

*Stevensite from the Whin Sill in the  
region of the North Tyne.*

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*Summary.* A stevensite occurring as an alteration product of pectolite in amygdale-like structures within the Whin Sill is described. Data given for the stevensite include optical properties, stain reactions, chemical analysis, X-ray powder data, and D.T.A. curves. The close similarity between many of the properties of sepiolite and stevensite is indicated and D.T.A. is shown to be the most satisfactory method of distinguishing between the two minerals.

STEVENSITE, which occurs as an alteration product of pectolite, was found during an investigation of the Whin Sill in the neighbourhood of Gunnerton, Northumberland. This is the first record of stevensite associated with the Whin Sill.

Stevensite and pectolite are found in large amygdale-like bodies in the upper portion of the sill, but not in the chilled facies near the contact. These bodies resemble pectolite inclusions reported by Tomkeieff (1929) at Caw Burn near Haltwhistle.

At the base of the amygdale-like structure is a layer of rock of coarser grain than the normal sill, which when slightly altered takes on a reddish hue (fig. 1). This 'pegmatitic' rock, which is rich in sulphides and contains over 3% of datolite by volume (first record of this mineral from the Whin Sill), differs slightly in composition from the normal dolerite.

Pectolite or stevensite forms the main part of the amygdale and invariably has a flattish base but a more undulating upper surface. The minerals show radiating structures, and the centres of growth lie at various points on the periphery. Calcite and datolite are usually present at the upper surface of the pectolite but occasionally are found at the other margins. The top of the amygdale is delineated by a thin layer of chlorite.

Associated with these amygdales are layers of dolerite pegmatite and a second type of amygdale usually only partially filled with smoky quartz and calcite. This second type of amygdale also has a 'pegmatitic'

base, but this base differs in composition from that found below the pectolite structures. Details of these pegmatites will be given in a later paper.

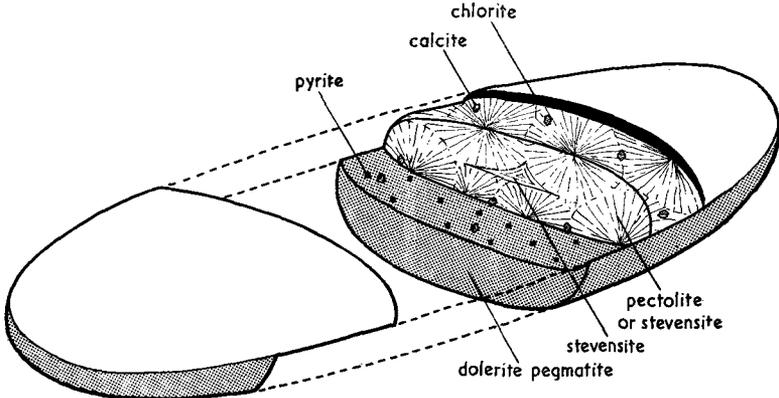


FIG. 1. 'Pull-apart' diagram of 'amygdale-like' body from the Whin Sill, Barrasford quarry, Northumberland.

Identification of the North Tyne mineral as stevensite was hampered by the relatively scarce data available about this mineral, and its close similarity to sepiolite in optical properties, chemical composition, and X-ray data.

The stevensite occurs in two forms: type I is fibrous, and is found as a complete replacement of pectolite, retaining the radiating structure of the original mineral; type II is an amorphous variety, found in small lacunae within the amygdales, encrusting pectolite.

Type I has an earthy lustre and variable colour. The most usual colour is cream, but greenish, brownish, and black varieties have been seen. Colour variations are common even within one radiating orb. Specimens exposed to a dry atmosphere frequently show darkening, become more fragile, and eventually crumble. Type II is usually a bluish-white colour, and possesses a dull lustre.

*Optical properties.* The two varieties of stevensite have different optical properties. Type I, of fibrous nature, is birefringent, shows straight extinction and positive elongation. The refractive indices of this type fall into two groups, one with  $\gamma' = 1.543$ ,  $\alpha' = 1.537$ ,  $(\gamma' - \alpha') = 0.009$  and the other with  $\gamma' = 1.519$ ,  $\alpha = 1.507$ ,  $(\gamma' - \alpha') = 0.012$ .

The type II stevensite is almost isotropic with  $n = 1.506$ . The two varieties of stevensite from the North Tyne are thus easily distinguished

by use of optical methods, yet they provide identical X-ray powder diffraction patterns.

Stevensite has both birefringent and isotropic forms and in this respect resembles sepiolite. Para-sepiolite is birefringent ( $(\gamma-\alpha) = 0.008-0.020$ ) and has quite variable refractive indices, while  $\beta$ -sepiolite is isotropic ( $n = 1.517 \pm$ ).

The variation in optical properties of the fibrous forms of both these minerals is probably related to variation in water content.

The *chemical analysis* shown in table I, col. 1, is of fibrous type I stevensite, and was made by Dr. R. A. Chalmers using a modified form of rapid analysis.

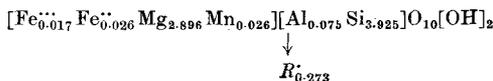
TABLE I. Chemical analyses of stevensite and sepiolite.

	1.	2.	3.
SiO <sub>2</sub> ... ..	54.5	57.30	54.83
TiO <sub>2</sub> ... ..	0.02	n.d.	n.d.
Al <sub>2</sub> O <sub>3</sub> ... ..	< 0.1	none	0.28
Fe <sub>2</sub> O <sub>3</sub> ... ..	0.34	0.32	0.45
FeO ... ..	0.45	none	n.d.
CaO ... ..	0.6	0.97	0.55
MgO ... ..	26.8	27.47	24.51
MnO ... ..	0.41	0.21	n.d.
Na <sub>2</sub> O ... ..	0.04	0.03	0.35
K <sub>2</sub> O ... ..	0.09	0.03	0.03
P <sub>2</sub> O <sub>5</sub> ... ..	0.01	n.d.	n.d.
H <sub>2</sub> O <sup>+</sup> ... ..	9.9	7.17	10.74
H <sub>2</sub> O <sup>-</sup> ... ..	6.6	6.69	8.18
	99.9	100.19	99.92

1. Stevensite Type I, North Tyne. Anal. R. A. Chalmers.
2. Stevensite, Springfield, New Jersey. G. T. Faust and K. J. Murata (K. J. Murata anal.), 1954.
3. Sepiolite, Yavapai County, Arizona. A. J. Kauffman, 1943.

The CaO and CaO+MgO were determined by micro methods and the end-point determined spectrophotometrically. Total iron was also done on a micro scale, solution B (Shapiro and Brannock, 1956) being passed through a silver reductor before titration with ceric sulphate.

Table I illustrates the close chemical relationship between stevensite and sepiolite. Since stevensite belongs to the montmorillonite group (Faust and Murata, 1954), the following formula was calculated according to the method outlined by Ross and Hendricks (1945):



*Staining tests* were carried out on the North Tyne material using methods described by Caillière (1936), Faust (1940), and Faust and Murata (1953). The results of these tests are compared in table II with results published for various clay minerals. When stained with malachite green after acid treatment, the North Tyne reaction was typical of neither stevensite nor montmorillonite (Faust and Murata, 1953), but resembled that of Hector clay.

TABLE II. Stain reactions for stevensite and other clay minerals. Colour in reflected light in parentheses where it differs from that in transmitted light.

	Stevensite N. Tyne, Type I.	Stevensite*	Hector clay†	Montmoril- lonite‡	Sepiolitell
<i>Malachite green in nitrobenzene:</i>					
Natural mineral	light green	emerald green	emerald green	—	—
Acid treated	dark emerald green	pale yellow	deep emerald green	yellow-yellow red	—
Alkali treated	dark emerald green	—	deep emerald green	—	—
<i>Methylene blue in nitrobenzene:</i>					
Natural mineral	deep blue green		greenish blue		
Acid treated	deep blue green		greenish blue		
Alkali treated	deep blue green		greenish blue		
<i>Aqueous solutions:</i>					
Malachite green	emerald green (turquoise)				brun violace
Methylene blue	turquoise (bright blue)				bleu violace
Eosin	rose pink (rose madder)				rose saumon
Fluorescein	yellow brown (gamboge)				jaune d'or
Benzidine	Hooker's green	light green powder blue later		purple blue	

\*Faust and Murata, 1953.

†Faust, 1940.

‡Mielenz, King, and Schieltz, 1950.

§Maillière, 1936.

*X-ray powder photographs* of the North Tyne material were obtained using copper radiation and a 9-cm. diameter camera, which, unfortunately, could not record  $d$  spacings greater than 10 Å. The  $d$  spacings recorded are listed in table III, together with data for stevensite and sepiolite. Both types of North Tyne stevensite are shown in this table, and it is interesting to note that there are only negligible differences in the two records. Whilst it is to be remembered that many minerals rich in magnesia have numerous  $d$  spacings in common, the patterns of sepiolite and stevensite are quite similar. The strong line at 9.78 Å. in the North Tyne material is interesting, because this line is not developed in normal stevensite or sepiolite, although similar lines are reported in both these minerals after heat treatment (Migeon, 1936; Brindley, 1955). The North Tyne material produces lines characteristic

TABLE III. X-ray powder diffraction data for the North Tyne stevensite (1, 2) compared with normal (5) and heated (6) stevensite and with sepiolite (4). Also for a mineral described as sepiolite (3) that appears to be really a stevensite.

1.		2.		3.		4.		5.		6.	
<i>d.</i>	<i>I.</i>										
								24			
9.78	st	9.78	st	10	100	12.15	10	11.2-12.4	10	9.6	m-st
		7.02	vw			9.8	st*				
		5.01	w	5	10	7.6	3				
4.52	st	4.53	st	4.52	90	5.05	2	4.89-4.96	2	4.8	w
4.29	vw					4.60	10	4.54	10	4.5	w
3.89	vw										
						3.82	5				
						3.60	1				
						3.40	2				
3.22	m-st	3.20	st b	3.20	70	3.22	5	3.0-3.5	5	3.18	m-st
3.04	m										
2.87	w										
2.67	w										
2.60	st	2.59	st			2.61	8	2.618	9		
				2.54	90						
2.49	st	2.49	st								
						2.45	7				
2.28	w-m	2.27	w	2.27	20	2.28	6	2.279	2		
2.24	w										
2.09	w-m	2.09	w			2.09	5				
		1.97	vw			1.97	1				
1.91	w-m	1.90	vw	1.92	10					1.92	w b
1.87	w-m					1.88	2				
1.81	vw										
1.72	m	1.72	m	1.72	30	1.71	2	1.725	4		
		1.70	w								
1.61	vw					1.60	4				
						1.56	4				
1.52	vst	1.52	vst	1.52	90	1.52	2	1.520	9		
1.43	vw										
1.37	vw					1.38	2				
						1.36	2				
1.31	st b	1.31	st	1.31	50	1.31	3	1.314	7		
1.26	w	1.26	w-m	1.26	10			1.265	2		
1.24	w									1.22	w b
1.18	vw										
1.14	vw										
1.04	w	1.04	vw					1.047	1		
0.992	m b	0.991	m b	0.993	30			0.994	3		
0.879	m-w	0.879	mb	0.879	30			0.879	3		

1. N. Tyne, Type I, fibrous stevensite.
2. N. Tyne, Type II, stevensite.
3. Stevensite ('sepiolite'). Copt Hill, A.S.T.M. index card no. 2-0048.

4. Sepiolite. Longchambon, 1937.
5. Stevensite. Brindley, 1955.
6. Stevensite heated to 400° C. Brindley, 1955.

\* Only appears after heating to 300° C. or above.

of both normal and heat-treated stevensite. This would suggest that the transformation of pectolite to stevensite took place above normal temperatures, probably before the final cooling of the sill.

There is close similarity between the North Tyne material and a mineral in the A.S.T.M. index reported as sepiolite. This mineral occurs as a coating on apophyllite that rests on pectolite from the Whin Sill at Copt Hill, and is almost certainly a type I stevensite.

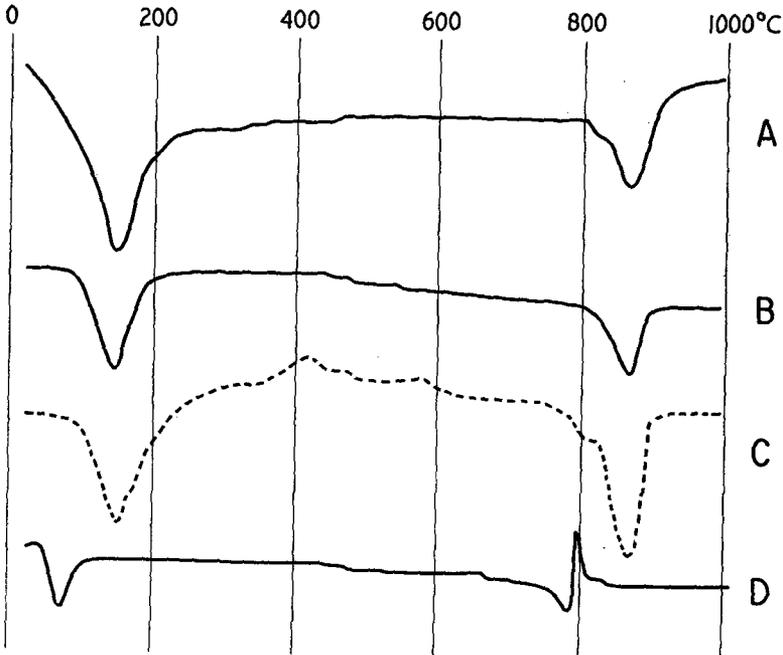


FIG. 2. Differential thermal curves of: (A and B) stevensite, type I, N. Tyne; (C) stevensite, Springfield, New Jersey (after Faust and Murata, 1953); (D) fibrous sepiolite, Ampandrandava, Madagascar (B.M. 1940, 40).

*Differential thermal analysis.* Fig. 2 shows D.T.A. curves for the North Tyne type I stevensite and a fibrous sepiolite from Ampandrandava, Madagascar, derived from analyses carried out on the same apparatus.<sup>1</sup> A curve for stevensite after Faust and Murata, 1953, is

<sup>1</sup> The thermal curves reproduced here were obtained with a medium sensitivity apparatus, without a pre-amplifier, using a 'Kent' potentiometer-type temperature-difference recorder and chromel-alumel thermocouples. The test sample was very small (less than 0.2 g.) and was sandwiched between calcined kaolin in a silica crucible. The thermocouples were placed horizontally and the crucible was finally tamped down with calcined kaolin.

also depicted as a dashed line; in this representation the various peaks are accurately positioned with regard to temperature, but the amplitude of the curve is not to the same scale as the others.

The curves for the North Tyne material compare favourably with the standard stevensite, showing two important endothermic peaks at about 150° C. and 860° C. and a small endothermic peak about 820° C. The sepiolite curve has two endothermic peaks at about 55° C. and 760° C. and a well-defined exothermic peak at about 780° C. Thus there is little similarity between the D.T.A. curves of the two minerals, and D.T.A. appears to be a satisfactory method of distinguishing between them.

It is interesting to note that the peaks on the curve for sepiolite occur at lower temperatures than those illustrated by Caillière and Hénin (1957). This variation is almost certainly due to the different conditions under which the analyses were carried out. The curves illustrated by Caillière and Hénin were obtained using an uncovered crucible (oxidizing conditions), while the new curves result from a study in a sealed crucible (reducing conditions).

*Discussion and conclusions.* The type I stevensite from the North Tyne region is an alteration product of pectolite, but the type II material may well be an original mineral in the amygdale-like structures found in the Whin Sill. Glenn (1916) suggests that stevensite from Springfield, New Jersey, was formed from pectolite. In the process he envisages, percolating rainwater becomes enriched in magnesia while passing through basalt, and the solution so formed reacts with pectolite transforming it into stevensite. If the strong line at 9.78 Å. is evidence of natural heat treatment, the above process could not apply in this case and the replacement of pectolite by stevensite would be penecontemporaneous with the infilling of the amygdales. The reacting solutions would then be magmatic, or partly so, at a temperature of about 400° C. It would appear, therefore, that Ca (to form pectolite) and Mg (to form stevensite) were concentrated in the residual phases of the Whin Sill magma of this area.

Many of the properties of stevensite closely resemble those of sepiolite, but D.T.A. is a satisfactory method of distinguishing between these two minerals.

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