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The nature of kerolite, its relation to talc and stevensite

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SUMMARY. Kerolites from Goles Mountain (Yugoslavia), Wiry (Poland), Madison Co. (North Carolina), and Kremze (Czechoslovakia) are compared with talc and stevensite. Chemical analyses give a composition for kerolite near $R_3Si_4O_{10}(OH)_2.nH_2O$ with R mainly Mg and n about 0·8-1·2. Infra-red data and dehydration-rehydration experiments suggest that the additional water is partly surface-held hydrogen-bonded molecular water, lost up to about 300 °C and easily recoverable, and 'water' held as surface hydroxyls, lost at temperatures up to about 650 °C and less easily recoverable. The surface area of kerolite from North Carolina by nitrogen absorption measurements is 196 m^2/g.

X-ray data show broad basal reflections, a basal spacing (after Lorentz-polarization correction) of about 9·6 Å and a crystallite size of about five structural layers, which is consistent with the large surface area. Two-dimensional *hk* bands indicate a randomly stacked layer structure with $b \approx 9{\cdot}14$ Å and a crystallite 'diameter' of about 150 Å. The basal spacing shows no expansion in water and no thermal contraction up to 500 °C. A partial and irregular swelling with ethylene glycol is obtained only after prolonged exposure (several weeks). In both respects, kerolites differ from stevensite. Kerolites come close to talc in structure and composition but differ in having a highly random layer arrangement, a slightly enlarged basal spacing, which could be due to misfit of layers caused by random stacking, and weaker interlayer bonding.

Kerolite is considered to be a useful varietal name for this talc-like mineral in agreement with the views of D'yakonov and of Maksimovic. It cannot be defined as serpentine + stevensite.

THE name kerolite, suggested by Breithaupt (1823, p. 254) for a mineral of waxy appearance, was derived from the Greek κηρος (wax) and λιθος (stone). In English, two spellings have been commonly used, kerolite and cerolite; the former is preferred here because it appears to have priority and reflects more obviously the Greek origin of the word. The name has appeared in most of the major mineralogical texts but over the years has tended to become discredited owing to difficulties in obtaining an adequate definition and significant chemical formula; a useful survey has been given by Stoch (1974, pp. 286-8).

Occurrence. Kerolite is commonly considered to be of low temperature origin; field evidence and the colloform texture support a deposition from colloidal suspension. It occurs generally in association with weathered ultramafic rocks as coatings and as veins filling cracks and often is intimately mixed with a poorly crystalline serpentine mineral. Maksimovic (1973) found that kerolite occurred at the bottom of a weathering profile in association with partially weathered and fresh rock. This description accords with our field observations, which indicate that kerolite is consistently found only where fresh or partially altered rock outcrops.

Kerolite as a mineral species. Materials called kerolites are always extremely fine-grained and often occur as mixtures of minerals resembling talc or stevensite and a mineral of the serpentine group probably similar to lizardite. These components are recognized principally by their basal X-ray reflections from spacings of about 7·2 Å and 10·0 Å for the two components in question. The reflection profiles are broad and indicate extremely small crystal size or extreme disorder or both. All other diffraction features are two-dimensional *hk* bands, which overlap completely for the two components.

The composite nature of the materials cannot be adequately determined without careful application of X-ray diffraction (XRD) methods, and studies prior to the use of XRD methods must be largely discounted.

Two main schools of thought regarding kerolite are present in the literature: the first considers kerolite to be a mixture name and the second regards kerolite as a single talc-like mineral often occurring together with fine-grained serpentine. Vitovskaya and Berkhin (1968, 1970) emphasized, on the basis of geological studies, that these mixtures occur under particular genetic conditions and that kerolite is a useful name for them. This usage is similar to that of the term 'garnierite' for fine-grained hydrous nickel silicates (Pecora *et al.*, 1949; Faust, 1966). D'yakonov (1963*a*, *b*) on the other hand, from a detailed study of five samples, concluded that the serpentine was an impurity and that the name kerolite could be kept for the talc-like mineral with very few swelling layers. All of the above investigators considered both Mg- and Ni-containing materials to be kerolite. Maksimovic (1966), following the usage of D'yakonov, described the kerolite–pimelite series of Mg- to Ni-containing talc-like material. Thus he regarded material low in nickel as kerolite.

In all the above studies, the nature of the 10 Å mineral was not well established although D'yakonov clarified the situation considerably. He found variable proportions of swelling layers in the talc-like material and described it as a randomly stacked 9·6 Å mineral with *a* and *b* parameters approximately the same as those of talc and Mg-montmorillonite. Maksimovic concurred with this description; both authors emphasized the small proportion of swelling layers.

The present investigation is concerned with establishing the structure, composition, and relevant properties of the Mg end-member of the '10 Å' minerals, which we refer to as kerolite.

Materials examined

Kerolite, Goles Mountain, Yugoslavia. Kerolite from this locality was described and analysed by Maksimovic (1966) and by Brindley and Pham Thi Hang (1973). An additional sample, no. 328, supplied by Dr. Z. Maksimovic has been examined in the present work. All three analyses are given in Table I and are in good agreement.

Kerolite, Kremze, S. Bohemia, Czechoslovakia. A sample labelled no. 39538 from Kremze was made available by Dr. Maksimovic and came from the collection of Dr. E. Slansky who had previously described kerolite from this area (Slansky, 1955).

Kerolite, Wiry, L. Silesia, Poland. This sample, labelled no. W. 186, was made available by Mr. Antoni Wala and Mr. Karol Prochazka, Geological Institute, Cracow, Poland. Wiry is located about 10 km east of Swidnica and 40 km south-west of Wroclaw.

Kerolite, Carter's Mine, Madison Co., N. Carolina. A sample labelled no 481.90 from the F. A. Genth Collection in the Pennsylvania State University. A second sample from Carter's Mine, collected September 1975 by the authors from mine dumps, also has been examined.

Stevensite. A sample labelled R 4710, supplied by the U.S. National Museum, Washington, D.C., previously analysed by Faust and Murata (1953) and also studied by Brindley (1955) and Faust *et al.* (1959).

X-ray diffraction data

The materials studied gave broad 10 Å diffraction peaks with no noticeable 7 Å reflections. There is the possibility that a few percent of a serpentine impurity may be present, which is not detectable by XRD methods. In the following sections we make a detailed comparison of these materials with talc and with stevensite.

Comparison of kerolite with talc. Powder diffraction patterns of kerolites show broad basal reflections, 001 and 003, and two-dimensional diffraction bands corresponding to a randomly stacked layer structure. Fig. 1 compares the diffraction patterns of kerolite (Goles Mountain) and of a fine-grained talc (Manchuria). To check whether fine-grained, massive talcs from other localities show similar structural disorder, we have examined more than twenty samples from different localities, some of which were studied previously by Stemple (1958), and others have been made available by the Smithsonian Institution, Washington, D.C. and by the Institute for Geological Sciences, London. Most of the samples examined gave patterns similar to that of the talc from Manchuria; a few showed appreciably broadened reflections and none showed the extreme layer-stacking disorder exhibited by kerolites. We cannot categorically claim that intermediate states of disorder do not exist, but the evidence available points to this conclusion. By excessive ball-milling, a well-ordered talc can be made to give a diffraction pattern approaching that of kerolite. The very different degrees of structural order and disorder found in normal talcs and in kerolite almost certainly reflect very different environments of formation. Normal talc occurs as a product of hydrothermal alteration or low-grade metamorphism whereas kerolite occurs in weathering horizons and its colloform texture supports a low-temperature formation from an initial gel-like state.

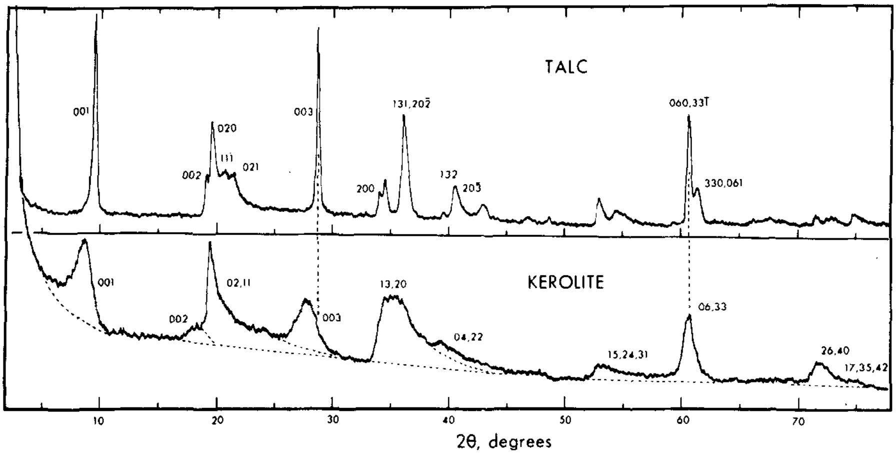


FIG. 1. X-ray powder diffraction patterns of kerolite and talc. Ni-filtered Cu-$K\alpha$ radiation, recorded at 1°2θ/min. Powders packed gently into shallow cavities.

The basal spacing of kerolites taken directly from the broad 001 diffraction peak is about 10·0 Å, but after correction for the Lorentz-polarization factor the resulting peak profile gives a spacing of about 9·6$_5$ ± 0·05 Å. The 003 diffraction peak gives a value for *d*(003) of about 3·20 Å, which corresponds to the corrected value of *d*(001). The Lorentz-polarization correction for the 003 peak is negligible. The displacements of these basal reflections from the corresponding talc reflections are clearly seen in fig. 1. D'yakonov also observed the apparent increase of *d*(001) to about 10 Å, but did not apply the Lorentz-polarization correction. The basal spacing of talc is 9·38 Å (Rayner and Brown, 1973). Heat-treatment of kerolite at 500 °C for several days produced little change in the basal spacing, but after 6 h at 660 °C, a reduction to about 9·45 Å was obtained. No change was observed in the *hk* bands and therefore no detectable improvement in the layer-stacking order was obtained.

The *b* parameter of kerolite, taken from the 06 diffraction peak, is 9·14 Å, a value near to that for talc, 9·18 Å.

The increased basal spacing of the materials studied, 9·6 Å, as compared with that of talc, 9·38 Å, may arise from the disordered layer-stacking. Rayner and Brown (1973) showed that adjacent layer surfaces in talc are situated so that oxygen atoms partially pack together and thereby bring the layers closer together than otherwise would be the case. They remarked that if the distance between oxygen ions, 3·093 Å, is maintained and the oxygen planes are displaced so that the ions no longer pack together, then the layers would be 0·27 Å further apart. This increase corresponds very well with the observed spacing of kerolites; 9·38 Å for normal talc, plus 0·27 Å due to disorder, gives 9·65 Å as found for kerolites. As we shall discuss later, other properties of kerolites may be related to the disordered layer-stacking.

Comparison of kerolite with stevensite. Fig. 2 compares diffraction patterns of kerolite (Goles Mountain) and stevensite (no. R4710) after treatment with ethylene glycol and after exposure to various relative humidities. The other kerolites behave very similarly. Kerolite shows a negligible variation with relative humidity and only a poor response to ethylene glycol; the

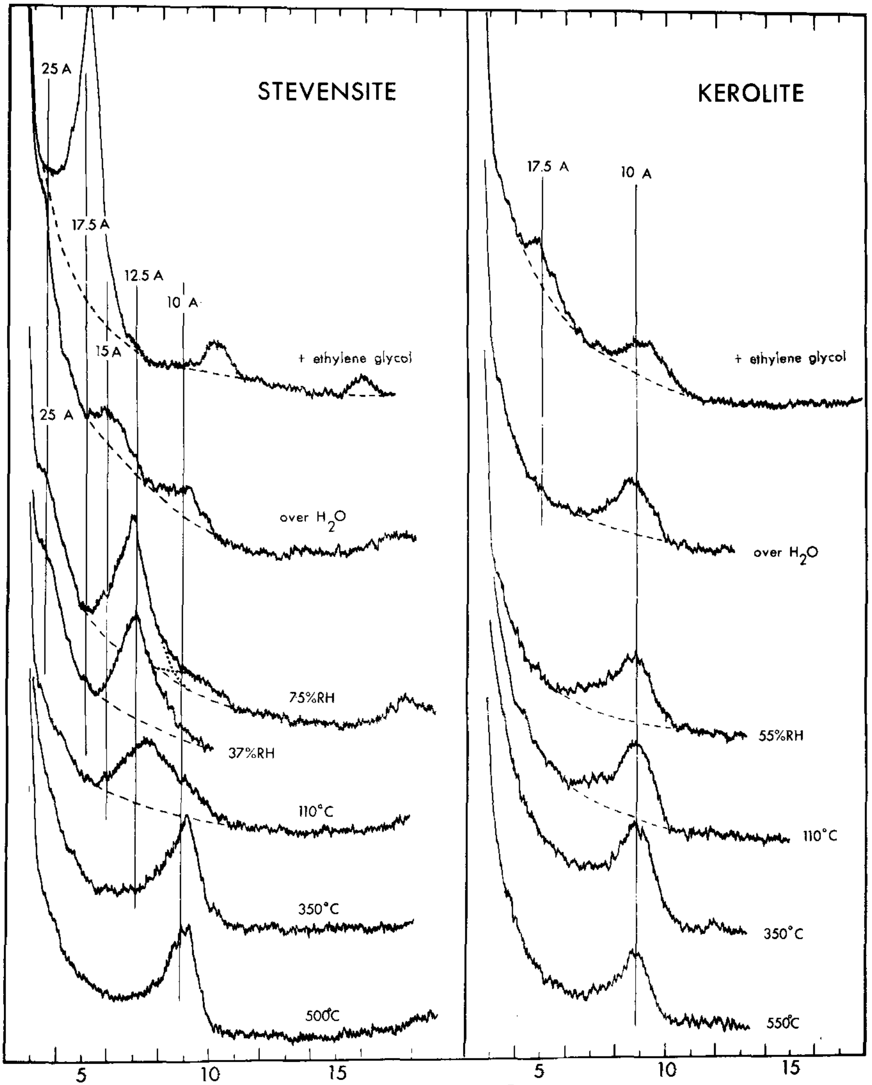


FIG. 2. X-ray powder diffraction patterns of kerolite and stevensite, Cu-*K*α radiation. Samples mounted as thin layers on glass slides. Conditions of treatment of samples are indicated.

pattern illustrated in fig. 2 was obtained only after the sample was held at about 40 °C in ethylene glycol vapour *for several weeks*. Stevensite behaves in the manner expected of a smectite with basal spacings near 10·0 Å, 12·5 Å, and 15·0 Å at various humidities and a well-defined, readily developed spacing near 17·0 Å with ethylene glycol.

These observations indicate that kerolite is essentially different from stevensite. Consequently we consider that the statement 'kerolite = serpentine + stevensite' (Fleischer, 1965) is incorrect.

Chemical analyses, structural formulae

Materials dried to constant weight at 110 °C were heated for 3-h periods at constant temperatures at intervals of about 50 °C to a maximum temperature of 1100 °C. After each heating the samples were cooled in a desiccator and re-weighed. Fig. 3 shows percentage weight loss *vs.* temperature for the samples from (*a*) Wiry, (*b*) Kremze, and (*c*) Goles Mountain. The weight loss from 110 °C–1100 °C was taken as H_2O+ in the chemical analysis. The material from N. Carolina was heated directly from 110 °C to 1100 °C. Fig. 3 also records the weight-loss curve of a fine-grained well-crystallized talc from Manchuria.

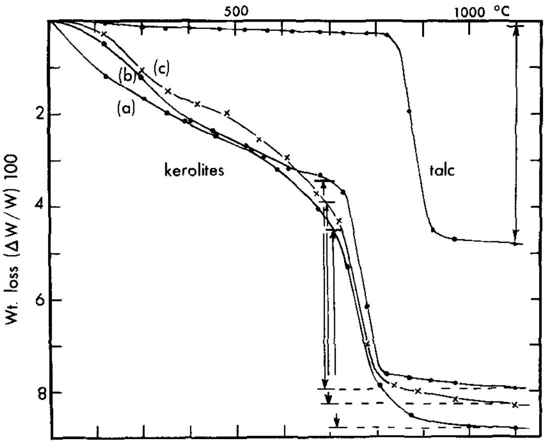


FIG. 3. Percentage weight loss of three kerolites and talc against temperature of heat-treatment. Curves (a), (b), (c) refer to kerolites from (*a*) Wiry, Poland, (*b*) Kremze, Czechoslovakia, (*c*) Goles Mountain, Yugoslavia. Arrows indicate the loss of water corresponding to $(OH)_2$ in the mineral formulae.

After heating to 1100 °C, the resulting samples were analysed by atomic absorption spectrometry using essentially the $LiBO_2$ fusion procedure by Medlin, Suhr, and Bodkin (1964) and a Perkin-Elmer 403 instrument. The chemical analyses are given in Table I. Data also are given for the hydrated talc (no. A 6414A) studied by Imai *et al.* (1973) and for stevensite from Springfield, New Jersey (no. R4710), analysed by Faust and Murata (1953).

Structural formulae (Table I) are based on an anionic composition $O_{10}(OH)_2$ and total cation valence +22. The small number of Na^+, K^+, and Ca^{2+} ions may come from traces of impurities or may be exchangeable cations. Faust and Murata (1953) measured the exchange capacity of stevensite R4719 as 36 meq/100g, which corresponds to 0·075 R^{2+} per $O_{10}(OH)_2$, with R^{2+} mainly Ca^{2+} and Mg^{2+}. Maksimovic (1966) measured the exchange capacity of kerolite from Goles Mountain as 29 meq/100g, with 0·03 Mg^{2+} and 0·02 Ca^{2+} per $O_{10}(OH)_2$. Consequently, because of the small numbers involved, we neglect exchange cations in our chemical analyses. In column 3, Table I, the item 3·44% MnO is omitted from the formula because black specks of

TABLE I. *Analyses and chemical formulae of kerolite, talc, hydrated talc, and stevensite*

1	2	3	4	5	6	7	8	9	10	11
				Kerolite						
	Talc, Manchuria	Hydrated talc, Japan	Stevensite, Springfield, New Jersey	Goles Mt., Yugoslavia (i)	(ii)	(iii)	Wiry, Poland	Kremze, Bohemia	Madison County, North Carolina (i)	(ii)
SiO_2	63·90	57·01	57·30	58·63	58·35	57·87	57·98	61·55	62·98	58·33
TiO_2	0·10	0·00	—	—	—	0·08	0·09	0·10	—	—
Al_2O_3	0·03	0·92	0·00	0·05	0·03	0·07	0·07	0·02	0·07	0·09
Fe_2O_3	0·21	0·62	0·32	0·10	0·11	0·01	0·55	0·01	0·51	0·53
FeO	—	0·03	0·00	—	—	—	—	—	—	—
MgO	31·49	28·76	27·47	30·84	31·6	31·41	30·79	29·44	30·19	32·02
NiO	0·00	—	—	0·05	0·26	0·38	0·39	0·20	0·01	0·27
MnO	—	3·44(*a*)	0·21	—	—	—	—	—	—	—
CaO	0·08	0·00	0·97	0·33	0·32	0·19	0·15	0·32	0·17	0·14
Na_2O	0·02	0·08	0·03	—	0·24	0·10	0·04	0·04	0·01	0·00
K_2O	0·01	0·12	0·03	—	0·04	0·07	0·03	0·10	0·14	0·04
H_2O+	4·86	6·83	7·17	8·29	9·8	8·35	8·93	8·02	7·38	8·50
H_2O-	—	2·27	6·69	3·87	—	—	—	—	—	—
Total	100·70	100·08	100·19	102·16	100·75	98·53	99·02	99·80	101·46	99·92
Si	4·01	3·935	4·01	3·935	3·91	3·90	3·91	4·03	4·03	3·88
Ti	0·005	—	—	—	—	0·005	0·005	0·005	—	—
Al	—	0·065	—	0·005	—	0·005	0·005	—	0·005	0·01
Fe^{3+}	—	—	—	0·005	—	—	0·03	—	—	—
Σ Tetr.	4·015	4·00	4·01	3·945	3·91	3·91	3·95	4·035	4·035	3·89
Fe^{3+}	0·01	0·03	0·02	—	—	0·00	—	0·00	0·02	0·03
Mg	2·945	2·955	2·86	3·085	3·16	3·15	3·09	2·88	2·88	3·17
Ni	—	—	—	0·005	0·01	0·02	0·02	0·01	—	0·01
Other	—	(Al)0·01	(Mn)0·02	—	—	—	—	—	—	—
Σ Oct.	2·955	2·995	2·90	3·09	3·17	3·17	3·11	2·89	2·90	3·21
Na	0·002	0·010	0·004	—	0·03	0·013	0·005	0·005	0·001	0·00
K	0·001	0·009	0·002	—	0·00	0·006	0·002	0·009	0·01	0·003
Ca	0·005	0·000	0·073	0·024	0·02	0·014	0·011	0·022	0·011	0·01
H_2O+	1·02	1·57	1·68	1·86	2·18	1·88	2·01	1·76	1·58	1·89

2. Analyst, H.-M. Wan.
3. Hydrated talc, no. A 6414, Imai *et al.* (1973); (*a*) MnO not included in formula calculation.
4. Stevensite, R 4710, U.S. National Museum, Faust and Murata (1953).
5. Maksimovic (1966).
6. Brindley and Pham Thi Hang (1973).
7. Sample no. 328 from Z. Maksimovic; analyst H.-M. Wan.
8. Sample W.186; analyst H.-M. Wan.
9. Material described by Slansky (1955), supplied by J. Ulrych, labelled no. 39538; analyst H.-M. Wan.
10. Sample from Carter's mine, collected 1975. Minor carbonate removed by treating with dilute HCl for 5 min; analyst D. L. Bish.
11. Sample no. 481.90, F. A. Genth collection, Carter's mine; analyst D. L. Bish.

MnO impurity were recognized. In column 4, the uncertain 1 % correction to SiO_2 made by Faust and Murata (1953, p. 981) is not applied.

The main features of the kerolite analyses are that the tetrahedral cations are close to 4·0 but usually slightly less, 3·89–3·95, and the octahedral cations, mainly Mg^{2+}, are close to 3·0 but usually slightly more. The deviations from 4·0 and 3·0 respectively can be related to a general formula $T^{4+}_{4-x}\ R^{2+}_{3+y}\ O_{10}(OH)_2$ with y necessarily equal to $2x$. Impurities and analytical errors will modify the final formula in this way, provided Na^+, K^+, and Ca^{2+} ions are negligible. Any serpentine impurity will lead to octahedral cations in excess of 3·0 and tetrahedral cations less than 4·0. The results therefore may point to some contamination with a serpentine impurity. The main conclusion is that the cation contents of the kerolites examined deviate very little from the talc composition.

Kerolites, however, show considerably more H_2O+ than talc (cf. the curves of fig. 3) and the additional H_2O+ evidently is the water lost in the temperature range 110°–700 °C. On the kerolite curves, arrows indicate the weight losses corresponding to the water arising from the $(OH)_2$ in the assumed formula. Some of the additional water must be held rather strongly since it is retained up to 500–700 °C; the question is discussed later.

The increased basal spacing of kerolites and their higher contents of H_2O+ were taken previously as an indication that extra water might be located between the silicate layers (Brindley and Pham Thi Hang, 1973). However, it is difficult to accept any large amount of retained interlayer water after several days at 500 °C although evidence points to some being present at lower temperatures. Infra-red data discussed later suggest that much of the additional water may be surface-held 'water', both molecular water and hydroxyl 'water'.

Other data pertinent to the structure and water content of kerolite

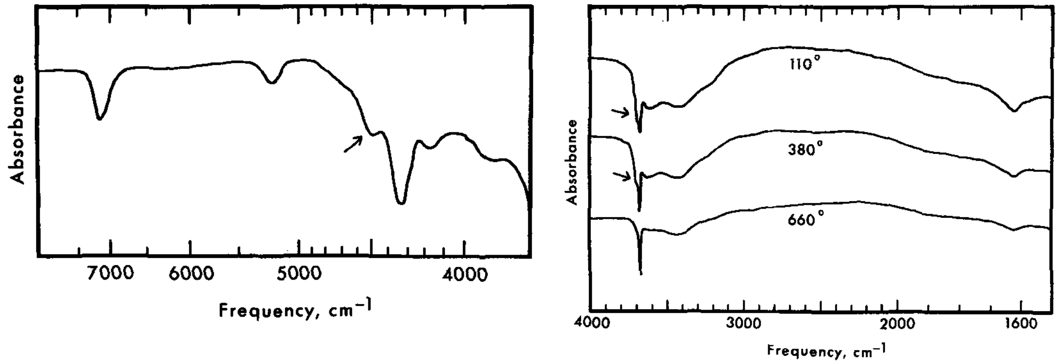
Crystallite size based on X-ray data. The broad basal diffraction profiles, after correction for the Lorentz-polarization factor and for instrumental broadening, indicate a crystal thickness of about five structural layers by application of the Scherrer equation. The small correction for instrumental broadening was estimated from quartz diffraction peaks. The value of five layers represents a lower limit because peak broadness is also contributed to by the presence of any distribution of basal spacings.

The layer dimensions can be estimated from the width of the 02, 11 diffraction band at half-maximum height by the approximate formula of Warren (1941): $L = 1{\cdot}84\lambda/B\cos\theta$, where L is the particle diameter. Application of this formula gives $L \approx 150$ Å.

Surface area and particle size from nitrogen adsorption isotherms. Nitrogen adsorption measurements and application of the B.E.T. gas adsorption isotherm gave a specific surface area of 196 m^2/g for kerolite from N. Carolina. If the particles are treated as circular discs of radius r and thickness t, in Å, and having a talc-like structure, the specific surface area in m^2/g is: $A = \{(1/r)+(1/t)\}7400$. If $r \gg t$, then with $A = 196\ m^2/g$ a value for t of 38 Å is obtained, corresponding to four layers/particle. If we take $r = 75$ Å, i.e. half the diameter determined from the X-ray data, then $t = 76$ Å or about eight layers.

Thus the small particle size determined from the X-ray data and the surface measurements are mutually consistent. Electron micrographs of kerolite from Goles Mountain taken at $10^6\times$ magnification (Uyeda *et al.*, 1973) show extremely thin platy material where individual particles could be as small as 100 Å. The small cation exchange capacity of kerolites determined by Maksimovic (1966) evidently can be attributed to cations associated with the large surface area.

Infra-red spectroscopic data. Several kerolites were examined by infra-red spectroscopic methods to obtain additional information on the nature of the extra 'water'. Spectra were taken between 8300 and 3700 cm^{-1} (i.e. 1·2–2·7 μm) using the diffuse reflectance attachment of a Beckman DK-2A spectrometer and powder samples. Fig. 4 shows a typical spectrum of kerolite after heating at 100 °C. Absorption at 5260 cm^{-1} (1·90 μm) indicates molecular water. Most of the water is removed by 300 °C, but is regained very rapidly upon exposure to the atmosphere. An absorption at ~ 4500 cm^{-1} (2·2 μm), marked by an arrow in fig. 4, has been designated as an Si–O–H combination band (Scholze, 1960*a*, *b*). This band is present in all kerolite spectra and in the spectra of very finely ground (< 1 μm particle size) talc and quartz but is not present with well-crystallized talc and quartz. Additional absorptions attributable to combinations and overtones of structural OH vibrations also are present. Heating experiments show that structural OH is perturbed and decreased at 750 °C and is virtually gone by 800 °C.



FIGS. 4 and 5: FIG. 4 (*left*). Near infra-red spectrum of kerolite from N. Carolina. The arrow indicates the 4500 cm^{-1} (2·2 μm) band attributed to Si–O–H vibrations. FIG. 5 (*right*). Infra-red spectrum of kerolite from N. Carolina, heated to the designated temperatures for 6 h, powder mounted in a pressed KBr pellet. Arrows indicate the high-frequency shoulder possibly due to edge hydroxyls.

Infra-red spectra between 300 and 4000 cm^{-1} were taken using a Perkin-Elmer 621 spectrometer and kerolite powder in pressed KBr pellets. All kerolites show the SiO vibration at ~ 1000 cm^{-1} and various lower frequency absorptions. Fig. 5 shows typical spectra in the range 1500–4000 cm^{-1} of kerolites heated for 6 h at various temperatures. Broad absorptions at 1620 and 3420 cm^{-1}, and a sharp one at 3680 cm^{-1} are due to adsorbed water and structural OH respectively (Farmer, 1974, pp. 352, 354). A broad band at 3600 cm^{-1} and a shoulder at ~ 3700 cm^{-1} (see arrow, fig. 5) are affected only slightly by heating to 380 °C for 6 h, but are greatly reduced in intensity after heating to 670 °C for 6 h. Absorption at ~ 3620 cm^{-1} in smectites is attributed by Farmer (1974, p. 352) to O–H stretching associated with hydrogen bonds between interlayer water and surface oxygens. In view of the disordered structure and large surface area of kerolite, this is a probable explanation for the observed band near 3600 cm^{-1}. In the absence of any other plausible explanation, we consider that the shoulder near 3700 cm^{-1}, which decreases with increasing temperature, is probably due to edge hydroxyls possibly co-ordinated to less than the usual three Mg^{2+} ions, e.g. $Mg_2\square OH$, or to Si, i.e. Si-OH, or both.

Dehydration-rehydration experiments. Two sets of three samples of kerolite were equilibrated in sealable containers at 110 °C for 48 h to remove loosely adsorbed surface molecular water and then weighed. One set was heated to 300 °C and the other to 650 °C for 24 h, weighed, and then placed in 75 % and 100 % relative humidity atmospheres respectively for several days. They were then reweighed, heated to 110 °C for 24 h and weighed again. These results, and a second set after reheating to 300 °C and 650 °C again, indicated that the weight loss to 300 °C is almost completely reversible, and the weight loss to 650 °C is about 70–90 % reversible.

Thus it appears that there are at least two contributions to the weight loss in the temperature range 110°–650 °C: adsorbed molecular water hydrogen-bonded to surface and interlayer oxygens, which is removed up to about 300 °C, and surface hydroxyls, which are important because of the large surface area. Some molecular water probably is retained between the layers and located more or less in the 'hexagonal' holes of the Si–O networks; the amount of this water is probably small.

Bonding energy of layers and expandability. The slightly expanded basal spacing of kerolite compared with that of talc implies that the silicate layers in kerolite are less strongly bonded than in talc. Besides the van der Waals attraction between layers, Giese (1975) has shown that there is also a significant electrostatic attraction between the layers. The latter diminishes to near zero when the separation of the layers is increased by about 1 Å. The van der Waals attraction also decreases with increased separation of the layers. Giese's calculations show that the electrostatic energy of attraction diminishes by about 35–40 % of the normal value when the separation is increased by about 0·25 Å. Conceivably the decrease in electrostatic and van der Waals attractions with increasing separation may explain the penetration of ethylene glycol between some or all of the kerolite layers when no penetration occurs between the layers of normal talc. When kerolite is heated to 660 °C and the layer spacing diminishes to about 9·45 Å, the mineral no longer expands in ethylene glycol even after exposure of several weeks; presumably the total attractive forces are now sufficient to prevent such penetration.

The absence of expansion of kerolite in water may be attributed to the absence of hydrateable interlayer cations. The mechanism by which ethylene glycol causes expansion is still not clear, but a similar result has been shown with reduced charge montmorillonites, namely that when the interlayer charge is reduced to values such that expansion no longer occurs in water it still occurs readily with ethylene glycol (Brindley and Ertem, 1971).

Discussion

Kerolite is chemically and structurally similar to talc, but secondary differences arise from the extreme layer-stacking disorder. The large surface area and mainly non-swelling character of kerolite permit a study of surface properties (and possibly surface reactions) without the complications that arise with smectites due to their swelling behaviour. The additional water in kerolites is largely surface-held molecular water and 'water' in the form of hydroxyls at surface imperfections, including 'broken bonds' at edges of layers. The measured Mg/Si atom ratio departs slightly from 3/4 due to undetected serpentine impurity and possibly non-ideal layer structures. The basal spacing of kerolite, after correction of peak profiles by the Lorentz-polarization factor, is near 9·6 Å. The *b* parameter is 9·14 Å. The expanded basal spacing as compared with that of talc, 9·38 Å, is probably related to the disordered layer stacking and misfit of the layers. Consequently the bonding energy of the layers in kerolite is less than in talc. This may be the reason for partial swelling of kerolite after long exposure, several weeks, to ethylene glycol. Kerolite shows no intra-crystalline swelling in water.

Kerolites are distinguished from fine-grained well-crystallized talcs by their X-ray diffraction data (enhanced basal spacing and *hk* diffraction bands, see fig. 1), by the form of the thermogravimetric curves (see fig. 3), and by their partial expansion with ethylene glycol after long exposure. Kerolites clearly differ from smectites by their complete absence of swelling in water and hydrous atmospheres, and by their extremely slow and poor response to ethylene glycol. These properties are so dissimilar to those of stevensite (or any other smectite) that the description (Fleischer, 1971, 1975; Gary *et al.*, 1972; Roberts *et al.*, 1974) 'kerolite = mixture of serpentine + stevensite' is incorrect.

The similarity of kerolite to talc is such that kerolite, although it has the distinguishing characteristics stated in the previous paragraph, cannot be regarded as a wholly distinct mineral species. We consider that the name 'kerolite' is a useful varietal name because of the structural and genetic implications. We believe that our results and conclusions are entirely in harmony with those of D'yakonov and of Maksimovic.

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