Truscottite.

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INTRODUCTION.

THE mineral truscottite was discovered at the Lebong Donok mine, Benkulen, Sumatra, by Hövig[1] in 1914. He considered it to be a hydrated calcium silicate of composition $CaO.2SiO_2.\frac{1}{2}H_2O$. Later work by Grutterink[2] suggested a different formula, $2(Ca,Mg)O.3SiO_2.2H_2O$, the water content being reduced to 1·3 molecules after drying at 120°. Grutterink noted that the composition, general character, and optical properties indicated a similarity to gyrolite. Flint, McMurdie, and Wells[3] concluded from X-ray powder photographs that the two species were identical, although they detected quartz as an impurity in the truscottite examined. All known specimens of truscottite come from the original locality, and no further investigations have been reported.

THE PRESENT INVESTIGATION.

Material.—A specimen (B.M. 1925,1044) was kindly made available by the Trustees of the British Museum. It consisted of aggregates of plates having a pearly lustre; the appearance, and also the optical properties, agreed closely with the earlier descriptions. In parts of the specimen, closely intergrown quartz was detected optically and by X-ray powder photographs. No other minerals were observed, but powder photographs suggested that traces of some additional species, possibly calcite, might be present.

[1] P. Hövig, Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië, Batavia, 1914, vol. 41 (for 1912), p. 202. [Min. Mag. **20**-466.]

[2] J. A. Grutterink, Verh. Geol.-Mijnb. Genootschap Nederland, Geol. Ser., 1925, vol. 8, p. 197. [M.A. **3**-271.]

[3] E. P. Flint, H. F. McMurdie, and L. S. Wells, Journ. Res. Nat. Bur. Standards, U.S.A., 1938, vol. 21, p. 617. [M.A. 7-283.]

X-Ray single-crystal examination.—X-ray oscillation, rotation, and Weissenberg photographs indicated a hexagonal unit-cell with a $9.72\pm$ 0.01 and c 18.71 ± 0.03 Å., having c perpendicular to the principal cleavage. The c-rotation photograph is shown in fig. 1a with that of gyrolite[1] for comparison (fig. 1b).
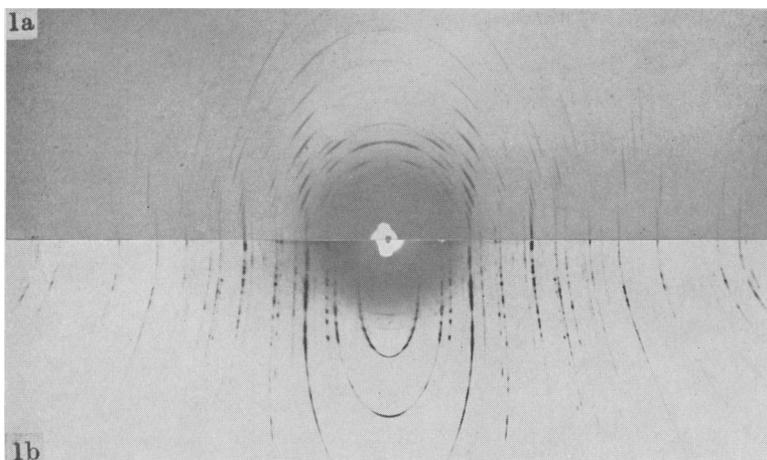

Fig. 1a. X-ray single-crystal photograph of truscottite. Rotation about the c-axis. Cu-$K\alpha$ radiation.

Fig. 1b. Ditto of gyrolite (Mackay and Taylor, 1953).

Two kinds of disorder were observed in all the flakes examined. Firstly, c-rotation photographs (fig. 1a) show considerable angular spread of all reflections, implying that the c-axes of the crystal particles are dispersed by up to 10° in all directions from the mean direction normal to the cleavage. Secondly, Laue photographs, taken with the X-ray beam perpendicular to the cleavage, showed that even the smallest flakes examined were composed of several individuals markedly rotated in the plane of the flake with respect to each other. Because of the disorder, determination of the exact symmetry is difficult. One Laue photograph gave definite indications of trigonal rather than hexagonal symmetry. All oscillation photographs about the c-axis showed slight departures from an equatorial plane of symmetry, but no systematic absences were observed. Certain classes of absences would be obscured by the disorder, but there are certainly no absences among the $000l$'s

[1] A. L. Mackay and H. F. W. Taylor, Gyrolite. Min. Mag., 1953, vol. 30, pp. 80–91. (Correction, p. 80: for B.M. 1925,1044 read B.M. 93504.)

(fig. 1a) and the lattice is therefore not rhombohedral. $h0hl$ and $h.h.\overline{2h}.l$ reflections are present whether l is even or odd, showing that no c-glide-plane exists. These facts indicate that the Laue symmetry is $\bar{3}$ or $\bar{3}m$, and the diffraction symbol $\bar{3}P-$ or $\bar{3}mP- - -$. The space group could therefore be $P3$, $P\bar{3}$, $P3m1(P31m)$, $P321(P312)$, or $P\bar{3}m1(P\bar{3}1m)$.

X-ray powder examination.—X-ray powder data, obtained using

TABLE I. X-ray powder data for truscottite (B.M. 1925,1044).
(Cu-$K\alpha$ radiation.)

Observed.		Calculated.		Observed.	
d(Å.)	Int.	Indices.	d(Å.)	(dÅ.)	Int.
19	s	0001	18·71	1·469	vw
9·4	s	0002	9·36	1·439	vw
7·65	mw	$10\bar{1}1$	7·65	1·417	vvw
6·30	w	0003	6·24	1·407	w
5·02	vw	$10\bar{1}3$	5·02	1·381	vvw Q
4·65	mw	0004	4·68	1·371	vw Q
4·13	s	$20\bar{2}0$	4·20	1·348	w
3·80	mw	$11\bar{2}3$	3·83	1·316	w
3·71	w	0005	3·74	1·298	vw
3·47	mw	$20\bar{2}3$	3·49	1·266	vvw
3·34	w Q	$(10\bar{1}5)$	(3·42)	1·240	vw
3·14	s	$\big\{\,21\bar{3}1$	3·14	1·215	vvw
—	—	$\big\{\,0006$	3·12	1·200	vvw Q
3·00	m *	$21\bar{3}2$	3·01	1·181	w
2·83	s	$21\bar{3}3$	2·84	1·175	vvw
2·63	s	$21\bar{3}4$	2·63	1·165	w
2·49	vw	$20\bar{2}6$	2·51	1·055	vw
2·42	w	$21\bar{3}5$	2·42	1·035	w
2·26	w Q	$31\bar{4}2$	2·27		
2·23	w Q	$21\bar{3}6$	2·23		
2·08	w	$31\bar{4}4$	2·09		
2·04	w	$21\bar{3}7$	2·05		
1·921	w	$32\bar{5}0$	1·934		
1·893	vw	$21\bar{3}8$	1·885		
1·836	ms	$41\bar{5}0$	1·835		
1·801	w	$41\bar{5}2$	1·806		
1·762	w	$41\bar{5}3$	1·762		
1·750	mw	$21\bar{3}9$	1·741		
1·717	vvw	$41\bar{5}4$	1·710		
1·690	vvw	$22\bar{4}8$	1·687		
1·652	w	$41\bar{5}5$	1·650		
1·618	vvw	$2.1.\bar{3}.10$	1·616		
1·585	vw	$42\bar{6}0$	1·590		
1·569	vw	$42\bar{6}2$	1·570		
1·557	vw	$21\bar{4}9$	1·553		
1·507	w	$42\bar{6}4$	1·508		

Intensities estimated visually; s strong, m moderate, w weak, v very. Q, line due partly to quartz. *, line due partly to unidentified species (calcite?). Calculated spacing and indices in parentheses, line probably due almost entirely to quartz. Lines due wholly to quartz are omitted.

cameras of 6 cm. and 19 cm. diameter with Cu-$K\alpha$ radiation, are given in table I. Unlike the gyrolite photograph, all lines in the pattern were sharp. The spacings were indexed by direct comparison with single-crystal photographs; comparison with a c-rotation photograph of gyrolite was also useful for determining the hk indices. The specimen contained a small proportion of quartz, and traces of a further unidentified impurity, possibly calcite; the lines due to these phases could be distinguished by their rough appearance, and also by the fact that corresponding reflections did not appear on single-crystal photographs.

Chemical analysis and specific gravity.—The results obtained in the present and earlier investigations are given in table II, columns 1–4.

TABLE II. Chemical analyses of truscottite.

	1.	2.	3.	4.	5.		6.	7.
SiO_2 ...	62·52	63·94	57·83	58·95	50·23	Si	... 22·9	24
Al_2O_3	1·24	2·68	{ 0·95	1·03	2·19	Al	... 0·5	—
Fe_2O_3			{ 0·08	0·03	0·20	Mn	... 0·1	—
MnO ...	—	—	0·25	0·18	—	Mg	.. 0·2	—
MgO ...	—	—	5·33	0·27	0·13	Ca	... 10·7	12
CaO ...	30·20	29·20	26·43	25·54	34·04	Na	... 0·8	—
Na_2O ...	—	—	0·78	1·03 }		K	... 0·7	—
K_2O ...	—	—	0·73	1·37 }	0·14	S	... 0·7	—
SO_3 ...	—	—	—	2·57	—	C	... 1·2	—
CO_2 ...	—	—	—	2·32	0·95	H	... 12·0	12
H_2O+	3·85	2·68	{ 4·10	4·61 }	11·98	O	... 68·9	66
H_2O-			{ 3·41	1·07 }				
	97·81	98·50	99·89	98·97	99·86			

1. P. Hövig, loc. cit. Analyst, J. E. Clennell.
2. P. Hövig, loc. cit. Analyst, R. T. G. Bayley.
3. J. A. Grutterink, loc. cit. Analyst, J. de Vries; mean of two similar analyses. Also, TiO_2 and F absent; total Fe as Fe_2O_3; $H_2O \pm 120°$ C.
4. New analysis, by F. J. McConnell (Building Research Station, Watford, Hertfordshire), on 450 mg. Also TiO_2 absent; $H_2O \pm 110°$ C.
5. Gyrolite, for comparison; analysis by F. J. McConnell in A. L. Mackay and H. F. W. Taylor, loc. cit.
6. Atomic contents of unit-cell, calculated from column 4 after deduction of $H_2O - 110°$.
7. Atomic contents of unit-cell, calculated for $12[CaO . 2SiO_2 . \frac{1}{2}H_2O]$.

For comparison, an analysis of gyrolite (column 5) is included. The specific gravity of the present material was found by suspension to be 2·48.

Dehydration curve.—A dehydration curve was determined and is given in fig. 2. At temperatures up to 560° C., the partial pressure of water-vapour was maintained at 6 mm. The corresponding curve for gyrolite

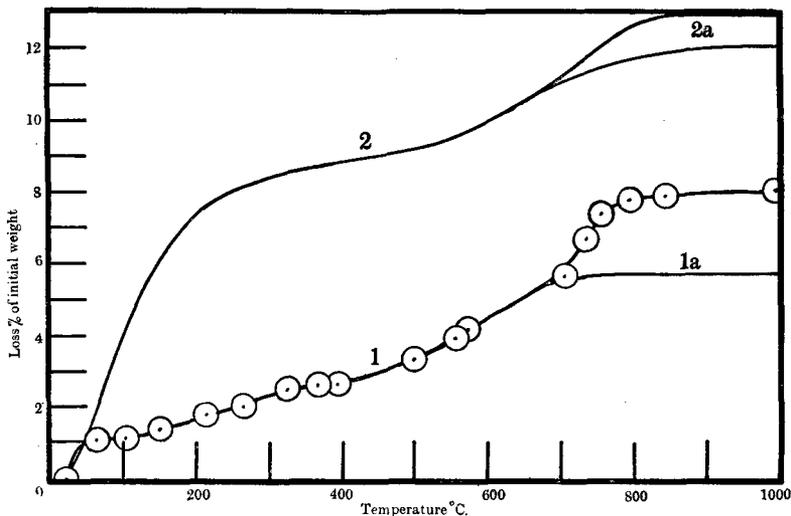(Mackay and Taylor, loc. cit.) is included for comparison; the method employed in both cases is described elsewhere.[1]

FIG. 2. Dehydration curves: 1, of truscottite; 2, of gyrolite (Mackay and Taylor, 1953); 1a and 2a after correction for CO_2.

X-ray investigation of dehydrated material.—X-ray photographs were taken of single crystals which had been heated to various temperatures for from four to twelve hours. Heating at 110°, 450–500°, or 700° C. caused no detectable change in the pattern. Heating at 770° brought about partial conversion into an unidentified phase giving a weak X-ray pattern with only slight preferred orientation. At 870°, the truscottite pattern disappeared entirely and the unidentified phase alone appeared to be present. After heating at 950–1000°, a strong pattern was again obtained, which indicated the presence of wollastonite (or parawollastonite) with smaller amounts of pseudowollastonite and cristobalite. No preferred orientation was observed. Heating to 1200° gave a pattern indicating predominantly pseudowollastonite.

DISCUSSION.

The relationship of truscottite to gyrolite.—The present results show that truscottite is a distinct species, not identical with gyrolite, although a close relationship exists between the two minerals. Significant differences

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[1] H. F. W. Taylor, Journ. Chem. Soc. London, 1953, p. 163. [M.A. 12–172.]

exist in the unit-cell dimensions and in the composition. Both in truscottite and in gyrolite the unit-cell is hexagonal (or trigonal), and the a-axes of the two minerals are identical; it is therefore probable that truscottite has basically the same (as yet unknown) layer-structure as gyrolite. The c-axes differ, however, being 18·71 Å. in truscottite against 132·8 ($6 \times 22\cdot13$) Å. in gyrolite (Mackay and Taylor, loc. cit.). Rotation photographs about c (figs. 1a and 1b) thus show the same series of row-lines but their layer-lines do not coincide.

Comparison of figs. 1a and 1b shows that all the strong arcs in the truscottite photograph have their centres on groups of strong spots in the gyrolite photograph. Certain points of resemblance in the powder photographs thus also occur, although these cannot be considered identical. The 000l reflections of truscottite are strong and weak in bands at much the same θ values as in the case of gyrolite although the indices for regions of corresponding intensity do not coincide.

The above circumstances very strongly indicate that the basic structural units of truscottite and gyrolite are the same. If this is so, and the difference between the minerals resides in the way in which the units are stacked (and also in the possible inclusion of a layer of water molecules in the case of gyrolite), then the continuous transforms of the basic units are identical, but due to the repetition of the pattern at different intervals the transform is sampled in different places. The resultant X-ray patterns are therefore dissimilar in detail, but the general distribution of intensity is much the same in each case.

The composition of truscottite.—The analysis of the present specimen is given in table II, column 4. Together with the unit-cell dimensions already given, this yields the atomic cell contents given in column 6; in making the calculation $H_2O-110°$ was assumed to be uncombined, because the dehydration curve (fig. 2, curve 1) showed that no loss occurs between 65° and 110°. The results are in substantial agreement with the view, expressed in column 7, that the unit-cell contents are 12[CaO. $2SiO_2.\frac{1}{2}H_2O$], with some isomorphous replacement, especially in the case of the calcium. More detailed interpretation of the analysis seems unjustified, in view of uncertainties regarding the role of some of the minor constituents (Al_2O_3, CO_2 and SO_3).

The present results thus support the formula originally proposed by Hövig, rather than the one ($2(Ca,Mg)0.3SiO_2.2H_2O$) later proposed by Grutterink. A further objection to the latter formula can be made on crystallographic grounds, in that attempts to reconcile it with the unit-cell dimensions and specific gravity indicate non-integral numbers of

molecules in the unit-cell. As shown above, this objection does not apply to Hövig's formula, $CaO.2SiO_2.\frac{1}{2}H_2O$, which yields results compatible with the observed symmetry.

The main discrepancies between Grutterink's analyses (table II, column 3) and the present one (column 4) lie in the higher content of MgO and in the absence of values for CO_2 and SO_3. Hövig's analyses (columns 1 and 2), although difficult to interpret, give no indication of MgO. The high content of MgO found by Grutterink was possibly caused by impurity, since he states (loc. cit., p. 198) that the powder taken for analysis was not completely homogeneous.

Although the formula accepted here is not the same as that of gyrolite, it shows a resemblance in that the number of Si atoms in the cell is the same (24) as the number in the layers, 22·13 Å. thick along the c-axis, which constitute one-sixth of the unit-cell of gyrolite. This is in accordance with the view that the structures of the two minerals are related.

Behaviour on dehydration.—The dehydration curves (fig. 2) of truscottite and gyrolite both show a break at about 400° C., and if it is assumed that CO_2 is not lost below this temperature, the quantities of water (expressed as $H_2O : SiO_2$ molar ratios) remaining at 400° are approximately the same (1 : 6). The percentage cf water lost below 400° is, however, considerably larger in the case of gyrolite. It has been suggested (Mackay and Taylor, loc. cit.) that this water may be present in the form of molecules, and the presence of a larger number of water molecules, and also of additional calcium ions, could account for the expansion of the layer thickness from 18·71 Å. in truscottite to 22·13 Å. in gyrolite.

When gyrolite undergoes complete dehydration at 1000° C. the principal product is oriented pseudowollastonite (Mackay and Taylor, loc. cit.), but truscottite at this temperature yields mainly unoriented wollastonite. In the case of gyrolite, the formation of pseudowollastonite at temperatures at which it was only metastable was assumed to indicate a similarity in structure, and it might therefore have been supposed that truscottite would behave in the same way. That it does not may possibly be due to the fact that pseudowollastonite is much less able to accommodate other atoms in its lattice in place of calcium than is wollastonite, for the extent of such replacement is somewhat greater in truscottite than in gyrolite (table II, columns 4 and 5). After heating gyrolite to 1000° or above, no products other than pseudowollastonite or wollastonite were detected by X-rays, but when truscottite is heated to 1000°, cristobalite can be found among the products. This difference may partly be due to the greater proportion of silica set free in the case

of truscottite, which would make its X-ray pattern more readily discernible in that of the mixture. The silica appears also, however, to be in a more crystalline condition.

The dehydration mechanisms of gyrolite and truscottite evidently differ. In the first case, it appears likely that, with the expulsion of the water and part of the silica, relatively small atomic displacements suffice to convert the structure into that of pseudowollastonite, which is therefore formed although it is unstable under the prevailing conditions. With truscottite, on the other hand, a more drastic rearrangement occurs, giving as the immediate product (at 750–850° C.) an unidentified intermediate phase with very little preferred orientation. At about 900° this loses silica and is converted to wollastonite, which is stable at this temperature. A little pseudowollastonite is apparently formed at 1000°, possibly by the mechanism which operates in the case of gyrolite, but pseudowollastonite is the main product only when the material has been heated to 1200°, under which conditions the normal transition from wollastonite to pseudowollastonite takes place.