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THE INTERGROWTH OF FIBROUS BRUCITE AND FIBROUS MAGNESITE WITH CHRYSOTILE

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Abstract

Nemalite (fibrous brucite) from Jeffrey mine, Québec, has been investigated by electron microscopy and diffraction. The material consists of an association of fibrous brucite with chrysotile–$2M_{c1}$ and parachrysotile. The brucite is present in laths elongated along the x axis and not invariably lying on (0001). The laths are associated with fibrils of chrysotile had been a common initial constituent of orientation of the nemalite would correspond to the orientation of the outer brucite-like layer of the fibrils, and therefore be dependent on whether those fibrils are normal or parachrysotile. Elongation of the laths is frequently opposite to that predicted. This may be due to the fact that parachrysotile had been a common initial constituent of the material during the formation of the brucite, but that it subsequently recrystallized to more stable normal chrysotile. The genetic relationship between the brucite orientation in the Jeffrey nemalite and its chrysotile component is paralleled by supposed nemalite from Cassiar, B.C., which is composed of fibrous magnesite with minor chrysotile; the varied orientation of the magnesite fibrils is explained by steric rather than structural considerations.

Sommaire

Nous avons étudié la némalite (brucite fibreuse) de la mine de Jeffrey (Québec) par microscopie et diffraction électroniques. Les échantillons montrent l'association brucite fibreuse, chrysotile–$2M_{c1}$ et parachrysotile. La brucite se présente en languettes qui sont allongées suivant [$2\bar{1}\bar{1}0$], ne reposant pas toujours sur (0001). Ces languettes sont associées à des fibrilles de chrysotile; on s'attendrait à une orientation de la némalite correspondant à celle de la couche extérieure, de type brucite, des fibrilles, orientation qui dépendrait donc de la nature minéralogique – chrysotile normal ou parachrysotile – de ces dernières. La prédiction de l'allongement est souvent contraire aux faits. On peut supposer que, pendant la formation de la brucite, le parachrysotile ait été un constituant initial recristallisé par la suite sous la forme plus stable du chrysotile normal. La relation génétique entre l'orientation de la brucite et celle du chrysotile dans la némalite de Jeffrey rappelle la soi-disant némalite de Cassiar, C.B., qui consiste en magnésite fibreuse avec chrysotile accessoire, et dans laquelle l'orientation variable des fibrilles de magnésite s'expliquerait par des considérations stériques plutôt que structurales.

(Traduit par la Rédaction)

Introduction

Nemalite, a fibrous form of brucite, was first described by Nuttall (1821). It commonly occurs in slip-fibre veins in serpentine; the fibres can be very long, some specimens approaching a length of 3 m, although the distance over which fibres are continuous is difficult to establish.

Textures of different specimens have been investigated a number of times by X-ray diffraction (Berman 1932, Garrido 1936, de Jong 1938, Eckhardt 1956), and it has been shown by these authors that the ultimate fibrils are sufficiently fine that a handleable specimen gives a rotation-type X-ray diffraction pattern. These authors found that the z axes of the component brucite crystallites are perpendicular to the length of the fibres. It follows that they have grown to disproportionate lengths in different symmetry-related directions in the basal plane, with the ratio of length to width being in the order of 10^6 if the fibril width is less than 1 μm, as has been shown by Garrido (1936) and by Donnay (1944). The morphology of the brucite fibres was investigated by electron microscopy by Eckhardt (1956), who found the fibres to consist of laths lying on their (0001) faces. This work was extended further by Liebling & Langer (1972).

This remarkable morphology seems to be connected with intergrown chrysotile fibres, which are usually, if not invariably, present. Such intergrowths are mentioned by most of the authors quoted above and are present in several specimens we have examined. Berman (1932) suggested that a structural relationship between the brucite and chrysotile had led to an oriented replacement of chrysotile by brucite, but this was suggested before the structure of chrysotile was known. Now that the external surface of chrysotile is known to be virtually identical to that of brucite, it is clear that such a relationship would require a correspondence between the fibre repeat of the two minerals. The fibre repeat of chrysotile (a = 5.34 Å) corresponds structurally to the orthohexagonal b dimension along the six related zone-axes of brucite [$10\bar{1}0$], [$\bar{1}100$] and [$0\bar{1}10$] and their negatives (in terms of Weber symbols). However, Berman found the length of brucite fibres to be along the x axis with a fibre repeat of 3.16 Å, and with the corresponding Weber symbols [$2\bar{1}\bar{1}0$], [$\bar{1}2\bar{1}0$] and [$\bar{1}\bar{1}20$] and their negatives. De Jong (1938) also found this as the major orientation for the brucite fibres in a specimen from Lojana, Yugoslavia, but in addition he reported a second component with the z axis perpendicular to the fibre axis but otherwise random. Garrido (1936) also found that the main layer lines indicate a 3.15 Å repeat, but a very few weak reflections indicate a 2.74 Å repeat, (*i.e.*, ½ × 5.48 Å, in agreement with the orthohexagonal b axis). [Note that there is some confusion in nomenclature in Garrido's paper in that the 3.15 Å repeat is said to be along [$10\bar{1}0$] and the 2.74 Å repeat along [$11\bar{2}0$]. These two zone-axis symbols should clearly be interchanged. There are also misprints in the indices of some of the reflections, leading to impossible indices such as 1100.] Strong Debye arcs with specific cutoff points (as in de Jong's specimen) showed the presence of fibres with their lengths in all possible crystallographic directions perpendicular to their z axis. Eckhardt (1956), on the other hand, found a 5.5 Å fibre-repeat which he described as [$1\bar{1}0$] (*i.e.*, in terms of the x_1, x_2 and z axes only, equivalent to the Weber symbol [$1\bar{1}00$]); he noted the relationship of this to the a dimension of chrysotile. He also found, however, that this [$1\bar{1}00$] axis was offset from the fibre axis by amounts varying from 2 to 7° by rotation of the crystallites about their z axes.

It seems that the crystallographic orientation of nemalite presents an anomaly. On occasion, the orientation is what one would expect if the growth of the brucite had been controlled epitaxially by the replaced chrysotile, but in general the observed orientation is perpendicular to the one expected.

Present Observations

A specimen of nemalite from a slip-fibre vein at Jeffrey mine, Asbestos, Québec, was examined by electron microscopy and diffraction on an A.E.I. EM6G electron microscope operating at 100 kV. The specimens were dispersed in water and supported on carbon films or sometimes directly on copper grids. The brucite component consisted of laths ½ to 1 μm wide, elongate along the x axis [$2\bar{1}\bar{1}0$] with a fibre-axis repeat of 3.1 Å. As the laths generally did not give a diffraction pattern of hexagonal symmetry, they were evidently not lying on (0001) faces. Associated with the brucite were fibres of chrysotile–$2M_{c1}$, chrysotile–D_c and parachrysotile, the last showing evidence of polygonal morphology (Middleton & Whittaker 1979).

Another specimen of supposed nemalite from Cassiar mine, B.C., was studied by X-ray diffraction. It consisted of an intergrowth of a minor quantity of chrysotile with magnesite, not brucite, and its texture also differed from that of nemalite in several ways. Although the parting of the material into fibres appeared to be on quite a fine scale, X-ray specimens (of the order of 0.1 mm thick or more) had a coherent single crystallographic orientation and gave oscillation photographs that could contain weak reflections of a chrysotile (rotation-type) photograph. Furthermore, in spite of a very perfect morphological fibrous direction, such oscillation photographs showed that the magnesite was slightly offset from a rational crystallographic axis. Divergences of 0.5 and 4° between the fibre axis and the nearest crystallographic axis were noted in different specimens. When the crystal was adjusted to that the crystallographic axis coincides with the oscillation (or rotation) axis, indexable photographs were obtained. One showed that the crystallographic axis was close to (though not coincident with) the fibre axis, which had a fibre repeat of 7.34 Å and was identified as [$11\bar{1}$] (referred to rhombohedral axes). The other specimen had two sets of layer lines of comparable strengths giving repeats of 7.9 and 11.8 Å. These were identified as [$11\bar{2}$] and [$11\bar{3}$], respectively.

Discussion

It is surprising that the brucite laths in the nemalite from Jeffrey mine do not lie on (0001), since this implies that their smallest dimension is not generally perpendicular to the basal plane. No complete explanation of this orientation can be offered, but it may be due to interfibrillar constraints during growth.

The discovery of parachrysotile in the nemalite suggests a solution to the anomalous crystallographic orientation of the brucite fibres that has been found to predominate in all the specimens studied, except that of Eckhardt. Parachrysotile has its fibre axis parallel to *y*, which is structurally equivalent to the *x* axis ([$2\bar{1}\bar{1}0$], *etc.*) of brucite and with $b_{chr} = 3a_{br}$. The usual orientation of the brucite would therefore be explained if it had formed by epitaxial replacement of parachrysotile rather than of normal chrysotile. It is, of course, the latter that is much more common, both generally and in association with nemalite, but we suggest that this may not always have been true. Yada & Iishi (1974) have shown that in some circumstances parachrysotile is the first-formed product of the serpentinization of forsterite, and Hargreaves & Taylor (1945) have shown that parachrysotile is relatively unstable and extractable by water. We therefore suggest that the usual orientation of brucite in nemalite is a relict indication that the brucite formed epitactically on parachrysotile fibres which have since been removed or have recrystallized as ordinary chrysotile.

Figure 1 shows a hypothetical cross-section of a bundle of nemalite fibres indicating schematically the control exercised by a small proportion of partly polygonal chrysotile fibres over the main body of brucite.

The supposition that the usually rather perfect orientation of brucite in nemalite is structurally controlled receives circumstantial support from the very different findings on the fibrous magnesite. In the three orientations that were found, the fibre repeat has no obvious relationship to that of chrysotile, and in any case was not strictly parallel to it. The only face of magnesite that has an obvious potential for an epitactic relationship with chrysotile is $(111)_{rh}$, *i.e.*, the basal plane, (0001) in terms of hexagonal axes. This plane is parallel to the carbonate groups, whose oxygen atoms lie in an approximately close-packed array, though drawn together in groups of three where they are bonded to carbon. The (111) face lies in the zone [$11\bar{2}$] but not in either of the other two zones whose axes were identified. Since there was no evidence for a predominance of the [$11\bar{2}$] orientation, it seems unlikely that epitaxy is involved, and this conclusion is strengthened by the imperfection of the alignment of the crystallographic axes with the fibre axis. We suggest that the magnesite has grown between, and replaced, fibres of chrysotile and that this process has exercised a geometrical control over the morphology, but that the crystallographic orientation of the magnesite is a result of the accidents of nucleation, modified by the effects of differential growth rates of nuclei in different orientations. No specific explanation is offered for the curious numerical relationship between the three zone-axes observed nor for the relationship between the two differently oriented components found associated together in one specimen.

Somewhat similar phenomena have been found in magnetite fibres that are occasionally found intergrown with chrysotile in veins. Such fibres from Shabani, Rhodesia, were found having their fibre axes parallel to either [100] or [111]; neither of these orientations would permit an

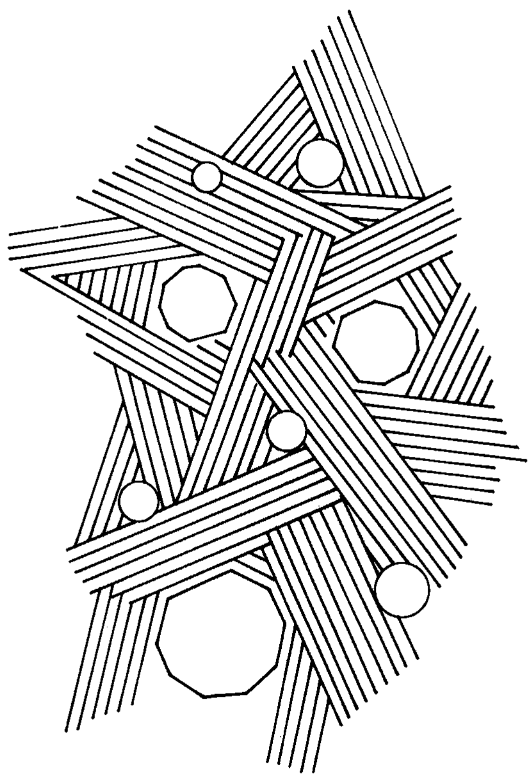

FIG. 1. Hypothetical cross-section of a bundle of nemalite fibres. The polygons and circles represent chrysotile cross-sections. The orientation of the 0001 planes in the sections of the brucite laths is shown by the lines, but their spacing is not to scale. At least some of the laths have cross-section shapes that could permit them to lie on faces other than (0001).

epitactic relationship to the chrysotile. By contrast, magnetite fibres in the nemalite from the Jeffrey mine show no preferred crystallographic axis along their length.

The fraction of brucite in Garrido's specimen of nemalite that has random crystallographic orientations in the (0001) plane parallel to the fibre axis presumably grew under similar nonepitactic controls, except for those imposed geometrically by plane surfaces on the nucleation of (0001) planes. In this case there seems to have been no differential growth rate for different orientations of this part of the material. It is by no means clear, however, how the specific discrepancies found by Eckhardt between the crystallographic and fibre axes might have arisen.

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