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Notes on a Co-Ni disulphide and a Co-Ni-Fe thiospinel from the Kalgoorlie district, Western Australia

DURING an examination of sulphide-mineralized greenschist-level metamorphic rocks in the Kalgoorlie district, Western Australia, the writer noted the presence of a number of sulphide grains which extend the recorded compositional range of members of the cattierite-vaesite disulphides and linnaeite group thiospinel minerals.

The determinative techniques used for identification were essentially the same as those used in a previous report on the linnaeite minerals of the area (Ostwald, 1978). Results of electron probe microanalyses (average composition for four areas of each grain) and atomic ratios for three grains of the cattierite-vaesite disulphides and the linnaeite group thiospinels are shown in Table I. Compositions of the cobalt-nickel disulphides are plotted in fig. 1 and compositions of the cobalt-nickel-iron thiospinels in fig. 2.

The cattierite-vaesite occurred as small anhedral grains, 20-100 μm in size, in a talc-carbonated serpentinite in the area of the Scotia mine to the north of Kalgoorlie. Two compositions were detected by EPMA:

- (i) grains of nickel disulphide containing minor amounts of iron and cobalt (K142). These are much lower in reflectivity than pyrite, R %

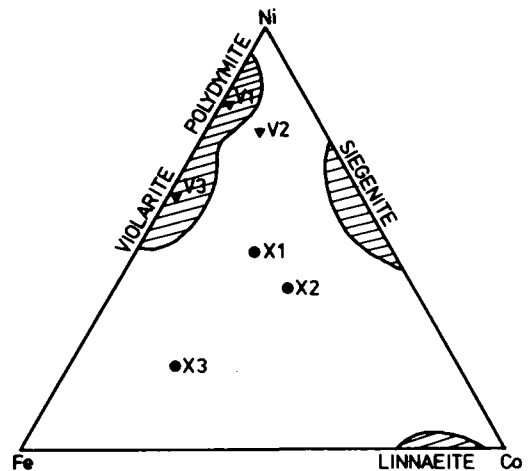
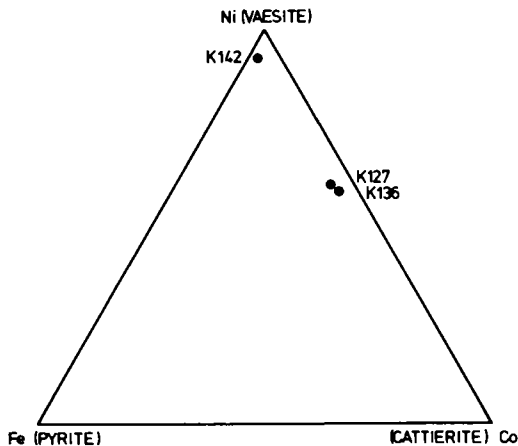
(589 nm) = 31, and are pale violet grey in colour. VHN (100 g) indicated 800-30. On the basis of chemistry and reflectivity this mineral was identified as vaesite (Kerr, 1945).

- (ii) grains intermediate between CoS_2 and NiS_2 in composition (K127, K136). These are optically similar to the vaesite, with R % (569 nm) = 31.6 and VHN (100 g) of 850-80.

The compositions of natural Fe-Co-Ni disulphides have recently been discussed by Vaughan and Craig (1978). Their data indicate that compositions intermediate between FeS_2 and NiS_2 are

TABLE I. Electron probe microanalyses and atomic ratios of metals to sulphur for disulphide ($M\text{S}_2$) and thiospinel ($M_3\text{S}_4$) minerals from the Kalgoorlie district

	Ni	Fe	Co	S	Ni	Fe	Co	Σ	Type
K142	47.9	2.6	1.1	48.4	0.93	0.05	0.02	1.0	$M\text{S}_2$
K136	27.2	1.9	17.0	52.9	0.59	0.04	0.37	1.0	
K127	31.1	2.4	17.8	48.7	0.61	0.05	0.34	1.0	
X ₁	27.9	15.0	15.7	41.4	0.47	0.27	0.26	3.1	$M_3\text{S}_4$
X ₂	23.7	13.9	22.6	39.7	0.39	0.24	0.37	3.3	
X ₃	12.3	32.7	13.9	41.1	0.20	0.57	0.23	3.2	



FIGS. 1 and 2. FIG. 1 (left). Compositions of vaesite (K142) and cattierite-vaesite solid solutions (K127, K136) from the Kalgoorlie district. FIG. 2 (right). Compositions of cobaltian violarite in relation to other thiospinels of the Kalgoorlie district.

common; compositions intermediate between FeS_2 and CoS_2 are rare, and compositions intermediate between CoS_2 and NiS_2 are unknown. The existence of CoS_2 - NiS_2 solid solution above 400°C has, however, been recorded by Klemm (1965) and thus it appears likely that the grains K127, K136 represent metastable catterite-vaesite solid solutions.

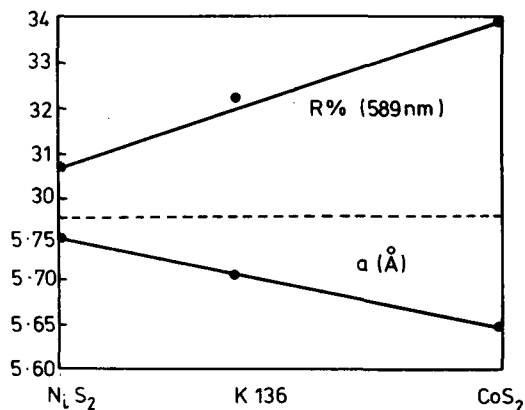


FIG. 3. Reflectivity at 589 nm and cell edge of catterite-vaesite solid solutions in relation to end members.

Reflectivity and unit cell dimension for grains K136 are plotted in fig. 3 together with data on vaesite and catterite taken from Vaughan and Craig (1978). It will be seen that NiS_2 - CoS_2 solid solutions appear to follow Vegard's law, though, in the absence of data on other compositions, this cannot be considered proved. The reflectivity at 589 nm is also intermediate between that of the two end-members but here the relationship is more complex than that of Vegard's law. In fact, a simple linear relationship of reflectivity variation is very unlikely in view of the experimental determinations of the complex refractive indices of FeS_2 , CuS_2 , NiS_2 and CoS_2 from 0 to 5 eV (Bither *et al.*, 1968) and the molecular orbital/band models determined for these minerals by Vaughan and Craig (1978).

The linnaeite-group mineral also occurred in the Scotia area rocks as discrete grains anhedral in shape and typically between 30 and 60 μm in size. In reflected light they are pinkish white in colour, isotropic and in fact they were initially considered

to be either violarite or siegenite on account of their colour. VHN determinations indicated a range of values between 360 and 430 for a 100 g load. The grains showed a range of reflectivities at each wavelength no doubt resulting from chemical and electronic structural differences. Measured $R\%$ values were 45.2-45.4 (546 nm); 45.8-46.0 (589 nm); 46.8-47.2 (644 nm).

These cobalt-nickel-iron minerals were classed as thiospinels on the basis of their optical isotropism and general M_3S_4 chemistry. They appear to be outside the compositional range of the well-defined end-member thiospinels linnaeite, siegenite, polydymite, and violarite. On the other hand the compositions of the grains are close to that of some thiospinels plotted by Vaughan and Craig (1978). This would suggest that the grains could be classified as cobaltian violarite. The mineralogy of cobaltian violarite has recently been examined in some detail by Riley (1980) who reported a maximum of 19.2 wt % Co in a grain from Mount Colin, north-west Queensland. One of the Scotia grains (X_2) with 22.6 wt % Co is therefore higher in cobalt than the maximum recorded by Riley while the other two are within the Mount Colin range of variation for this element.

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