

MINERALOGICAL NOTES

REFLECTANCE AND MICROHARDNESS OF SMYTHITE¹

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ABSTRACT

Smythite from the Silverfields Mine, Cobalt, Ontario, with the composition $\text{Fe}_{3.25}\text{S}_{4.00}$, has reflectance values of $R_{\text{max}}=46.0\%$, $R_{\text{min}}=42.0\%$ (at 546 nm), and a microhardness of 388 VHN. Both reflectance and microhardness are greater than those of co-existing monoclinic pyrrhotite.

INTRODUCTION

Literature references to the appearance of smythite in polished section tend to be misleading, with the result that many occurrences of smythite may be overlooked. Most literature references (Erd *et al.* 1957; Taylor, 1970) indicate that smythite is similar to, or indistinguishable from, pyrrhotite, and one report (Chukhrov *et al.*, 1965) states that smythite has a lower reflectance than pyrrhotite. Our work has shown, however, that smythite has a distinctly *higher* reflectance and a substantially greater indentation hardness than pyrrhotite. The chief purpose in reporting our results is to draw the attention of mineralogists to these differences so that smythite can be distinguished from pyrrhotite.

SAMPLE

A sample containing both smythite and pyrrhotite was obtained from the Silverfields Mine at Cobalt, Ontario through the kindness of Dr. W. Petruk of the Mines Branch, who has been conducting a comprehensive mineralogical investigation of the ores of the Cobalt-Gowganda District. His sample designation is "Silverfields No. 372". The compositions of the smythite and pyrrhotite, as determined by electron microprobe analysis, using synthetic nickeliferous and nickel-free pyrrhotite as standards, are shown in Table 1.

The composition of the smythite is identical to that reported by Taylor (1970), whose sample had also been obtained from the Silverfields mine. The point of particular interest with regard to the composition, also pointed out by Taylor, is the apparent metal excess over that in the

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TABLE 1. RESULTS OF ELECTRON MICROPROBE ANALYSES OF SMYTHITE AND CO-EXISTING PYRRHOTITE

	Smythite		Pyrrhotite	
	Wt. % ^a	At. props.	Wt. % ^b	At. props.
Fe	58.60±0.5	3.245	60.54±0.5	0.871
Ni	0.10	0.005	0.10	0.001
S	41.47±0.2	4.000	39.91±0.2	1.000
Total	100.17		100.55	

^a Average of 5 determinations; each determination represents at least 5 spot analyses.

^b Average of 6 determinations; each determination represents at least 5 spot analyses.

theoretical smythite composition of Fe_3S_4 . The X-ray powder diffraction pattern corresponds closely to the data given by Erd *et al.* (1957).

The pyrrhotite composition is quite close to Fe_7S_8 , the normal composition for monoclinic pyrrhotite.

REFLECTANCE

The reflectance measurements were made on a Leitz MPV reflectance apparatus equipped with an MPE photometer, and were made against silicon standard no. 2538.42, provided by the Commission on Ore Microscopy and calibrated by the N.P.L. A 45× objective with a numerical aperture of 0.65 was used. Such an objective is not ideal for accurate reflectance measurements because of its large numerical aperture and its sensitivity to focusing; this goes far toward explaining the rather large spread of values obtained (approx. ±1.0 percent in the middle spectral range; somewhat higher at the extremes). Nevertheless, an objective of lower power (and smaller numerical aperture) could not be used because of the small areas available for measurement. The areas measured were square, 0.007 mm. to a side. Figure 1 shows the minimum and maximum values obtained from 17 different smythite grains taken at random, and includes measurements made on five grains of co-existing monoclinic pyrrhotite. The horizontal smythite lines in Figure 1, connecting minimum and maximum values obtained for the same grains, should all touch, or cross, the median reflectance value; that they do not is evidence of measurement inaccuracies. These can be attributed chiefly to the high numerical aperture of the objective lens used and to the difficulty in locating the position of precise focus. In any case, the smythite clearly has a higher reflectance than pyrrhotite, although there may be a slight overlap between R_{\max} of pyrrhotite and R_{\min} of smythite. There-

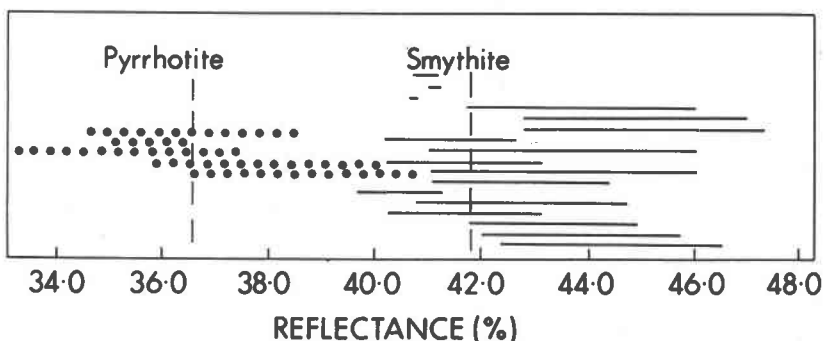


FIG. 1. Reflectance ranges at $\lambda = 546$ nm observed in five pyrrhotite grains (dotted lines) and 17 smythite grains (solid lines) taken at random. Vertical dashed lines indicate the approximate median reflectance.

fore it is entirely possible that pyrrhotite and smythite at certain orientations will have approximately the same reflectance. As an additional point of interest, it may be noted that the values obtained for monoclinic pyrrhotite in this study fall largely within the range reported for hexagonal pyrrhotite (von Gehlen and Piller, 1965).

Figure 2 shows the dispersion curves obtained from a grain that was found to approximate maximum bireflection, and the dispersion curves for hexagonal pyrrhotite, taken from von Gehlen and Piller (1965). This same smythite grain was measured twice, and the spread shown in Figure 2 is that obtained from the two sets of measurements. Figure 2 also clearly demonstrates that smythite has a higher reflectance than hexagonal pyrrhotite. The dispersion and bireflection of the two minerals are quite similar, which conforms to their microscopic appearance.

The reflectance data for smythite given by Chukhrov *et al.* (1965) are completely at variance with the results given here. Chukhrov *et al.* gave reflectance values at six wavelengths, ranging between 26.0 and 34.5 percent R —much lower than our measurements, and substantially lower than pyrrhotite. In addition, these values indicate a curious type of dispersion, peaking at 558 nm and dropping to lower reflectance values at both ends of the spectrum—not at all like the dispersion exhibited by our smythite and by pyrrhotite. If the measurements given by Chukhrov *et al.* were correct, then the colour of smythite would be greatly different from that of pyrrhotite—probably a purer yellow than pyrite. Perhaps some of the discrepancy can be attributed to compositional differences between our smythite and that of Chukhrov *et al.* but without knowing more about their measurement procedure, the possibility of error cannot be excluded.

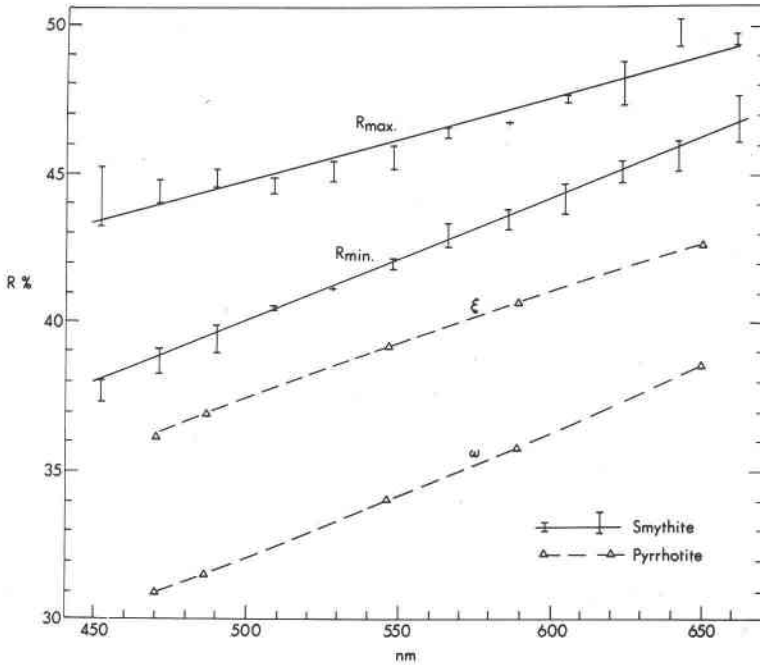


FIG. 2. Reflectance dispersion curves for smythite (solid lines) and hexagonal pyrrhotite (dashed lines; taken from von Gehlen and Piller, 1965). The vertical lines on and about the smythite curves indicate the spread of values obtained on re-measuring the same grain.

MICROHARDNESS

The indentation microhardness of the smythite and the co-existing monoclinic pyrrhotite were measured on a Leitz Durimet apparatus, using a 50-g load. This gave generally good indentations, with little or no peripheral fracturing, measuring between 15 and 20 microns per diagonal. Eleven different smythite grains and seven different pyrrhotite grains were measured. The hardness, in VHN units, was calculated from the average length (d) of the two diagonals comprising the indentations, using the formula $VHN = 1854P/d^2$, where P is the indenting load, in grams.

The hardness values for smythite, with one exception, fell within the range 353–404, giving a weighted average of 388 with a standard deviation of 15.7. Those of pyrrhotite, with one exception, ranged between 261 and 304, giving a weighted average of 277 with a standard deviation of 18.1. The two anomalous values were excluded from the calculation of the averages and standard deviations because they were substantially at

variance with the other measurements, probably because of sub-surface effects. In any case, smythite is clearly harder than pyrrhotite. As an indication of the consistency of the measurements compared with those in the literature it can be pointed out that the hardness values of the pyrrhotite reported here almost all fall within the range VHN 248-303 reported by Bowie and Taylor (1958).

CONCLUSIONS

Metal-excess smythite, represented by the composition $\text{Fe}_{3.25}\text{S}_{4.00}$, has an appreciably higher reflectance and greater hardness than monoclinic pyrrhotite, and the two minerals can therefore be distinguished in careful microscopic work. When the two minerals are in direct contact, the difference in reflectance is readily discernible (Fig. 3), but when they are separated by other minerals, they can generally not be distinguished by eye. In the latter case, however, the minerals can be distinguished by comparative reflectance measurements. The difference in hardness between the two minerals is also sufficiently great for polishing relief to be developed when a cloth lap is used for polishing.

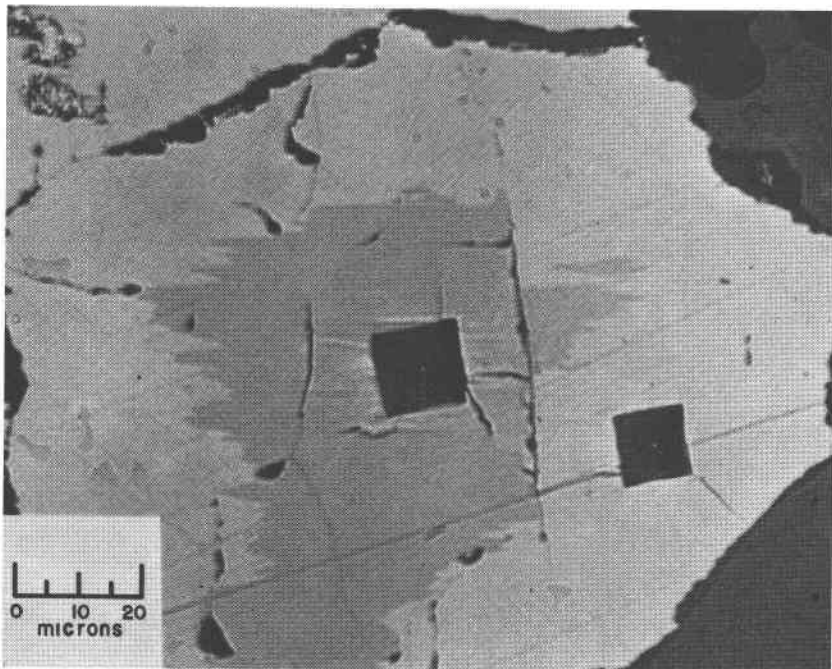


FIG. 3. Photomicrograph, oil immersion, of co-existing smythite (light grey) and pyrrhotite (medium grey) from Silverfield No. 372. Note the different sizes of the hardness indentations in the two minerals.

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THE AMERICAN MINERALOGIST, VOL. 56, JULY-AUGUST, 1971

HEMATITE TO GOETHITE SURFACE WEATHERING

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ABSTRACT

The hematite to goethite transformation by weathering has been followed with X-ray and optical methods. Evidence is given of the influence of the hematite growth steps and dislocations in such a process.

Hematite crystals from Elba Island, developed as (0001) platelets, often show on their surfaces formations of a substance whose color varies from a bright red to a reddish brown. X-ray powder diffractometry and film methods have proved the substance to be $\text{FeO}(\text{OH})$, goethite, or hematite-goethite mixtures in various percentages (with a higher hematite percent when the colour is bright red). Although sometimes the red substance has appeared to be amorphous, it is our opinion that these samples are not different from the previous ones; in agreement with what has been stated by Holser (1953) and authors he cites.

The substance is usually concentrated along crystallographic directions (at angles of 60° , according to the face symmetry) which follow either growth layer steps or straight traces of dislocation movements caused by natural stresses the crystal has undergone during its history (Sunagawa, 1960; 1962).