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MINERALOGICAL NOTES

NICKELIAN MACKINAWITE FROM VLAKFONTEIN, TRANSVAAL

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ABSTRACT

Information about the occurrence, optical properties, microhardness and cell-size is given for a nickelian mackinawite (Fe 38.1%, Co 3.3%, Ni 18.7%) from Vlakfontein in the Transvaal.

Mackinawite, the mineral first named as a tetragonal iron sulphide FeS, by Evans *et al.* in 1962, has since been described from Outukumpu, Finland, by Kuovo *et al.* (1963). Their chemical analyses gave the range of values Fe 64–54 percent, S 35 percent, Ni 0.2–8.3 percent, Co 0.2–10 percent with a formula still approximating to M_1S_1. Since this time mackinawite has been more widely reported but the compositional range has not been extended beyond the above values.

The author has identified mackinawite in polished sections from the Vlakfontein nickel pipe in the South African Transvaal, a previously unreported locality for this mineral, although Wagner (1929) described an unknown mineral with optics which are similar to mackinawite from this mine. The sulfides occur here in basic rocks. Large pyrrhotite crystals with intergrown coarse pentlandite are typical examples of this much described association. Some cubanite and chalcopyrite occurs associated with the pyrrhotite but younger in age and there are spinel fragments in the silicates. The mackinawite occurs within the pentlandite, evidently as a replacement product.

This mackinawite was examined in reflected light in both air and oil. It shows the very strong pleochroism and anisotropy characteristic of this mineral. In air, the pleochroism ranges from brownish-cream to brown-gray and under oil this bireflection is further exaggerated from greenish-cream to dark grey-brown. The anisotropic colors vary from creams to dark greys.

Quantitative determinations of the reflectivity were made using the Reichert reflex spectral microphotometer. This instrument is described in detail in a paper by Singh (1965). In all recorded values the reflectivity of the specimen was determined by comparison with a standard of known reflectivity, in this case a specimen of pyrite which had been calibrated by the National Physical Laboratory (NPL 1915.1). The extreme values of the reflectivity of mackinawite (R_p and R_G) as determined at 589 nm (in air) are given in Table 1. Spectral dispersion profiles for R_p and R_G

TABLE 1. MACKINAWITE ANALYSES AND PROPERTIES

Locality	Reflectivity (R%) Range at 589 nm	Wt % Fe	Wt % Co	Wt % Ni	Wt % Σ Me	Cell Size (Å) *a* *c* (±0.006 Å)	VHN_{25}[b]
Vlakfontein	33.8±11.1	38.1	3.3	18.7	60.1	3.670 4.997	94–181
Outukumpu	37.7±5.7	52.0	5.9	1.8	59.7	—	—
Outukumpu[a]	—	53.1±2	<0.2	5.4±0.3	58.7	3.676 5.032	—
Ylöjärvi[a]	—	63.2±2	0.2	0.2	63.7	—	—

[a] Data of Kuovo, Long, Vuorelainen.
[b] Vickers hardness at 25g./mm² load.

were also constructed from measurements made between 420 nm and 660 nm wavelengths. In Figure 1 the dispersion profiles for this Vlakfontein mackinawite are compared with similar profiles constructed from measurements made on mackinawite from Outukumpu (Finland).

Values for Vickers microhardness were also determined. The instrument used for these determinations was the Leitz Durimet microscope with a Vickers diamond indenter, described in greater detail by Young and Millman (1964).

Electron probe microanalysis was undertaken with a Cambridge MK I microanalyser using an excitation voltage of 25 kV and carbon-coated specimens. Allowance was made for background radiation and the results

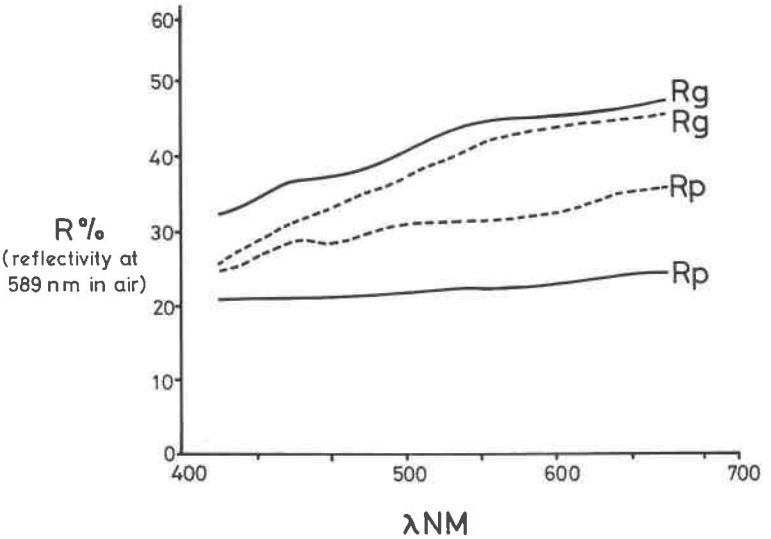

FIG. 1. Spectral dispersion profiles of mackinawite from Vlakfontein (—) and Outukumpu (---). Compositions: Vlakfontein Fe 38.1% Co 3.3% Ni 18.7%; Outukumpu Fe 52.0% Co 5.9% Ni 1.8%.

corrected for such errors as those caused by absorption, overvoltage, atomic number effect, characteristic fluorescence, background fluorescence *etc.* The results presented here show that the Vlakfontein mackinawite is exceptionally rich in nickel, justifying the name "nickelian mackinawite".

Finally, the identification of this mineral as mackinawite has been confirmed by X-ray powder photography and comparison with the published data of Kuovo *et al.* on Outukumpu material. The cell parameters have been determined from this data.

The reflectivity, microhardness, composition and cell-size data of Vlakfontein mackinawite are compared with data determined by the author from Outukumpu material, together with published data from Outukumpu and Ylöjärvi where possible. All of these data are given in Table 1.

Conclusions

From these data it can be seen that the cell size of mackinawite increases in the iron-rich members and consequently hardness would be expected to decrease. The decrease in cell size away from the iron-rich members has only been demonstrated though with respect to nickel, since cobalt-rich members have yet to be recorded. Variations in reflectivity are complex. The value for the bireflectance (R_G-R_p at 589 nm wavelength) of the Vlakfontein material is exceptionally high (22.2%). However, a lack of variation in orientations available for measurement may restrict the accuracy of the ranges for both reflectivity and microhardness measurements. The variation in total metal content suggests a degree of nonstoichiometry which or may not be real. If real, the outstanding optics of mackinawite may be related to this. In spite of the discovery of "nickelian mackinawite" at Vlakfontein, mackinawite compositions are still confined to a relatively restricted area of compositions, in which iron is dominant. This may be a restriction imposed by structure or due only to the availability of the metals.

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ELASTIC PROPERTIES OF FLUORAPATITE

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ABSTRACT

The elastic constants of Durango fluorapatite have been determined using the ultrasonic pulse superposition method. Room-temperature adiabatic stiffnesses are c_{11} 1.434, c_{33} 1.805, c_{44} 0.415, c_{12} 0.445, c_{13} 0.575, c_{66} 0.495 megabars. Comparison is made with measurements on bones and teeth.

Apatite occurs extensively in igneous rocks and is the most abundant phosphate mineral. It is also an important constituent of teeth and bones, so that its mechanical properties are of considerable medical interest. The elastic constants previously reported by Bhimasenachar (1945) have been questioned by Chung and Buessem (1967) who note a substantial deviation from the shear anisotropy curve obeyed by most hexagonal crystals. Because of their biological significance, we have re-measured the adiabatic stiffness coefficients of apatite by the ultrasonic pulse superposition technique.

Gem-quality yellow apatite from Durango, Mexico, was used in the ultrasonic experiments. Flawless, rectangular prisms about 1 cm^3 in volume were cut from two large hexagonal crystals after orienting the specimens from back-reflection Laue photographs. Scraps from the two crystals were used for the chemical analyses given in Table 1. The two are nearly identical in composition, and compared to other fluorapatites (Deer, Howie and Zussman, 1962) show unusually large silica and rare earth concentrations, but very little MnO. Densities were determined by