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X-RAY STUDY OF SIX-LAYER ORTHO-SERPENTINE

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Of all the serpentine minerals, the six-layer ortho-serpentine is least well characterized. It was originally described by Brindley and von Knorring (1954) with additional data given by Zussman, Brindley and Comer (1957), Zussman and Brindley (1957) and by E. Olsen (1963). It has been synthesized by Roy and Roy (1954) and by Gillery (1959). The structure of the mineral is not known and reports on the mode and the frequency of occurrence are scarce. During the investigation of the mineralogical composition of the well-developed serpentinite bodies in Yugoslavia. The mineral was found to be the main constituent of the black serpentinite that occurs as lenses in the Paleozoic schists at Korab Mt. As a pure component it forms thin sheets or lenses interbedded with asbestos veins in the same region. It is inferred from the scarcity of secondary magnetite grains that the rocks prior to serpentinization consisted mainly of high-magnesian olivine. The mineral is a main constituent of a large body of serpentinitized dunite at Radusa mine. It is always found in regions where serpentinite rocks have been altered hydrothermally.

X-RAY INVESTIGATION

Powder data were obtained from a 19 cm. camera using Cu (Ni-filtered) radiation, and fiber photographs were taken in a 6 cm. camera. A fiber photograph of a specimen whose powder pattern is given in column 3 of Table 1, and which is a pure six-layer ortho-serpentine, shows sharp reflexions on all layer lines which are, however, elongated along Debye arcs. On the zero layer line 00l, 0k0 and a few 0kl reflexions were

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TABLE 1. X-RAY POWDER DIFFRACTION DATA FOR 6-LAYER ORTHO-SERPENTINE—CLINOCHRYSOTILE SERIES

1	2	3	4	5	6	7	8	9	10	11	12	13	14
d_{calc}	hkl	d_{obs}	I	d_{obs}	I	d_{obs}	I	d_{obs}	I	d_{obs}	I	hkl	d_{calc}
7.284	006	7.30	10	7.30	10	7.31	10	7.30	10	7.30	10	002	7.30
4.612	020												
4.602	110	4.60	5	4.60	5	4.60	5	4.60	5				
4.503	112	4.51	$\frac{5}{2}$	4.50	$\frac{5}{2}$	4.50	$\frac{5}{2}$	4.51	$\frac{5}{2}$				
4.388	113	4.37	$\frac{5}{2}$	4.39	$\frac{5}{2}$	4.39	$\frac{5}{2}$	4.37	$\frac{5}{2}$				
4.241	114	4.26	$\frac{5}{2}$	4.26	$\frac{5}{2}$			4.24	$\frac{5}{2}$				
4.072	115	4.09	$\frac{5}{2}$	4.08	$\frac{5}{2}$			4.08	$\frac{5}{2}$				
3.891	116	3.89	$\frac{5}{2}$	3.90	$\frac{5}{2}$								
3.642	0.0.12	3.650	9	3.653	9	3.660	9	3.654	9	3.650	9	004	3.651
3.520	118	3.500	$\frac{5}{2}$	3.522	$\frac{5}{2}$								
3.340	119	3.334	$\frac{5}{2}$	3.340	$\frac{5}{2}$								
3.169	1.1.10	3.159	$\frac{5}{2}$	3.166	$\frac{5}{2}$								
3.007	1.1.11	3.005	$\frac{5}{2}$	3.000	$\frac{5}{2}$								
2.856	1.1.12	2.862	$\frac{5}{2}$	2.860	$\frac{5}{2}$								
2.661	130											130	2.655
2.656	131	2.658	2	2.655	2	2.660	2	2.652	2	2.652	2	200	2.651
2.655	200												
2.650	201												
2.641	132	2.644	3	2.640	3								
2.636	202												
2.612	203									2.598	3	131	2.600
2.580	204									2.586	3	201	2.584
2.540	205					2.538	2	2.532	2	2.527	2	20 $\bar{2}$	2.537
2.495	206	2.500	10	2.496	10	2.500	8	2.500	2	2.451	9	202	2.449
2.428	0.0.18	2.430	$\frac{5}{2}$	2.435	$\frac{5}{2}$	2.437	$\frac{5}{2}$						
2.330	209	2.336	5	2.340	5	2.340	3						
2.269	2.0.10			2.271	$\frac{5}{2}$	2.269	$\frac{5}{2}$	2.271	1	2.268	1	203	2.276
2.201	2.0.11			2.204	$\frac{5}{2}$	2.200	$\frac{5}{2}$	2.198	1	2.200	1	204	2.203
2.145	2.0.12	2.150	3	2.153	3	2.155	2						
2.084	2.0.13			2.091	1	2.088	4	2.085	5	2.085	4	20 $\bar{4}$	2.091
1.962	2.0.15	1.966	4	1.970	4	1.971	2						
1.821	0.0.24	1.820	$\frac{5}{2}$	1.820	$\frac{5}{2}$	1.820	$\frac{5}{2}$	1.824	1	1.824	1	008	1.825
1.792	2.0.18	1.791	2	1.793	2	1.790	$\frac{5}{2}$						
1.738	2.0.19	1.738	1	1.740	2	1.738	3	1.742	3	1.746	3	206	1.746
1.637	2.0.21	1.635	3	1.630	3	1.635	2						
1.534	060	1.531	8	1.532	8	1.530	8	1.532	8	1.532	8	060	1.534
1.502	2.0.24	1.500	4	1.501	3	1.502	2	1.503	1	1.503	1	062	1.501
1.457	0.0.30	1.460	$\frac{5}{2}$	1.454	$\frac{5}{2}$	1.460	$\frac{5}{2}$	1.456	1	1.456	1	0.0.10	1.460
1.420	2.0.26	1.415	2	1.415	2	1.421	$\frac{5}{2}$	1.414	$\frac{5}{2}$	1.414	$\frac{5}{2}$	064	1.414
1.382	2.0.27	1.374	1	1.374	1	1.372	$\frac{5}{2}$						
1.327	400	1.319	1	1.320	1	1.320	2	1.317	3	1.317	3	400	1.326
1.310	2.0.29	1.306	4	1.306	4	1.308	4	1.307	4	1.307	3	2.0.10	1.310

1. Calculated d values for 6-layer ortho-serpentine, based on unit cell dimensions $a=5.311 \pm 0.005 \text{ \AA}$, $b=9.202 \pm 0.010 \text{ \AA}$, $c=43.70 \pm 0.04 \text{ \AA}$, obtained by the least square refinement of the data in column 3.
2. Indices (hkl) of the six layer ortho-serpentine based on the above cell dimensions.
3. d values and visually estimated intensities for a pure 6-layer ortho-serpentine from Korab Mt.
5. d values and intensities of a 6-layer ortho-serpentine showing the presence of a small amount of clinochryso-tile: green serpentinite between asbestos veins, Korab Mt.
7. d values and intensities of a mixture of 6-layer ortho-serpentine and clinochryso-tile: platy serpentinite from Korlače.
9. d values and intensities of a clinochryso-tile with small amount of six-layer ortho-serpentine: platy serpentinite from Korlače.
- 11 & 12. d values and intensities of a pure clinochryso-tile (povlen-type): Povlen Mt.
- 13 & 14. Indices and calculated d values for specimen in col. 11: based on a cell with $a=5.310 \pm 0.008 \text{ \AA}$, $b=9.204 \pm 0.015 \text{ \AA}$, $c=14.627 \pm 0.025$, $\beta=93^\circ 12' \pm 15$ obtained by the least square refinement.

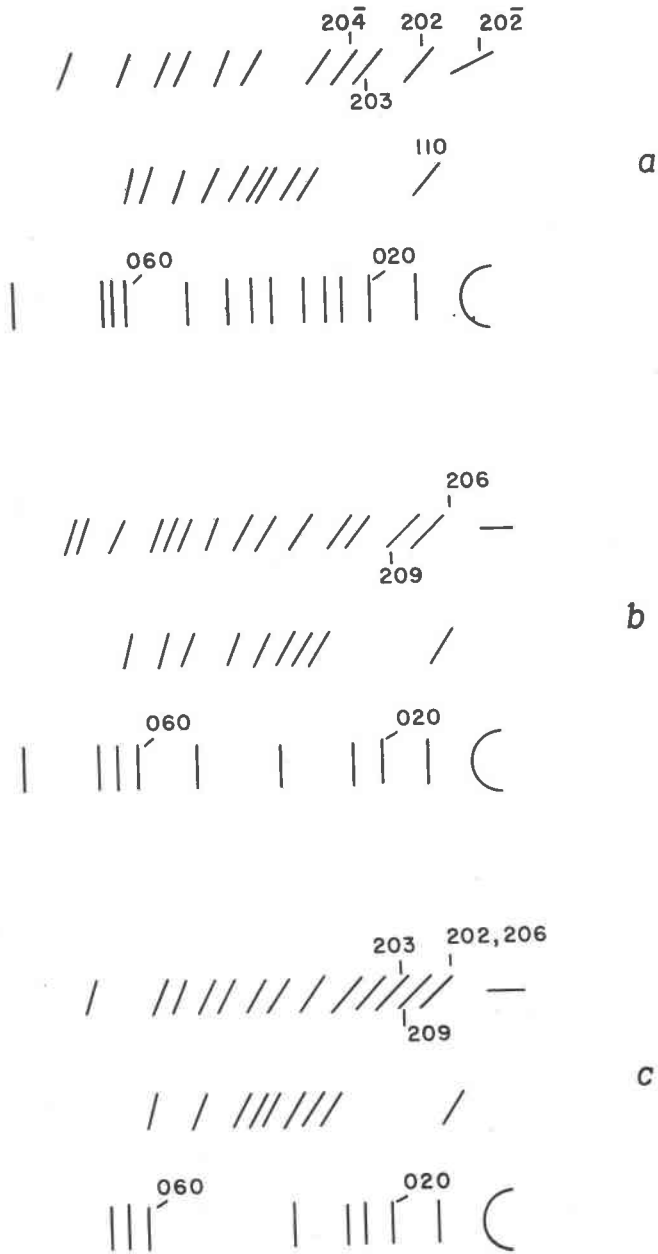


FIG. 1. Diagram illustrating fibre photographs of (a) povlen-type clinochrysotile; (b) six-layer ortho-serpentine and (c) mixture of the two serpentine minerals in approximately equal proportions. The tail following the 110 reflexion is not shown: it varies from one specimen to another.

identified. On the first layer line, one of the most prominent features of many of the fiber photographs is a long tail following the 110 reflexions. On closer examination it can be seen that the "tail" consists of a large number of reflexions which were previously indexed as 0kl reflexions. These reflexions were not clearly observed on the zero layer line, and in this paper they are indexed as 1kl's. Other hkl reflexions of medium to strong intensity are present on all odd layer lines. On the second and other even-numbered layer lines h0l reflexions are the most prominent.



FIG. 2. Electron micrograph of povlen-type clinochrysotile; $\times 8000$.

After taking over fifty fiber photographs of a six-layer ortho-serpentine it became apparent that another serpentine mineral is very often intimately mixed with it, and this was subsequently identified as a "povlen" type clinochrysotile (Fig. 1). In column 5 of Table 1, a pattern of a 6-layer ortho-serpentine is given which shows an additional line of a medium weak intensity having $d = 2.463 \text{ \AA}$. This reflexion cannot be indexed on the basis of a 6-layer cell nor does it have a counterpart on a fiber photograph. The powder diagram of a specimen given in column 7 shows this line to be more pronounced and to be accompanied by the disappearance of 1kl reflexions. In column 9 is a powder photograph of a specimen in which clinochrysotile is the predominant component while in column 11 is a powder diagram of a pure povlen-type clinochrysotile. Electron diffraction patterns of a mixed specimen, as well as fiber patterns, all

suggest that we are not dealing with a simple random mechanical mixture of two serpentine minerals, but with an intimate intergrowth of the two components having the a (fiber) axis in common.

The morphological features of povlen-type clinochrysotile and 6-layer ortho-serpentine are shown in electron micrographs of Figures 2 and 3. They cannot be distinguished on the basis of external morphology, and X-ray powder identification becomes difficult because, with the absence of weak $1kl$ or $0kl$ reflexions from the powder diagram, which is often the

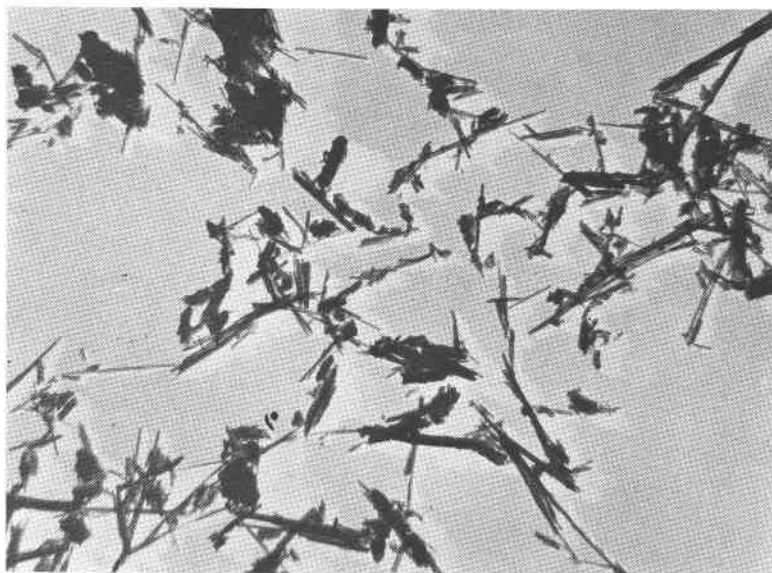


FIG. 3. Electron micrograph of six-layer ortho-serpentine; $\times 8000$

case, the powder pattern may simulate a mixture of other serpentine minerals. This is particularly apparent when identification of serpentine minerals is attempted on the basis of powder photographs taken in a camera of radius less than 9.5 cm. An electron replica micrograph of a naturally-broken surface of povlen-type clinochrysotile normal to the fiber axis is shown in Figure 3. With the resolution obtained, it suggests a layer structure.

Where 6-layer ortho-serpentine is a main constituent of the wall rocks of asbestos veins, the direction of the fiber axis of the clinochrysotile in the veins and of the 6-layer ortho-serpentine may nearly coincide. This is the case of asbestos deposits where the veins of clinochrysotile are interleaved with thin lenses of a pure 6-layer component. Furthermore, the close association of the two serpentine minerals as described above, is

additional evidence for the view expressed earlier (Krstanović and Pavlović, 1964) that the structure of povlen-type clinochrysotile is not based on a cylindrical lattice, but on a lattice where structural sheets are at least partly open.

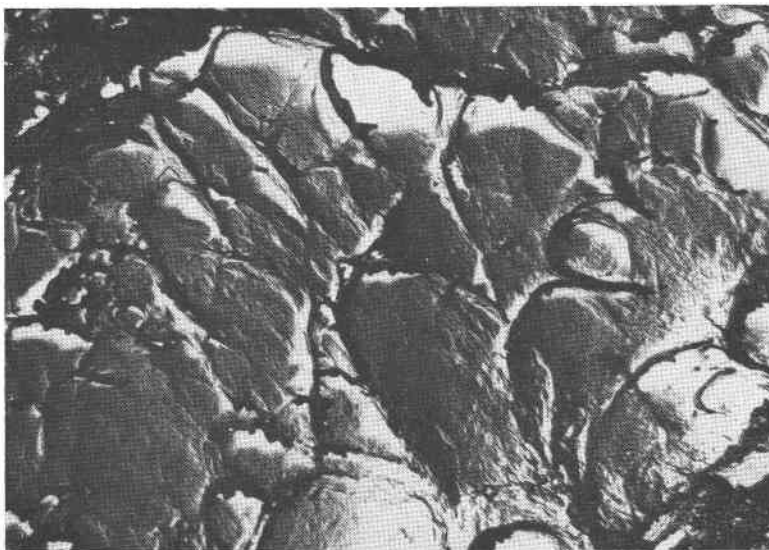


FIG. 4. Electron replica micrograph of povlen-type clinochrysotile normal to the fibre axis; 18,000 \times .

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