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MINERALOGICAL INVESTIGATION OF THE LOW-GRADE NICKEL-BEARING SERPENTINITE OF DUMONT NICKEL CORPORATION, VAL D'OR, QUEBEC

by

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MINERAL SCIENCES DIVISION

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SUMMARY OF RESULTS

A mineralogical examination of samples containing from 0.23 to 0.50 wt.% nickel from Dumont's low-grade nickel serpentinite deposit in Launay Township, Quebec shows that heazlewoodite, pentlandite and awaruite are the principal nickel-bearing phases, but that minor amounts of cobalt pentlandite are also present. Unaltered olivines, which are rare, contain 0.4% nickel, whereas nickel was not detected in the serpentine phases. Some of the magnetite, which is widespread, is nickeliferous and contains approx. 0.12 wt.% nickel. The textures of the sulphides and alloy suggest that they can be divided into two size ranges. 1) As finely dispersed particles generally less than 10 microns in diameter which are widespread and were observed in every polished section. These particles are too fine to be recovered by normal grinding and flotation methods, and represent a large fraction of the nickel content. 2) As coarse composite grains which consist of sulphides, awaruite and magnetite and which vary from fifty to several hundred microns in size. These grains appear to be distributed within zones in the orebody.

No differences were noted in grain size distribution in the higher-grade material which could lead to better metallurgical recoveries.

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INTRODUCTION

In March, 1971, Mr. G. Mathieu of the Mineral Processing Division requested a mineralogical examination of samples sent to the Mines Branch for beneficiation testing from Dumont's low-grade nickel deposit in Launay Township, Quebec. The purpose of this study is to determine the distribution of nickel in the serpentinized rock and in particular, the type and grain size of the various nickel-bearing phases.

Since mineralogists in the Mineral Sciences Division are currently engaged in a general study of low-grade nickel deposits in Canada, the opportunity arose earlier to examine samples from the deposit, mainly through the cooperation of Dr. O.R. Eckstrand of the Geological Survey of Canada. For this reason, more mineralogical information is included into this report than could be obtained from the samples submitted to the Mineral Processing Division.

SAMPLES

The bulk of the shipment received by the Mineral Processing Division, as listed in a covering letter from Mr. G.H. Dumont, were reject samples Nos. 15-107 to 15-355, inclusive, consisting of crushed BQ core from 590 ft. to 1835 ft. in hole E-15. The shipment consisted of 20 boxes weighing 1,550 lbs. From this shipment, Mr. Mathieu prepared composite samples from which several small chips and a small fraction of the head sample was submitted for mineralogical examination. Details of the composite samples with their corresponding nickel contents are listed in Table 1. The footage of the composite samples was taken from a copy of the log of hole E15, compiled by Dumont Nickel Corporation. In addition, similar samples from two other holes, W7 and E16 were submitted by Mr. G. Mathieu. Previous mineralogical examinations were made of samples from holes W-4 and E-16. Figure 1 shows a sketch map of the orebody indicating the drill holes discussed in this report.

PROCEDURE

Polished sections were prepared from the composite samples, with two sections prepared from the head sample and two sections from the chips, each containing 3 or 4 pieces that were selected at random.

A microscopic examination was then made of each section, noting the mineralogy, grain size and association. Following this, extensive electron microprobe analyses were made to determine the distribution of nickel. If the minerals could not be identified by their compositions and optical properties, X-ray diffraction techniques were used.

The limits of detection of nickel in the gangue minerals is estimated to be 0.02% while that in the magnetite is 0.04%.

RESULTS OF THE INVESTIGATION

General Description

The following minerals were identified by electron microprobe and X-ray powder diffraction techniques: pentlandite [$(Ni, Fe)_9S_8$], heazlewoodite (Ni_3S_2), cobaltian pentlandite (with 9.0-13.9% Co), cobalt pentlandite (the cobalt analogue of pentlandite), awaruite (Ni_3Fe), magnetite (some nickeliferous), chrome-spinel, native copper, valleriite [$(CuFeS_2) \cdot n(Mg(OH)_2)$], serpentine-type minerals, brucite and olivine.

The textures of the sulphides and alloy suggests that they can be grouped into two size ranges. The coarser aggregates or composite grains, which appear to be systematically distributed in the orebody, vary from fifty to several hundred microns in diameter. Some of these are macroscopically visible in the drill core. In polished section, these coarser aggregates (Figure 2) tend to occur between the grain boundaries of the altered olivine

TABLE 1

Sample Details

Mathieu's Head Sample No.	Hole	Dumont's Sample No.	Footage	Ni %
1	E15	100-200	560.00-1060.0	0.28
2	E15	200-237	1060.0-1245.0	0.50
3	E15	237-275	1245.0-1435.0	0.30
4	E15	275-301	1435.0-1565.0	0.44
5	E15	301+	1565.0-2136.0	0.29
6	W7	30, 31, 32, 33, 34	----	0.23
7	E16	111-122	----	0.23
2A	E15	----	1055-1247	0.50
3A	E15	----	1250-1435	0.30
4A	E15	----	1440-1530	0.43

grains. The second group is represented by finely dispersed particles, most of which are less than 10 microns in size. These particles were observed in all specimens and appear to show no preference as to their occurrence.

Silicates

The Dumont nickel deposit represents a large peridotite or dunite body which originally consisted essentially of roughly equidimensional grains of olivine, but which are now nearly to completely serpentinized. In most cases, the olivine has been completely altered to serpentine, although the original shape of each grain may be recognized. Unaltered olivines are rare and, when encountered, microprobe analysis showed a nickel content of 0.4%, whereas no nickel has been detected in the serpentine phases. All the samples consist largely of serpentine minerals, which generally are fine-grained, but frequently cut by asbestos veinlets. The colour of the serpentine varies from light pale green to greenish-yellow to colourless. X-ray powder identification of the serpentines indicates that the coloured ones were of the lizardite-antigorite varieties, while the colourless areas gave chrysotile patterns. Undoubtedly, several types of serpentines are present.

Oxides

Primary chrome-spinel, some of which has euhedral crystal morpholgy, occurs throughout the orebody. The mineral shows various shades of colour, ranging from a light pale grey to bluish-grey. Microprobe analysis of the larger unaltered bluish-grey crystals gave CrO 57.2, FeO 17.1, Al_2O_3 13.2, MgO 11.8, total 99.3%. Since nickel was not detected in the chrome-spinel, no attempt was made to determine the relationship between composition and colour. The chrome-spinel is always rimmed and partly replaced by magnetite (Figure 3) which is more widespread and can be seen in every polished section of serpentine. In grain size, the magnetite varies from micron-sized particles up to large irregular grains several hundred microns in diameter. Generally, it occurs as irregular grains distributed along the fracture and cleavage planes of the altered olivines, but more frequently around the grain boundaries. Quite often the larger magnetite grains contain inclusions of awaruite (Figure 4) and pentlandite or heazlewoodite. Magnetite is always associated with the coarser sulphide grains, where it is found either as fracture fillings (Figure 5) or completely enclosing the sulphides (Figure 6).

Some of the magnetite is nickeliferous, and this appears to be related to the mineralogical characteristics of the orebody. For example, magnetite which occurs in those parts of the orebody where pentlandite in the principal nickel sulphide, is nickel free, whereas the magnetite associated with heazlewoodite and cobalt pentlandite generally contains some nickel (0.07-0.3% Ni, ave. 0.12% Ni). However, even in these sections, some of the magnetite is nickel free.

Pentlandite

Pentlandite occurs as irregular grains varying from one micron and less up to several hundred microns in size. The coarser grained material is sometimes associated with awaruite, and has apparently been subsequently fractured and enclosed by magnetite to form the large composite grains shown in Figures 5, 6, 7, and 8. Where the pentlandite occurs as free grains in the serpentine, which probably accounts for a substantial fraction of the mineral, the grain size very seldom exceeds 10 microns. The fine-grained pentlandite is widespread and shows no tendency toward deposition along grain boundaries, fractures or cleavage planes. Microprobe analysis shows a slight variation in composition, with the nickel content for most pentlandites ranging from 26.5-29.3%; a typical composition is close to Ni 28.8, Fe 37.4, Co 0.9, S 33.2, total 100.3%. Only in the sections from Hole E15, 276-301 where no awaruite was observed, was a slightly lower nickel content noted for the pentlandite; these have the composition: Ni 23.8, Fe 41.2, Co 1.3, S 32.7, total 99.0%.

The cobalt content of the pentlandite varies throughout the ore body and even within one polished section. When the cobalt content is below 2.0%, the species is considered a normal pentlandite. However, in certain parts of the orebody, pentlandites with much higher cobalt contents were encountered. These varieties were identified in Hole W4 where heazlewoodite is the principal nickel-bearing sulphide. Optically, the varieties are indistinguishable from normal pentlandite and show the same range of grain sizes and associations. Electron microprobe analyses of several grains indicate that compositionally, the pentlandites can be grouped into two categories. In one group, the cobalt contents vary from 9.0-13.9%, hence these can be referred to as cobaltian pentlandites. An analysis of a representative grain gave Co 13.3, Fe 22.2, Ni 31.8 and S 32.5 wt.%.

The second group represents the mineral species cobalt pentlandite, described in 1959 by Kouvo et al (Amer. Min. 44, pp. 897-900) as the cobalt analogue of pentlandite. The mineral was identified in samples from Hole W4, Nos. 712 and 713 obtained from Dr. Eckstrand, Geological Survey of Canada. The cobalt contents for this mineral extend from 26.3 to 37.4% Co with a lower nickel content than observed in others pentlandites, except in the sample where awaruite was absent from the section. A representative analysis gave Co 29.7, Fe 13.9, Ni 23.6 and S 31.9 wt.%.

Heazlewoodite (Ni_3S_2)

Heazlewoodite is the second most important nickel-bearing sulphide in the ore. Like pentlandite, it occurs as finely dispersed grains (less than 10μ) in the serpentine, as inclusions in magnetite and as large composite grains enclosed in magnetite and associated with awaruite and at times with cobaltian pentlandite. Only where heazlewoodite occurs as inclusions in, or surrounded by magnetite does the grain size reach 100 microns or more. The textures exhibited by pentlandite, shown in Figures 6, 7 and 8, are also typical of heazlewoodite. Electron microprobe analyses gave small, but variable amounts of iron (up to 2.9%) while cobalt was not detected.

Awaruite

Awaruite, a nickel-iron alloy with an ideal formula of Ni_3Fe is widespread and can be seen in almost every polished section. It occurs as finely dispersed grains (Figure 9) in serpentine, as inclusions in magnetite, and associated and with both heazlewoodite and pentlandite (Figures 7 and 8). The grain size is variable, very seldom exceeding 100 microns; the range 1-10 micron is common. A large fraction of the awaruite seems to occur in magnetite (Figure 4). No difference was noted in the composition of the awaruite in contact with heazlewoodite or with pentlandite. All awaruite grains contain variable cobalt (mostly 0.6-3.0% Co with a high of 6.0%), small amounts of copper (0.2%) and variable nickel-iron ratios. Nickel values range from 70.0 to 75.3%.

Native copper is quite rare and was only observed in two polished sections. It occurs as separate grains in serpentine and as inclusions in awaruite, pentlandite and magnetite. The largest grain observed in this study was 40 microns.

Valleriite, likewise, is very rare, although it is frequently found as a secondary product in serpentinized bodies. It occurs associated with chromite, either as fracture fillings or as partial rims. Small amounts of chromium were detected in the valleriite, but these are probably due to impurities of chromite. Valleriite was observed in one piece of drill core where it is associated with brucite.

SUMMARY

Awaruite, pentlandite and heazlewoodite are the principal nickel-bearing phases in the Dumont ore. Awaruite was observed in almost every polished section, while the distribution of pentlandite and heazlewoodite appears to be more restricted. The mineral assemblage in samples from holes E15 and E16 is pentlandite-awaruite while samples from holes W4 and W7 contain mainly heazlewoodite-awaruite with minor cobalt pentlandite. The occurrence of heazlewoodite and normal low cobalt-bearing pentlandite has not been observed in the ore to date. This is surprising as the assemblage heazlewoodite-pentlandite-awaruite should be expected in this type of ore.

The grain sizes of the nickel-bearing phases can be grouped into two size ranges; either as finely dispersed particles generally less than 10μ, which were observed in all polished sections, or as composite grains several hundred microns in diameter. The latter appear to be distributed preferentially in certain parts of the orebody. Where the nickel-bearing phases appear as coarser aggregates, magnetite is a common constituent, occurring either as fracture fillings or completely enclosing the phases. Although minor amounts of nickel were detected in some of the magnetite, significance nickel values in magnetic fractions can be attributed to inclusions of awaruite, pentlandite or heazlewoodite, which at times grade down to a few microns in size. Awaruite, in particular, seems to occur more frequently as inclusions in magnetite than do the sulphides.

The only nickel-bearing silicate phase is the unaltered olivine, which is rare; none was detected in the serpentine.

In conclusion, the only components that are likely to give a concentrate high in nickel are awaruite, pentlandite and heazlewoodite. Since pentlandite and heazlewoodite were not observed in the same assemblage, their distribution within the orebody should be investigated further. Normal grinding and flotation appear to be inadequate for recovery of the fine-grained sulphides and awaruite, although suitable from the coarser fractions. On the other hand, concentration by magnetic means, which is probably easier, with further treatment of this fraction, may yield a more suitable nickel concentrate.

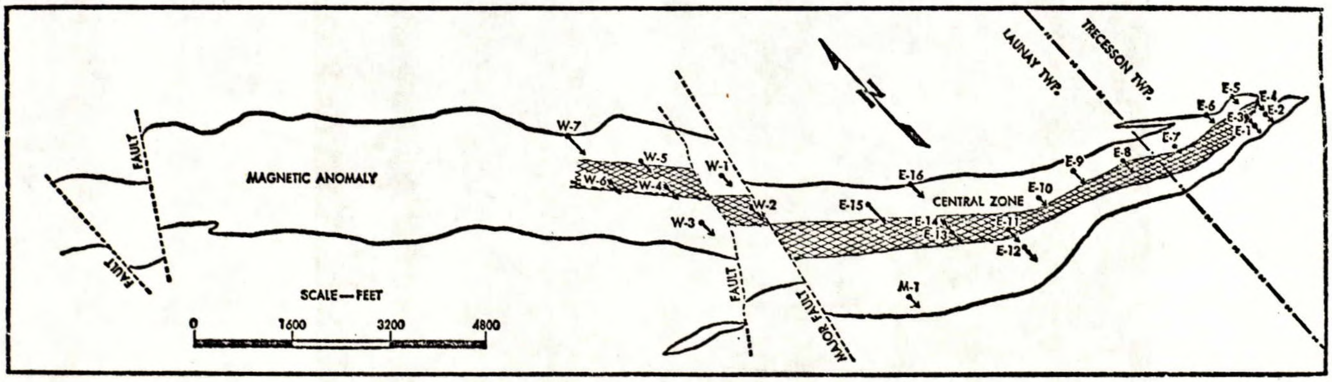

Figure 1. Sketch of orebody and drill holes (copy of sketch published in Northern Miner, Jan. 21, 1971).

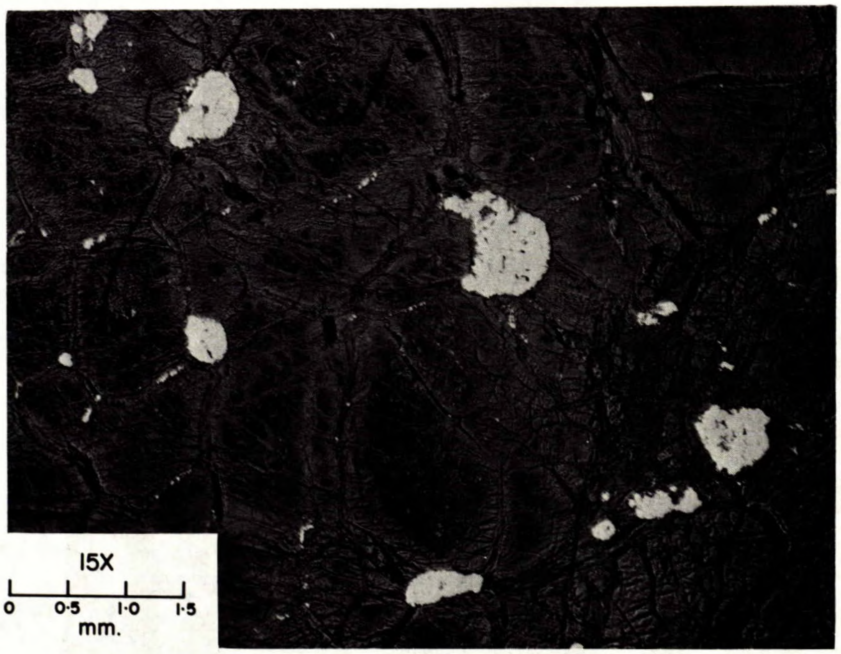

Figure 2. Photomicrograph of serpentinized equidimensional grains of olivine (fractured, in shades of grey) with coarser composite grains of magnetite-sulphide-awaruite (white) distributed around the olivine grain boundaries. Hole E15, 100-200.

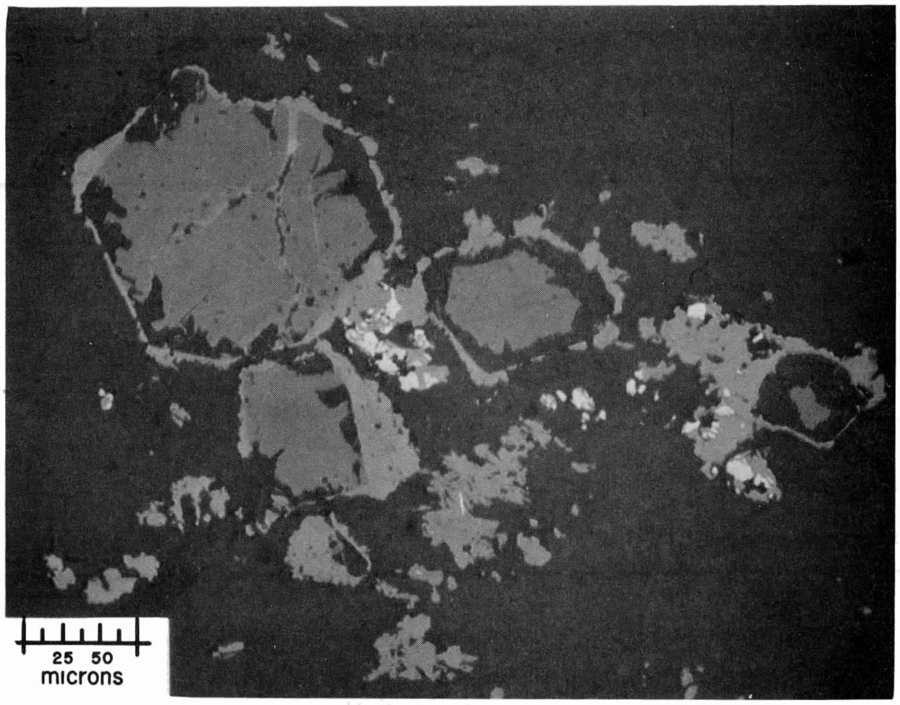

Figure 3. Photomicrograph showing altered euhedral chromite grains (medium grey) surrounded and partly replaced by magnetite (light grey); some pentlandite and awaruite (both white) occurs with the magnetite. Hole E15, 301+.

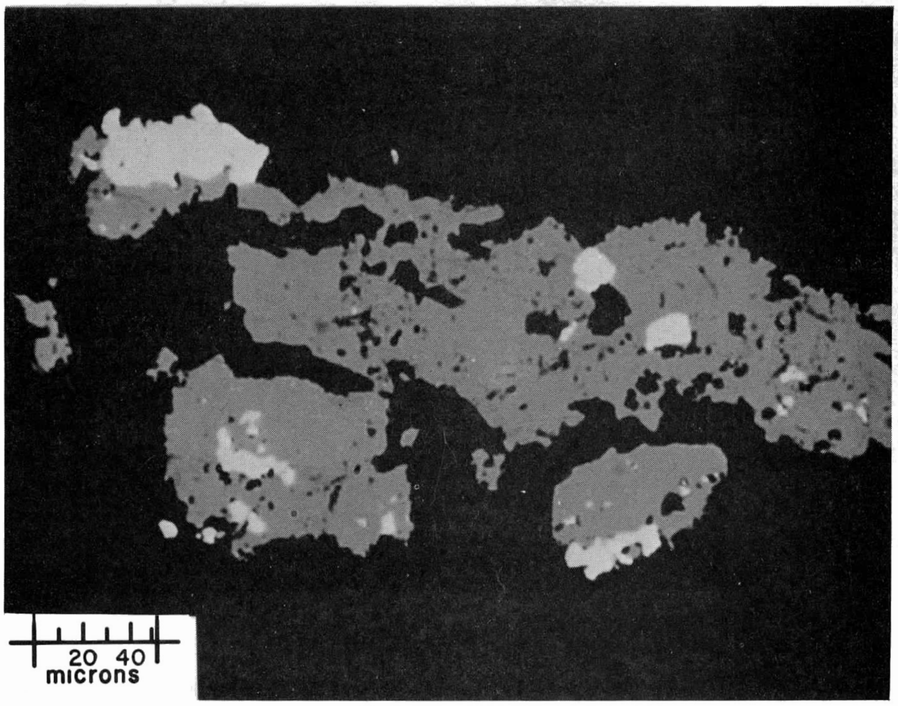

Figure 4. Photomicrograph of awaruite (white) in magnetite (grey). Hole W7.

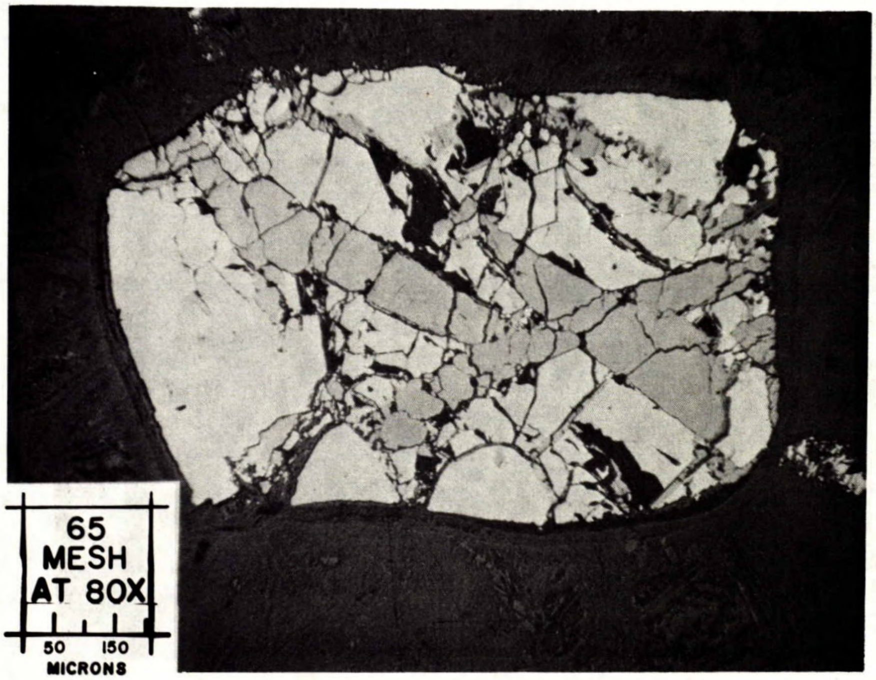

Figure 5. Photomicrograph of fractured pentlandite (greyish-white) and awaruite (white; left side and bottom of grain) with magnetite (grey) occurring along the fractures. Hole E16, 1175 ft.

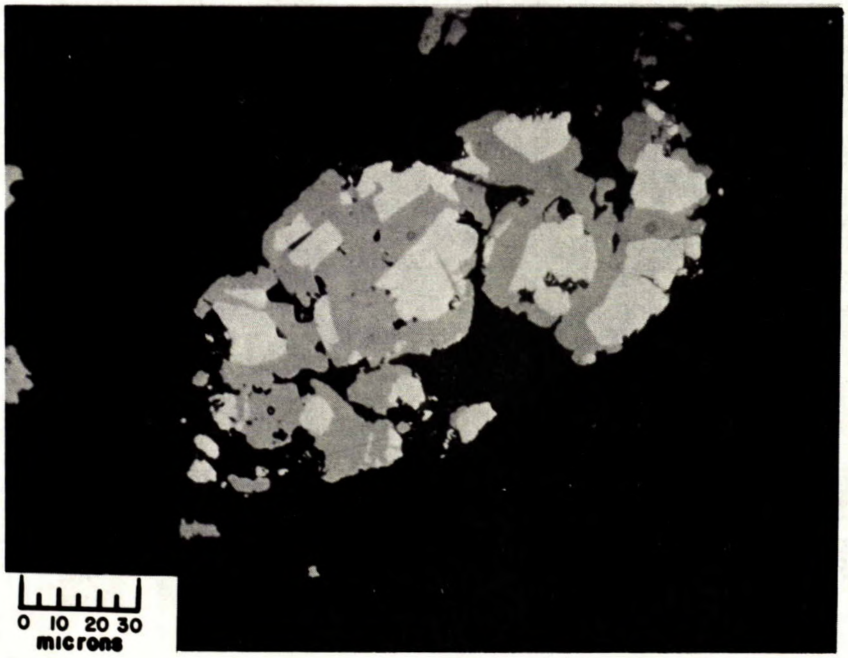

Figure 6. Photomicrograph showing angular fragments of pentlandite (white) enclosed in magnetite (grey). Hole E15, 301+'.

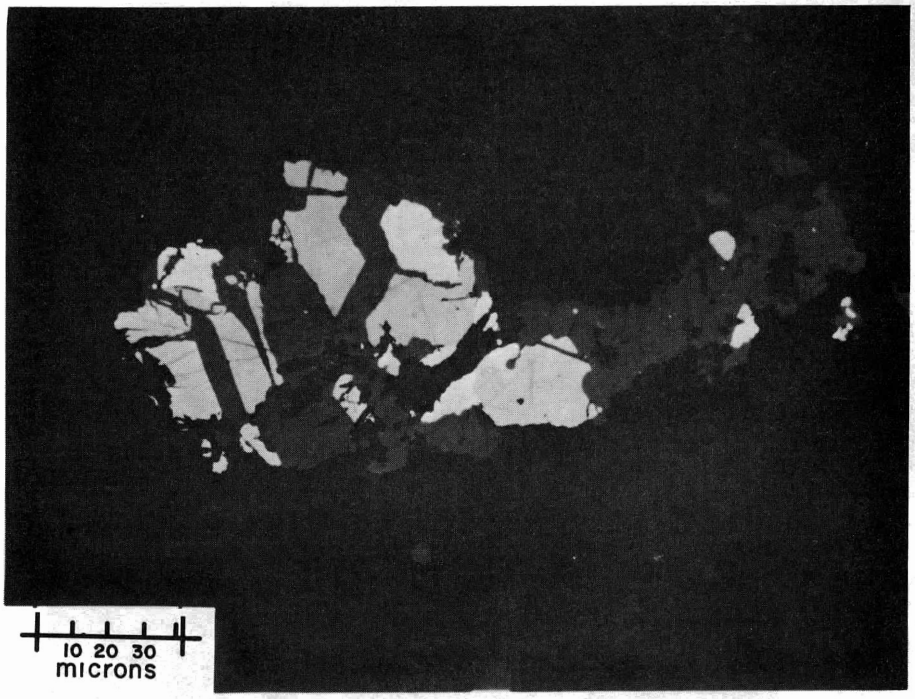

Figure 7. Photomicrograph showing a composite grain consisting of awaruite (white) with pentlandite (light grey) enclosed in magnetite (dark grey). The black groundmass is gangue. Hole E15, 301+.

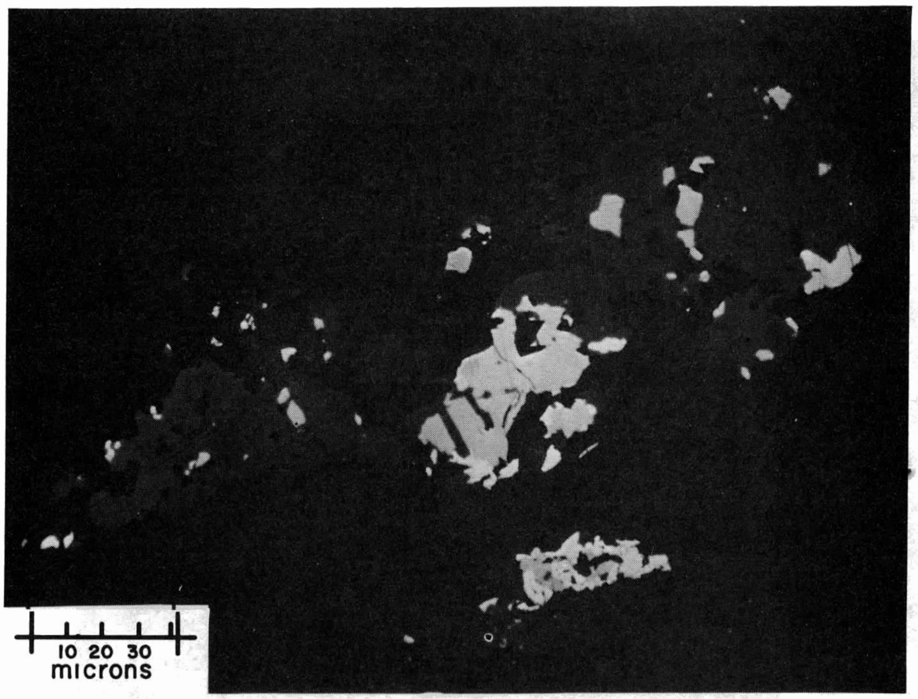

Figure 8. Photomicrograph of pentlandite (light grey) with smaller grains of awaruite (white) enclosed in an elongated irregular magnetite grain (dark grey). The black background is gangue. Hole E15, 301+.

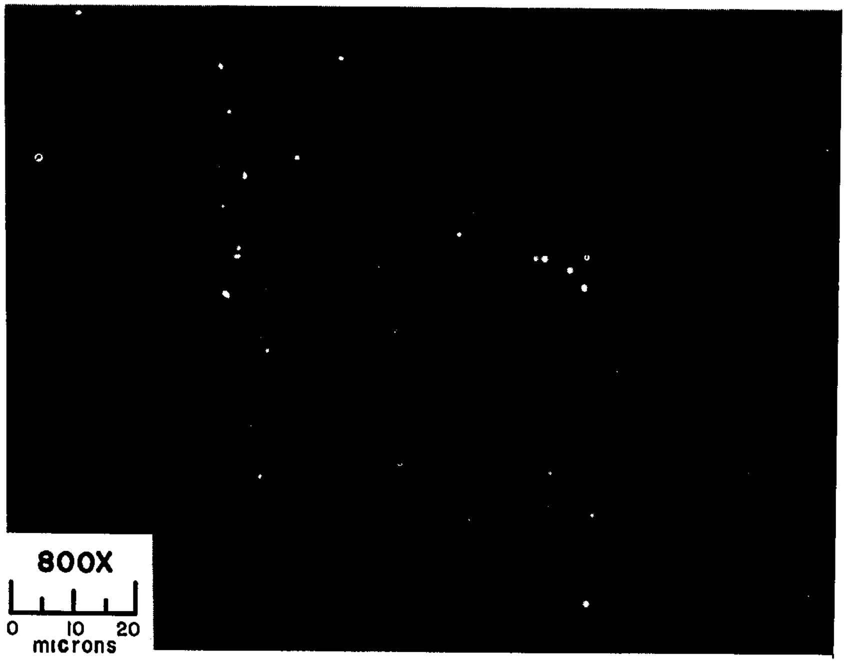

Figure 9. Photomicrograph of finely dispersed awaruite grains in serpentinized olivine. This texture is also typical of the sulphides. Hole W7.