Deweylites, mixtures of poorly crystalline hydrous serpentine and talc-like minerals

DAVID L. BISH AND G. W. BRINDLEY

Department of Geosciences, The Pennsylvania State University,
University Park, Pa 16802, U.S.A.

SUMMARY. An X-ray and chemical examination of deweylites reveals that they are intimate mixtures of very poorly ordered trioctahedral 2:1 and 1:1 layer silicates. The 2:1 mineral exhibits no swelling in the presence of ethylene glycol or water and is best described as an extremely fine-grained and highly disordered form of talc, for which the term kerolite is often used. Stevensite is not a component of deweylites. The 1:1 component most closely resembles a disordered chrysotile.

Evaluation of the chemical data, including values for H_2O+, shows that both end-members are hydrated to various degrees. This hydration is most probably attributable to the presence of water molecules and hydroxyls associated with the large surface areas and unbalanced surface bonds. Formulae for the end-members are approximately $R_3Si_4O_{10}(OH)_2 . 0\cdot3$ $0\cdot7$ H_2O and $R_3Si_2O_5(OH)_4 . 0\cdot3-0\cdot7$ H_2O where R is principally Mg, but samples with more or less H_2O are entirely possible due to variations in crystallinity. No specific formula can be given to deweylites as they are mixtures with variable proportions of the components. The name is useful, however, as a field or 'box' term, similar to the use of garnierite and limonite.

DEWEYLITE was described first in 1826 by Emmons (in Faust and Fahey, 1962) and has been poorly defined ever since owing to its chemical and mineralogical variability and poor structural order. Faust and Fahey (1962) gave a historical account of deweylite and Lapham (1961) described its occurrence. Recent papers describe it in relation to several different minerals and are not in agreement. Kato and Minato (1960) and Kato (1961) reported that it was a mixture of platy serpentine and talc, and Lapham (1961) attributed the 10 Å reflection to sepiolite and the 7 Å reflection to antigorite. Faust and Fahey (1962) described it as a mixture of serpentine and stevensite; this definition has been published in a number of places (Fleischer, 1975; Roberts, Rapp, and Weber, 1974; Gary, McAfee, and Wolf, 1972). More recently, Speakman and Majumdar (1971) described it as a mixture of poorly crystalline talc and serpentine, metastable with respect to the well-crystallized minerals, and Morandi and Poppi (1971) concluded that deweylite could be described as an 'immature cryptocrystalline chrysotile'.

Experimental methods and results

With a view to clarifying the confusion, we have examined a number of deweylites including samples from a serpentinite at Cedar Hill, Pennsylvania and from a dunite in Webster, North Carolina. All samples were X-rayed in cavity mounts and as oriented material deposited from suspensions on to glass slides. X-ray patterns were obtained with a Philips high-angle diffractometer scanning at 1° 2θ per minute, and samples were X-rayed: under ambient conditions of temperature and humidity; after heating to 200 °C for 36 hours; after being in an ethylene glycol atmosphere at 40 °C for two weeks; and after being in a 100% relative humidity atmosphere for two weeks. The X-ray pattern of a typical deweylite is shown in fig. 1, and patterns of a series of deweylites heated to 200 °C showing variations in the 7 and 10 Å basal reflections are given in fig. 2. The 02, 11 bands of the two components overlap completely and have maximum intensity at about 20° 2θ. Samples of stevensite (No. R 4710, from the Smithsonian Institution), a highly disordered variety of talc (kerolite, Brindley et al., 1977), and a normal form of talc also were examined under similar conditions.

Materials free of X-ray-visible quartz, carbonates, or other impurities were chemically analysed using the $LiBO_2$ fusion procedure of Medlin, Suhr, and Bodkin (1964); H_2O+ was taken as the weight loss from 110 °C to 1100 °C after equilibrating at 110 °C. Analyses are presented in Table I.

X-ray diffraction data. The results clearly show that all deweylite samples are mixtures of 1:1 and 2:1 type layer silicates in variable proportions, with basal spacings taken from higher order reflections of 7·3 and 9·6 Å and b parameters from near end-members of 9·24 and 9·14 Å respectively. Treatment
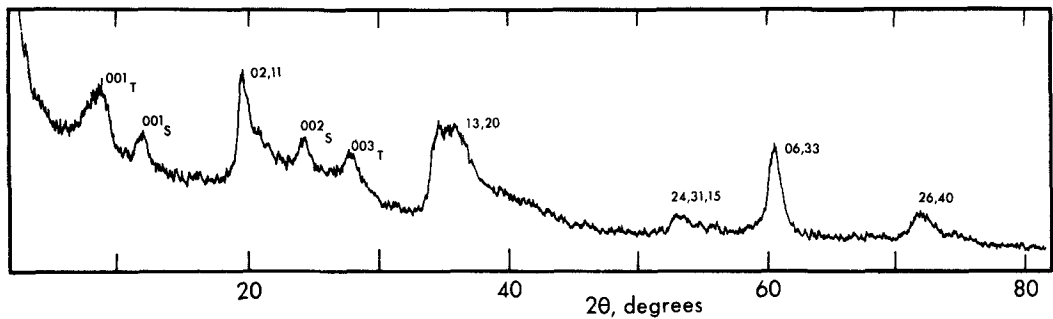
FIG. 1. X-ray diffractogram of a typical deweylite (No. 3 in Table I), with basal reflections from the talc (T) and serpentine (S) indicated.

TABLE I. *Chemical analyses of deweylites from Pennsylvania and North Carolina*

	1	2	3	4	5	6	7	8	9
SiO_2	56·35	54·84	54·34	54·09	53·89	53·13	52·10	49·98	48·90
TiO_2	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01
Al_2O_3	0·13	0·09	0·07	0·03	0·01	0·00	0·13	0·02	0·05
Fe_2O_3	0·07	0·07	0·07	0·07	0·05	0·07	0·04	0·05	0·07
MgO	34·33	35·02	34·99	35·10	35·36	35·54	36·20	37·22	37·91
NiO	0·01	0·04	0·00	0·00	0·00	0·00	0·01	0·00	0·01
Cr_2O_3	0·00	0·01	0·00	0·02	0·02	0·01	0·02	0·02	0·03
CaO	0·11	0·16	0·07	0·07	0·09	0·10	0·07	0·10	0·10
Na_2O	0·09	0·03	0·01	0·06	0·00	0·10	0·06	0·06	0·00
K_2O	0·07	0·05	0·06	0·04	0·04	0·05	0·04	0·04	0·03
H_2O+	9·12	9·73	9·81	10·45	10·48	11·15	11·39	12·62	13·45
Total	100·29	100·05	99·43	99·94	99·95	100·16	100·07	100·12	100·56

1, 2, 3, 7 from Webster, North Carolina.
4, 5, 6, 8, 9 from Cedar Hill, Pennsylvania.
Samples are arranged in order of increasing serpentine component as determined from fig. 3.

with ethylene glycol for *two weeks* reveals a very small, variable percentage of expandable layers as evidenced by the broadening of the '10 Å' peak towards lower angles, which may point to a minor amount of interstratification. However, no regular expansion of the kind shown by smectites (including stevensite) occurs. Exposure to an H_2O atmosphere produced no visible change in the diffraction pattern; the resulting material was virtually X-ray identical with the air-dried material. It must be emphasized that out of approximately forty samples of deweylite from six localities, none showed any swelling in H_2O and very few showed noticeable swelling in ethylene glycol. Heating to 200 °C resulted in a minor sharpening of the 7 and 10 Å basal reflections. Obviously, little ordering or collapse of the layers is produced by the heating.

Nature of the component minerals

The 10 Å component. The nature of the two components is difficult to characterize because of their poor crystallinity (with respect to structural order and crystal development) and our inability to separate them. However, it can be stated that the 10 Å component is not sepiolite nor is it stevensite. Sepiolite gives a very strong reflection from a spacing near 12 Å, and it is difficult to see how the 10 Å component could have been interpreted as sepiolite. We have already noted the absence of swelling in this component, which eliminates its description as a smectite (including stevensite). Faust and Fahey (1962) based their conclusion that the mineral was stevensite mainly on the presence of a low-temperature endotherm in their DTA curves. However, DTA performed by Morandi and
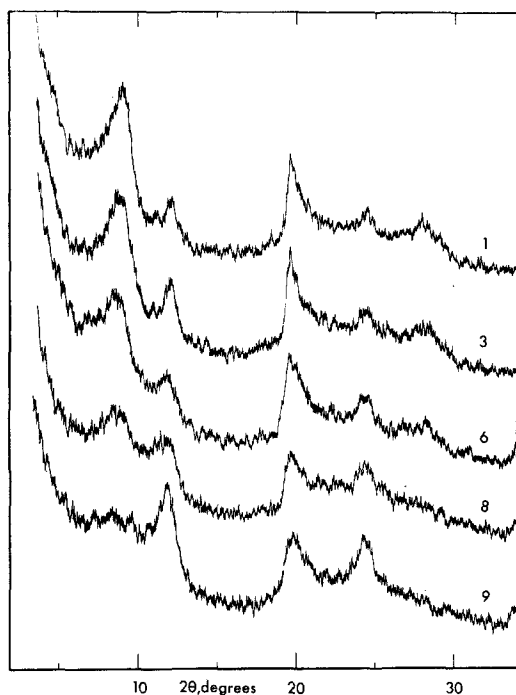
FIG. 2. X-ray diffractograms of a series of deweylites with increasing proportion of the 7 Å component. Numbers refer to the corresponding columns in Table I.

Poppi (1974) on deweylites with compositions very near the 7 Å end-member and on a sample of finely ground serpentine from Snarum, Norway revealed appreciable low-temperature endotherms, apparently not attributable to stevensite. Evidently, the identification of stevensite based on a low-temperature endotherm in the DTA pattern of very fine-grained, poorly crystalline materials is inconclusive.

Faust and Fahey indicated that X-ray powder diffraction had been employed in the examination but gave no X-ray data. They did not indicate whether X-ray patterns were taken of $H_2O -$ and of ethylene-glycol-saturated samples; rolled spindles were used in a powder camera. Stevensite behaves like a smectite in the presence of H_2O (liquid or vapour) and ethylene glycol, swelling rapidly and completely to 17·5 Å with ethylene glycol and to 12·5 to 15 Å in humid atmospheres according to the relative humidity (Brindley et al., 1977).

In our view, the X-ray data are consistent with an extremely disordered and poorly developed variety of talc referred to as kerolite and discussed in detail elsewhere (Brindley et al., 1977). This conclusion

agrees in general with that of Kato (1961), who referred to the 10 Å component as 'talc' and reported that it was not affected by ethylene glycol, and of Speakman and Majumdar (1971), who also described it as 'poorly crystalline talc'.

The 7 Å component. In our samples, this mineral best resembles a poorly crystalline chrysotile; however, the determination of the serpentine polytype is difficult and inconclusive because of the poor crystallinity. Faust and Fahey (1962) reported that deweylite contained either clinochrysotile or lizardite, Kato and Minato (1960) and Kato (1961) found a platy serpentine using electron microscopy, and Morandi and Poppi (1974) called the 7 Å component chrysotile on the basis of an X-ray study. Electron microscopy performed by us on several samples, using magnifications up to 80 000 times, revealed 'fluffy' particles with extremely poorly defined outlines; no tubular forms were observed. Since the crystallite size is of the order of 100 Å (as estimated from X-ray line broadening), microscopic examination at this magnification is probably inconclusive.

Chemical analysis

Interpretation of the analyses requires careful consideration. No single structural formula can be derived as has been done in the past by a number of investigators; such formulae are almost meaningless. The plot of octahedral versus tetrahedral cations used by Faust and Fahey shows the relative amounts of the 10 Å and 7 Å components with formulae of the type $R_3Si_4O_{10}(OH)_2$ and $R_3Si_2O_5(OH)_4$ respectively but ignores the associated water. It in no way proves that the 10 Å end-member is stevensite.

A useful method of interpreting the bulk composition is to plot the mole ratio $H_2O + /\Sigma(M^{2+} + 1\frac{1}{2}M^{3+})$ versus the ratio $Si/\Sigma(M^{2+} + 1\frac{1}{2}M^{3+})$ as shown in fig. 3. This plot is independent of any normalization process. It shows the relative proportions of 2:1 and 1:1 type layer minerals assuming cation proportions of R_3Si_4 and R_3Si_2 respectively; because the component minerals have equal numbers of octahedral cations per formula unit, the proportions vary linearly across the diagram. This plot also shows conveniently the amounts of $H_2O +$. For the normal talc and serpentine compositions with respectively 1 and 2 moles of $H_2O +$ per formula unit, we can draw the lower line between the points T and S in fig. 3. Likewise we can draw the upper line with one additional mole of $H_2O +$ per formula unit. The observed values of $H_2O +$ are seen to be between these two lines, and from their positions the amounts of $H_2O +$ can be readily estimated.
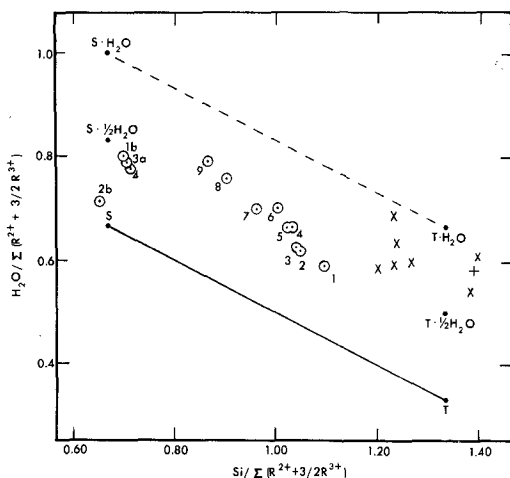
FIG. 3. Plot of chemical data for deweylites showing their relation to the end-member compositions and the excess H_2O+ over the amount present in normal, well-crystallized forms of the end compositions. 1–9, deweylites from this study, numbers refer to the corresponding columns in Table I. S = serpentine. T = talc. × Kerolite data from Brindley et al. (1977). + Stevensite (Faust and Murata, 1953). 1b, 2b, 3a, 4, deweylites from Morandi and Poppi (1974).

The amounts of CaO, Na_2O, and K_2O in the analysed deweylites are negligible and are not included in the calculations. Aluminum and iron are included as octahedral cations but are present in minor amounts and have a negligible effect on the plot. Compositions of the deweylites studied by Morandi and Poppi are also plotted, taking H_2O+ (110 °C) from their TGA curves; data for a number of kerolites (Brindley et al., 1977) and a stevensite (Faust and Murata, 1953) also are included.

Data plotted in this way suggest mixtures of end-members corresponding to $[R_3Si_4O_{10}(OH)_2]$. 0·3–0·7 H_2O and $[R_3Si_2O_5(OH)_4]$.0·3–0·7 H_2O, where R is principally Mg. The range of values in fig. 3 shows that the amounts of water in excess of the normal compositions vary more or less within these limits so that specific hydrated formulae cannot be given. Variations in structural development give rise to variable amounts of additional water. The smaller amounts of 'excess water' associated with the samples of Morandi and Poppi are consistent with the better structural order of their samples as shown by their X-ray patterns. The additional 'water' over that of the well-crystallized end-members agrees with that found by most previous investigators. This 'water' has been attributed by D'yakonov (1963) to residual interlayer water in the talc-like mineral and by Morandi and Poppi to 'high surface

activity and specific genetic conditions'. Brindley et al. (1977) attributed the extra H_2O+ in kerolite (disordered talc) to the very high surface area (200 m^2/g) and the poor structural order, extra 'water' being in the form of surface hydroxyls and hydrogen-bonded water molecules, both on the surface and between the layers. This appears to be a more likely explanation than interlayer water hydrating cations as in stevensite.

Discussion and conclusions

From the present X-ray and chemical data, it is considered that deweylites are mixtures of very poorly crystalline 2:1- and 1:1-type trioctahedral layer silicates. They have additional H_2O+ over that required by well-crystallized forms of talc and serpentine, probably attributable to adsorbed water and hydroxyls associated with the large surface area and large number of unbalanced surface bonds. The 7 Å component appears to be a poorly crystalline serpentine mineral, probably chrysotile. This conclusion agrees with that of Morandi and Poppi, but their contention that deweylites are composed solely of the 7 Å mineral appears to result from their sampling of approximately end-member material. The 10 Å material exhibits none of the characteristic swelling behaviour exhibited by stevensite and other smectites, even when kept in H_2O and ethylene glycol atmospheres for long periods of time. It is best described as a very poorly crystalline disordered talc (kerolite). There is, however, a small percentage of other layers present contributing to peak broadening at low angles. We therefore are in full agreement with the conclusions of Speakman and Majumdar (1971). When either end-member is present as an essentially pure component, it should be referred to by its appropriate name, kerolite or talc for the 10 Å material and chrysotile or serpentine for the 7 Å material. Deweylite should be used only for mixtures of very poorly crystalline talc (kerolite) and serpentine.

From consideration of literature data and our own results, we conclude that stevensite is not a detectable component of deweylites. The definition 'deweylite = mixture of stevensite + serpentine' appears to be a gross error, due to the inadequate identification of stevensite by DTA.

Since deweylite is a mixture of two layer silicates, it cannot be accepted as a distinct mineral species. It is, however, ubiquitous in association with weathered ultramafic rocks, containing variable percentages of the two components, and there is little disagreement in the literature as to the mixture nature and composition of deweylites. We therefore support the retention of the name dewey-

lite as a field or 'wastebasket' term, similar to garnierite and limonite, representing mixtures of poorly crystalline hydrous magnesium silicates of variable composition and mineralogy.

REFERENCES

Brindley (G. W.), Bish (D. L.), and Wan (H. M.), 1977. *Mineral. Mag.* **41,** 443–52.

D'yakonov (Yu. S.), 1963. *Min. Sbornik Vses. Nauchn.-Issled. Geol. Inst., No. 3,* 203.

Faust (G. T.) and Fahey (J. J.), 1962. *U.S. Geol. Surv. Prof. Pap.* **384-A.**

—— and Murata (K. J.), 1953. *Am. Mineral.* **38,** 973.

Fleischer (M.), 1975. *Glossary of Mineral Species,* p. 32. U.S. Geol. Surv.

Gary (M.), McAfee (R.), and Wolf (C. L.) (eds.), 1972. *Glossary of Geology,* American Geol. Inst., Washington, D.C.

Kato (T.), 1961. *Mineral. J.* (Japan), **3,** 107.

—— and Minato (H.), 1960. [*J. Mineral. Soc. Japan,* **5,** 11], in *Min. Abstr.* **16,** 57.

Lapham (D. M.), 1961. *Am. Mineral.* **46,** 168.

Medlin (J. H.), Suhr (N. H.), and Bodkin (J. B.), 1964. *Atomic Abs. Newsletter,* **8,** 25.

Morandi (N.) and Poppi (L.), 1974. *Mineral. Petrogr. Acta,* **20,** 49.

Roberts (W. L.), Rapp, Jun. (G. R.), and Weber (J.), 1974. *Encyclopedia of Minerals.* Van Nostrand Reinhold Co., New York.

Speakman (K.) and Majumdar (A. J.), 1971. *Mineral. Mag.* **38,** 225.