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Note on rock-forming minerals in the Joetsu district, Niigata Prefecture, Japan. (10) Pectolite from the Omi district.

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ABSTRACT

Pectolite, which is one of pyroxenoids, occurs as needle-like crystals in the albitite and serpentinite at the Kinzan valley, Omi, Niigata Prefecture. The pectolite is very pure in chemical composition. Pectolite coexists with albite, Mg-riebeckite, wollastonite and quartz. The coexisting pectolite and wollastonite suggest that it crystallized at about 400℃ during serpentinization. In the present study, the chemical composition and the physical properties of the pectolite are reported. The structural formula is $Ca_{4.00}\ Mn_{0.01}\ Fe_{0.01}\ Na_{1.98}\ H_2\ Si_{6.00}\ O_{18}$. The space group is $P\bar{1}$, and unit cell parameters are a=7.994(2) Å, b=7.039(5) Å, c=7.020(2) Å, α=90.34(5)°, β=95.25(3)° γ=102.65(5)° and V=383.7(3) Å^3.

KEY WORDS

Kinzan valley, Omi, Pectolite, Pyroxenoid, Riebeckite, Wollastonite

Introduction.

Pectolite occurs in basic igneous rocks (Wilshire 1967) and serpentinite (Harada 1934, Coleman 1961). Pectolite is found in a very pure state. Schaller (1955) reported that bivalent manganese can replace calcium in the structure. There is a complete range of specimens ranging from pectolite through manganoan pectolite to serandite. The structure of pectolite with space group $P\bar{1}$ was determined precisely by Buerger (1956).

Pectolite from the Omi-Kotaki is already reported by Seki et al. (1963) and Chihara (1987). Seki et al. (1963) described that pectolite coexisting with some of albite, chlorite, epidote, actinolite and grossularite was found as a constituent mineral of Paleozoic sediment, gabbro, albitite and jadeite-bearing rock included within serpentinite. However,

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they did not report the occurrence of the pectolite coexisting with wollastonite, and the chemical and physical properties of pectolite. In the present study, we give the occurrence, the chemical composition and the physical properties of pectolite from the Omi district.

Occurrence

Pectolite is found in the boulders of serpentinite and albitite from serpentinite cliff at the Kinzan valley. Pectolite occurs in the cavity of albitite (Fig. 1a), and occurs as milk-white vein in the boulder of serpentinite (Fig. 1b). It also forms as fibrous-radiating aggregates in the border zone of albitite within a serpentinite (Fig. 1c). Sometimes a milk-white vein of pectolite penetrated another vein in serpentinite (Fig. 1d).

Under the optical microscope, fine-grained pectolite crystals (KinPec-1) up to 0.1mm in length and green needle-like shaped Mg-riebeckite are found in albite (Fig. 2a). Fig. 2b shows the aggregate of fine fibrous pectolite in serpentinite (KinPec-2). On the other

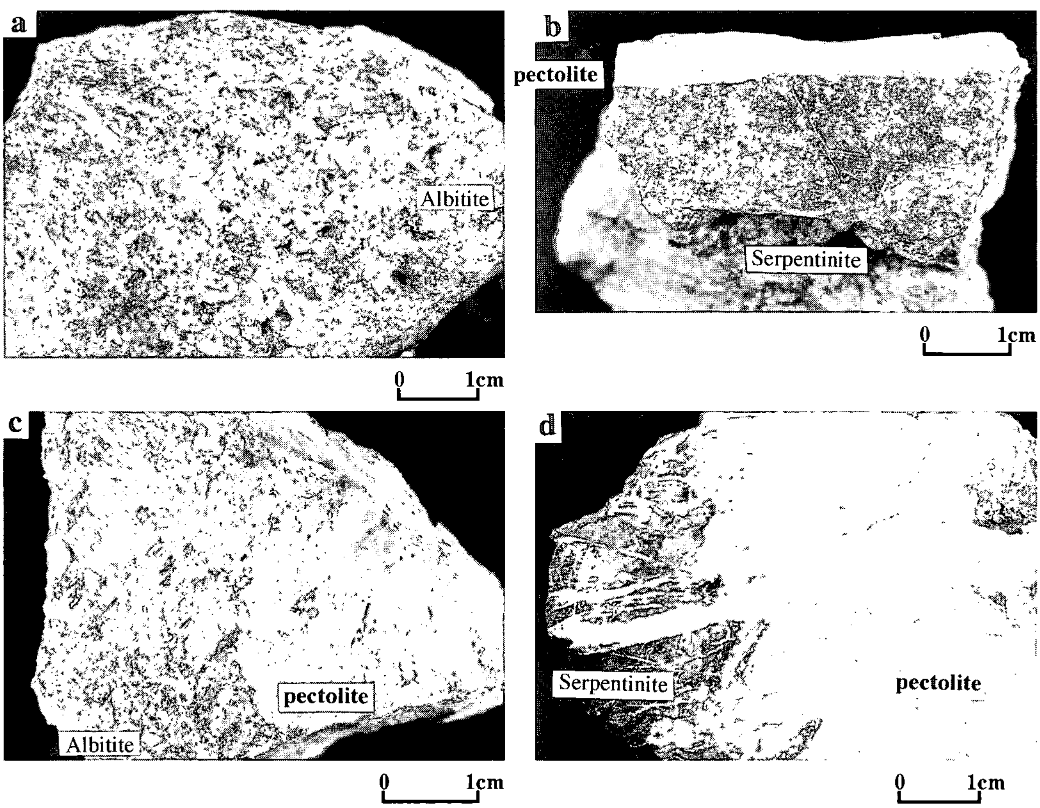

Figure 1. Photographs of the pectolite and albitite xenolith in the serpentinite from the Omi-Kotaki district. a: Pectolite is found in the cavity of albitite. b: Pectolite occurs as milk-white vein in serpentinite. c: Pectolite forms as fibrous-radiating aggregates on the surface of albitite. d: A milk-white vein of pectolite penetrates into another vein.

hand, a medium-grained prismatic pectolite (KinPec-3) coexists with small amounts of albite on the surface of albitite (Fig. 2c). Fibrous aggregates of pectolite (KinPec-4) associate with fibrous wollastonite in milk-white vein in serpentinite (Fig. 2d).

Mineralogical data and Discussion

X-ray analysis: The X-ray powder diffraction data for pectolite are listed in Table 1. Only KinPec-5 pectolite is measured by the Guinier-Hägg camera (Philips XDC-1000) at Gunma University. The unit-cell parameters were obtained from the sharp reflections with asterisk by using silicon as an external standard. Calculation was made on the computer program UNICS RSLC-3 (Sakurai 1968). The results given in Table 2 show that these unit-cell dimensions for four pectolites from the Omi district are in agreement with those of pectolite reported by Prewitt (1967) for comparison. For example, the unit cell parameters of KinPec-2 are a=7.994(2) Å, b=7.039(5) Å, c=7.020(2) Å, α=90.34(5)°, β=95.25(3)° γ=102.65(5)° and V=383.7(3) Å^3. The unit-cell dimensions supported that the pectolite is close to the end member of pectolite.

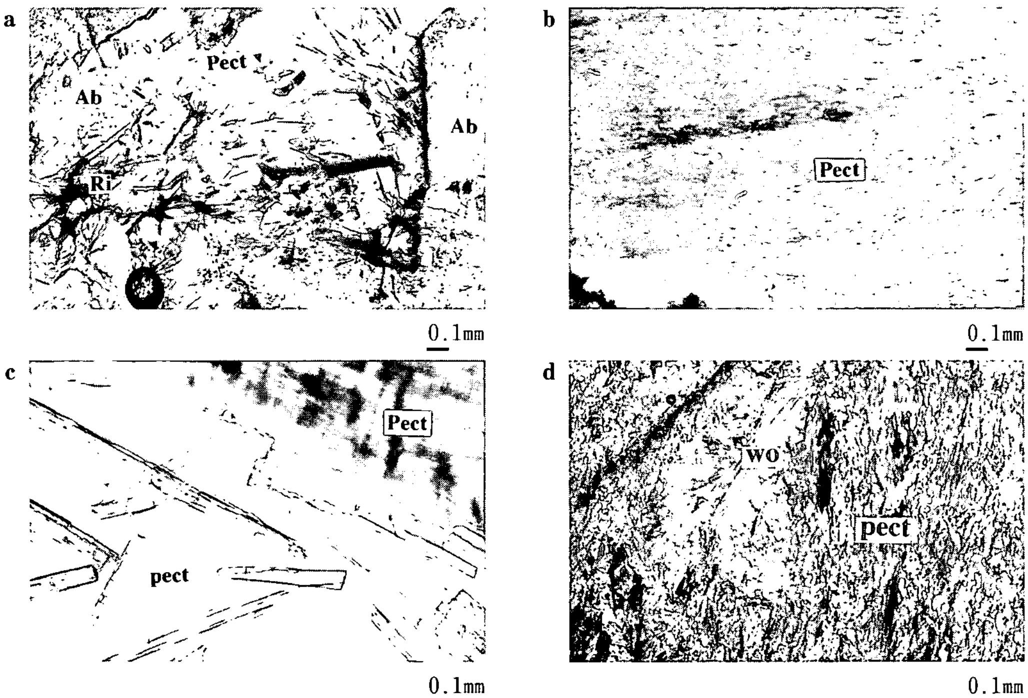

Figure 2. Photomicrographs of the pectolite in the serpentinite from the Omi-Kotaki district.
a: Fine-grained pectolite crystals and green needle-like Mg-riebeckite are formed in albite. b: Fine fibrous aggregates of pectolite. c: a medium-grained prismatic pectolite coexists with small amounts of albite. d: Fibrous aggregates of pectolite coexists with fibrous wollastonite. Ab: albite, Pect: pectolite, Ri: riebeckite, Wo: wollastonite.

Table 1. X-ray powder data of pectolites.

			KinPec-2			KinPec-3			KinPec-4			KinPec-5			Prewitt (1967)	
H	K	L	d(obs)	d(cal)	I/Io	d(obs)	d(cal)	I/Io	d(obs)	d(cal)	I/Io	d(obs)	d(cal)	I/Io	d(obs)	I/Io
1	0	0	7.78*	7.76	6	7.78*	7.76	5	7.72*	7.76	15				7.77	6
0	0	1	7.00*	6.99	15	7.00*	6.99	10	7.00*	6.99	9	7.01*	7.00	10	6.99	7
$\bar{1}$	0	1	5.47*	5.46	12	5.46*	5.45	9	5.45*	5.46	14	5.46*	5.46	5	5.46	6
2	0	0	3.884*	3.882	28	3.879*	3.878	24	2.882*	3.879	56	3.883*	3.884	10	3.882	14
0	0	2		3.494		3.494*		28	3.502*	3.497	25	3.499*	3.498	25	3.497	13
$\bar{2}$	1	1		3.417		3.412*	3.412	3		3.414		3.410*	3.410	3	3.412	8
$\bar{1}$	0	2	3.307	3.306	73	3.305	3.305	47	3.308*	3.307	76	3.308*	3.309	40	3.307	30
2	0	1		3.264		3.263*	3.264	51	3.262*	3.264	81	3.267*	3.267	25	3.266	25
0	$\bar{1}$	2	3.147*	3.148	13	3.150*	3.151	8	3.147*	3.148	14	3.152	3.154	5	3.154	20
1	0	2	3.080*	3.078	100	3.079*	3.080	100	3.080*	3.080	100	3.082	3.082	50	3.081	53
$\bar{1}$	$\bar{1}$	2	2.906*	2.901	28	2.904*	2.902	13	2.904*	2.902	26	2.908*	2.907	100	2.907	3
$\bar{2}$	2	0		2.909			2.907			2.903			2.904		2.906	100
$\bar{2}$	0	2	2.729*	2.729	30	2.726*	2.727	17	2.726*	2.729	31	2.731*	2.731	15	2.730	19
3	0	0	2.587*	2.588	29	2.585*	2.585	22	2.585*	2.586	73	2.589*	2.589	10	2.588	14
0	$\bar{2}$	2		2.482		2.482*	2.484	2	2.478*	2.480	10				2.487	1
1	$\bar{2}$	2		2.429			2.432			2.427		2.433*	2.432	3	2.434	9
2	2	0	2.328*	2.329	13	2.328*	2.328	8	2.330*	2.328	13	2.332*	2.336	5	2.333	11
0	0	3		2.329			2.330			2.331					2.331	5
$\bar{1}$	0	3	2.292*	2.291	36	2.290*	2.292	27	2.292*	2.293	39	2.294*	2.294	30	2.293	18
$\bar{3}$	0	2		2.181		2.178*	2.178	6	2.181*	2.180	19	2.182*	2.182	3	2.181	6
3	$\bar{2}$	1		2.165			2.164		2.161*	2.161	11	2.165	2.166	5	2.164	19
0	3	1		2.157		2.158*	2.157	4		2.156					2.518	4
$\bar{2}$	0	3		2.086		2.086*	2.085	3		2.087					2.087	2
$\bar{2}$	1	3	2.044	2.051	18		2.049			2.051		2.041	2.050	3	2.050	4
3	0	2	1.991*	1.991	9	1.989	1.991	5		1.991					1.992	4
$\bar{4}$	1	0		1.986			1.983		1.985*	1.983	8				1.985	4
$\bar{1}$	2	3	1.940	1.941	9	1.940*	1.940	3	1.939	1.942	9				1.939	1
$\bar{4}$	0	1	1.918*	1.917	7	1.916	1.915	5	1.916*	1.916	12				1.918	3
1	$\bar{2}$	3		1.872			1.874			1.872					1.877	4
2	2	2		1.874			1.874		1.876*	1.875	6				1.875	4
2	$\bar{3}$	2		1.835			1.836			1.832		1.840	1.836	1	1.837	3
3	1	2		1.824		1.824*	1.824	5	1.825*	1.824	14				1.826	3
$\bar{1}$	4	0		1.759			1.759			1.757		1.757	1.760	40	1.760	17
0	0	4	1.747*	1.747	16	1.746	1.747	11	1.747*	1.748	18	1.749*	1.749	10	1.748	8
1	3	2		1.746			1.745			1.746			1.749		1.747	1
$\bar{2}$	$\bar{2}$	3		1.712		1.714	1.713	3	1.713*	1.712	9	1.720	1.713	3	1.716	10
$\bar{4}$	2	2	1.710*	1.708	6		1.706			1.707		1.706	1.705	3	1.706	10
1	0	4	1.670*	1.670	6	1.670	1.671	5	1.671*	1.672	6	1.672*	1.673	1	1.672	3
$\bar{2}$	0	4	1.654*	1.653	7	1.653	1.652	7	1.654*	1.653	10	1.655	1.654	1	1.654	4
$\bar{4}$	0	3	1.566*	1.566	7	1.564*	1.564	3		1.565					1.566	5
1	$\bar{2}$	4	1.548	1.547	7	1.549*	1.549	3	1.547*	1.547	11				1.550	3
5	0	1	1.486*	1.486	7	1.485*	1.485	7	1.485*	1.485	18	1.487*	1.487	5	1.487	7
1	2	4	1.460*	1.460	6	1.458	1.460	2	1.457	1.462	8				1.461	7
5	0	2	1.372*	1.371	7	1.370	1.371	5	1.371*	1.371	9				1.372	5

Table 2. Unit-cell parameters of pectolite.

	a Å	b Å	c Å	α °	β °	γ °	V Å^3
KIN-2	7.994(2)	7.039(5)	7.020(2)	90.34(5)	95.25(3)	102.65(5)	383.7(3)
KIN-3	7.984(5)	7.038(5)	7.023(3)	90.44(4)	95.16(5)	102.62(7)	383.3(4)
KIN-4	7.985(4)	7.029(5)	7.026(2)	90.30(4)	95.24(4)	102.56(5)	383.2(3)
KIN-5*	7.987(1)	7.039(1)	7.028(1)	90.48(8)	95.19(1)	102.33(1)	384.2(3)
Pectolite**	7.988	7.040	7.025	90.52	95.18	102.47	

*measured by the Guinier-Hägg camera.
**Prewitt (1967)

Infrared absorption spectra: The infrared absorption spectrum of pectolite are measured with a furier transform infrared spectrometer (FT/IR-350) at Joetsu University of Education. The result is given in Table 3 and Fig. 3. The infrared absorption bands of pectolite in the present study are in agreement with the bands reported by Ryall and Threadgold (1966). The characteristic band of OH bending mode for pectolite at 1397 cm^{-1} is observed.

Chemical composition: The chemical compositions of pectolite were determened with a JEOL 8060 superprobe, using standard procedure at Niigata University. EPMA analyses of pectolites are given in Table 4 together with their structural formulae, calculated on the basis of 17 oxygen atoms. They are the average compositions of

Table 3. Frequencies of absorption maxima of pectolite.

Band Assigment	present study	Ryall and Threadgold (1966)
(Si-O-Si)	530m	532m
stretching	644s	644m
	670s	671m
(Si-O)	860m	
	903s	903vs
stretching	925sh w	925s
	972sh w	972sh, w
	997m	998s
	1032sh w	1030sh, w
	1060sh w	1044vs
(OH)	1397m	1395m
bending		1610w
and	3420w	3400w
stretching		

Band intensity; vs: very strong, s: strong, m: medium, w: weak, sh: shoulder on a stronger band.

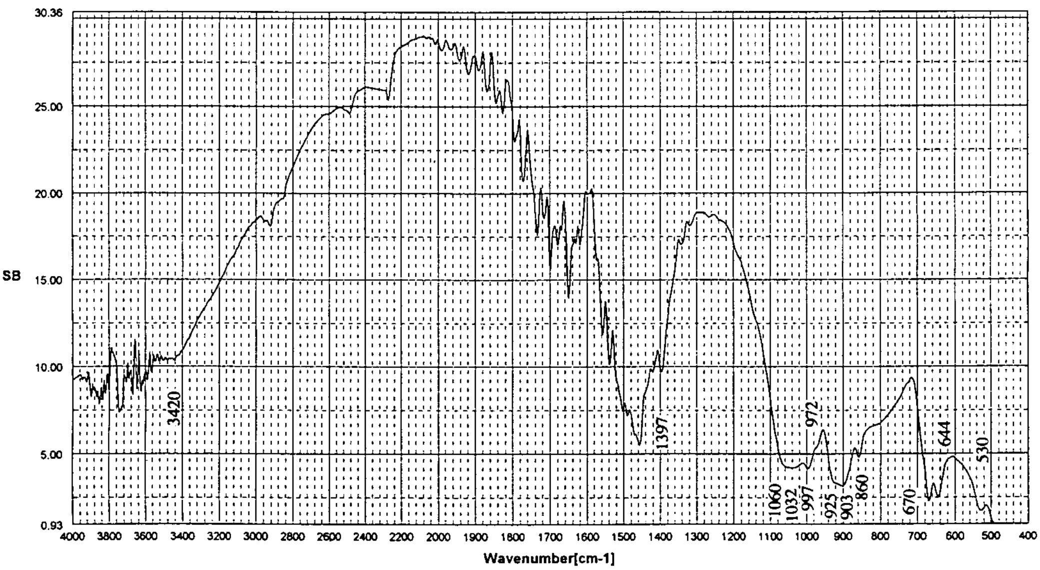

Figure 3. Infrared absorption spectra of pectolite from the Omi district.

Table 4. Chemical compositions and formulae of pectolite and coexisted minerals.

	KinPec-1		KinPec-2	KinPec-3		KinPec-4	
	pect	pl	pect	pect	pl	pect	wo
SiO_2	54.29	69.12	54.48	54.77	69.11	54.36	52.21
TiO_2	0.03	0	0	0	0.01	0	0.02
Al_2O_3	0.04	19.43	0	0.01	19.40	0.02	0.03
Cr_2O_3	0.02	0	0.09	0.03	0	0	0.03
FeO	0.18	0.90	0.05	0.45	0.48	0.21	0.18
MnO	0.31	0.01	0.07	0.43	0.04	0.04	0.05
MgO	0.01	0	0	0.04	0	0	0.02
CaO	32.39	tr.	33.89	33.45	0.04	33.98	47.57
Na_2O	7.78	11.49	9.27	8.96	11.99	9.20	0.07
K_2O	tr.	0.01	0	0	0.01	0.01	0.01
Total	96.05	100.96	97.85	98.14	101.08	97.82	100.19
oxygen	17	8	17	17	8	17	6
Si	6.057	2.997	5.996	6.010	2.994	5.989	2.011
Al^{IV}		0.993			0.991		
Al^{IV}	0.005		0	0.001		0.003	
Ti	0.003	0	0	0	0	0	0.001
Cr	0.002	0	0.008	0.003	0	0	0.001
Mg	0.002	0	0	0.007	0	0	0.001
Fe	0.017	0.033	0.005	0.041	0	0.019	0.001
Mn	0.029	0	0.007	0.040	0	0.004	0.002
Ca	3.872	0	3.996	3.933	0	4.011	1.963
Na	1.899	0.966	1.978	1.906	1.007	1.966	0.005
K	0	0.001	0	0	0.001	0.001	0.001
Total	11.886	4.990	11.990	11.941	4.993	11.993	3.986
Ca	98.8		99.7	97.8		99.4	
Mn	0.7		0.2	1.0		0.1	
Mg+Fe	0.5		0.1	1.2		0.5	

pect: pectolite, pl: plagioclase, wo: wollastonite

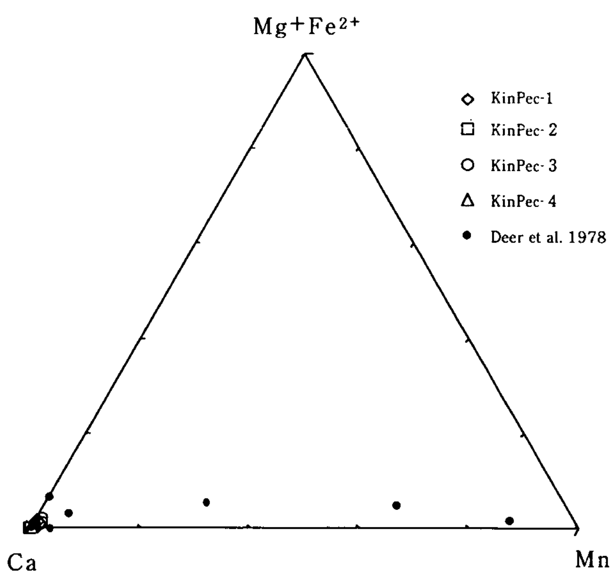

Figure 4. Plots of pectolites in the Ca-Mn-Mg+Fe^{2+} diagram. Solid circles indicate pectolite to serandite quoted by Deer et al. (1978).

several grains. The structural formulae of KimPec-1, KinPec-2, KinPec-3 and KinPec-4 are $Ca_{3.87}$ $Mn_{0.03}$ $Fe_{0.02}$ $Na_{1.90}$ $Al_{0.01}$ H_2 $Si_{6.06}$ O_{18}, $Ca_{4.00}$ $Mn_{0.01}$ $Fe_{0.01}$ $Na_{1.98}$ H_2 $Si_{6.00}$ O_{18}, $Ca_{3.93}$ $Mn_{0.04}$ $Mg_{0.01}$ $Fe_{0.04}$ $Na_{1.91}$ H_2 $Si_{6.01}$ O_{18} and $Ca_{4.01}$ $Fe_{0.02}$ $Na_{1.97}$ H_2 $Si_{5.99}$ O_{18}, respectively. The analyses indicate that all pectolites from four different occurrences in the Omi district are close to the end member of pectolite. In the Ca-Mn-Mg+Fe^{2+} diagram (Fig. 4), all pectolites in the present study are plotted on the corner of Ca. Pectolite, schizolite and serandite listed by Deer et al. (1978) are plotted near the join Ca-Mn and they contain only a very small amount of Mg and Fe^{2+}.

Thilo and Funk (1950) reported on the basis of experiment that pectolite lost water above 400℃ and changed to a mixture of wollastonite, SiO_2 and pectolite. Then, the latter altered to pectolite when heated with water at 200℃. We can use their experimental result to guess the pressure-temperature conditions of crystallization of the pectolite because it is pure on chemical composition. Seki et al. (1963) suggested that the formation of pectolite-bearing mineral assemblage must have been due to high water pressures and/or strong desilication. Therefore, the experimental result and the coexisting pectolite and wollastonite indicate that pectolite from the Omi district crystallized at about 400℃ during serpentinization.

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