THE PECTOLITE-SCHIZOLITE-SERANDITE SERIES*

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Abstract

A study of the pertinent recorded analyses of pectolite, schizolite, and serandite, indicates that they are members of an isostructural series from pectolite ($4CaO \cdot Na_2O \cdot 6SiO_2 \cdot H_2O$ or $Ca_2NaSi_3O_8(OH)$) to serandite ($4MnO \cdot Na_2O \cdot 6SiO_2 \cdot H_2O$ or $Mn_2NaSi_3O_8(OH)$), another example of a series in which calcium and manganese proxy each other. The only recorded analysis of serandite is that of a calcian serandite. Schizolite is a manganoan pectolite and should not be rated as a species.

The specific gravity and indices of refraction for the calcium and for the manganese end members are:

Pectolite, $Ca_2NaSi_3O_8(OH)$, G = 2.86; $\alpha = 1.595$, $\beta = 1.605$, $\gamma = 1.633$.

Serandite, $Mn_2NaSi_3O_8(OH)$, (by extrapolation) G = 3.32; $\alpha = 1.680$, $\beta = 1.682$, $\gamma = 1.705$.

Introduction

The pectolite-schizolite-serandite series is an example of an isostructural series in which bivalent manganese (I.R. 0.80) proxies for calcium (I.R. 0.99) at least to an extent of 77 per cent. The calcite-rhodochrosite series is even more complete for it indicates "complete ionic substitution of Mn^{++} to Ca^{++} in nature." as expressed by Kulp, Kent, and Kerr (1951) or, as stated earlier by Kulp, Wright, and Holmes (1949): "Therefore, it seems that the substitution of Ca^{++} for Mn^{++} is continuous for rhodochrosite to calcite." These conclusions confirm the earlier work of Krieger (1930). The wollastonite-bustamite series is another example in which manganese (plus a little ferrous iron) proxies the calcium in wollastonite to the extent of at least 70 per cent, with retention of the wollastonite structure (Schaller).

The maximum content of MnO+FeO so far found, in a bustamite from Australia, is about 28 per cent MnO with 8 per cent FeO. Several additional bustamites from other localities contain almost as much manganese and iron (Schaller). For axinite the ratio of CaO to FeO+MnO+MgO was formerly held to be constant (Schaller, 1911) but recent studies by Milton, Hildebrand, and Sherwood (1953) show it to be variable.

In rhodonite and pyroxmangite the amount of calcium proxying for manganese is variable but always small. The maximum content of CaO in rhodonite is about 11 per cent (Schaller, 1938, p. 582). The so-called

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"high lime rhodonites" listed in standard reference books are either bustamite, johannsenite, or a mixture of rhodonite and johannsenite (Schaller, 1938, p. 580). In other calcium-manganese minerals, such as inesite (Glass and Schaller, 1939) and johannsenite (Schaller, 1938) the content of CaO is constant and calcium and manganese do not proxy each other.

In all three of the series mentioned in which the proxying of manganese for calcium is complete or nearly so, the almost manganese-free calcium end member is by far the commonest and most abundant. For those series (rhodonite, pyroxmangite) in which the manganese end member is the commonest and most abundant, calcium seems to be always minor in amount.

That serandite, the manganese richest member of the pectolite-

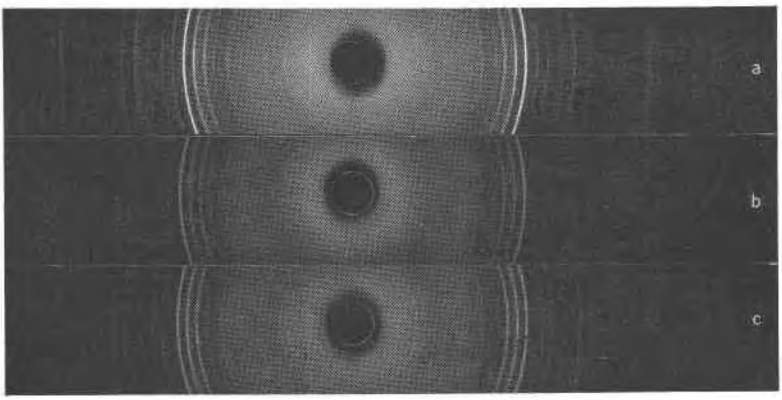

FIG. 1. (*a*) Pectolite; (*b*) Schizolite; (*c*) Serandite.

schizolite-serandite series is a pectolite in which manganese proxies calcium to an extent greater than a 1:1 ratio, was shown by Machatschki (1932). Schizolite is intermediate between pectolite and serandite and the close morphological relationship of the triclinic crystals of schizolite and pectolite was shown by Peacock (1935) and by Ito (1939).

The similarity of the *x*-ray powder patterns of the three minerals is shown in Fig. 1 and the shifts in the positions of the lines in Table 1. Many pectolites contain small quantities of manganese, as well as iron, though it is believed that the MnO content of the manganpectolite from Magnet Cove, described by Williams (1891) and reported to be 4.25 per cent MnO, is much too high, like the MnO and FeO percentages given by him for the wollastonite and natroxonotlite from Potash Sulphur Springs, Arkansas (Schaller, 1950). That the content of MnO in the manganpectolite from Arkansas is not as high as reported is also indi-

TABLE 1. POWDER DATA FOR THE COMPARISON OF PECTOLITE, SCHIZOLITE, AND SERANDITE

Pectolite		Schizolite		Serandite	
d	*I*	*d*	*I*	*d*	*I*
7.83	5	7.73	mw	7.55	ms
7.03	5	6.92	mw	6.75	ms
5.50	5	5.39	mw	5.24	mw
3.90	6	3.85	ms	3.77	ms
3.52	5	3.47	mw	3.38	mw
3.33	6	3.27	ms	3.19	s
3.10	8	3.06	ms	3.00	s
2.92	10	2.89	s	2.85	s
2.74	6	2.69	ms	2.62	ms
2.60	6	2.56	ms	2.51	ms
2.30	6	2.27	ms	2.21	ms
2.17	6	2.15	ms	2.12	mw

s = strong.
ms = moderately strong.
mw = moderately weak.

cated by the value of its specific gravity, namely, 2.845, as given by Williams, which is lower than the specific gravity (2.86) of pectolite free from manganese.

X-RAY PATTERNS

X-ray diffraction patterns of these minerals were taken some years ago by W. E. Richmond, formerly of the U. S. Geological Survey, and more recently by Fred A. Hildebrand.

The specimens for which patterns were obtained, are as follows:

Pectolite from Bergen Hill, New Jersey, U.S.N.M. 82452. Film No. 5502.
Manganpectolite from Magnet Cove, Arkansas, U.S.N.M. R-3097. Film No. 240.
Schizolite from Julianehaab, Greenland, U.S.N.M. 95502. Film No. 5752.
Serandite from Los, French Guinea, U.S.N.M. 96515. Film No. 5739.

From a comparison of their patterns, C. L. Christ and J. M. Axelrod, of the U. S. Geological Survey, conclude that the same general pattern prevails and that all four samples are isostructural. The patterns of pectolite and of manganpectolite are identical; those of schizolite and of serandite contain some difference in line position and line intensity. However, it seems very likely that these differences can be ascribed to the differences in chemical composition. The patterns for schizolite and for serandite are very similar; their differences are less than their differences from the patterns of pectolite. But the overall similarity is retained and it must be concluded, on the basis of their powder patterns, that pectolite, manganpectolite, schizolite, and serandite form an isostructural series.

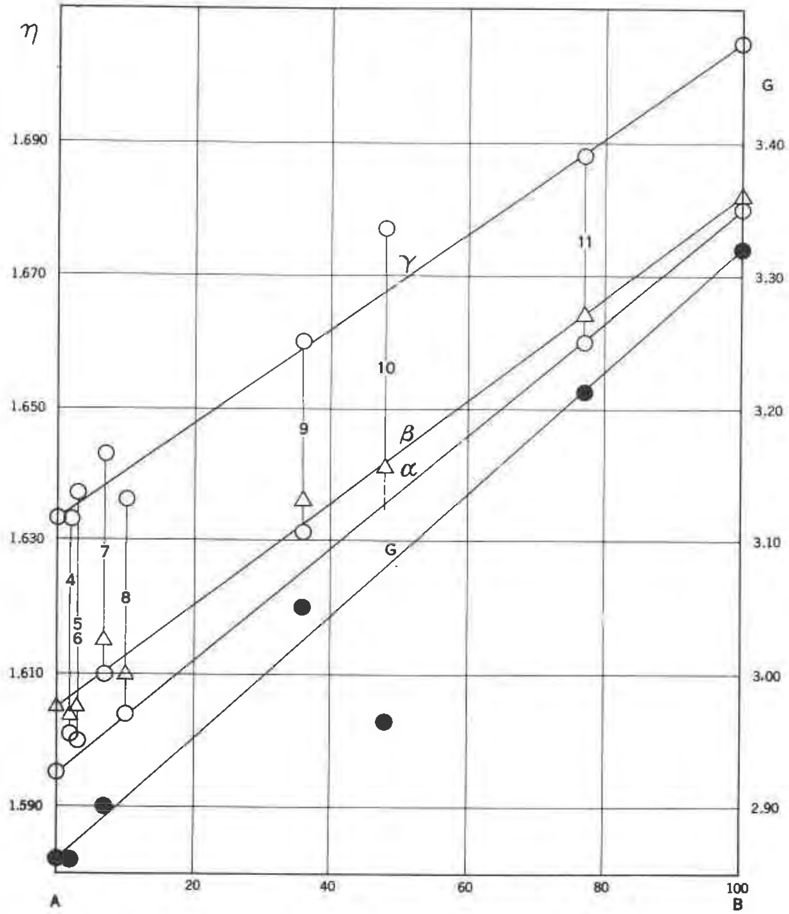

FIG. 2. Variation curves for G (specific gravities) and *n* (indices of refraction α, β, γ) for the pectolite-schizolite-serandite series. The values for alpha and gamma are represented by circles whereas those for beta are represented by triangles, so as to avoid confusion. Solid dots represent specific gravities.

A. Pectolite. $Ca_2NaSi_3O_8(OH)$.

B. Serandite. $Mn_2NaSi_3O_8(OH)$.

The powder data given in Table 1 were kindly furnished by Fred A. Hildebrand and are given here to show the isostructural relationship between pectolite, schizolite, and serandite. Measurements for *d* were made with a *m.m.* scale and *I* was estimated visually for schizolite and serandite. Corrections which would make very minor changes in *d* were not considered.

The patterns of the three minerals shown in Fig. 1 were taken with Debye Scherrer powder cameras (114.59 mm. diameter), FeK_α (Mn filter), $\lambda = 1.9373$Å.

Compilation of Properties

The available pertinent literature data on the properties of pectolite, schizolite, and serandite are shown in the following compilation (Table 2) and the variation curves for specific gravity and for the indices of refraction are given in Fig. 2. The component weight percentages are calculated on the basis of the determined values for MnO and FeO. The Ca-component is then obtained by difference. Both the specific gravities and the indices of refraction increase with increasing amounts of manganese. The continuous shift of the lines of the x-ray patterns has been given in Table 1.

The data are meager and there is little assurance that the physical properties were always determined on the actual samples analyzed. For example the three analyses of schizolite from Greenland (No. 9 in Table 1) given by Bøggild show considerable variation in the percentages of MnO (9.84, 11.69, and 12.90), and correspond to 32, 35, and 40 weight per cent of the calcium-free manganese and iron end members. The specific gravity of the mineral is given as within the range 2.97–3.13. The only indices of refraction of schizolite found in the literature are those given by Larsen (1921) for an unanalyzed specimen in the Harvard collection. The values plotted in Fig. 2 for schizolite are the average of the available data.

For pectolite, with less than one per cent of the calcium-free manganese and iron end member, Harada (1934) gives the indices of refraction for three analyzed samples (average given in column 3, Table 2). He also gives the indices for three additional samples not analyzed. His values agree very closely with those given in Larsen's Tables.

	α	β	γ
Harada analyzed	1.595	1.604	1.632
	1.594	1.603	1.631
	1.595	1.605	1.633
Harada not analyzed	1.595	1.604	1.633
	1.596	1.605	1.635
	1.594	1.604	1.632
Larsen's Tables, 1st ed.	1.595	1.606	1.633 (p. 118)
	1.595	1.606	1.634 (p. 216)
Larsen's Tables, 2nd ed.	1.595	1.604	1.633 (p. 110)
Average	1.595	1.605	1.633

TABLE 2. COMPILATION OF DATA ON THE PECTOLITE-SCHIZOLITE-SERANDITE SERIES

Reference Locality	Pectolite					
	1 —	2 Moravia	3 Japan	4 Ontario	5 New Jersey	6 Russia
Ca-comp.	100	100	100	98	97	96
Mn(Fe)-comp.	0	0	0	2	3	4
% MnO+FeO	0.00	0.00	0.15	0.76	1.12	1.53
α	1.595	1.600	1.595	1.601	1.600	1.600
β	1.605	—	1.604	1.604	1.605	—
γ	1.633	1.632	1.632	1.633	1.636	1.638
B	.038	.032	.037	.032	.036	.038
2V	63°[a]	—	60°	—	50°	—
G	2.86	—	2.86	2.86	—	—
SiO_2	54.23	52.73	52.99	53.28	53.80	54.02
CaO	33.74	32.78	33.89	33.41	33.20	32.20
MnO	—	0.00	—	.33	.12	1.53
FeO	—	.05[b]	.15	.43[b]	1.00	—
Na_2O	9.32	7.97	8.97	9.14	9.01	8.88
H_2O	2.71	4.70	3.33	2.70	2.94	3.00
Etc.	—	1.86	.56	.67	—	.36
	100.00	100.09	99.89	99.96	100.07	99.99

[a] Computed.

[b] Given as Fe_2O_3 but changed to its equivalent FeO where both iron oxides were not separately determined.

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TABLE 2. COMPILATION OF DATA ON THE PECTOLITE-SCHIZOLITE-SERANDITE SERIES—*Continued*

Reference Locality	Pectolite		Schizolite		Serandite	
	7 Russia	8 New Jersey	9 Green-land	10 Russia	11 French Guinea	12 —
Ca-Comp.	93	90	64	52	23	0
Mn(Fe)-Comp.	7	10	36	48	77	100
% MnO+FeO	2.60	3.86	13.99	18.66	30.32	39.16
α	1.610	1.604	1.631	—	1.660	1.680
β	1.615	1.610	1.636	1.641	1.664	1.682
γ	1.643	1.636	1.660	1.677	1.688	1.705
B	.033	.032	.029	—	.028	.025
2V	53°	—	47°	51°	36°	33°[a]
G	2.90	—	3.05[b]	2.965[b]	3.215	3.32
SiO_2	50.34	52.04	51.19	54.84	48.72	49.79
CaO	32.36	31.15	20.97	14.21	10.42	—
MnO	1.52	2.57[c]	11.48	17.78[d]	28.99	39.16
FeO	1.08[e]	1.29	2.51	.88[e]	1.33	—
Na_2O	8.33	7.97	10.06	8.62	7.38	8.56
H_2O	3.65	3.07	1.39	1.28	2.67	2.49
Etc.	2.45	2.12	2.42	2.39	.69	—
	99.73	100.21	100.02	100.00	100.20	100.00

[a] Computed.

[b] Average of the ranges given, 2.97–3.13 for column 9 and 2.955–2.974 for column 10. These last values are probably low due to presence of MnO_2.

[c] Includes 0.26 per cent ZnO.

[d] After deducting 9.35 per cent MnO_2 and recalculating to 100 per cent. Given as 15.92 per cent MnO and 9.35 per cent MnO_2.

[e] Given as Fe_2O_3 but changed to its equivalent FeO as both iron oxides were not separately determined.

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12. Theoretical calcium-free manganese end member of the pectolite-schizolite-serandite series. The extrapolated values are: $\alpha=1.680$, $\beta=1.682$, $\gamma=1.705$, G.$=3.32$.

The atomic ratios are calculated for four representative analyses, namely pectolite No. 5, schizolites Nos. 9 and 10, and serandite No. 11. The results are shown in Table 3 (next page).

Summarizing the results:

	Si	Ca, Mn, etc.	Na, K	OH
Pectolite 5	2.99	2.03	0.97	1.09
Schizolite 9	2.93	2.01	1.12	.53
Schizolite 10	3.10	1.79	1.00	.48
Serandite 11	2.93	2.21	.88	1.06
Average	2.99	2.01	0.99	0.79

These ratios indicate the type formula $(Ca, Mn)_2 NaSi_3O_8(OH)$ for all these members of the series. The determinations of water in the schizolites seem to be too low.

Table 3. Atomic Ratios of Selected Analyses

	Pectolite 5 New Jersey			Schizolite 9 Greenland			Schizolite 10 Russia			Serandite 11 Fr. Guinea		
Si	2.993		2.99	2.930		2.93	3.098		3.10	2.912	2.932	2.93
Al	—			—			—			.020		
Ti	—			.019			.001			—		
Fe'''	—			—			—			.001		
Ce	—			.009			—			—		
Y	—			.017			.027			—		
Fe''	.047			.121	2.013	2.01	.041	1.785	1.79	.067	2.208	2.21
Mn	.005	2.029	2.03	.557			.845			1.466		
Mg	—			.004			—			.006		
Ca	1.977			1.286			.860			.668		
Sr	—			—			.004			—		
Ba	—			—			.007			—		
Na	.972		.97	1.117		1.12	.943	1.004	1.00	.854	.876	.88
K	—			—			.061			.022		
OH	1.089		1.09	.529		.53	.482		.48	1.062		1.06

Conclusion and Nomenclature

The meager data here presented on the pectolite-schizolite-serandite series indicate that these minerals are isostructural and are members of a continuous series. As in the calcite-rhodochrosite series, and in the wollastonite-bustamite series, they present an example of manganese proxying for calcium, for the pectolite series up to 77 per cent of the manganese (plus a little iron) end member.

Those with dominant Ca are pectolite. If desired, those varieties with considerable manganese (but less than 50 per cent molecularly of the manganese end member), such as the schizolites, can be designated as manganoan pectolites. The term schizolite can then be discarded as an unnecessary species name. The statement by Peacock (1935, p. 109) that "Pectolite and the manganese pectolite, schizolite" should read: "Pectolite and the manganoan pectolite, schizolite." Serandite is the "manganese pectolite" and the name serandite is to be applied to those members of the series with more than 50 per cent molecularly of the manganese end member. The only recorded analysis of serandite is that of a calcian serandite.

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