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SIX-LAYER ORTHO-HEXAGONAL SERPENTINE FROM THE LABRADOR TROUGH

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Brindley and von Knorring (1954) described a new variety of ortho-antigorite from Unst in the Shetland Islands. In an *x*-ray powder pattern the mineral is characterized by a band of eleven closely spaced lines with the band head at (020). These lines indicated a superstructure parameter in either the x or z direction. By analogy with synthetic 6-layer Ge analog of serpentine prepared by Roy and Roy (1954), Zussman and Brindley (1957) re-indexed the pattern on the basis of a 6-layer ortho-hexagonal cell ($c=43.59$ Å) and demonstrated excellent agreement between calculated and observed *d*-values. The new polytype was called 6-layer ortho-hexagonal, or Unst-type, serpentine. Additional occurrences of this mineral are rare. Gillery (1959) reported 6-layer mixed with 1-layer serpentine from films supplied by W. S. Bailey, University of Wisconsin.

In 1957, during the course of an investigation of the serpentinized ultramafic sills along the eastern side of the Labrador Trough (Quebec-Labrador), the writer collected unusual serpentine material which was subsequently identified as the Unst-type.

OCCURRENCE

The occurrence is located 3.5 miles east of Thompson Lake at 55°20′ N., 66°10′ W. Thompson Lake is 45 air miles northeast of the town of Knob Lake, Quebec-Labrador. The mineral occurs in veins cutting a serpentinite sill. The vein material is naturally broken up into conchoidally fractured, potsherd-like pieces. It is dull dark green on the fresh surface and completely grainless, texturally resembling flint. It is monominerallic and free of even the usual magnetite impurity of the serpentinites. The sill is an altered wehrlite (olivine-clinopyroxene) which has been largely converted to antigorite, chrysotile and tremolite, with remnants of chrysolite and diopsidic augite. Both the sill and the surrounding country rocks (metasediments and metavolcanics) have mineralogies consistent with the epidote-amphibolite facies.

OPTICAL

In thin section, with transmitted light, the vein rock is medium green. The grain size is too small to be clearly resolved and interference figures are unobtainable. The birefringence appears to be of the order of 0.003.

It looks quite similar to the petrographically recognized "mineraloid" called serpophite (Lodochnikov, 1936; Kerr, 1959, p. 415). Crushed fragments immersed in oil showed a fair match around 1.565. Each fragment, of course, consisted of an aggregate of minute grains.

CHEMICAL

An analysis of the mineral is given in Table 1. Zussman (1956), Brindley (1954, 1956), and Brindley and von Knorring (1954) have already noted the difficulties in assigning a structural formula to the Unst-type serpentine. A variety of forms are possible depending on the assumptions used. Without going further into the matter, the structural formula below was calculated on the basis of 18 oxygens which is a standard first approximation and serves for comparison.

$[Mg_{5.277}Mn_{0.004}Fe''_{0.101}Fe'''_{0.243}Cr_{0.003}Al_{0.064}Na_{0.031}Ti_{0.005}]$ 5.734 atoms
$[Si_{3.611}Al_{0.389}]$ 4 atoms
$[O_{9.373}(OH)_{8.627}]$ 18 atoms

(For purposes of computation all R_2O was calculated as Na_2O.)

This formula is similar to the 18-oxygen formulae of Brindley and von Knorring (1954) in the following respects: the silicon ion content is below, and the hydroxyl ion content above the ideal proportions by amounts larger than analytical error; the octahedral total is below the ideal value of 6. In contrast, the Thompson Lake sample is much higher in total R_2O_3 than the analyzed samples from Unst.

Gillery (1959) made a hydrothermal study of Mg-Al serpentines and chlorites. His starting gels were mixed according to: $(6-x)MgO$, xAl_2O_3, $(4-x)SiO_2$, $4H_2O$. Fibrous serpentines lie between $x=0$ and $x=0.24$ (approx.). Natural platy serpentines are stable between $x=0.24$ and $x=0.50$. Above 0.50 chlorite is stable, though 1 and 6-layer serpentines may form metastably as transient phases. On the basis of Gillery's

TABLE 1. CHEMICAL ANALYSIS OF 6-LAYER SERPENTINE, THOMPSON LAKE, QUEBEC-LABRADOR

SiO_2	38.50	Na_2O K_2O	0.17
TiO_2	0.07		
Al_2O_3	4.09	H_2O^+	13.79
Fe_2O_3	3.52	H_2O^-	0.94
FeO	1.29	CO_2	0.00
MnO	0.05	Cr_2O_3	0.05
MgO	37.75		
CaO	0.00	Total	100.22

Analyst: Dr. H. B. Wiik, Helsinki, 1960.

diagram (Fig. 1, p. 149) the Thompson Lake sample lies at $x=0.35$ R_2O_3. With respect to the 18-oxygen formula given above the partition of trivalent ions between tetrahedral and octahedral positions is 0.39 and 0.32, respectively. Gillery's formula ideally implies equality between these two positions.

It is puzzling that the analyzed Unst samples (Brindley and von Knorring, 1954) give values of x at 0.11 and 0.12 R_2O_3, which places them in the field of fibrous serpentines on Gillery's diagram. However, Gillery examined compositions at $x=0$ and $x=0.25$ and none between. He based his break between fibrous and platy forms (approx. 0.24) on the statement of Nagy and Faust (1956) that analyses in the literature show that fibrous polytypes may carry up to $2.9 \pm 1.9\%$ R_2O_3. However, the very careful analyses of Kalousek and Muttart (1957) give average Al_2O_3 at $0.23 \pm 0.12\%$ and Fe_2O_3 at $0.67 \pm 0.41\%$. These percentages indicate a maximum x-value around 0.06 R_2O_3 for their data on fibrous serpentine. Kalousek went to great pains to purify his sample from oxide impurities. The writer has often observed opaque grains in thin sections where the grains were barely resolvable specks of dust size. It is likely that contaminants were present in many of the older analyses, such as those referred to by Nagy and Faust. On this basis it is suggested that the break point between fibrous and platy polytypes might more properly lie around $x=0.10$ $R_2O_?$. This would place the platy Unst minerals in the appropriate field.

POWDER DIFFRACTION DATA

The diffraction pattern of the Thompson Lake serpentine was made on a Norelco powder camera (114.5 mm.) using filtered FeKα radiation, and repeated on a General Electric XRD-5 diffractometer using filtered CuKα radiation. The observed data given in Table 2 were made from the film measurements. Forty-three lines were observed; however only the first thirty-five are reported in order to compare them with the data of Zussman and Brindley (1957).

The spacings are closely comparable to those of Zussman and Brindley (1957) with less than 0.5% difference between their observed values and those found for the Thompson Lake sample. However, the spacings (006), (025), (00,12), (02,13) and (00,18) show differences of 0.82%, 2.00%, 0.93%, 2.24% and 0.50% respectively. All these differences, except (02,13), are in the direction of being shorter than the observed spacings in the Unst sample. Although no consistent pattern is followed throughout the data, they do suggest that $(00l)$ spacings, at least, reflect the differences in composition between the two samples. Gillery (1959) noted that the basal spacing in 6-layer serpentine decreases with

TABLE 2. *X*-RAY POWDER DATA

Unst (Zussman & Brindley, 1957)			Thompson Lake (FeKα, λ=1.93728 Å)		(*hkl*)
$d_{obs.}$	d_{calc}	I/I$_0$	$d_{obs.}$	I/I$_0$	
7.33	7.265	100	7.27	100	006
4.597	4.610	60	4.581	50	020
4.403	4.393	10	4.420	10	023
4.250	4.245	10	4.271	10	024
4.088	4.075	10	4.006	10	025
3.903	3.892	1	3.892	1	026
3.662	3.632	100	3.628	70	00, 12
3.528	3.519	1	3.517	1	028
3.348	3.338	1	3.339	1	029
3.172	3.167	1	3.167	1	02, 10
3.015	3.005	1	3.019	1	02, 11
2.865	2.853	1	2.851	1	02, 12
2.720	2.711	1	2.781	1	02, 13
2.623	2.618	30	2.624	30	203
2.502	2.499	100	2.503	80	206
2.450	2.458	10	2.449	1	02, 15
2.425	2.422	10	2.413	5	00, 18
2.335	2.332	70	2.334	40	209
2.149	2.147	60	2.147	30	20, 12
1.9629	1.9626	70	1.9597	40	20, 15
1.8154	1.8162	1	1.8090	1	00, 24
1.7905	1.7911	10	1.7845	10	20, 18
1.7392	1.7424	10	1.7400	10	310
1.6360	1.6368	40	1.6331	20	20, 21
1.5354	1.5367	80	1.5399	60	060
1.5013	1.5033	70	1.5048	30	20, 24
1.4520	1.4530	½	1.4480	1	00, 30
1.4148	1.4152	20	1.4154	10	06, 12
1.3793	1.3803	20	1.3750	10	20, 27
1.3271	1.3252	10	1.3290	5	403
1.3092	1.3090	50	1.3119	20	406
1.2958	1.2975	½	1.2975	½	06, 18
1.2832	1.2832	1	1.2846	1	409
1.2759	1.2752	1	1.2720	1	20, 30
1.2100	1.2108	10	1.2105	5	00, 36

increase in x-value and increase in pressure. He explained the dependence of basal spacing on Al (or Fe‴) substitution on the basis of the higher electrostatic charge of opposite sign created by equivalent substitution in the 6 and 4 coordination layers.

Gillery makes a distinction between two types of 6-layer structure:

6(3) type with $l=2n$ usually more intense than $l=2n+1$; 6(2) type with $l=3n$ usually more intense than $l=3n+1$. Examination of the observed intensities for the Thompson Lake sample fixes it as a 6(2) type, which is also true of the Unst sample.

Although the relative intensities fit this scheme, the Thompson Lake sample gives an overall lower intensity pattern than the Unst sample, when (006) is set at 100. This difference may be more apparent than real, and can represent differences in sample handling, equipment and degree of preferred orientation in the powder.

CONCLUSIONS

The formation of 6-layer serpentine is apparently not a function of trivalent substitution alone. However, compositional data are somewhat scanty at present. It is suggested that the division between fibrous and platy serpentines may lie around 0.6% R_2O_3 (in the analysis) rather than around 4.5% as suggested by Gillery (1959). The "mineraloid," serpophite may be 6-layer serpentine, at least in part.

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