NOTES AND NEWS

STABILITY OF CHRYSOTILE ASBESTOS

BARTHOLOMEW NAGY AND THOMAS F. BATES, *The Pennsylvania State College, State College, Pa.*

Recent investigations have been conducted on the group of minerals, commonly referred to as the serpentine group, which possesses the general chemical formula $3MgO \cdot 2SiO_2 \cdot 2H_2O$ and the kaolinite type crystal structure. These studies have shown that chrysotile has the lowest chemical and thermal stability of the group.

On the basis of theoretical considerations Pauling (1930) came to the conclusion that if serpentine had a kaolinite type crystal structure, it would have a tendency to curve because of the misfit of the octahedral and tetrahedral layers of the unit cell. After Warren and Hering (1941) established a kaolinite type crystal lattice for chrysotile, Bates, Sand and Mink (1950) and Noll and Kircher (1950) decided on the basis of electron microscope studies, that the fibers of chrysotile asbestos are hollow tubes formed by the curvature of the kaolinite type layers. Bates and Mink (1950) attributed the flaky morphology of antigorite to replacement of the Mg^{++} ions of the octahedral layer by trivalent ions (chiefly Al^{+++} and Fe^{+++}), resulting in the disappearance of the size difference between the octahedral and tetrahedral layers.

The investigations just completed have shown that chrysotile has a higher solubility in hydrochloric acid than antigorite. The effects of chemical attack have been studied by *x*-rays, differential thermal analysis and electron microscopy.

Figure 1 shows the percentage weight loss of Thetford, Quebec, chrysotile and Unionville, Pennsylvania, antigorite plotted against various concentrations of HCl. The two curves are similar with the exception that the sudden increase in the solubility of chrysotile appears between 1 and 5 normal HCl, in contrast to the case of antigorite where 5 to 10 normal HCl is required to produce the same effect. Furthermore it was observed that treatment in low concentrations of HCl and in distilled water dissolves more chrysotile than antigorite.

In the *x*-ray diffraction diagrams the effect of acid treatment was to lower the intensities rather than shift the position of the reflections. In the case of chrysotile the reflections disappeared completely after treatment in 1 normal HCl, whereas disappearance of the antigorite peaks did not take place until concentrated HCl was used.

Differential thermal analysis showed that 1 normal hydrochloric acid treatment did not affect the antigorite pattern but changed the chrysotile curve into a nearly straight line exhibiting only one endothermic reaction

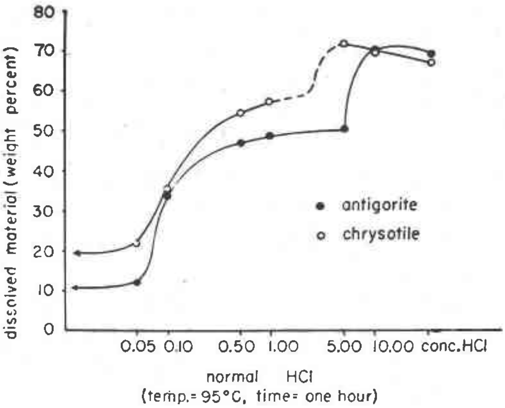

FIG. 1. Percentage weight loss of chrysotile and antigorite during acid treatment for one hour at 95° C.

at 125° C. due to the loss of the water adsorbed on the surface of the particles and a small exothermic peak at 830° C.

The result of 1 normal HCl treatment on the morphology of chrysotile is shown in Fig. 3. Those features of the chrysotile fibers which indicate a tubular morphology disappear causing the fibers to look like flat laths (*A*) having serrate and pitted surfaces (*B*). The untreated fibers are shown in Fig. 2, where (*A*) indicates a single chrysotile tube, (*B*) several tubes and (*C*) concentric tubes. In order to achieve a three dimensional effect Figs. 3 and 4 were prepared by enlarging from superimposed negative and positive plates which had been shifted very slightly with respect to each other. This procedure results in the accentuation of some of the details of the pictures but the loss of some of the fine structure

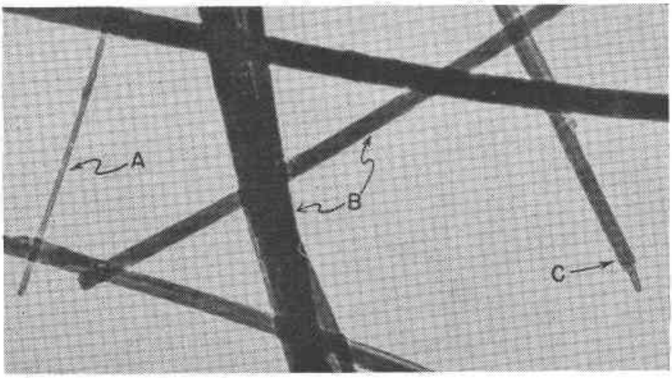

FIG. 2. Untreated chrysotile fibers, Thetford, Quebec. 46,000×.

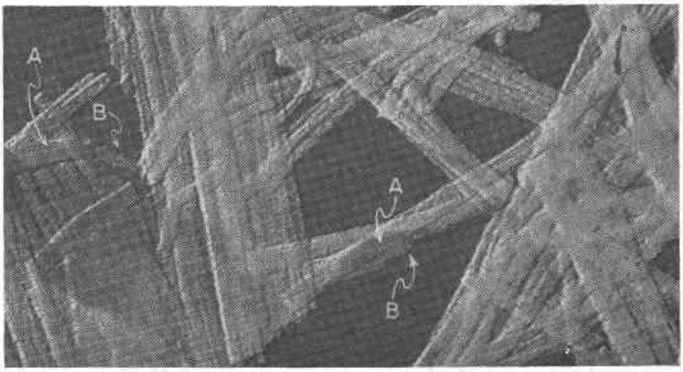

FIG. 3. One normal hydrochloric acid treated chrysotile fibers. 61,000×.

and therefore could not be used in the case of the untreated chrysotile. One normal HCl treatment did not produce any noticeable changes in the morphology of antigorite.

It was also observed that chrysotile has a relatively low thermal stability compared to other hydrous silicate minerals. The heat of the electron beam causes a very rapid change in the morphology of the fibers, and prolonged exposure to electron bombardment results in complete disintegration of the material, as reported by Noll and Kircher (1952). Figure 4 shows fibers which were subjected to electron bombardment for two minutes, whereas for figures 2 and 3 a fifteen second bombardment took place. Figure 4 indicates that although the outer surface of the tubes is "fused" resulting in rounded edges (*A*), in many cases the tubular morphology of the still unaffected tubes can be observed inside this "fused" coating (*B*). The chrysotile fibers are so sensitive to the heat of the electron beam that the "unfused" tubes can be observed only if

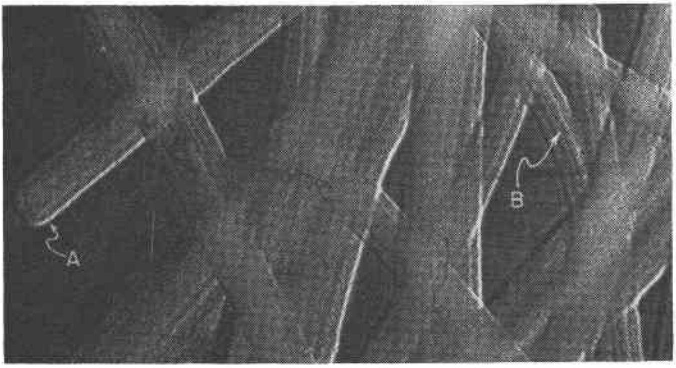

FIG. 4. Chrysotile fibers subjected to two minutes of electron bombardment. 75,000×.

the sample is subjected to the electron beam for not longer than about 30 seconds at a magnification of approximately 5700 times and very low electron beam intensity.

These results indicate that the stability of chrysotile is relatively low in comparison to that of antigorite and other hydrous silicate minerals. Surface area measurements using the B.E.T. gas adsorption method yielded a value of 7.24 m^2/gm for the chrysotile sample used in the experiments and 11.40 m^2/gm for the antigorite sample. The similarity in magnitude of these values indicates that the difference in the stability cannot be attributed to different surface areas. A possible explanation of the lower stability of chrysotile may be related to the strain that is believed to exist in the tubes. Bates, Hildebrand and Swineford (1950) pointed out that theoretically the unstrained portion of the endellite tubes is only one unit cell thick in the *c* direction and that with increase or decrease in radius of curvature the strain in the other layers also increases. Noll and Kircher (1951) used the same line of reasoning in discussing the morphology and structure of chrysotile.

REFERENCES

1. BATES, T. F., HILDEBRAND, F. A., AND SWINEFORD, ADA (1950), Morphology and structure of endellite and halloysite: *Am. Mineral.*, **35**, 463–484.
2. BATES, T. F., AND MINK, J. F. (1950), Morphology and structure of the serpentine minerals antigorite and chrysotile: (abstract), *Geol. Soc. Am. Bull.*, **61**, (12), 1442.
3. BATES, T. F., SAND, L. B., AND MINK, J. F. (1950), Tubular crystals of chrysotile asbestos: *Science*, **111**, 512–513.
4. NOLL, W., AND KIRCHER, H. (1950), Zur Morphologie des Chrysotilasbestes: *Naturw.*, **37**, 540–541.
5. NOLL, W., AND KIRCHER, H. (1951), Über die Morphologie von Asbesten und ihren Zusammenhang mit der Kristallstruktur: *Neues Jb. Mineral.*, *Mh.* **10**, 219–240.
6. NOLL, W., AND KIRCHER, H. (1952), Veränderungen von Chrysotilasbest im Electronenmikroscop: *Naturw.*, **39**, 188.
7. PAULING, L. (1930), The structure of the chlorites: *Proc. Nat. Acad. Sci.*, **16**, 578–582.
8. WARREN, B. E., AND HERING, K. W. (1941), The random structure of chrysotile asbestos: *Phys. Rev.*, **59**, 925.

SECOND OCCURRENCE OF BAYLEYITE IN THE UNITED STATES

T. W. STERN AND ALICE DOWSE WEEKS, *U. S. Geological Survey, Washington, D.C.*

Bayleyite, $Mg_2UO_2(CO_3)_3 \cdot 18H_2O$, is one of three new uranium minerals first described from the Hillside mine, Yavapai County, Arizona, by Axelrod, Grimaldi, Milton, and Murata (1951). The minerals occurred at the 300-ft level of the mine and the authors state (1951, p. 2) that "In the mine, bayleyite crystals are sharp and well faceted. In the drier atmosphere of Washington, [D. C.] they soon become dull, losing