

## STEVENSITE, REDEFINED AS A MEMBER OF THE MONTMORILLONITE GROUP\*

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### ABSTRACT

Stevensite, a hydrous magnesium silicate, typically pseudomorphous after pectolite in basalt, has been restudied. X-ray diffraction analysis, staining tests, and differential thermal analysis all indicate that the mineral is a member of the montmorillonite group of clay minerals.

Stevensite differs from saponite in lacking essential amounts of aluminum and from hectorite in lacking lithium and fluorine. As is indicated by its formula,  $[\text{Mg}_{2.83}\text{Mn}_{0.02}\text{Fe}_{0.02}][\text{Si}_4\text{O}_{10}(\text{OH})_2 \times 15]$ , stevensite has an abnormally low base-exchange capacity compared with the average value for montmorillonite of 0.37 equivalent per formula weight. This low capacity is believed to be due to the unique and probably restricted manner in which the charge deficiency apparently originates in the mineral—namely, through a deficiency in the total number of ions in positions of octahedral coordination. Multivalent ions, whose higher charge would compensate for the deficiency in number, as in saucornite, are practically absent in stevensite.

### HISTORY OF STEVENSITE AND ITS SYNONYMS

Professor Albert R. Leeds, of the Stevens Institute of Technology, Hoboken, New Jersey, in 1873 published a description and analysis of a mineral which he called talc pseudomorphous after pectolite. An examination of his paper (Leeds, 1873) shows, however, that he was not convinced of the interpretation of his analysis, for he writes (p. 24):

“While closely approaching talc in its physical properties this pseudomorph after pectolite is near sepiolite in its chemical composition.”

The mineral which he analyzed was found “in veins of calcite which traverse the trap rock in the vicinity of Bergen Hill Tunnel, Hoboken, New Jersey.” His analysis, Table 1, shows that his sample was nearly but not quite pure.

According to Chester (1896) the name stevensite was subsequently proposed by Leeds in 1873 in honor of E. A. Stevens, the founder of the Stevens Institute of Technology. Chester (p. 257) describes the naming as follows: “This name was suggested in 1873 at a meeting of the N. Y. Lyceum of Natural History, but not published though soon after used on labels.” Chester cites a reference to a note by Leeds published in “The Naturalists Leisure Hour” for 1889, but a search of two copies of this publication (from the Library of Congress and the American Museum of

\* Publication authorized by the Director, U. S. Geological Survey.

TABLE 1. CHEMICAL ANALYSES OF STEVENSITE, PECTOLITE, AND OF NATURAL MIXTURES

Analysis No.	1	2	3	4	5	6	7	8	9
Name	Stevensite	Stevensite	Stevensite	Stevensite + pectolite	Magnesium-pectolith	Walkerie	Pectolite	Pectolite	"Stevensite"
Locality	Springfield, N. J.	Bergen Hill Tunnel, Hoboken, N. J.	Hartshorn Quarry, Springfield Twp., N. J.		Burg Herborn, Germany	Corstorphine Hill, Scotland	Paterson, N. J.	Theory	Jersey City, N. J.
	U.S.N.M. R4719								Selfridge No. 51
SiO <sub>2</sub>	57.30	60.55	58.03	53.84	56.22	52.20	53.80	54.2	57.24
Al <sub>2</sub> O <sub>3</sub>	None	1.02	0.37	1.18	0.67	—	0.00	—	None
Fe <sub>2</sub> O <sub>3</sub>	0.32	—	—	—	—	—	0.00	—	1.14
FeO	None	0.72	—	—	—	1.33	1.00	—	0.12
MnO	0.21	0.65	0.03	0.13	—	—	0.12	—	0.75
MgO	27.47	26.56	27.66	9.81	5.76	5.12	0.00	—	27.89
CaO	0.97	1.41	1.61	22.59	24.72	28.64	33.20	33.8	0.38
Na <sub>2</sub> O	0.03	—	3.73	5.59	6.89	6.50	9.01	9.3	—
K <sub>2</sub> O	0.03	—	—	—	0.21	0.85	0.00	—	—
H <sub>2</sub> O <sup>+</sup>	7.17	—	—	6.76	5.53	5.28	2.94	2.7	7.69
H <sub>2</sub> O <sup>-</sup>	6.69	9.30	8.45	*	*	*	—	—	4.76
F	None	—	—	—	—	—	—	—	None
	100.19	100.21	99.88	99.90	100.00 <sup>+</sup>	99.92	100.07	100.0	99.97
Analyst	K. J. Murata	A. R. Leeds (1873)	M. L. Glenn (1916)	M. Dittich (Reuning, 1907)	M. F. Heddle (1880)	F. A. Gonyer (Peacock, 1935)			K. J. Murata

\* Sample dried at 110° C. before analysis.

Natural History) failed to reveal any mention of the naming of this mineral. Chester also cites the erroneous usage of stevenite for stevensite.

After Leeds' work was published two other closely related magnesium silicates were described. Heddle (1880) named a magnesium silicate from Corstorphine Hill, Scotland, walkerite. Walkerite (not walkererde of Hintze = walkerite of Dana's System of Mineralogy, 1892) contains 5.12 per cent MgO. (See Table 1.) Reuning (1907) described a mineral which he called magnesiumpektolith (magnesium pectolite) from the diabase at Burg bei Herborn, Driesdorf, Germany.

Valiant (1904) included stevensite in his list of New Jersey mineral localities.

The problem of the character and composition of stevensite was reopened by Glenn (1916). He made an analysis of stevensite and of a partly altered specimen of pectolite from the Hartshorn quarry in Springfield Township, Essex County, New Jersey. From a study of these two analyses he concluded that walkerite and magnesiumpektolith were mixtures of stevensite and pectolite.

Hilgard (1916) found a peculiar clay at Hacienda Santa Lucia near Mexico City which on analysis showed 17.10 per cent MgO. He named this mineral lucianite.

Rogers (1917) in a review of the status of amorphous minerals suggested that (1) "stevensite . . . is probably the amorphous equivalent of crystalline talc" and (2), referring to lucianite, Hilgard's clay, "This substance . . . is probably a synonym of stevensite."

The occurrence of stevensite at nine localities in the Watchung basalt of New Jersey is given by Manchester (1931), who considered it to be a variety of talc.

Lorent (1933) in studying the hydrothermal alteration of the limburgite of Sasbach in the Kaiserstuhl discovered a gel-like substance which he called a "magnesiumsilikatgel." Analysis of a sample weighing only 0.3793 gram showed it to consist of 46.1 per cent H<sub>2</sub>O; 26.7 SiO<sub>2</sub>, 2.8 Al<sub>2</sub>O<sub>3</sub>, 0.6 CaO and 24.7 MgO; sum = 99.7 per cent. The ratio of MgO to SiO<sub>2</sub> shows that this mineral, if homogeneous, is not stevensite.

Stevensite was reported in the matrix of the Mayville iron ore of Wisconsin by Hawley and Beavan (1934), who identified it by optical and microchemical tests.

Selfridge (1936) included some data on stevensite in his paper on the serpentine minerals. He listed stevensite with deweylite and commented as follows (p. 484): "No explanation could be found for the higher indices of No. 51. Duplicate x-ray patterns show that it is deweylite. Optically it approaches serpentine," and (on p. 500) "The deweylite pattern of Specimen No. 51, which displayed optical characters similar to those near

the low index of serpentine, indicates the need for further study between deweylite and serpentine."

The most detailed description of stevensite appeared in the *Ergänzungsband* of Hintze's *Handbuch der Mineralogie* (1936-1937), where two pages (649-650) are devoted to the description of this mineral and its synonymy.

Strunz (1941) in his *Mineralogische Tabellen* considered stevensite to be talc pseudomorphous after pectolite; walkerite to be weathered pectolite; and lucianite to be stevensite (amorphous talc?).

Ross and Hendricks (1945) in their paper on the minerals of the montmorillonite group observed that the lucianite of Hilgard is "essentially similar to saponite and differs only in being a little higher in calcium oxide and lower in magnesia than most saponites."

Hey (1950) in his book, *An index of mineral species and varieties*, lists stevensite as "talc pseudomorphous after pectolite"; walkerite as a variety of pectolite, and gives as a synonym magnesium-pectolite. He also interprets lucianite as "probably an impure saponite."

#### DESCRIPTIONS OF THE SPECIMENS STUDIED

*Stevensite* No. 1. Locality: Springfield, New Jersey (U.S.N.M. R4719).

Pseudomorphous after pectolite. Pink masses. Analysis 1, Table 1.

*Stevensite* No. 2. Locality: Jersey City, New Jersey (Selfridge No. 51).

Deweylite, "Serpentine after pectolite." Amber masses. Analysis 9, Table 1.

*Stevensite* No. 3. Locality: Paterson, New Jersey (F-1104). Pseudomorphous after pectolite. Buff, in part resinous in appearance.

*Pectolite* No. 1. Locality: Paterson, New Jersey (F-1103). White, radiating needles.

#### X-RAY POWDER DIFFRACTION STUDY

X-ray powder diffraction patterns of stevensite, saponite, and pectolite, made from spindles prepared with Duco cement or cellulose acetate dissolved in toluene as the binder, were obtained using filtered copper radiation. Indices were assigned to stevensite on the basis of the work of Faust (1951) on the related mineral sauconite.

The data in Table 2 show that the x-ray powder diffraction data for stevensite are practically identical with those of the montmorillonite mineral saponite.

The measurements in Table 2 were made on stevensite No. 1 dried at room temperature. A small amount of stevensite was treated with ethylene glycol, and it was found that (001) advanced from  $14 \pm \text{Å}$  to  $15.1 \text{ Å}$ .

Stevensite No. 3, from Paterson, New Jersey, yielded a pattern showing (001), for air-dried material mounted in ethyl cellulose in toluene, to be  $16 \pm \text{Å}$ .

TABLE 2. X-RAY POWDER DATA FOR STEVENSITE, SAPONITE, AND TALC DRIED AT ROOM TEMPERATURE  
(Cu/Ni;  $\lambda = 1.5418 \text{ Å}$ )

Stevensite No. 1 Springfield, New Jersey				Saponite, Cathkin near Glasgow, Scotland				Talc Brindley (1951)	
U.S.N.M. R4719 Miller Indices	d(Å)	I	Notes	Miller Indices	d(Å)	I	Notes	d(kX)	I
(001)	14. $\pm$	s	Shows a "tail" Center of Duco band	(001)	14.8	vs			
	5.14	s		(002)	7.71	m	Broad	9.4	8
				(003)	5.14	m	Broad		
(110)(020)	4.55	s		(110)(020)	4.59	ms	Broad	4.69	4
					4.34	vvf			
(005)?	3.20	m		(004)	3.79	vw		3.88	1b
				(005)	3.09	m		3.37	3
(130)	2.63	m	} Not a good separation		2.613	m		3.11	10
(200)	2.53	w-m		(200)	2.545	m	Diffuse	2.70	1
							2.59	2	
(220)(040)	2.284	vw	Diffuse				2.47	5	
					1.852	vvf		2.32	1
								2.20	3
(240)	1.722	w		(150)	1.747	w		2.09	2
				(310)	1.703	w		1.92	$\frac{1}{2}$
(060)	1.526	s		(060)	1.543	s	Broad	1.86	3
					1.498	vvvf		1.725	2
					1.458	vvvf		1.67	4
(260)(170)	1.315	mw			1.327	m	Broad	1.652	1-
(400)	1.265	vw		(260)	1.278	vvvf	Broad	1.632	1b
				(400)	0.999	vvvf	Diffuse	1.55	3
(290)(460)	0.990	vvw						1.52	4
(380)(520)								1.501	2
(480)	0.879	vvw		(550)(390)	0.890	vvvf	Broad	1.461	1
								1.446	$\frac{1}{2}$
								1.405	2
								1.390	3b
								1.330	2
								1.315	2
								1.291	2

Stevensite No. 2, which is part of the material studied by Selfridge (1936) and which he called deweylite No. 51, was chemically analyzed and the data are recorded in Table 1. Microscopic examination of some acid-treated material showed the presence of a little quartz. X-ray study suggests that this material is a mixture of talc and stevensite.

X-ray examination of the material produced by the dissociation of stevensite in the differential thermal analysis study, record C-123, showed it to consist of enstatite.

### PHYSICAL PROPERTIES

#### *Specific gravity*

The specific gravity of stevensite as reported in the literature is given in Table 3.

TABLE 3. SPECIFIC GRAVITY OF STEVENSITE, TALC, SAPONITE AND MONTMORILLONITE

Species	Locality	Specific gravity	Reference
Stevensite	Bergen Hill Tunnel, Hoboken, N. J.	2.565	Leeds (1873)
Stevensite	Hartshorn quarry, Springfield Township, Essex County, N. J.	2.15-2.20	Glenn (1916)
Talc	Various	2.7-2.8	Dana-Ford (1932)
Talc	Theoretical ( <i>x</i> -ray)	2.824	Gruner (1934)
Montmorillonite, variety: saponite		2.26±	Larsen and Berman (1934)
Montmorillonites, various		2.04-2.52	Rosenholtz and Smith (1931)

An examination of these data shows that the specific gravity range reported for stevensite is within the commonly accepted range of values given for montmorillonite and is definitely lower than that of talc.

#### *Hardness*

The hardness determination made on nearly pure material by Leeds (1873) is 2.5. Glenn (1916) confirmed this for his specimens. Rogers (1917) and others ignored this property in relegating stevensite to the status of an amorphous equivalent of talc.

#### *Swelling characteristics*

Glenn (1916) noted, "In H<sub>2</sub>O some pieces crumble and give off air bubbles with a crackling sound." A small fragment of stevensite No. 3 when dropped in water gives off air bubbles but shows no easily detectable swelling.

#### *Staining relations*

Stevensite was examined by the staining tests devised by Faust (1940)

for differentiating the clay minerals of the montmorillonite group from those of the kaolinite group. Briefly, the method is as follows: a small pinch of the ground mineral is placed on a microscope slide. The fragments are covered with a drop of the staining solution, such as malachite green dissolved in nitrobenzene. A cover glass is placed over the preparation and it is then examined under the microscope. This shows whether the fragments have been stained, and if so the color of the stained fragments is normally emerald green. A small amount of the mineral in its natural state is ground and then heated with a 10 per cent solution of hydrochloric acid. The acid-treated mineral is washed by decantation until it is free of acid, and then dried on a steam bath. This material is then stained as described above. If the mineral is a member of the montmorillonite group the fragments are stained yellow, if of the kaolinite group they are emerald green.

Stevensite No. 1 stained deep emerald green in a solution of malachite green dissolved in nitrobenzene. The acid-treated stevensite stained a very pale yellow.

The reaction of stevensite with an aqueous solution of benzidine was also investigated. It was found that the instantaneous reaction between stevensite and benzidine solution produced a light-green coloration. This green deepened in tone after 2 hours of contact, and after 18 hours the color changed to a light powder blue. Stevensite thus behaves like a montmorillonite in forming a colored reaction product with benzidine. The mechanism of this rearrangement of benzidine by montmorillonites has been discussed by Hendricks and Alexander (1940).

#### CHEMISTRY

##### *Methods of chemical and spectrographic analysis*

A 1-gram sample of stevensite No. 1 and a half-gram sample of stevensite No. 2 were first dried to constant weight at 110° C. and then ignited at 900° C. in order to determine  $H_2O-$  and  $H_2O+$ . During ignition the color of stevensite No. 1 changed from pink to black and finally to white, as was noted by Leeds (1873) with his sample. The ignited materials were fused with three times their weight of sodium carbonate and the subsequent chemical analysis done by conventional methods (Hillebrand, 1919). Ferrous iron was determined on separate half-gram portions of the original samples. A qualitative test for fluorine, based on the color change of the zirconium-alizarin lake and sensitive to 0.02 per cent F, was negative. The results of the chemical analyses are given in Table 1.

A semiquantitative spectrographic analysis of stevensite No. 1 was also made in order to determine the minor elements. Twenty-five milli-

gram duplicate samples were loaded into graphite electrodes, ignited over a Meker burner, and excited by means of the d-c arc. The spectrographic equipment, the general procedure, and the comparison standards used were the same as those described in Gordon and Murata (1952). The orders of magnitude of the various elements were estimated by visual comparison with previously exposed spectrograms of pegmatite base standards. Besides the elements reported in the chemical analysis, the following were determined in the spectrograms of stevensite No. 1: 0.0X per cent B, Al; 0.00X per cent Sr; 0.000X per cent Cu; elements looked for but not detected were Ag, As, Ba, Be, Bi, Cd, Co, Cr, Ga, Ge, In, La, Li, Mo, Nb, Ni, P, Pb, Sb, Sc, Sn, Ti, Tl, V, W, Y, Yb, Zn, and Zr.

#### *Base-exchange capacity*

After stevensite had been found by other techniques to be a member of the montmorillonite group, closely allied to saponite, it became desirable to determine its base-exchange capacity and the ratios of the exchangeable bases present. M. D. Foster, of the Geological Survey, kindly determined these values for us. Her report is given in Table 4.

TABLE 4. BASE-EXCHANGE RELATIONS OF STEVENSITE NO. 1

[Determinations by M. D. Foster]

Locality		Exchangeable bases					Total exchangeable bases determined	Total base-exchange capacity
		CaO	MgO	ZnO	Na <sub>2</sub> O	K <sub>2</sub> O		
Springfield, New Jersey	%	0.93	0.25	0.00	0.03	0.03		
U.S.N.M. R4719	milli- equiv./g	0.33	0.13	0.00	0.00	0.06	0.46	0.36

The sum of the exchangeable bases is larger than the determined exchange capacity. This may be explained by the presence of about a half per cent of fine-grained calcite in the sample, which could not be removed, and which would appear as excess calcium in the base-exchange solution. In all of the calculations reported later in the paper, the determined capacity was used rather than the sum of the bases. The ex-



change capacity of 0.36 milliequivalent per gram is considerably lower than the mean value of 0.95 found by Foster (1951) for 14 montmorillonitic clays. The low exchange capacity of stevensite is probably due to the unusual way in which the charge deficiency originates in the mineral, as discussed in the following section.

*Formula*

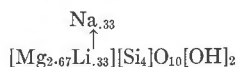
Two previously established magnesium-rich members of the montmorillonite group of minerals are saponite and hectorite. Stevensite differs from them by not containing essential amounts of aluminum, lithium, or fluorine.

In the absence of aluminum, the tetrahedral positions in the structure of stevensite must be filled solely by silicon. The formula of stevensite No. 1 has been calculated according to the method outlined by Ross and Hendricks (1945, p. 42). A preliminary calculation indicated a slight excess of silica. Although no separate silica phase was noticed in this material, a small amount of quartz was observed microscopically in stevensite No. 2, analysis 9 of Table 1.

Y, Ross and Hendrick's notation for the number of aluminum atoms in tetrahedral positions, becomes zero when 1 per cent excess silica is assumed to be present in stevensite No. 1. The formula calculated under this assumption is as follows:



In the absence of aluminum, no deficiency of charge can arise in the tetrahedral Si positions; therefore, the charge deficiency equal to the exchange capacity must originate in the octahedral Mg positions. An example of such an origin of charge deficiency is found in hectorite, whose formula may be written

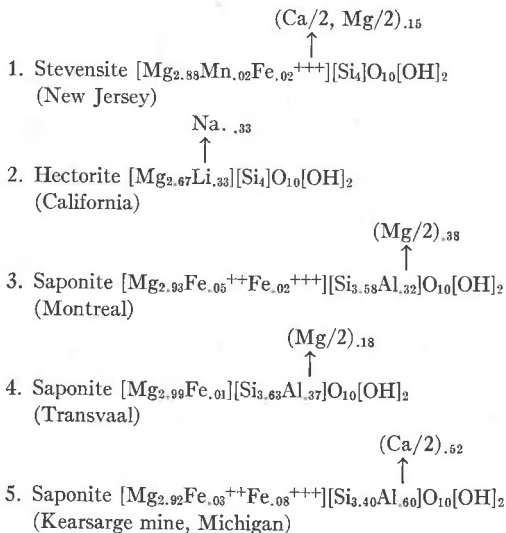


In hectorite the octahedral positions are completely filled ( $\Sigma = 3.00$ ), and the charge deficiency is due to the substitution of monovalent Li for divalent Mg. In stevensite, the octahedral positions are not completely filled ( $\Sigma = 2.92$ ), and the charge deficiency is to be ascribed to an insufficiency of ions in these positions. Perhaps only a limited amount of charge deficiency can arise in this manner, resulting in a low base-exchange capacity for the mineral.

Incompletely filled octahedral positions ( $\Sigma = 2.70-2.90$ ) have been noted in sauconite (Ross, 1946). However, in this mineral, the presence

of substantial amounts of trivalent aluminum and iron substituting for bivalent zinc and magnesium, produces an excess of charge rather than a deficiency in the octahedral positions. Nevertheless, the example of sauconite is valuable in showing that incompletely filled octahedral positions are possible in trioctahedral clay minerals. In stevensite, an insufficiency of magnesium ions leads directly to a charge deficiency because trivalent ions are virtually absent. Such an origin for charge deficiency has not been hitherto recognized, and should be looked for in other trioctahedral clay minerals that are low in multivalent ions.

A comparison of the formula of stevensite with those of other saponites, taken from the paper of Ross and Hendricks, arranged according to increasing alumina, is given to show the relationship among them. A recent formula (No. 4) of Schmidt and Heystek (1953) was added after this paper was prepared.



#### *Interpretation of the chemical analyses of stevensite and related minerals*

Stevensite is commonly derived by the action of magnesium-bearing solutions on pectolite, and as a result pectolite laths may be present as an impurity. This genetic relationship has been observed for much of the stevensite in the Watchung basalt of New Jersey, for the magnesiumpectolith from Germany, and for the walkerite from Scotland. A graphical study of analyses 1 through 8 of Table 1 is presented in Figure 1. Calcium oxide was selected as the constituent for the primary location of the analysis on the line stevensite-pectolite. It is probably the most reliable index, although a very small amount of the calcium reported in the

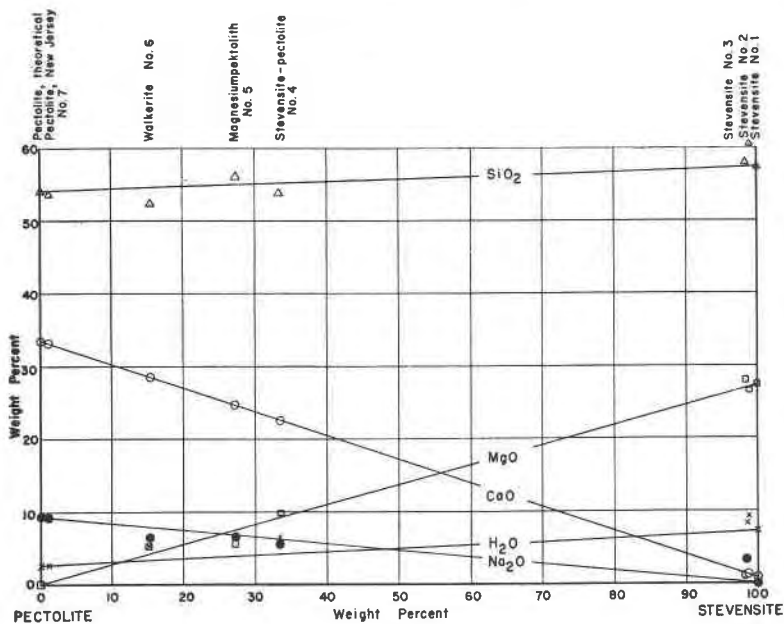


FIG. 1. A graphical study of chemical analyses of stevensite and of natural mixtures of stevensite and pectolite. The ordinate represents the percentage of a given constituent in each analysis. The abscissa gives the compositions of the natural mixtures.

analysis is actually base-exchangeable and a still smaller amount may be present as calcite. The value of H<sub>2</sub>O— was ignored. Within the limitations of the data, the graphical relationships support the interpretations of the chemical analyses in terms of two phases, stevensite and pectolite.

#### DIFFERENTIAL THERMAL ANALYSIS

A differential thermal analysis was made on part of the tube sample of stevensite No. 1, used for the analytical studies, and the results are shown in Figure 2. Differential thermal analysis curves are given for saponite, talc, and the serpentine minerals chrysotile and antigorite. The data obtained from these curves are summarized in Table 5.

Comparison of these curves shows clearly that stevensite is a member of the montmorillonite group and is definitely not talc or a serpentine mineral. The curve of stevensite is very closely related to that of saponite.

#### NOTES ON SOME SUPPOSED HYDRATED TALCS

The possibility that stevensite might be a hydrated form of talc such as described by Foshag and Wherry (1922) was considered. Differential

TABLE 5.—OBSERVATIONS ON THE THERMAL CURVES OF STEVENSITE, SAPONITE, TALC, CHRYSOTILE AND ANTIGORITE

Mineral	Record no.	Temperature of peaks (° C.)								Locality	Weight of sample used (gram)
		Low temperature		Intermediate temperature		High temperature		Exo-thermic	Exo-thermic		
		Endo-thermic	Exo-thermic	Endo-thermic	Exo-thermic	Endo-thermic	Exo-thermic				
Stevensite No. 1	C-123	152	420	639	583	805	865	—	—	Springfield, N. J. (U.S.N.M. R4719)	0.4762
Saponite	C-185	159	400	562	—	—	840	—	—	Truckee River Canyon, about 20 miles east of Reno, Nev. (on U. S. Highway 40)	0.5177
Talc	C-130	—	—	—	—	—	—	999	—	Balsam Gap, N. C.	0.4828
Chrysotile	C-489	—	—	670	—	—	—	—	807	Synthetic, T2-29C (Bowen and Tuttle)	0.2382
Antigorite	C-64	—	—	—	—	774	845	1003	—	Antigoro Valley, Italy (U.S.N.M. 96,917)	0.4613

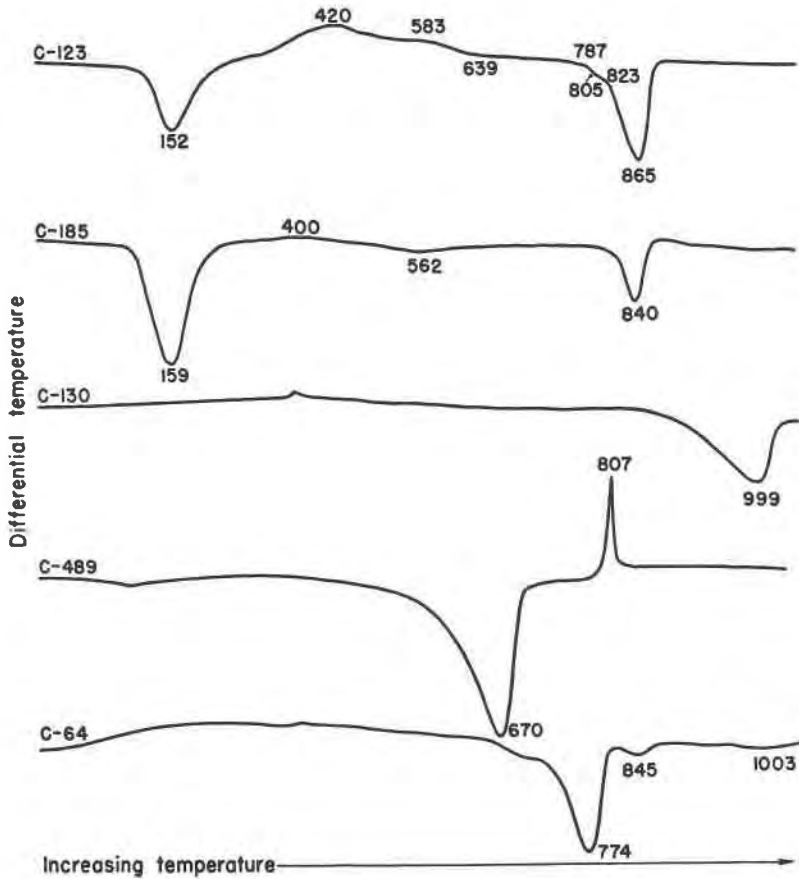


FIG. 2. Differential thermal analysis curves for stevensite No. 1, Springfield, New Jersey, C-123; saponite, Truckee Canyon, near Reno, Nevada, C-185; talc, Balsam Gap, North Carolina, C-130; chrysotile, synthetic, Bowen and Tuttle preparation T2-29C, C-489; and antigorite, Antigoro Valley, Italy, C-64.

All temperatures are given in degrees Centigrade. These curves were all obtained with a resistance of 600 ohms in the galvanometer circuit.

thermal analysis curves of material studied by Foshag and Wherry were obtained and they indicated mixtures of talc and serpentine.<sup>1</sup>

Strunz (1941) in his Tabellen lists "talkhydrat" as brucite and hydro-talc as penninite.

Bowen and Tuttle (1949) in their study of the system  $MgO-SiO_2-H_2O$  found no place in the system for a hydrous form of talc. They made a specific point of studying the variability in the composition of talc and found none. They write:

<sup>1</sup> Faust, George T., Unpublished data.

"The water content is also in accord with that formula,  $\{Mg_3Si_4O_{10}(OH)_2\}$  analysis of our product showing 4.6 per cent  $H_2O$ . The theoretical value is 4.75 per cent."

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