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AN ASSOCIATION OF AWARUITE WITH HEAZLEWOODITE

K. L. WILLIAMS, *Mineragraphic Investigations, Commonwealth Scientific and Industrial Research Organization, University of Melbourne, Carlton, Victoria, Australia.*

Awaruite, the naturally occurring alloy of iron and nickel, has been observed by Ramdohr (1950) in association with pentlandite and heazlewoodite in specimens from Trial Harbour, Tasmania. The awaruite in the specimens studied by Ramdohr was rare and extremely fine grained, and was identified by a process of elimination. Its identity could not be confirmed by etch, microchemical or x -ray examination.

Recently, during the development of the Lord Brassey mine at

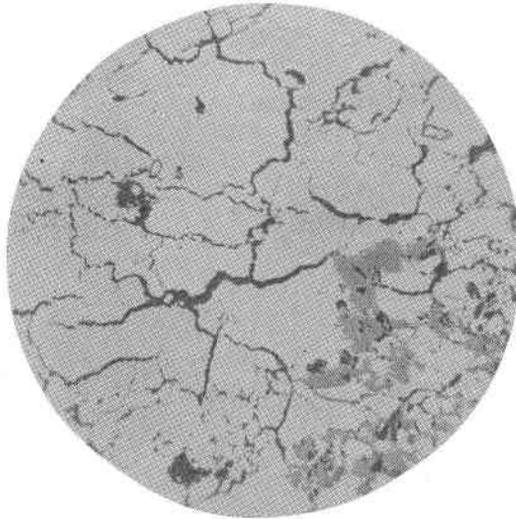


FIG. 1. "Net-like" intergrowth of awaruite (black, etched with 1:1 HNO_3 for 4 seconds) and heazlewoodite (white), with some magnetite (gray). Polished section $\times 150$.

Heazlewood, north-western Tasmania, a seam of high grade heazlewoodite ore was encountered in a cross-cut adjacent to the main adit. Examination of heazlewoodite collected from this seam in May, 1959, has revealed an occurrence of awaruite intergrown with the heazlewoodite (Fig. 1).

The awaruite is white in reflected light and slightly harder than the associated heazlewoodite. It is isotropic, with a reflectivity higher than that of the heazlewoodite (51.6–59.3 per cent; Williams, 1958) but lower

than that of native copper (61–89 per cent; Uytenbogaardt, 1951), which occurs in minute amounts in some of the specimens. It polishes readily to a smooth, scratch-free surface.

The etch reactions of the awaruite were found to be as follows: HNO_3 —etches rapidly black, with effervescence; HCl —negative; KCN —negative; FeCl_3 —etches black almost instantaneously; KOH —negative; HgCl_2 —variable, sometimes negative and sometimes etching slowly black. Positive microchemical tests for iron and nickel were obtained, though these were both open to some doubt because of the strong possibility of contamination with finely intergrown magnetite and heazlewoodite.

Strong adherence of the mineral powder to the needle of the solenoid-type microdrill used to obtain material for microchemical testing suggested that the awaruite is highly magnetic.

Awaruite from Awarua Bay, New Zealand, was found to give similar etch reactions. The statement by Uytenbogaardt (1951), after Schneiderhöhn and Ramdohr (1931), that awaruite is insensitive to all standard etch reagents is, therefore, incorrect. The possibility that the observed behaviour is anomalous, because of galvanic or other effects induced by the adjacent heazlewoodite, was considered but was rejected in view of the similar etching behaviour of the pure New Zealand awaruite. Ramdohr (1951) describes the etch behaviour of awaruite as “nicht untersucht” (not investigated).

X-ray powder diffraction photographs of the Heazlewood and New Zealand awaruites gave the lines listed in Table 1. Both resemble that of

TABLE 1. AWARUITE—(Ni, Fe); X-RAY POWDER DATA

Cubic, $Fm\bar{3}m$.

Radiation: $\text{CuK}\alpha_1$; $\lambda = 1.5405 \text{ \AA}$. Camera Diameter: 114.6 mm.

Heazlewood, Tasmania		<i>hkl</i>	Awarua Bay, New Zealand	
$d_{\text{mens.}} \text{ \AA}$	$I_{\text{est.}}$		$d_{\text{mens.}} \text{ \AA}$	$I_{\text{est.}}$
2.044	10	111	2.044	10
1.775	6	200	1.772	6
1.255	4	220	1.253	3
1.070	5	311	1.069	4
1.024	2	222	1.023	1
0.815	2b*	331	0.814	1b
0.793	2b	420	0.792	1b
$a_0: 3.549 \pm 0.003 \text{ \AA}$			$3.545 \pm 0.003 \text{ \AA}$	

* b denotes a broad line.

metallic nickel, although each has a slightly different unit cell parameter. The cell edge of the Heazlewood mineral was calculated from the observed spacings as 3.549 ± 0.003 Å. Donnay and Nowacki (1954) record 3.525 ± 0.001 Å for the cell edge of pure nickel; this corresponds to the value of 3.5171 "Å" (probably kX units) given by Owen, Yates and Sully (1937). The difference in cell parameters can probably be attributed largely to the presence in the awaruites of alloyed iron.

The Heazlewood awaruite occurs as fine, ramifying intergrowths with heazlewoodite and magnetite (Fig. 1); the net-like appearance of the intergrowth is frequently reminiscent of grain boundary segregations or replacements. Individual areas of awaruite seldom exceed 0.3 mm. in diameter.

Because the awaruite is so fine grained and is present in such small proportions, its chemical composition could not be determined by direct chemical analysis. Its magnetic character could not be used to prepare a concentrate because of the presence of relatively large proportions of magnetite; in any event the intergrowths are so fine that mechanical separation of the awaruite from the heazlewoodite and magnetite would be extremely difficult.

However, comparison of its measured unit cell parameter with the data of Owen, Yates and Sully (1937), who determined the variation in cell parameter for the series Fe—(Fe,Ni)—Ni, suggests a composition within the range 77–82 per cent nickel.

As a check on the reliability of such an estimation, the New Zealand awaruite was examined further, since it was available in quantities sufficient for chemical analysis. The cell edge of this awaruite, 3.545 ± 0.003 Å suggests a composition within the range 80–85 per cent nickel; however a chemical analysis (Table 2), made on a hand-picked sample of 0.25 g.,

TABLE 2. CHEMICAL ANALYSES

	1	2	3
Fe	27.02	27.34	25.2
Ni	69.06	69.88	70.2
Co	2.75	2.78	4.0
Cu	—	—	0.3
Insol.	1.28	—	—
	100.11	100.00	99.7

1. Awaruite, Heazlewood, Tasmania—analyst: P. J. Sinnott.
2. (1), after removal of insolubles and recalculation to 100 per cent.
3. Nickel-iron, Eastern Townships, Quebec (Nickel, 1958).

showed only 69.8 per cent nickel. This lack of agreement can possibly be attributed, at least in part, to the unknown effect on the parameter of the presence of extraneous elements, notably cobalt. The New Zealand awaruite contains 2.78 per cent cobalt.

A similar, but smaller, discrepancy is apparent in the results of Nickel (1958), who found $a_0 = 3.551\text{--}3.555 \text{ \AA}$ for awaruite (nickel-iron) from Quebec, suggesting, from the data of Owen, Yates and Sully, a nickel content of 75–78 per cent. Chemical analysis, however, showed only 70.2 per cent nickel, together with 4.0 per cent cobalt.

It is thus apparent that awaruite compositions estimated from cell parameters in this way are approximations only, with wide limits of error.

Some published figures for the unit cell parameters of awaruite (Ramdohr, 1951) and nickel-iron (Palache, Berman and Frondel, 1944) agree on 3.59 \AA , a figure significantly different from those obtained by the author and by Nickel (1958). However, the former determinations appear to have been made on meteoritic taenites, with much lower nickel contents of 30–40 per cent. In this event they agree fairly well with the results of Owen, Yates and Sully, who obtained $a_0 = 3.577 \text{ kX}$ for an alloy containing 30 weight per cent nickel, and 3.590 kX for one with 40 weight per cent nickel (both figures originally quoted as Ångstrom units). A general figure of $3.54\text{--}3.55 \text{ kX}$ (i.e. $3.55\text{--}3.56 \text{ \AA}$) seems more appropriate for terrestrial awaruite.

REFERENCES

- DONNAY, J. D. H., AND NOWACKI, W. (1954): Crystal Data. *Geol. Soc. Amer., Mem.* **60**.
- NICKEL, E. H. (1958): Occurrence of native nickel-iron in the serpentine rock of the Eastern Townships of Quebec Province, Canada. *Geol. Soc. Amer., Bull.*, **69**, 1623.
- OWEN, E. A., YATES, E. L., AND SULLY, A. H. (1937): An x-ray investigation of pure iron-nickel alloys. Part 4: The variation of lattice parameter with composition. *Proc. Phys. Soc.*, **49**, 3, 315–322.
- PALACHE, C., BERMAN, H., AND FRONDEL, C. (1944): Dana's System of Mineralogy, ed. 7. New York.
- RAMDOHR, P. (1950): Über das Vorkommen von Heazlewoodit Ni_3S_2 und über ein neues ihn begleitendes Mineral: Shandit $\text{Ni}_3\text{Pb}_2\text{S}_2$. *Sitzungsberichte der deutsch. Akad. wiss.*
- RAMDOHR, P. (1955): Die Erzminerale und ihre Verwachsungen. Berlin.
- SCHNEIDERHÖHN, H., AND RAMDOHR, P. (1931): Lehrbuch der Erzmikroskopie. Berlin.
- UYTENBOGAARDT, W. (1951): Tables for Microscopic Identification of Ore Minerals. Princeton.
- WILLIAMS, K. L. (1958): Nickel mineralization in western Tasmania. *Aus. Inst. Min. Met., Stillwell Anniversary Volume*.