

Native nickel from the Jerry River, South Westland, New Zealand: an example of natural refining

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SUMMARY. Native nickel of composition Ni 96.3 %, Fe 1.77 %, and Co 0.69 % was found as tiny flakes up to 0.75 mm across in a heavy mineral concentrate from stream sediments in the Jerry River, South Westland, New Zealand. The locality is approximately 13 km downstream from the original locality for awaruite (Ni₃Fe), and it is shown that the nickel content of detrital grains increases with distance from the source of the awaruite in serpentinites of the Red Hills Range. It is proposed that the native nickel has been derived from awaruite by leaching of iron.

A NUMBER of tiny, silver-coloured flakes up to 0.75 mm across and 0.02 mm thick were noted during examination of a heavy mineral concentrate from a stream sediment collected by Mr. P. Taylor of New Zealand Mines Department in the Jerry River, 30 m upstream from its junction with the Gorge River, South Westland, New Zealand (fig. 1). As the nickel-iron alloy, awaruite (Ni₃Fe or Ni₂Fe), is known to occur in serpentinites of the Red Hills Range about 16 km to the west, and detrital grains of awaruite have been found in several of the rivers draining the Red Hills Range, it was at first thought that the silver-coloured flakes were a nickel-iron alloy. However, the flakes were considerably brighter and less tarnished than is usual in awaruite, which normally forms rather thick, 'nuggetty' grains, and not thin flakes. The flakes from the Jerry River were examined on the electron-probe microanalyser and by X-ray diffraction, and proved to consist essentially of metallic nickel, with only minor amounts of cobalt and iron.

Two grains of native nickel from the Jerry River sediment were examined, and for comparison six grains of awaruite were also analysed. Four of the awaruite grains came from the Gorge River, approximately 3 km west of the Red Hills Range, and the other two grains came from the Gorge River approximately 8 km west of the ultramafic rocks (fig. 1).

Physical properties. The flakes of native nickel range in size from 0.12 to 0.75 mm across, and are no more than 0.02 mm thick. They are bright silver in colour, with a high metallic lustre, and are soft and malleable. Two of the larger flakes have spots of brownish tarnish on the surface, particularly near edges. The awaruite grains range from 0.75 mm to 1.75 mm across, and are approximately 0.5 mm to 1.0 mm thick. The difference in appearance of awaruite from the headwaters of the Gorge River and from further downstream is shown in fig. 2. Grains a-d are from the locality approximately 3 km from the ultramafic rocks and at this point the grains are generally under 1 mm in size and have a nuggetty form with a rough, tarnished surface. Further

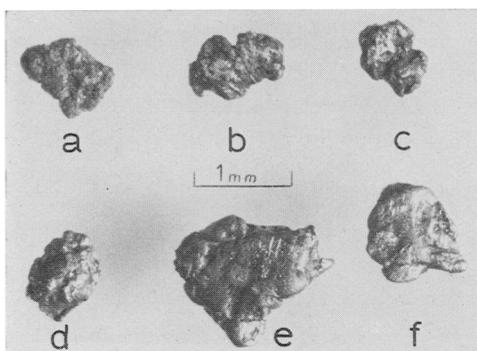
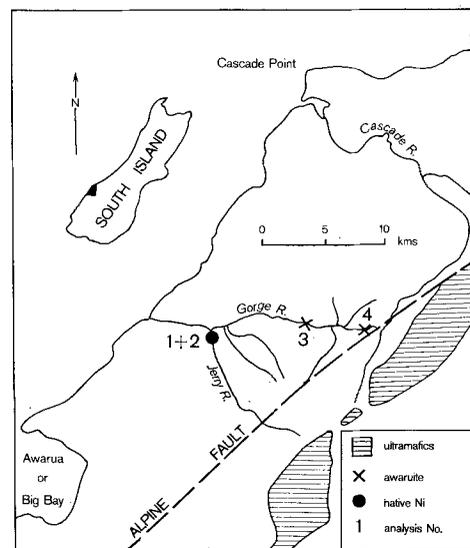
downstream (fig. 2, *e, f*) grains are generally larger, flattened in form, and bright silver in colour with little tarnish on the surface.

Polishing the tiny flakes of native nickel for reflectivity and microhardness measurements was extremely difficult and the values obtained cannot be regarded as very satisfactory. All reflectivity measurements were carried out at 546 nm using Elba pyrite as a standard. Microhardness measurements were made with a 50 g load.

In reflected light, the native nickel was white, with a conspicuously higher reflectivity than awaruite. Reflectivity, measured on the only grain of native nickel large enough to be polished, was 61.5 %, and microhardness was VHN 172–84. This compares with a reflectivity of 63.2 % and microhardness of 186–210 for native nickel given by Uytendogaardt and Burke (1971). The lower reflectivity of the Jerry River sample is probably due to the small size and poorish polish, and the slightly lower values for microhardness could be due to error introduced by a combination of the very thin flake of a soft mineral in a relatively soft mounting medium (Specifix).

The awaruite grains gave a range of reflectivity and microhardness values. Grains with average Ni of 67 % had a reflectivity of 58.5 % and grains with Ni 79.3 % had a reflectivity of 61.2 %. Microhardness ranged from 320 to 380 on grains with the lower nickel content, and from 265 to 290 on grains with higher nickel contents.

X-ray data. A powder photograph was obtained from a small flake of native nickel mounted on a glass fibre. A 114.6-mm-diameter camera with Straumanis mounting was used, with Cu radiation



FIGS. 1 and 2: FIG. 1 (top). Locality map showing occurrence of detrital native nickel and awaruite. FIG. 2 (bottom). Detrital awaruite. Grains a–d from Gorge River, 3 km west of Red Hills Range. Grains e–f from Gorge River, 8 km west of Red Hills Range.

and 24-hour exposure. The lines obtained were slightly spotty, but quite sharp, although even with the long exposure only five lines could be measured. The *d* values are given in Table I together with those of nickel metal. There is fairly close agreement between the pattern for the naturally occurring native nickel and that of nickel

metal (ASTM card no. 4-850). The calculated unit cell dimension for the native nickel is 3.5230 Å compared with 3.5238 Å for nickel metal; the presence of 1.77 % Fe might be expected to increase rather than decrease the cell size, and the smaller size is probably due to error resulting from absence of higher-angle reflections.

Powder photographs of two grains of awaruite of compositions Ni 67.0 % and Ni 79.3 % were also taken. The lines were very spotty and accurate measurement was difficult. However, there was a distinct decrease in cell size from 3.558 to 3.544 Å with increase in nickel content. The unit cell dimensions agree reasonably well with those determined in the experimental system Ni-Fe (Jette and Foote, 1936).

TABLE I. Analyses of native nickel and awaruite, and X-ray powder data for native nickel

	1*	2*	3*	4*	5†	<i>hkl</i>	<i>I</i> _{obs}	<i>d</i>
Ni	96.30	8.50	79.30	67.00	67.63	111	100	2.029
Fe	1.77	90.40	19.70	31.40	31.02	200	40	1.761
Co	0.69	0.33	0.58	0.68	0.70	220	10	1.243
Total	98.76	99.23	99.58	99.08	99.35	311	10	1.061
						222	10	1.0165

* Electron-probe analysis by G. A. Challis.

† Chemical analysis by Skey (1885).

1. Native nickel, Jerry River, 30 m upstream from junction with Gorge River, South Westland, New Zealand.

2. Edge of grain of native nickel. Locality as for 1.

3. Awaruite. Gorge River, 8 km west of Red Hills Range, South Westland, New Zealand.

4. Awaruite. Gorge River, 3 km west of Red Hills Range, South Westland, New Zealand.

5. Awaruite. Gorge River, South Westland, New Zealand. Contains Si 0.22 % and SiO₂ 0.43 %.

Electron-probe microanalysis. Analyses were carried out on an AEI SEM/2 electron probe using pure metals as standards. Analyses were corrected for absorption and fluorescence and are the average of at least six counts on each grain. Very little variation in composition was found within individual awaruite grains, but the two native nickel grains examined showed patchy iron enrichment, particularly near edges of grains (fig. 3).

The result of the analyses are given in Table I. Both grains of native nickel gave almost identical values for Ni, Fe, and Co over most of the grain, with the exception of patches of Fe enrichment already mentioned (Table I, analysis no. 2). For the three grains of awaruite represented by analysis no. 3, the range in composition was Ni 80.0–78.2 %, Fe 20.4–18.6 %, and Co 0.65–0.52 %. For analysis no. 4 the range was Ni 67.2–66.4 %, Fe 32.0–31.2 % and Co 0.69–0.66 %.

Discussion. Native nickel has only been recorded once, from New Caledonia, where it was considered to be an alteration product of heazlewoodite (Ramdohr, 1967). However, the locality and paragenesis of the New Caledonian native nickel is not known, although it is thought to come from a vein of massive heazlewoodite at Bogota, near Canala. Ramdohr does not give a complete analysis, but states that Co

is less than 2 % and Fe even lower. Therefore, the New Caledonian material, if natural, is probably over 98 % pure Ni.

The New Zealand occurrence of native nickel is very different. It occurs as detrital grains and the source of the nickel must be sought. Nickel sulphides are rare in New Zealand ultramafic rocks, but native metals and alloys are relatively common, particularly awaruite (Ni_3Fe or Ni_2Fe). Native copper is also common in New Zealand serpentinites, but native nickel has not been found in the rocks despite fairly intensive investigation. The possibility that native nickel in the Jerry River is not a natural occurrence was discounted. The area is very remote, seldom visited, and has no past or present history of mining or habitation. Awaruite was first found in stream sediments in the Gorge River approximately 13 km upstream from its junction with the

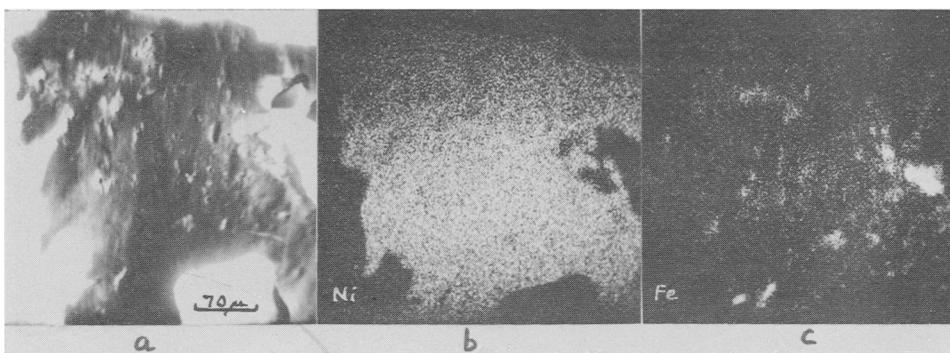


Fig. 3. (a) Electron image of flake of native nickel. (b) X-ray distribution image for Ni. (c) X-ray distribution image for Fe.

Jerry River (Skey, 1885). It was later found in other streams draining the Red Hills Range, and finally its origin was traced to serpentinites of the Red Hills Range (Ulrich, 1890).

The composition of awaruite in Red Hills serpentinite ranges from 64.5 to 67.0 % Ni. The composition range of naturally occurring nickel-iron alloys is given by Ramdohr (1950, p. 391) as $\text{Ni}_{67.63}\text{Fe}_{31.02}$ to $\text{Ni}_{76.60}\text{Fe}_{21.45}$. However, these analyses were of detrital grains, and more recent analyses, by electron probe and wet chemical methods, of awaruite in host serpentinites, suggest lower Ni values of 72 to 63 % (Nickel, 1959; Kanehira *et al.*, 1964; Chamberlain *et al.*, 1965).

Detrital awaruite from the Gorge River approximately 8 km from the ultramafic source rocks has the highest Ni content so far recorded (79.3 %), whereas the sample collected only 3 km from the Red Hills Range contains 67.0 % Ni. Ramdohr (1969, p. 361) in discussing awaruite notes that 'Recrystallization has been observed exceptionally well in a few instances in the outer portions which have been strongly affected by the fluvial transport.' Unfortunately no analyses of the recrystallized outer portions of grains are given, but Ramdohr's observation brings to mind the well-known phenomenon of the increase in fineness of gold with distance from the source (Lindgren, 1928, pp. 62-3): the amount of silver alloyed with gold is known to progressively

decrease with distance from source, and grains are found to be depleted in silver towards the margins; the loss of silver is attributed to its greater solubility, but differing rates of diffusion and oxidation might also be important.

The native nickel found in the Jerry River has almost certainly been derived from the Red Hills Range and has suffered considerable transport in a fast-flowing torrent. The compositional changes described provide strong circumstantial evidence for derivation of the native nickel by removal of iron from awaruite. Native nickel in the Jerry River has an over-all Fe content of 1.77 % and this rises to 90.4 % in a few small areas (fig. 3). Thus, movement of iron appears to have occurred, but there are not enough samples to trace the process in detail, and the way in which iron is removed from the awaruite is not well understood. Iron would be less stable in water than nickel (Garrels and Christ, 1965, p. 247) and if oxidation takes place, as is suggested by the rusty surface of grains nearest the source (fig. 2, *a-d*), then iron would be more easily removed. Mechanical pounding and thinning of the grains also probably assists the refining process as grains become progressively flattened and thinner during their journey downstream (fig. 2). Emmons observes of gold (1937, p. 9) 'In general, the more finely divided the placer gold the less silver it will carry.'

Therefore, by analogy with the removal of silver from detrital gold, it is suggested that a similar process of natural refining has produced the native nickel found in the Jerry River.

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