

It is clear from Table III that the refractive indices of the mineral are higher than would be expected for the percentage of  $\text{Cr}_2\text{O}_3$  and NiO that it contains. But the chromian chlorite series, with varying proportions of NiO, has not yet been investigated sufficiently to justify any generalizations in this respect.

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#### ON THE OCCURRENCE OF ASBESTOS IN CHAMOLI, U.P., INDIA

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#### INTRODUCTION

Asbestos (Bowles, 1959) mineralization was noted in Kandhara ( $30^{\circ} 26' 10'' : 79^{\circ} 5' 0''$ ) and Jalai villages ( $30^{\circ} 27' 20'' : 79^{\circ} 5' 0''$ ) on the left bank of Mandakini river in the Garhwal Himalaya (Narain, 1954). During 1960-61 Dalela was associated with the prospecting party (Prakash,

*et al.* 1961) that found lenticular mineralization along an outcrop length of 15 miles.

The mineralization is confined to a sequence of metamorphosed orthoquartzites and clastic carbonate rocks, injected by dolerites now converted to amphibolites. The carbonate rocks commonly have been replaced by coarsely crystalline dolomites and siderite which contain the asbestos. Later tectonics have caused these units to become dislocated, and lenticular fracturing and brecciation are prominent near the mineralized zone. Slip-fiber asbestos in veins up to 6 inches thick occurs discontinuously in the more deformed zones close to the mafic intrusives.

TABLE 1. CHEMICAL ANALYSIS

Constituents	White silky variety	Brown fibers	Dolomite	Basic rock
SiO <sub>2</sub> +Insol.	55.24	53.21	14.30	53.83
R <sub>2</sub> O <sub>3</sub>	—	—	10.15	—
Al <sub>2</sub> O <sub>3</sub>	3.68	Traces	—	13.49
Fe <sub>2</sub> O <sub>3</sub>	0.80	9.71	—	12.65
FeO	2.99	16.81	1.62	3.46
MnO	0.06	1.03	0.17	0.13
CaO	12.01	0.62	35.18	8.35
MgO	20.79	16.74	5.98	4.90
Ignition loss	3.49	1.61	32.82	1.46
Total	99.06	99.73	100.22	98.27

The orientation of the asbestos fibers invariably is parallel to slickensides; often also to the axes of minor folds, directions that are normal to each other.

The dolerite intrusives contain a chloritic mantle along their margins; significantly, doleritic dikelets curl around and traverse cross-fractures in the dolomite boudins. In some such cross-fractures, cross fiber asbestos veins occur instead of dolerite dikelets. Around boudins margins the asbestos is slip fiber. Relict dolomite is present in thin asbestos veins.

The chemical (Deer *et al.*, 1963) and petrographic analyses of asbestos from different portions of the belt are comparable to either (1) actinolite or (2) cummingtonite, in part with grunerite. Type 1, associated with coarse-grained dolomites, under the microscope shows straight needles with upper second order interference colors and with an extinction angle from 13° to 20°. Type 2 is identified as amosite and is restricted to sideritic rocks. It consists of yellowish brown, flexible fibers up to 3 inches

long. Under the microscope it shows high refractive indices, high third order interference colors and parallel extinction.

The MgO in the asbestos appears to have been derived mainly from the coarsely crystalline dolomite, for the dolomites near asbestos veins show a lower MgO content than usual. The invariable presence of slip fibers and impersistence of the mineralization with depth leads us to believe that its origin is probably connected to metamorphism and shearing.

#### RESULTS OF ANALYSES

The chemical analyses of two samples and samples of basic rock and limestone were carried out by means of standard techniques. The  $x$ -ray powder photographs, were taken with a Debye Scherrer camera (diam. 114.6 mm., Fe-filtered Co radiation).

#### DISCUSSION

Chemical analyses of the two samples and comparison with available data show that they belong to either of the two types (Deer, 1963) (i) actinolite (ii) cummingtonite. The latter variety has been called amosite. It may also be seen that magnesia is very high in the case of actinolite and cummingtonite as compared to host basic rock and dolomite.

The  $x$ -ray diffraction data fully confirm that the white silky variety is actinolite and the brown tinted sample is cummingtonite. The values of spacings are in complete agreement with the latest corresponding data (A.S.T.M., 1960). They are identical with almost exact correspondence of about 70 "lines" of measurable intensity down to 0.89 Å. The strong lines in the case of asbestos sample from Jalai are the reflections at 2.75 Å (10), 3.07 Å (8) and 8.34 Å (9), whereas in the case of white silky sample they are at 2.71 Å (10), 3.14 Å (7), and 8.41 Å (7).

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ORDERING OF Fe AND Cr IN CHRYSOBERYL<sup>1</sup>

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Refinement of the chrysoberyl structure (Farrell *et al.*, 1963) showed that the two aluminum octahedral sites differ significantly in size. Half of the aluminum atoms occupy Al<sub>I</sub> sites with inversion symmetry, and the remainder are in Al<sub>II</sub> mirror-plane positions. The average nearest-neighbor distances are Al<sub>I</sub>—O = 1.890 and Al<sub>II</sub>—O = 1.934 Å. Because of the differences in size and symmetry, trivalent cations substituted for Al might prefer one site to the other. Experimental evidence for selective substitution in Al<sub>2-x</sub>Fe<sub>x</sub>BeO<sub>4</sub> and Al<sub>2-x</sub>Cr<sub>x</sub>BeO<sub>4</sub> solid solutions is presented.

Polycrystalline ceramic specimens of Al-Cr, Al-Fe, and Cr-Fe chrysoberyl were prepared by firing the coprecipitated metal-ion hydroxides between 900° and 1300° C. X-ray diffractometer patterns were used to determine the lattice parameters and cation ordering. Al<sub>2</sub>BeO<sub>4</sub> and Cr<sub>2</sub>BeO<sub>4</sub> form a complete solid-solution series and our lattice-parameter measurements agree with those published by Weir and Van Valkenburg (1960). About 50 atomic per cent iron can be substituted in Al<sub>2</sub>BeO<sub>4</sub> or Cr<sub>2</sub>BeO<sub>4</sub>; unit-cell dimensions for the Al<sub>2-x</sub>Fe<sub>x</sub>BeO<sub>4</sub> and Cr<sub>2-x</sub>Fe<sub>x</sub>BeO<sub>4</sub> solid solutions are shown in Fig. 1. Iron substitution causes both structures to expand, as expected from the Goldschmidt ionic radii (Al<sup>3+</sup> 0.57, Cr<sup>3+</sup> 0.65, Fe<sup>3+</sup> 0.67 Å). Three phases were identified in specimens containing more than 50% iron: chrysoberyl solid solution, corundum solid solution and beryllia.

The intensities of five prominent low-angle reflections especially sensitive to cation distribution were used to determine ordering in Al-Cr and Al-Fe chrysoberyl. The difference between the atomic scattering factors of Fe and Cr is too small to permit study of the Fe-Cr system. Data for two of the samples are given in Table 1. The calculated structure factors were computed for several values of the ordering parameter *M* using the refined Al<sub>2</sub>BeO<sub>4</sub> atomic coordinates (Farrell *et al.*, 1963). *M* is defined as

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