A serpentine mineral from Kennack Cove, Lizard, Cornwall.[1]

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Introduction.—A white soapy mineral which could not easily be identified in the hand-specimen was collected from a vein in the serpentine rock at Kennack Cove, Lizard, in April 1949. From a preliminary optical examination the mineral was thought to be saponite, and therefore of interest to clay mineralogists. Chemical analysis, X-ray, thermal, and optical investigations were carried out at the Building Research Station.

Occurrence and optical data.—The mineral occurs in a vertical vein cutting the serpentine rock on the north-east side of Kennack Sands. The vein is about 2–3 inches wide and shows up very white against the dark serpentine rock. The mineral is pure white in colour, soapy to the touch, and soft (H. 2). It is an irregular aggregate of small crystals, which are for the most part hexagonal plates. In thin section the mineral is seen to have a distinct basal cleavage and a birefringence of about 0·01. Microscopical examination of powder specimens shows the plate-like habit of the grains, and also the presence of a second mineral which is probably talc. The plates, when lying flat, give a centred uniaxial negative interference figure. The mineral has ϵ 1·545 and ω 1·555, $\omega-\epsilon$ 0·01. These optical properties may be easily confused with those of saponite. Chemical analysis (table II) or X-ray examination (table III) will, however, distinguish between these two minerals. Table I gives the optical properties, with those of saponite, chrysotile, and antigorite for comparison.

Table I. Comparison of optical data.

	Serpentine mineral.	Saponite.	Chrysotile.	Antigorite.
ϵ	1·545	—	α 1·493–1·546	α 1·555–1·564
ω	1·555	1·555	β 1·504–1·550	β 1·562–1·573
$\omega-\epsilon$ ...	0·01	0·01±	γ 1·517–1·557	γ 1·562–1·573
2V ...	0°	0°	0–50°	20–90°
Sign ...	negative	negative	positive	negative

Chemical analysis.—The analysis (table II) calculated on the basis of 10 oxygens gives the formula $Mg_{5\cdot6}(Si,Al)_4O_{10}(OH)_{7\cdot9}$. Making allowance for the talc impurity, it is probable that the mineral is analogous to either chrysotile or antigorite $Mg_6Si_4O_{10}(OH)_8$, and so should be regarded as a serpentine mineral.

TABLE II. Chemical analysis of serpentine mineral from Kennack, Lizard. (Analyst, L. J. Larner.)

SiO_2	44·49	CaO	0·03
Al_2O_3	2·26	TiO_2	0·03
MgO	40·27	Fe_2O_3	0·48
H_2O+	12·80		
			100·36

Thermal analysis.—A differential thermal analysis of a small sample was carred out by D. B. Honeyborne of the Building Research Station, and the resultant curve is reproduced as fig. 1. The curve is very like others obtained from some magnesium silicate minerals, for example antigorite.[1]

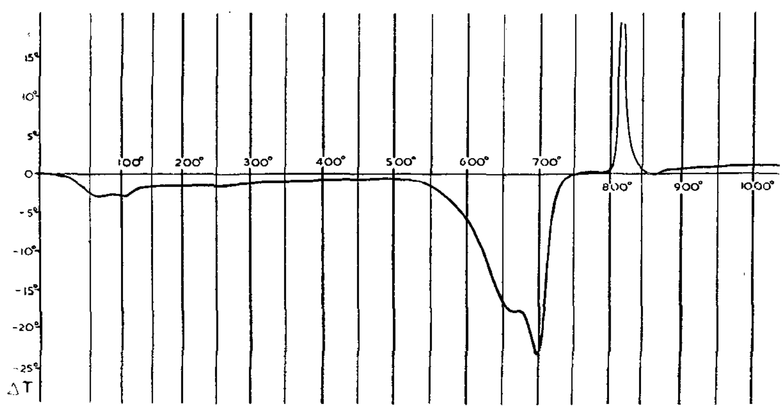

FIG. 1. Differential thermal analysis of serpentine mineral.

X-ray investigations.—Powder photographs and single-crystal rotation photographs of the serpentine mineral were taken. The powder photographs were taken on a 10-cm. camera using filtered Cu-$K\alpha$ radiation, λ 1·5374 Å. The measurements of spacings are given in table III. A powder photograph of a sample of saponite[2] from the Lizard (kindly

[1] S. Caillère and S. Hénin, Ann. Agronom. Paris, 1947, n. ser., vol. 17, p. 23. [M.A. **11**–175.]

[2] This material is white or stained red, soft (H. 2) and soapy to the touch. It forms a granular mass of micro-crystals with refractive index about 1·555.

supplied by Dr. G. F. Walker) was also taken, and the spacings for this mineral are given for comparison, together with the spacings for chrysotile and antigorite as recorded by Selfridge.[1] It can be seen that there is no resemblance between the serpentine mineral and the saponite; and that there is some resemblance between the chrysotile, antigorite, and the serpentine mineral, but not complete agreement.

TABLE III. Comparison of X-ray powder spacings and intensities.

Serpentine mineral d_{hkl} Å.	I.	Chrysotile* d_{hkl} Å.	I.	Antigorite* d_{hkl} Å.	I.	Saponite d_{hkl} Å.	I.
(9·4	5)†	—		—		18·8	10
7·51	10	7·364	9	7·355	8½	9·1	5
5·20	½	—		—		6·05	1
4·59	5	4·431	6	4·668	4	4·54	5
3·94	½	—		—		3·605	5
3·73	10	3·658	9½	3·641	9	3·00	4
3·105	3	—		—		—	
2·75	1	—		—		—	
2·635	1	—		—		2·605	6
2·580	1	2·571	8	—		—	
2·490	9	2·424	8	2·558	10	2·48	3
2·420	1	—		—		—	
2·29	½	—		—		2·26	2
2·205	½	—		—		—	
2·14	5	2·089	6	2·186	7	2·00	1
1·814	1	—		1·845	3	—	
1·780	3	—		1·794	4	—	
1·725	1	1·729	6	—		1·733	4
1·686	1	—		—		—	
1·657	½	—		—		—	
1·550	½	—		1·583	7½	—	
1·525	5	1·522	10	1·553	7½	1·533	7
1·497	5	—		—		—	
1·450	1	—		—		—	
1·407	½	—		—		—	
1·322	½	—		—		1·318	4
1·300	3	1·301	7	1·326	6	—	
1·268	3	—		1·273	4	1·268	2
1·238	½	—		—		—	
1·208	½	—		—		—	
1·159	2	1·187	½	1·160	2	—	
1·099	1	—		1·061	3½	—	
1·068	2	—		—		—	
1·051	2	1·039	2	—		—	

* Data from G. C. Selfridge, 1936 (loc. cit.). † Line due to talc impurity.

Since the mineral occurs as small flakes with distinct basal cleavage,

[1] G. C. Selfridge, Amer. Min., 1936, vol. 21, p. 463. [M.A. **6**–476.]

it was possible to pick out individual flakes, one of which was mounted and used for rotation photographs. A 6-cm. single-crystal camera was used with filtered Cu-$K\alpha$ radiation, λ 1·5374 Å. The flake was set up to give *a*, *b*, and *c* rotation photographs. The films produced are marred by the fact that some of the spots are extended into Debye powder lines. On indexing, however, it was found that the *hk*0 reflections were always spots, while *hkl* reflections were Debye powder lines. This suggests that there is preferred orientation of the layers.

The mineral was found to have a monoclinic unit cell with *a* 5·29, *b* 9·18, *c* 7·45 kX; β 91·4°; this cell leads to a calculated density of 2·52 g./c.c. The density determined by suspension in a bromoform-benzene mixture was 2·56 g./c.c.

In *h*0*l* planes *h* is always even, in *hkl* planes *h* plus *k* is always even, indicating that the monoclinic cell is centred on 001, and that the probable space-group is *C*2/*m*, *Cm*, or *C*2.

The cell dimensions of chrysotile and antigorite have been given by Aruja[1] as:

Antigorite . . . *a* 43·39, *b* 9·238, *c* 7·265 kX; β 91·4°.
Chrysotile . . . *a* 5·32, *b* 9·2, *c* 14·62 kX; β 93·2°.

The serpentine mineral from Kennack has a smaller unit cell than antigorite, but since the ratio of the *a*-axes is about one-eighth and the other dimensions are similar it is possible that the two minerals have a similar structure. Using the kaolinite-like sheet structure suggested by Aruja for antigorite as a basis, the intensities of the various reflections were calculated. It was necessary to adjust the *z*-coordinates of the ions to allow for the difference between the *c*-axes of antigorite (7·265 kX) and serpentine mineral (7·45 kX). The calculated intensities for the reflections falling on the equators of the *a* and *b* rotation photographs are given in table IV, and it can be seen that there is reasonable agreement.

Conclusions.—The white mineral from Kennack with a formula of $Mg_6Si_4O_{10}(OH)_8$ has a monoclinic unit cell with *a* 5·29, *b* 9·18, *c* 7·45 kX, β 91·4°, probable space-group *Cm*, *C*2, or *C*2/*m*. It probably has a kaolinite-like sheet structure with all the octahedral positions filled with magnesium ions and so is the magnesium analogue of kaolinite. It is probably a variety of antigorite with very little iron substitution and thus has optical properties (uniaxial, negative ϵ 1·545, ω 1·555, $\omega-\epsilon$ 0·01) different from those usually associated with antigorite.

[1] E. Aruja, Ph.D. thesis, Cambridge, 1943; Min. Mag., 1945, vol. 27, p. 65.

TABLE IV.

Equator of *a* rotation photograph.

$4\sin^2\theta$ (calc.)	*hkl.*	F^2 (calc.)	Int. (obs.)	$4\sin^2\theta$ (obs.)
0·205	001	165·0	10	0·205
0·340	020	17·0	4	0·34
0·394	021	5·4	9	0·405
0·410	002	48		
0·533	022	7	—	—
0·615	003	18	3	0·615
0·680	040	1	1	0·680
0·704	023	3		
0·710	041	3	—	—
0·795	042	0	—	—
0·820	004	2	½	0·85
0·914	024	0	—	—
0·918	043	2	—	—
1·020	060	33	9	1·01
1·025	005	9		
1·040	061	6		
1·070	025	0	—	—
1·090	044	1	½	1·06
1·100	062	1	1	1·10
1·190	063	3		
1·230	006	3	½	1·27
1·233	045	0	—	—
1·27	026	0	—	—
1·325	064	0	—	—
1·360	080	1	—	—
1·400	046	0	—	—
1·435	007	1	—	—
1·470	027	0	—	—
1·58	047	0	—	—
1·64	008	0	—	—
1·67	028	0	—	—

Equator of *b* rotation photograph.

$4\sin^2\theta$ (calc.)	*hkl.*	F^2 (calc.)	Int. (obs.)	$4\sin^2\theta$ (obs.)
0·205	001	165	10	0·205
0·410	002	48	8	0·42
0·580	200	28	3	0·58
0·615	003	18	10	0·615
	201	75		
	$20\bar{1}$	39		
0·705	202	8	3	0·71
0·715	$20\bar{2}$	2		
0·82	004	2	1	0·84
0·83	203	1		
0·86	$20\bar{3}$	3	2	0·86
1·019	204	6	3	1·025
1·025	005	9		
1·040	$20\bar{4}$	7		
1·17	205	1	2	1·16
1·18	400	3		
1·19	$20\bar{5}$	3	3	1·19
	401	5		
1·20	$40\bar{1}$	9	2	1·20
1·23	006	3	½	1·23
	402	0	—	—
1·25	$40\bar{2}$	3	½	1·255
1·32	403	3	½	1·32
1·34	$40\bar{3}$	1	—	—
1·35	206	0	—	—
1·37	$20\bar{6}$	1	—	—
1·43	007	2	½	1·43
1·53	207	1	—	—
1·56	$20\bar{7}$	0	—	—
1·64	008	1	—	—
1·73	208	0	—	—
1·74	600	5	2	1·75
1·75	$20\bar{8}$	0	—	—
	601	2	1	1·76
	$60\bar{1}$	1		
1·78	602	1	½	1·79
1·80	$60\bar{2}$	0	—	—
1·84	603	2	1	1·83
1·845	009	2	—	—
1·86	603	3	½	1·86