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THE CHARACTERIZATION OF SERPENTINE MINERALS

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Abstract

Two papers published in recent issues of The American Mineralogist (Nagy & Faust, 1956; Kalousek & Muttart, 1957) have dealt with serpentine minerals under the titles "Serpentines: natural mixtures of chrysotile and antigorite" and "Studies on the chrysotile and antigorite components of serpentine" respectively. Certain statements in these papers are at variance with results presented in our paper (Whittaker & Zussman, 1956) and we therefore offer the following comments. Whereas the above two papers classify all serpentine minerals into two categories only, we believe that it is necessary to take account of at least one other serpentine variety whose character is as distinctive as that of chrysotile or antigorite.

Nagy & Faust (p. 825) state that "the existence of distinct serpentine minerals other than chrysotile and antigorite (or their polymorphs), is not confirmed on the basis of chemical, morphological, optical, differential thermal analysis, and *x*-ray data," and their main conclusion (p. 833), which is also embodied in the title of the paper, is that "these experimental studies show that minerals classified as serpentines are either chrysotile or antigorite or mixtures of these two minerals." The evidence which they present (with the exception of that based on differential thermal analysis) is, however, of such a nature that it would not be expected to reveal the existence of other distinct serpentine minerals even if they were present, as the following considerations will show, and it cannot therefore lead to so positive a conclusion.

(i) Chemical data. The statistics quoted for $Al_2O_3+Fe_2O_3$ contents of chrysotile and antigorite have such large standard deviations that they do not permit a significant assignment of most specimens of serpentine to one species or the other on this basis. It is indeed notable that the undoubted antigorites F-1 and F-14 of Table 2 have Al_2O_3 contents substantially lower than the mean given for chrysotile. Furthermore the fact that the $Al_2O_3+Fe_2O_3$ content of most serpentines lies within the (overlapping) ranges for chrysotiles and antigorites by no means precludes the existence of yet other distinct serpentine species.

(ii) Morphological data. It is stated that "electron micrographs of serpentines (natural mixtures) show fibrous (tubular) or irregular or flaky particles or both." No reason is suggested for believing that distinct serpentine minerals other than chrysotile and antigorite would not have one or other of these morphologies. In fact they would be expected to do so, and the morphological data would therefore be incapable of revealing them.

(iii) Optical data. In view of the wide variations in refractive indices of acknowledged samples of chrysotile and antigorite, the possibility that other species may occur with refractive indices within the scatter of the values for those species cannot be neglected, so that the evidence from these data also is inconclusive.

(iv) Differential thermal analysis data. This might be expected to reveal other serpentine species if they exist, and it is fair to say that it does not confirm their existence. A similar conclusion has been reached on similar evidence by Kourinsky & Satava (1954). It is however not sufficient evidence to establish that such species do not exist in the face of *x*-ray evidence, and in fact the D.T.A. curve for lizardite illustrated by Midgley (1951) is very similar to that of chrysotile although the two minerals are readily distinguishable by morphology and diffraction.

(v) *X*-ray diffraction data. No *x*-ray diffraction data are presented by Nagy & Faust apart from the use of the intensity of a single *x*-ray reflection to assess the degree of structural collapse of various specimens as a result of a certain acid treatment. In this connection they show:

   (a) As judged by the effect on the intensity of a certain *x*-ray reflection, chrysotile is decomposed and antigorite is not decomposed by this treatment.

   (b) Mixtures of chrysotile and antigorite are partly decomposed by this treatment to an extent which depends on the chrysotile content.

   (c) All serpentine minerals are also either decomposed, not decomposed, or partially decomposed when submitted to the same treatment. The only conclusion which can be drawn from these data is that the serpentine minerals do not all consist of pure chrysotile or pure antigorite. Given (a) and (b) there is no conceivable behaviour under the prescribed acid treatment which could confirm the existence of other serpentine species.

Thus the only part of the statement by Nagy & Faust on p. 825 of their paper which is justifiable is that the existence of distinct serpentine minerals other than chrysotile and antigorite (or their polymorphs) is not confirmed by differential thermal analysis. But this does not disprove the existence of such minerals. Lizardite (Whittaker & Zussman, 1956) justifies consideration as a distinct serpentine mineral just as much as do chrysotile and antigorite. Admittedly all three minerals may be regarded as polymorphs (at least to a first approximation), but if it is desired to distinguish any different types of serpentine mineral it is necessary to distinguish all three types. Lizardite differs from the other two in its diffraction effects, and, while it resembles chrysotile in some respects (optics and D.T.A.), it resembles antigorite in others (morphology and behaviour with acid). We have treated green massive serpentine (which had been identified as lizardite by *x*-ray diffraction) with one normal HCl at 95° C. for one hour as prescribed by Nagy & Faust, and have found that its powder diffraction pattern is only slightly weakened. (Treatment with somewhat stronger acid destroys the lizardite structure while still not affecting that of antigorite). It is therefore probable that much of what was recorded by Nagy & Faust as antigorite was in fact lizardite, a very common constituent of massive serpentine. Their quantitative analyses of serpentines in terms of chrysotile and antigorite must therefore be subject to revision in the light of new data. It is of course not denied that the acid treatment test can give a useful quantitative analysis of specimens which are known on other grounds to contain only chrysotile and antigorite.

A further minor criticism of Nagy & Faust's paper relates to their Fig. 3 showing photographs of a glass rod and a glass tube. While we believe that tubular chrysotile fibres do exist, the evidence that fosters this belief does not include that suggested by these photographs. The illustration of glass rod and glass tubing seen in ordinary light is not an appropriate analogy to the electron micrograph since the phenomenon it demonstrates is mainly one of refraction rather than absorption.

The possibility that the use of the term antigorite to include lizardite may lead to erroneous conclusions is illustrated in the paper by Kalousek & Muttart who appear to equate antigorite with the matrix rock in which chrysotile veins occur. In particular the comparison of the observed density of the matrix (Table 6 of their paper) with the calculated density of antigorite is misleading since the latter is based on incorrect data. It has been pointed out (Zussman, 1954) that the figure 5.42 Å often assumed for the cell parameter of antigorite has no structural or experimental foundation and was obtained merely by dividing the measured value of c_0 (Aruja, 1944) by eight. It has also been shown that the true cell of antigorite does not contain the ideal atomic proportions. The measured density of antigorite is approximately 2.6, not 2.5 gms./cc., i.e. it is greater than that of chrysotile not less. The correspondence of the measured density of the matrix material with that calculated for antigorite is thus both fortuitous and unfortunate. In fact the vein-bearing matrix material of most of the specimens which we have examined by *x*-ray diffraction has been found to consist of lizardite or some other flat layer variant, or chrysotile or mixtures of these.

Another criticism of the paper by Kalousek & Muttart is that the implications of their *x*-ray data have not been adequately considered. Sufficient information is now available for most serpentine powder patterns to be assigned to specific varieties, and, moreover, to have their lines indexed. It is therefore possible to tell with certainty whether impurity lines are present. The authors do in fact recognise that "the serpentine specimens from Globe, Arizona, and from Eden Mills, Vermont, contained a second phase, possibly chlorite and magnesite, respectively," (though the Globe matrix also contains 21% CaO), and that "the Montville fibre also probably contained an unidentified impurity." They assumed that the other specimens were homogeneous phases, and "extraneous ions were assumed to be lattice constituents." No comment was made on the fact that impurity lines are present in the powder patterns of other specimens referred to in their Table 4, so that conclusions about details of their ion distributions are weakened. The presence of impurities may also affect the interpretations of the density measurements and the details of the thermal effects which are discussed. The pattern from the matrix from Globe, Arizona contains too few serpentine lines to permit its identification with any particular serpentine mineral; however, the positions of serpentine powder lines in the patterns from all other matrices in their Table 5, when compared with published data for antigorite show clearly that none of them is in fact antigorite. Thus Kalousek & Muttart's results are relevant to the distinctions between fibre and matrix but have not the relevance to antigorite which is implied in the title of the paper and elsewhere. None of the specimens dealt with was identified as a true antigorite, but among them Yu-Yen stone is now known to be predominantly antigorite by its electron diffraction patterns (Zussman, Brindley & Comer, 1957), and powder x-ray diffraction pattern (unpublished).

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REFERENCES

ARUJA, E. (1944), An x-ray study of the crystal-structure of antigorite. *Mineral. Mag.*, **27,** 65–74.

KALOUSEK, G. L., AND MUTTART, L. E. (1957), Studies on the chrysotile and antigorite components of serpentine. *Am. Mineral.*, **42,** 1–22.

KOURINSKY, J., AND SATAVA, V. (1954), A contribution to the question of the determination of minerals of serpentine group. *Sbornik Narodniko Musea v. Praze*, **10,** No. 4.

MIDGLEY, H. G. (1951), A serpentine from Kennack Cove, Lizard, Cornwall. *Mineral. Mag.*, **29,** 526–530.

NAGY, B., AND FAUST, G. T. (1956), Serpentines: Natural mixtures of chrysotile and antigorite. *Am. Mineral.*, **41,** 817–838.

WHITTAKER, E. J. W., AND ZUSSMAN, J. (1956), The characterisation of serpentine minerals by x-ray diffraction. *Mineral. Mag.*, **31,** 107–126.

ZUSSMAN, J., BRINDLEY, G. W., AND COMER, J. J. (1957), Electron diffraction studies of serpentine minerals. *Am. Mineral.*, **42,** 113–153.

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