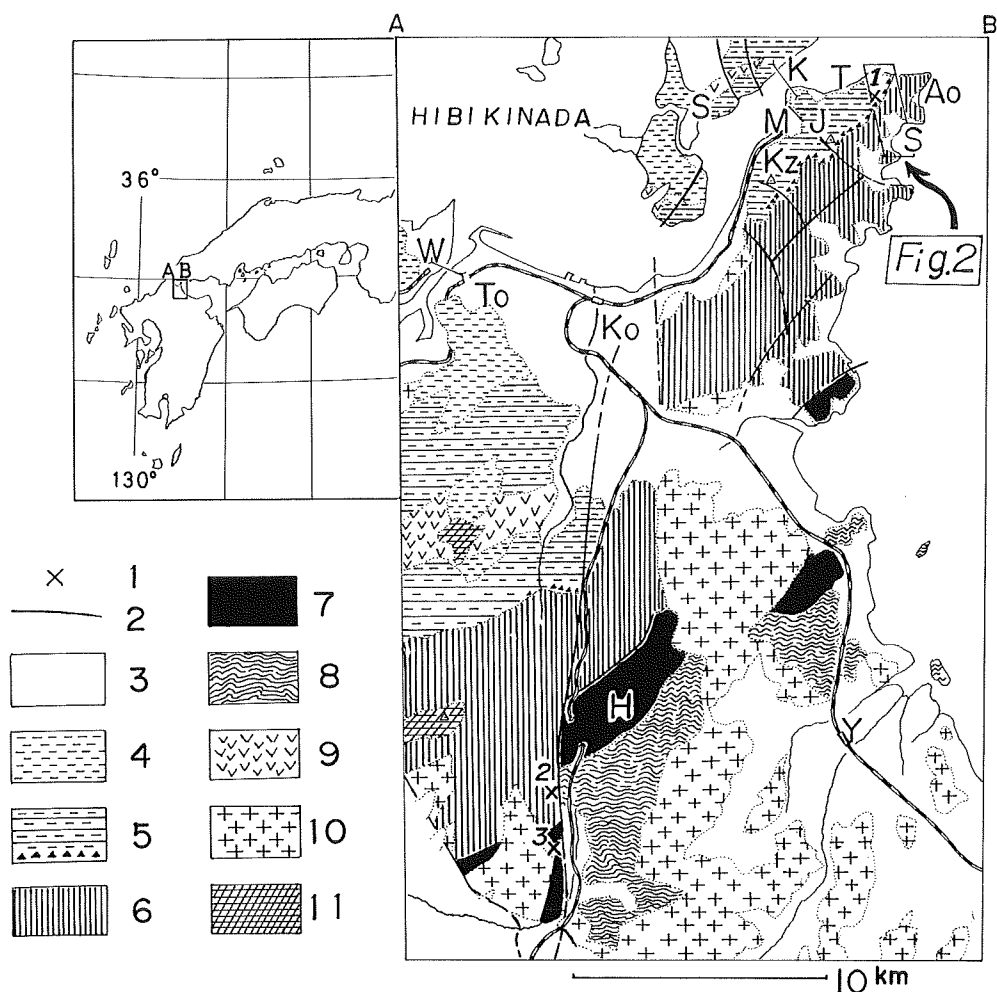


Fig. 1 Left: Index map of the locality. AB shows the upper side of the geological sketch map (right).

Right: Geological sketch map of the Kiku Peninsula and its southern environs.

Legend: 1. Some localities of excellent wollastonite crystals, including the present one, 1: Moji 2: Kiku Mine, Taniguchi, Kawara-Machi, Tagawa-Gun. 3: Between Sannotake and Ninotake, both being included in Kawara-dake, Kawara-Machi.

2. Fault

3. Post-Mesozoic

4. Shimonozeiki Subgroup } Kwanmon Group

5. Wakino subgroup }

6. Chichibu System

7. Limestone in Chichibu System

8. Sangun Metamorphics

9. Porphyrite, quartz-porphyrite

10. Granodiorite, diorite

11. Hornblendite, lamprophyre

K: Kwanmon Bridge	W-To: Wakato Bridge
S: Shimonoseki	M: Moji Port
T: Tanoura Port	Ao: Aohama
S: Shiranoe	J: Jari-yama
Kz: Kazashi-yama	Ko: Kokura, Kitakyushu City
H: Hirao-dai	Y: Yukuhashi City

chert, characteristic to the Chichibu Formation of the Japanese Paleozoic is also well exposed at Noedani (Fig. 1).

The lower Cretaceous basal conglomerate is composed mainly of limestone pebbles, and some shale and sandstone debris, all of which are cemented by siliceous shale matrix. At the gorge of Kanayama, 2.5 km southwest of the locality, fusulina was found in the limestone pebbles of the basal conglomerate, and *Triticites simplex* (Schellwien) (?), *Triticites cfr. tantula* Toriyama and *Neoschwagerina donvillei* Ozawa were identified.

Mode of occurrence

All sedimentary rocks in the vicinity of the present locality are thermally metamorphosed, probably by the intrusion of the granite porphyry exposed to the east, though the direct contact was not observed in the field (Fig. 2). Wollastonite is found in crystalline limestone pebbles included in the basal conglomerate, developed only within a restricted small area. Wollastonite can be easily identified by its pure white color and vitreous luster on the well-developed cleavage planes. It is cemented by calcite and other associated minerals, such as salite, vesuvianite and prehnite.

Microscopic observation

Wollastonite forms colorless, euhedral to subhedral, elongated crystals or platy crystals, always exhibiting well-developed cleavages. Sometimes it occurs completely surrounded by calcite (Fig. 3). The optic properties are determined as follows:

α	1.619 ± 0.001	2V(—)	40°
β	1.631 ± 0.001	c $\wedge$ X	30°
γ	1.634 ± 0.001		
γ - α	0.015		

Optic orientation is shown in Fig. 4.

Salite is not distinct in the sample to the naked eye, but is always present,

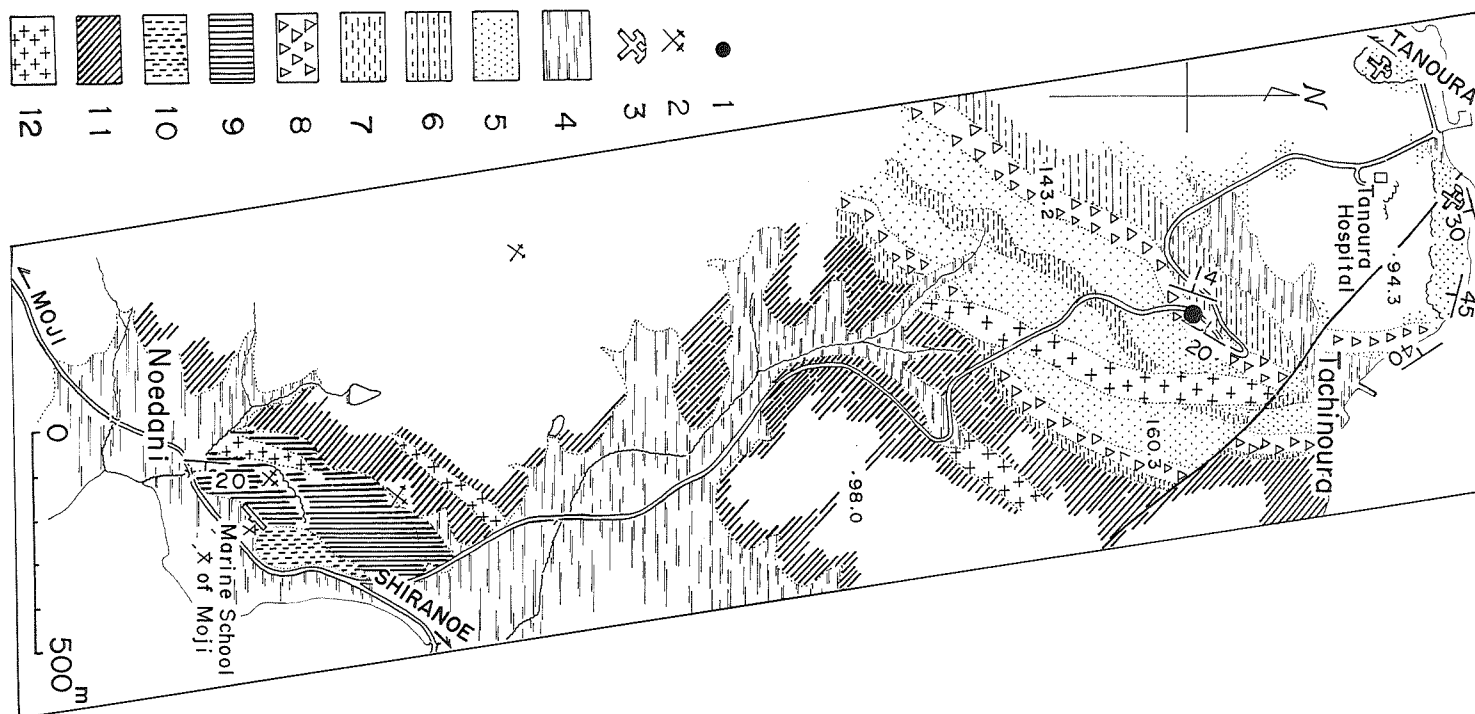


Fig. 2 Route map from Ta-noura Hospital to Noedani, Moji-ku, Kitakyushu City

Legend.

- | | |
|---|--|
| 1: Locality of wollastonite | 7: Brownish red tuff, frequently serves as a key bed |
| 2: Locality of clay for cement industry use | 8: Conglomerate, breccia, ill-sorted. |
| 3: Quarry for concrete material | 9: Red chert, Chichibu System |
| 4: Alluvials | 10: Graywacke-black shale association in the Chichibu System |
| 5: Sandy tuff, greenish gray | 11: Chichibu System, shale, hornstone, schalstein etc. |
| 6: Felsic tuffaceous shale with white spots, in which actinolite or pyrite is aggregated in some cases. | 12: Granite porphyry, quartz porphyry. |
| | 5-8: Wakino Subgroup |

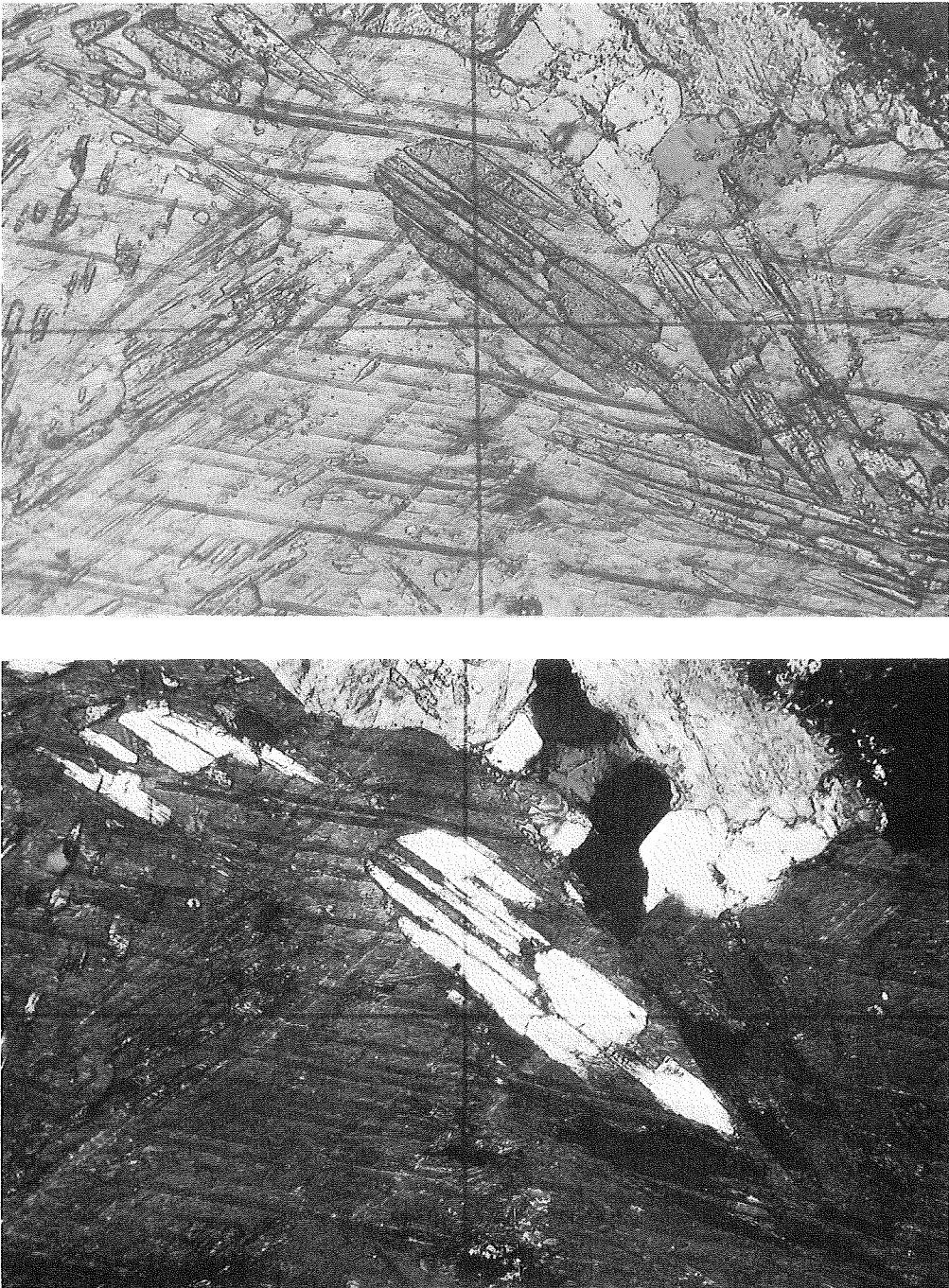


Fig. 3 Photomicrograph: wollastonite lamellae enclosed in calcite crystals. Upper: Open nicols, Lower: Crossed nicols.

0.1 mm

intimately associated with wollastonite. It forms fine grains, euhedral to subhedral, more or less granular in shape. Almost colorless or very pale brownish or greenish in tint. Not pleochroic. Polysynthetic twinning on (100) is well-developed in some crystals. From the optic properties given below the mineral is identified as salite.

α	1.681 ± 0.001	$2V(+)$	$60^\circ \sim 62^\circ$
β	1.690 ± 0.001	$c\Delta Z$	$42^\circ \sim 43^\circ$
γ	1.712 ± 0.001		
$\gamma-\alpha$	0.031		

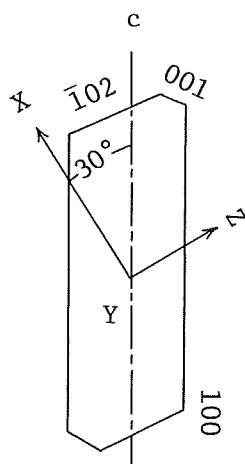


Fig. 4 Optic orientation in wollastonite.

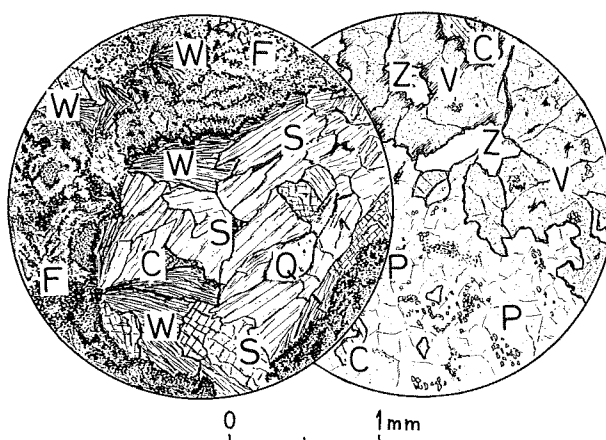


Fig. 5 Microscopic sketches:

W: Wollastonite	Q: Quartz
S: Salite	Z: Zeolite
V: Vesuvianite	F: Fine-grained aggregates
P: Prehnite	of various minerals in rock
C: Calcite	fragments

Vesuvianite is common, forming rectangular or rhomboidal crystals, with shagreen surface. Uniaxial, negative. Slightly pleochroic: X: pale brownish yellow and Z: pale gray to pale brownish yellow. The mineral can easily be distinguished by its extremely high refractive indices and very low birefringence.

Prehnite occurs as subhedral or anhedral crystals, and is characterized by high refractive indices and moderate birefringence. $2V(+)$ $61^\circ \sim 67^\circ$, and straight extinction. Cleavages are poor. It includes many minute grains of salite.

Zeolite occurs rarely as anhedral, colorless crystals. Straight extinction and uniaxial negative, and both refractive indices and birefringence are very low. Cleavages are poor. From these features the zeolite is identified probably

chabazite.

Allanite is only rarely found, forming minute prismatic crystals. Pleochroism is distinct: X: pale reddish brown Z: deep reddish brown. Often the crystal is heterogeneous in color due to metamict phenomenon.

Quartz is common as granular crystals.

X-ray data of wollastonite and salite

X-ray diffraction data obtained on these two minerals on the condition: CuK α 35KV, 20mA, scanning speed 1/2 degree per minute, are given in Tables

Table 1 X-ray diffraction patterns of wollastonite

hkl	(1)		(2)	
	d	I	d	I
200	3.83	100	3.84	31
$\bar{2}01$	} 3.51	59	} 3.52	5
002				
$\bar{1}02$	3.31	99	3.32	55
210	} 3.08	48	3.09	8
102			3.09	42
$\bar{2}20$	} 2.97	46	2.98	100
120			2.98	99
112	2.72	29	2.72	1
300	2.55	51	2.56	10
202	} 2.475	20	2.479	11
$1\bar{2}2$			2.476	11
022			2.475	12
003	} 2.342	25	2.346	8
$\bar{2}22$			2.340	3
$\bar{1}\bar{2}2$	2.335	18	2.338	3
$\bar{1}03$	2.301	34	2.306	27
221	2.182	8	2.183	20
302	1.980	12	1.982	8
400	} 1.917	28	} 1.922	5
$2\bar{1}3$				2
004	1.758	32	1.759	17
$\bar{1}04$	1.753	21	1.752	5
$\bar{4}22$	1.722	13	1.722	8
$\bar{3}22$	1.717	15	1.719	8
$3\bar{2}4$	1.361	11	1.363	3
$\bar{4}24$	1.343	10	1.343	1
$\bar{3}\bar{2}4$	1.340	10	1.342	1

(1) Present work

(2) Buerger and Prewitt (1969)

Table 2 X-ray diffraction patterns of salite

hkl	(1)		(2)	
	d	I	d	I
220	3.20	62	3.23	25
$\bar{2}21$	3.00	100	2.99	100
310	2.97	86	2.95	27
$\bar{3}11$	2.90	30	2.89	39
$\bar{1}31$	2.57	25	2.56	25
$\bar{2}02$	2.53	64	2.53	2
330	2.163	33	2.155	11
$\bar{3}31$	2.136	42	2.132	21
$\bar{4}21$	2.111	28	2.107	10
041	2.047	16	2.041	21
$\bar{4}02$	2.103	17	2.014	13
331	1.870	8	1.860	2
510	} 1.845	13	1.836	7
222			1.831	3
150	1.760	36	1.753	15
$\bar{5}31$	} 1.630	26	1.625	16
$\bar{2}23$			1.624	19
600	1.571	17	1.563	4
350	1.556	17	1.550	5
531	1.432	28	1.423	20
$\bar{3}52$	1.412	28	1.409	11

(1) Present work

(2) Diopside from Gouverneur, N.Y. Clark et al. (1969)

1 and 2, compared with the standards. The correspondence is fairly good in salite, but some discrepancy in the intensity is noticed in the case of wollastonite. The reason for this is not clear.

The unit cell dimensions of the two minerals are given below:

Wollastonite

a	$7.931 \pm 0.007 \text{ \AA}$
b	$7.341 \pm 0.014 \text{ \AA}$
c	$7.061 \pm 0.004 \text{ \AA}$
α	$89.92^\circ \pm 0.09^\circ$
β	$95.41^\circ \pm 0.06^\circ$
γ	$103.61^\circ \pm 0.10^\circ$

Salite

a	$9.780 \pm 0.004 \text{ \AA}$
b	$8.960 \pm 0.003 \text{ \AA}$
c	$5.296 \pm 0.006 \text{ \AA}$
β	$105.40^\circ \pm 0.05^\circ$

Preparation of the sample for analysis

The method for obtaining pure sample for chemical analysis may warrant a brief description. First the hand specimen was crushed and wollastonite-rich

fragments were hand-picked. They were crushed again and ground in an agate mortar and washed with water. Small amounts of heavy minerals were removed by panning on a wooden pan. Then the mixture of various minerals were separated in the heavy liquids by means of a centrifugal elutriation with separator tubes. Heavy liquids used were mixtures of CH_2I_2 - CCl_4 with specific gravity, ranging from 2.75 to 3.0, and the separation was carried out repeatedly.

Wollastonite was collected as floated materials in the heavy liquid with S.G. of 3.0. The last separation was carried out in the medium of pure di-methylene iodide with S.G. of 3.32, and salite was obtained as precipitate.

Samples of wollastonite and salite thus obtained amounted to 1.43 gr and 0.45 gr, respectively. When examined under the microscope the impurity in wollastonite was estimated to be about 3~4%, since very minute grains of associated minerals such as salite, prehnite or vesuvianite, could not be completely eliminated in the present procedure. The sample of salite had less impurity than wollastonite. The procedure is schematically shown in Table 3. Specific gravity of wollastonite and salite measured by a pycnometer is 2.92, and 3.37, respectively.

Chemical composition

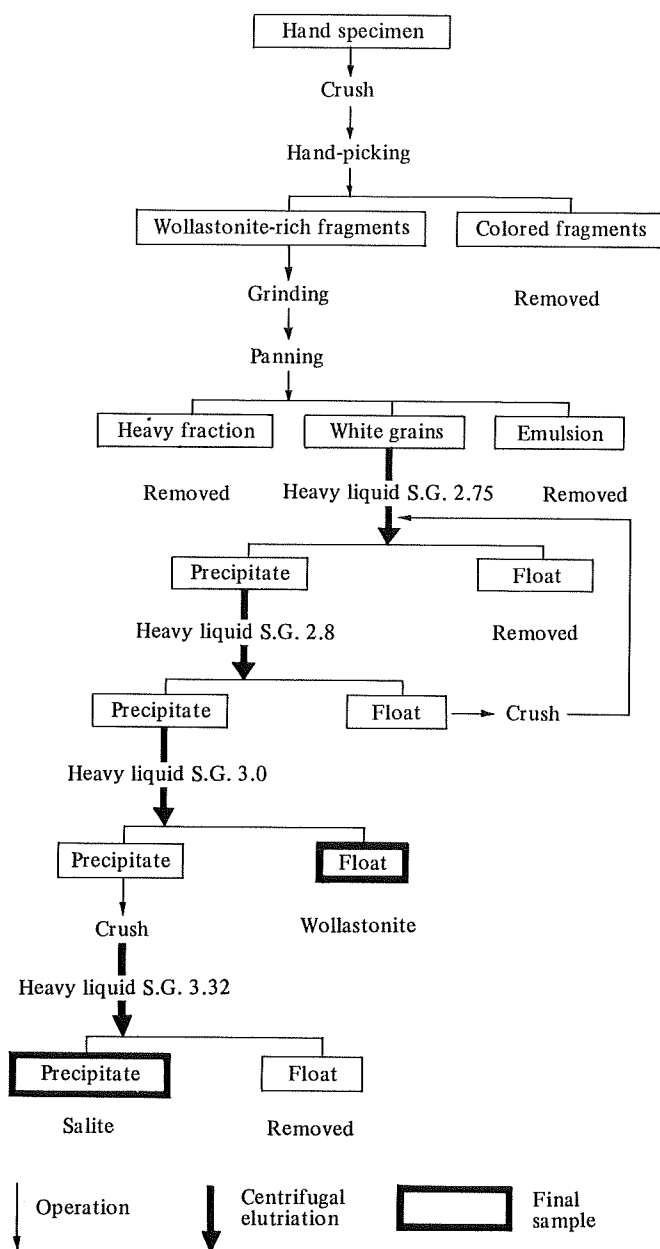
Chemical composition of wollastonite and salite by wet chemical method is given in Table 4, together with wollastonite from Hôkizawa, Kanagawa Prefecture (Kamiyama and Katayama, 1934). It is noted that CaO is slightly low, and Al_2O_3 is fairly high, while Fe-oxides and MgO are moderate. This is probably due to the presence of minute inclusions of some Al-bearing minerals such as vesuvianite or prehnite. Consequently in the atomic ratios on the basis of $\text{O} = 6.000$, XY is 1.979 against $\text{Z} = 2.000$. Pyroxene molecules of salite calculated from the composition are

Wo 51.9, En 29.0, Fs 19.1 mol %.

Genetic consideration

The mineral assemblage of wollastonite + salite + vesuvianite indicates that these minerals are the products of the contact metamorphism of the impure limestone with the invading granite porphyry. Presence of prehnite is interesting, since the mineral generally occurs either as metamorphosed products of limestone or as vein-filling hydrothermal products. In the present case the texture indicates that prehnite was probably formed in the later stage of the contact metamorphism, but not in the hydrothermal stage. On the other

Table 3



hand, zeolite is interpreted to have deposited in the hydrothermal stage within the cavities in vesuvianite or other minerals.

Table 4 Chemical composition of wollastonite and salite

	1	2	3	1-a		3-a	
SiO ₂	51.47	50.50	50.94	Si 1.981	2.000	1.944	2.000
TiO ₂	0.08	n.d.	0.50	Al 0.096		0.080	
Al ₂ O ₃	2.11	0.40	1.78	Ti 0.002		0.014	
Fe ₂ O ₃	0.13	tr.	0.82	Fe ³⁺ 0.004	1.979	0.023	0.968
FeO	0.56	n.d.	10.54	Fe ²⁺ 0.018		0.336	
MnO	0.09	n.d.	0.30	Mn 0.003		0.010	
MgO	0.33	0.40	9.85	Mg 0.019	6.000	0.561	6.000
CaO	44.40	48.08	24.58	Ca 1.831		1.005	
Na ₂ O	0.27	n.d.	0.34	Na 0.020		0.025	1.035
K ₂ O	0.10	n.d.	0.10	K 0.005	6.000	0.005	
H ₂ O	n.d.	0.45	n.d.	O 6.000		6.000	
Total	99.54	99.83	99.75				

1 Wollastonite from Moji. Analyst: S. Kanisawa.

2 Wollastonite from Hokizawa. Analyst: T. Kamiyama (Kamiyama and Katayama, 1934).

3 Salite from Moji. Analyst: S. Kanisawa.

1-a Atomic ratio of wollastonite from Moji.

3-a Atomic ratio of salite from Moji.

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