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A HYDROMUSCOVITE WITH THE $2M_2$ STRUCTURE, FROM MOUNT LYELL, TASMANIA[1]

I. M. THREADGOLD, *Mineragraphic Investigations, C.S.I.R.O., Melbourne, Victoria.*

ABSTRACT

A fine-grained mica from Mount Lyell, Western Tasmania, shown by chemical analysis to be a hydromuscovite, probably of metasomatic origin, gives an x-ray powder pattern similar to that of a $2M_2$ ($6M$) mica polymorph. This structure was previously only known to occur in lepidolites containing 4.0–5.1% Li_2O. A differential thermal analysis of the hydromuscovite has been carried out.

INTRODUCTION

Associated with the copper orebodies of the Mount Lyell field, in Western Tasmania, are foliated masses of extremely fine-grained green micaceous minerals. These minerals, which have been referred to collectively in the past as "batchelorite," following Petterd (1910), consist chiefly of muscovite (sericite), pyrophyllite and mixtures of these two minerals, with or without some admixed chlorite. The masses occur mainly at the contact of the ore with the enclosing schists and tend to be associated with the higher grade ore. They were particularly prominent in association with the rich sections of the North Lyell and Lyell Comstock orebodies. The North Lyell orebody consisted essentially of bornite, chalcopyrite, pyrite and quartz, with bornite the dominant copper mineral, in places almost to the exclusion of chalcopyrite. The Lyell Comstock orebody consisted of chalcopyrite and pyrite disseminated through schists, with small amounts of bornite locally in pockets and disseminations (Edwards, 1939).

In the course of examining a suite of specimens of these green micaceous minerals, one specimen,* from the No. 4 level of the Lyell Comstock Mine, was found to consist of hydromuscovite with the $2M_2$ structure.

MOUNT LYELL HYDROMUSCOVITE

Physical Properties

The hand specimen is similar to many of the other specimens of fine-grained micaceous minerals from Mount Lyell. It is dark emerald green in color, with a waxy luster, extremely fine-grained, foliated and is slightly greasy to the touch.

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* Specimen labelled "batchelorite" in the collection of the Geology Department, University of Melbourne, Victoria (Reg. No. 2900).

Scattered through the specimen are numerous specks of sulphide. A polished section reveals that these specks are ragged particles of pyrite ranging from about 0.50 mm. to 0.01 mm. across. Occasional particles contain small inclusions of chalcopyrite up to about 0.02 mm. across.

Chemical Composition

The chemical analysis, given in Table 1, is similar to that of the well characterized hydromuscovite from Ogofau described by Brammall, Leech and Bannister (1937).

The most noticeable features of the analysis are that the alkalis are lower and the H_2O^+ higher than in a normal muscovite. The structural formula calculated from the analysis on the basis of a total of 24 oxygen and hydroxyl ions per structural unit gives:

$$(K, Na, Ca, Ba)_{1.72}(Al, Fe^{3+}, Fe^{2+}, Cr^{3+}, Mg)_{3.90}(Si, Al)_8O_{19.38}OH_{4.62}$$

This formula shows considerable deviation from the ideal muscovite formula in regard to the number of interlayer cations and the number of hydroxyl ions. To account for the marked deviations of hydrous micas from the ideal muscovite formula, Brown and Norrish (1952) suggested

TABLE 1. CHEMICAL ANALYSIS AND IONIC COMPOSITION OF HYDROMUSCOVITE FROM MOUNT LYELL, TASMANIA

	1	2	Atomic proportions	Atoms per structural unit on the basis of 24(O+OH) per unit	Atoms per structural unit on the basis of Twenty O & Four OH per unit
SiO_2	46.54	45.65	0.7601	Si 6.00	6.06
Al_2O_3	36.37	36.03	0.7068	Al 5.58	5.63
Fe_2O_3	0.72	1.80	0.0226	Fe^{3+} 0.18	0.18
FeO	0.36	0.13	0.0018	Fe^{2+} 0.01	0.01
Cr_2O_3	—	0.25	0.0032	Cr^{3+} 0.03	0.03
MgO	0.50	0.52	0.0129	Mg 0.10	0.10
CaO	0.22	0.23	0.0041	Ca 0.03	0.03
BaO	—	0.22	0.0014	Ba 0.01	0.01
Na_2O	0.46	1.23	0.0396	Na 0.31	0.32
K_2O	8.06	8.18	0.1736	K 1.37	1.38
$H_2O+(105°)$	6.31	5.27†	0.5850	H 4.62	$\begin{cases}0.66=0.22\ H_3O^+\\4.00=4.00\ OH\end{cases}$
$H_2O-(105°)$	0.52	0.68†			
FeS_2	—	0.27			
	100.31*	100.46‡			
Less O=F	0.01	Less O=S 0.05			
Total	100.30	100.41			

* Includes $TiO_2=0.17$, $P_2O_5=0.06$, $F=0.02$, Li_2O = trace.

† Water determined at plus and minus 110° C.

‡ Elements also sought include TiO_2 = trace, MnO = trace, P_2O_5 = nil, Li_2O = nil.

1. Hydromuscovite A from Ogofau, Carmarthenshire (Brammall, Leech and Bannister, 1937).
2. Hydromuscovite from Lyell Comstock Mine, Mount Lyell, Tasmania. Analyst I. M. Threadgold.

that the low alkali and the high water content are due to the replacement of interlayer potassium ions by oxonium ions (H_3O^+). The following structural formula, obtained using the method of Brown and Norrish* (1952), is in good agreement with that of a normal dioctahedral mica:

$$(K, Na, Ca, Ba, H_3O)_{1.96}(Al, Fe^{3+}, Fe^{2+}, Cr^{3+}, Mg)_{4.01}(Si, Al)_8O_{20}OH_4$$

Muñoz Taboadela and Aleixandre Ferrandis (1957), following Mackenzie's classification of the clay micas, give suggested limits for K_2O+Na_2O percentages, K^++Na^+ ionic ratios and H_3O^+ ionic ratio for muscovite and hydromuscovite. These values, quoted below, show that the mica from Mount Lyell lies outside the suggested limits of a hydromuscovite, being intermediate between muscovite and hydromuscovite.

	K_2O+Na_2O %	K^++Na^+ Ionic ratios*	H_3O^+ Ionic ratio†
Muscovite	9	1.6–2+	—
Hydromuscovite	8–9	1.3–1.6	0.4–0.6
Hydromuscovite (Mount Lyell, Tasmania)	9.41	1.68	0.22

* Values calculated on the basis of $O+OH=24$.

† Values calculated by the method of Brown and Norrish (1952).

However, it is sufficiently hydrated to warrant the name hydromuscovite, as the prefix draws attention to the hydrated nature of the mica, and it is suggested that the limits set by Mackenzie should be extended.

A semi-quantitative spectrographic analysis showed the presence of titanium, manganese and vanadium, each ranging from 0.01 to 0.001%. The following additional elements, arranged in approximate order of decreasing abundance, were detected in trace amounts: Sr, Cu, Ni, Zr, Rb. Lithium was not detected and, if present, its concentration is below 0.01%.

X-Ray Powder Data

Apart from a number of weak lines, the *x*-ray powder pattern of the hydromuscovite, the interplanar spacings of which are given in Table 2, is similar to that of the 6-layer monoclinic ($6M$) polymorph of lepidolite recorded by Levinson (1953).

Smith and Yoder (1956) have found that the $6M$ polymorph, originally described by Hendricks and Jefferson (1939), can be indexed on the basis of a 2-layer monoclinic cell. This polymorph they renamed $2M_2$

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* There is a printer's error in the second equation of Brown and Norrish p. 931. Equation given as $24+y/n=$ (Atomic proportion of oxygen) should read $24/n+y=\sum$(Atomic proportion of oxygen).

TABLE 2. *X*-RAY POWDER DATA. Cu/Ni RADIATION

$2M_2$ hydromuscovite, Lyell Comstock Mine, Mount Lyell, Tasmania				$2M_2$ ($6M$) lepidolite, Gunnison County, Colorado (Levinson, 1953)			
d (Å)	I (est.)	*d*	I	*d*	I	*d*	I
10.0	8	2.19	½	9.89	MS	2.190	VVW
5.01	4	2.14	¼	4.99	M		
4.48	9	2.08	1½	4.49	M	2.039	VW
4.39	½	2.00	3			1.985	S
4.27		1.716	¼				
3.89	3	1.691	½	3.84	W	1.684	VVW
3.66	4	1.667	½	3.61	M		
3.50	3½	1.638	½	3.47	M	1.633	VVW
3.34	6	1.619	¼	3.31	M		
3.20	4	1.586	½	3.19	M	1.572	VVW
3.06	3½	1.565	¼	3.07	M		
3.01	½	1.503	5			1.506	M
2.93	½	1.480	¼				
2.87	3	1.427	½	2.88	M		
2.81	3	—	—	2.775	M	1.393	VVW
2.58	10	1.355	¼	2.572	VS	1.355	VVW
2.46	2	1.315	¼			1.319	VVW
2.40		1.298	2	2.416	M	1.300	W
2.25	1	1.250	1	2.248	VVW	1.239	VVW

to distinguish it from the more common 2-layer monoclinic polymorph $2M_1$, which has a different stacking arrangement. *X*-ray powder photographs of a $2M_1$ muscovite and the $2M_2$ hydromuscovite, from Mount Lyell, are reproduced in Fig. 1.

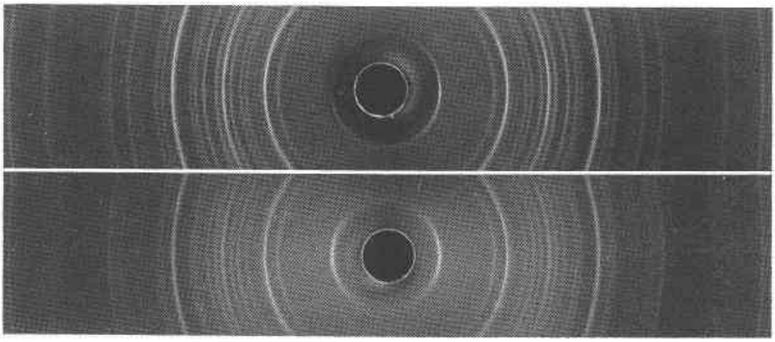

FIG. 1. Top: *X*-ray powder pattern of a fine-grained muscovite with $2M_1$ structure, from Mount Lyell, Tasmania.

Bottom: *X*-ray powder pattern of hydromuscovite with $2M_2$ structure, from No. 4 level, Lyell Comstock Mine, Mount Lyell, Tasmania.

Differences in the observed intensities of corresponding reflections, given in Table 2, are in part due to preferred orientation in the powdered specimen and the differences in the chemical compositions of the two minerals. Significant differences may be expected in the intensities of the (00*l*) reflections, in view of the replacement of a considerable part of the octahedral Al^{3+} by Li^+ in the lepidolite.

Previously the $2M_2$ ($6M$) mica polymorph was only known to exist in lepidolites having a Li_2O content within the range 4.0–5.1% (Levinson 1953). Levinson (1955), after examining a number of illites and hydrous micas, recognized within this group the existence of $1M$, $1Md$, $3T$ polymorphs and the normal $2M_1$ polymorph, but not the $2M_2$ type described here.

Differential Thermal Analysis

The *DTA* apparatus used in this investigation was that described by Carthew and Cole (1953), modified by having a 24—12W (chromium-tungsten) heat resistant steel sample block and a Sunvic D.C. amplifier.

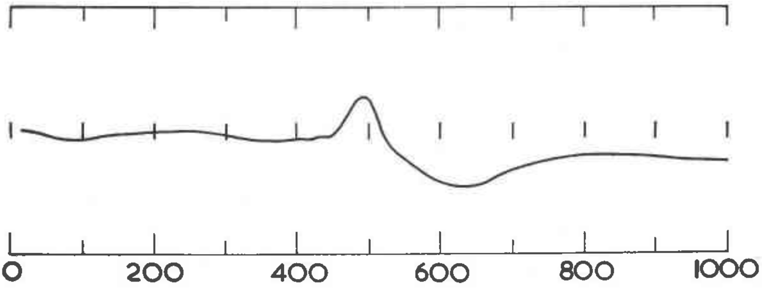

FIG. 2. DTA curve of hydromuscovite from No. 4 level, Lyell Comstock Mine, Mount Lyell, Tasmania.

The *DTA* curve shown in Fig. 2 is, except for the exotherm at 495° C., similar to the curves of a number of fine-grained muscovites from Mount Lyell. The broad, shallow, low temperature endotherm extending up to about 250° C. is associated with the loss of hygroscopic and interlayer water, presumably in the form of H_3O^+. Oxidation of the small amount of sulfides in the sample, chiefly pyrite, gives rise to the exotherm at 495° C. This exotherm is immediately followed by a broad endotherm, with a peak at 630° C., corresponding to the loss of hydroxyl water. Depression of the base line following this reaction can be assumed to be due to changes in the specific heat and the bulk density of the sample. As this feature has not been observed in any of the *DTA* curves of previously examined fine-grained muscovites from Mount Lyell, it is probably the result of oxidation of the sulfides.

Between 250° C. and the beginning of the exotherm at about 430° C. there is a shallow "apparent" endotherm which probably represents the commencement of the endotherm due to the loss of hydroxyl water, the smooth contour of the curve being interrupted by the oxidation of the sulfides.

Discussion

Except for the high water to alkali ratio the hydromuscovite is chemically similar to a normal muscovite. This deviation from the ideal muscovite composition may be explained by the presence of oxonium ions substituting for interlayer K^+ ions. If this is true, it is unlikely that the existence of interlayer oxonium ions is the cause of the $2M_2$ crystallization of the hydromuscovite, as the H_3O^+ and K^+ ions have approximately the same ionic radii.

Since the specimen was collected from the workings of the Lyell Comstock Mine, in which fine-grained masses of "sericite" were not uncommonly associated with the orebody, it is most probable that the hydromuscovite is a product of interaction between hydrothermal ore-forming solutions and the schistose country rocks, that consist chiefly of sericite, quartz and chlorite. This is supported to some extent by the fine grain size and the presence of sulfides.

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