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THE TRIOCTAHEDRAL BRITTLE MICAS[1,2]

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ABSTRACT

All known trioctahedral brittle micas are shown to be similar, particularly in respect to chemical composition, crystallography, and geological occurrence. Thus there is no need for such species and varietal names as xanthophyllite, valuevite, brandisite, disterrite, holmite, holmsite, holmesite, and chrysophane. Arguments are given for choosing *clintonite* rather than seybertite as the species name.

A new chemical analysis of clintonite is given: SiO_2 19.38, Al_2O_3 39.69, Fe_2O_3 0.35, FeO 1.48, CaO 12.72, MgO 20.99, Mn 0.001, SrO 0.14, H_2O 3.04, F 1.91, Cl 0.07.

The brittle micas represent an uncommon group of micas in which the layer charge, caused by tetrahedral substitution of Al^{+3} for Si^{+4}, is greater than in the more usually encountered micas. They are divided into two sub-groups, dioctahedral and trioctahedral, with the former represented by the mineral margarite. This report is concerned only with the trioctahedral sub-group, which encompasses such species and varietal names as xanthophyllite (Rose, 1842), valuevite (Koksharov, 1875), brandisite (Haidinger, 1846), seyberite (Clemson, 1832), clintonite (Mather, 1843), and others. The intention is to describe these minerals and to demonstrate that they are all of one species that can be represented by the name *clintonite.*

Excepting the chemical analysis, which was done by one of the authors (J. A. Maxwell), all aspects of the investigation were carried out by the other authors.

MATERIALS

Brandisite is a green brittle mica very similar in colour and appearance to valuevite. Two small samples were obtained from the British Museum-BM 24332 from Monzoni, Val di Fassa, Trentino, Italy; and BM 60173 from Val San Pellegrino, Val di Fassa, Trentino, Italy.

Clintonite (or seybertite) is unique in colour among the brittle micas, being a reddish-brown. There is only one major occurrence, namely in the state of New York, and variously referred to as Warwick, Orange County, and Amity. In addition there is a minor occurrence in California. A number of samples of this mineral were labelled seybertite and some clintoite. They are, of course, the same mineral. The samples obtained were BM 96544 from War-

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wick, Orange Co., New York, BM 60175 from Orange Co., New York, both labelled clintonite, ROM M6353 labelled seybertite from Montezuma Valley, San Diego Co., California.

Xanthophyllite and valuevite have been described by Forman *et al* (1966) and their data are used here.

METHODS

X-ray diffraction examinations were carried out on all the brandisite, seybertite, and clintonite samples using precession, Weissenberg, and powder techniques. All dimensions and space groups were derived by using a combination of all *x*-ray data.

A complete chemical analysis and specific gravity determination was carried out on seybertite (ROM M6353) after carefully cleaning the powdered material by repeated centrifugations with suitable heavy liquids.

RESULTS AND DISCUSSION

Crystallography. The single-crystal studies were rather interesting. Seybertite in every case, demonstrated diffuse scattering from *hkl* reflections in all levels in which *k* was not a multiple of three, whereas brandisite showed this feature in most, but not all, crystals. In some cases in which diffuse scattering occurred there was slight thickening at those points on the diffuse streaks where reflections would normally occur. In general, these were too diffuse to measure accurately. Diffuse scattering in micas from *hkl* reflections in which *k* is not a multiple of three has been explained by Hendricks (1939) with further amplification by Yoder and Eugster (1955) and by Smith and Yoder (1956). It is attributed to the random layering of successive mica layers so that there is no definite *c* periodicity except where the *k* index is a multiple of three. The latter would give the periodicity of a single layer mica, as it does in the case of the minerals used in this study. Of course, in the present case, there is evidence that the layering is not completely random. The tendency towards nodes along the diffuse scattering streaks, mentioned above, indicates that there exist a number of domains with organized layering. The crystals of brandisite which did not demonstrate diffuse scattering showed marked $\pm 120°$ polysynthetic spiral twinning about c^* as described by Sadanaga and Takéuchi (1961) and similar to that shown by Forman *et al* (1966) to occur in xanthophyllite. Apart from the lowering in intensity of the *hkl* reflections in the powder patterns of those samples possessing considerable diffuse scattering, the powder patterns were identical. In view of this, it was assumed that they all possessed the same space group, $C2/m$, and were, accordingly, all indexed on the same basis as xanthophyllite in Forman *et al* (1966).

Thus, all the trioctahedral brittle micas are judged to be single-layer structures in the context of Hendricks (1939) discussion of layer types. The cell dimensions are all the same and were determined from a combination of single-crystal and powder data as follows: $a=5.14_1$, $b=9.01_0$, $c=9.86_4$ Å, $\beta=100°04/\text{min}$.

TABLE 1. CHEMICAL ANALYSES OF TRIOCTAHEDRAL BRITTLE MICAS

	(1)	(2)	(3)	(4)	(5)
SiO_2	19.38	20.13	19.19	20.00	18.75
TiO_2	0.58				
ZrO_2	n.d.	0.68			
Al_2O_3	39.69	38.68	39.73	43.22	39.10
Fe_2O_3	0.35	3.48	0.61	3.60	3.24
P_2O_5	n.d.				
FeO	1.48		1.88		1.62
CaO	12.72	13.35	13.11	4.00	12.14
MgO	20.99	21.65	21.09	25.01	20.46
MnO	0.01				
SrO	0.14				
Na_2O	0.00	1.14			
K_2O	0.00	0.29		0.57	
H_2O	3.04	1.05	4.85	3.60	5.35
CO_2	n.d.				
F	1.91		1.26		
Cl	0.07				
S	n.d.				
Total	100.36	100.45	101.72	100.00	100.66
Less O=F, Cl	0.81		0.53		
Net Total	99.55		101.19		
S.G.	3.102 (24.03/4°C)			3.047	3.090
Tetrahedral Al/Si	2.64/1.36	2.61/1.39	2.67/1.33	2.63/1.37	2.70/1.30

(1) Seybertite from Montezuma Valley, San Diego Co., Calif. (ROM M6353). Analysis by J. A. Maxwell, this paper.
(2) Seyberite. Analysis by Brush in Hintze (1897).
(3) Seyberite. Analysis by Sipöcz in Hintze (1897).
(4) Brandisite. Analysis by Kobell (1847).
(5) Brandisite. Analysis by Sipöcz in Hintze (1897).
n.d.=not determined.

Composition. The new chemical analysis of seyberite (ROM M6353) is given in Table 1. Using the above cell dimensions, the structural formula, based on $M=VG/A$, is $2[(Ca_{0.96}Sr_{0.01})\ (Mg_{2.20}Mn_{<0.01}Fe_{0.09}^{+2}Fe_{0.02}^{+3}Ti_{0.03}Al_{0.65})\ (Al_{2.64}Si_{1.36})O_{10.07}(OH_{1.42}F_{0.42}Cl_{0.01})]$ or nearly $2[Ca(Mg, Al)_3(Al,Si)_4O_{10}(OH,F)_2]$. This conforms well with calculations made on data from earlier analyses (Table 1) of seybertite by Brush (Hintze, 1897) and by Sipöcz (Hintze, 1897), and shows a slightly lesser charge on the lattice resulting from tetrahedral substitutions of Al for Si than xanthophyllite. The analyses, given in Table 1, for brandisite by

Sipöcz in Hintze (1897) and by Kobell (1847) give a similar tetrahedral substitution of Al for Si as in seybertite but other portions of the analyses show some inconsistencies. It can be deduced, however, that the analyses for brandisite do not differ appreciably from those of seybertite and that both are trioctahedral. Thus, chemically, all the trioctahedral brittle micas have essentially the same composition and vary only moderately in the amount of tetrahedral substitution of Al for Si.

Geological occurrence. Finch (1829) appears to have made the first published reference to what can be deduced to have been a trioctahedral brittle mica, clintonite, although he erroneously called it bronzite. He described it as occurring in Orange County, New York in a vein about four inches wide in calcareous rocks. This description was confirmed by Clemson (1832) who named it seybertite. Mather (1843) described this area as consisting of recrystallized limestone caused by intrusives of granitic or syenitic composition.

The specimen of xanthophyllite which led to its first description was given to Rose (1842) by a collector, at Zlatoust, U.S.S.R. The exact location is not known but the specimen can be inferred to have come from the schists a few kilometres to the west. These schists are adjoined by limestones which have been penetrated by diorite intrusives. Thus, the setting, except for the diorite, is in many respects similar to that of clintonite.

Koksharov (1875) discovered valuevite near Achmatovsk, about 15 kilometres north of where xanthophyllite is believed to have been found, in a similar geological setting. Eakle (1916) found valuevite at Crestmore, California in recrystallized limestone near the contact between the limestone and a granodiorite intrusive. Sanero (1940) described the valuevite crystals used in this study as coming from the contact zone of domolitic limestone and tonolitic diorite at Vacca Lake, Adamello, Italy. The valuevite studied by Harada *et al* (1965) was obtained from the contact zone involving limestone intruded by quartz diorite at the Chichibu Mine, Saitama Prefecture, Japan. Other occurrences of valuevite could be cited but, to the authors' knowledge, all occur either in the contact zone of limestone and an igenous intrusive, or in a geological setting that has not been described.

Brandisite has been reported only from Mount Monzoni in Fassathal, Tyrol, by Haidinger (1846) but without a description of the geological setting. However, Hintze (1897) describes it as occurring in the contact of limestone and a gabbro intrusive.

Thus it seems that all the trioctahedral brittle micas have a similar type of geological occurrence, in that limestone affected by an igneous intrusive is involved in every case. On the other hand, the nature of the intrusive varies from granite or syenite for clintonite to medium basic for xanthophyllite to basic for brandisite.

Nomenclature. All the trioctahedral brittle micas are so similar in crystallography, chemical composition and in mode of origin that it hardly seems justified to have species names for what are essentially differences in colour. The claim in Dana (1892) that brandisite is distinguished from seybertite (clintonite) by the difference in orientation of the optic axial plane [seybertite (clintonite)$\perp b$: brandisite $\| b$] is probably not valid in the light of the complications observed above in which diffuse X-ray scattering and polysynthetic spiral twinning are so characteristic of these materials.

It is not difficult to eliminate most of the names applied to the trioctahedral brittle micas. Such names as disterrite, brandisite, holmite (Thomson, 1836) (later changed to holmesite), xanthophyllite, valuevite, and chrysophane, are all distinctly later than either seybertite or clintonite. The real choice rests between clintonite and seybertite and, while their descriptions are poor by present-day standards, they were quite adequate by the standards of 1830 and 1840.

The name clintonite was first formally published by Mather (1843) in which the following footnote appeared: "This mineral was first found by Dr. Horton, Mr. John Finch, and myself, in the summer of 1828. We conceived it to be a new mineral and gave it the name of clintonite. . . . It was afterwards called seybertite, and afterwards holmsite (*sic*). As one of the original discoverers of the mineral, I claim the name originally given. . . ." Seybertite was first published by Clemson (1832). Therefore, on the basis of formal publication date, there would seem to be very little question that seybertite should have precedence over clintonite. However, as will be shown below, there is some substance to Mather's claim of precedence for the clintonite. Dana gave seybertite first priority in 1837, gave clintonite first priority in 1844 and again in 1854. In 1868 Dana gave seybertite first priority again. Dana (1892) continued to give seybertite first priority as the species, but elevated clintonite to a group name, of which seybertite was a species; brandisite was relegated to a variety of seybertite in which they were distinguished from each other by the relative positions of their axial planes.

Although first formal publication of clintonite came in 1843, considerable support can be developed for Mather's claim that it had been conceived in 1828. There is much evidence that it had crept into general use well before 1843 and, indeed, before 1832, the date credited to seybertite. For example, Rose (1842) was aware of the name. Breithaupt (1832) in his publication on chrysophane, mentioned it. The earliest printed reference to clintonite that the authors were able to find was made in 1831 in the proceedings of the Lyceum of Natural History of New York in which the following statement was made: "Dr. Torrey presented bronzite (clintonite), from Orange Co. N. Y.". This is well before the publication of the name seybertite by Clemson (1832).

CONCLUSIONS

Since all presently-known trioctahedral micas have been shown to represent a single species, it is strongly recommended that only one species name be used. In light of the foregoing discussion, the choice of a species name is reduced to seybertite and clintonite. Since the latter name has come into much more general use than the former, and has served for many years as the group name, it is suggested that *clintonite* serve as the species name in the future.

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