geothermometrical data of zircon (Pupin and Turco, 1972c), that these crystals were the last to appear in these populations. Crystals of this kind thus represent a highly particular mode of occurrence and must be distinguished from other sorts of tabular zircons with an elongation ratio less than 1, dominant prism {100} and lack of the central mark previously defined, such as that of fig. 1g.

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Compositional relationships of Fe–Ni alloy and coexisting phases in serpentinite, Red Mountain, New Zealand

CHALLIS (1975) noted a range in composition of detrital Fe–Ni alloys in the Jerry and Gorge Rivers of south Westland, New Zealand. She attributed this range, from weight per cent Ni_{67} to $Ni_{96.3}$, to partial removal of iron during fluvial transport, analogous to the process of natural refining of gold (Lindgren, 1928; Challis, 1975).

The Red Mountain area of north-west Otago and south Westland includes the dominantly harzburgitic peridotite mass near the head of the Jerry River, and probably provides the source for much or all of the ultramafic detritus in it. Most of the altered peridotites at Red Mountain contain sulphide and alloy minerals, including pyrrhotine, pentlandite, heazlewoodite, native copper, and Fe–Ni alloys. These minerals are present only in serpentinites and in serpentine veins in weakly altered peridotites; unaltered Red Mountain peridotites do not contain sulphides nor alloys. Many of the opaque grains in Red Mountain rocks are composite aggregates of

TABLE I. *Selected microprobe analyses of sulphide and alloy minerals in Red Mountain Ultramafites*

	Pyrrhotine			Pentlandite			Heazlewoodite		Awaruite			Copper
Sample	37002	31409		37002	37167		37167	31378	31409	37142	37031	37167
Fe	62·5	63·8	64·1	41·5	33·7	32·6	0·00	0·01	31·2	27·6	8·51	0·08
Ni	0·13	0·03	0·13	23·5	31·9	34·0	73·8	73·9	64·2	69·3	89·1	2·86
Co	0·00	0·05	0·08	1·95	0·55	0·55	0·00	n.d.	3·44	2·10	n.d.	0·00
Cu	n.d.	n.d.	n.d.	n.d.	1·13	0·01	0·07	n.d.	n.d.	n.d.	n.d.	96·8
Total	62·6	63·9	64·3	67·0	67·3	67·2	73·9	73·9	98·0	99·0	97·6	99·7
Fe <	1·119	1·142	1·148	0·742	0·603	0·584	0·000	0·002	0·558	0·494	0·152	0·001
Ni	0·002	0·000	0·002	0·366	0·544	0·579	1·257	1·259	1·109	1·180	1·517	0·049
Co	0·000	0·001	0·001	0·033	0·009	0·000	0·000	—	0·058	0·056	—	0·000
Cu	—	—	—	—	0·018	0·000	0·001	—	—	—	—	1·523
S*	1·167	1·124	1·124	1·040	1·021	1·025	0·816	0·807	—	—	—	—

* Calculated.
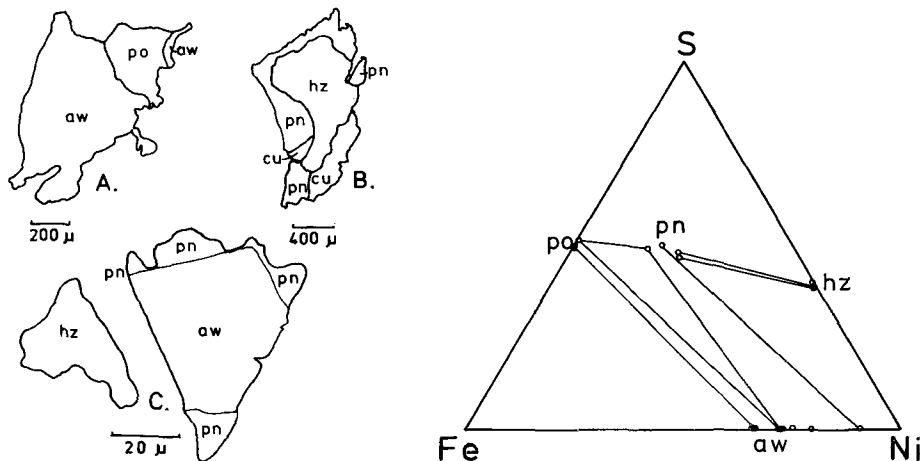
FIGS. I and 2: FIG. I (left). Textural relations among sulphides and alloys in Red Mountain Ultramafites: A, awaruite (aw) and pyrrhotite (po) in O.U. 37002; B, heazlewoodite (hz), pentlandite (pn), and native copper (cu) in O.U. 37167; C, awaruite, pentlandite, and heazlewoodite in O.U. 37023. Numbers prefixed by O.U. refer to samples catalogued in the University of Otago Geology Department. FIG. 2 (right). Fe–Ni–S compositional relations among pyrrhotite (po), pentlandite (pn), heazlewoodite (hz), and Fe–Ni alloys (aw = awaruite) in Red Mountain Ultramafites. Tie lines connect analyses of minerals occurring within single samples.

awaruite and sulphides, the latter commonly forming partial rims on awaruite cores (fig. 1).

These minerals have been analysed using the JEOL JX-5A electron microprobe at the University of Otago Geology Department. An accelerating potential of 15 kv was used for Fe, Ni, and Co and 20 kV for Cu. Standard materials were hematite (Fe), NiO (Ni), and metallic Co and Cu. The correction procedure was that of Sweatman and Long (1969). Sulphur was not determined, and was calculated in sulphides assuming the minerals to be pure Fe–Ni–Co–Cu–S mixtures.

Analyses of some of the opaque minerals (Table I) show that there is a considerable range already present in *in situ* Fe–Ni alloys at Red Mountain. The patchy distribution of iron described by Challis has not been observed in Red Mountain alloys, but compositions ranging from $Ni_{66.1}\,Fe_{33.9}$ to $Ni_{90.9}\,Fe_{9.1}$ have been determined. Cobalt is also present in significant amounts (Table I).

Compositional relations among analysed Ni–Fe–S minerals are shown in fig. 2. Tie lines connect analyses of mineral grains that occur within single samples but which do not necessarily represent equilibrium assemblages. However, the arrangement of tie lines is consistent with equilibrium at temperatures of less than 550 °C (Kullerud *et al.*, 1969). The data also suggest that Fe/Ni of the alloys is mainly controlled by bulk composition (i.e. rock plus fluid) during serpentinization. The most iron-rich alloys occur with pyrrhotine (po), whereas iron-poor alloys occur with pentlandite (pn).

Although the mechanism proposed by Challis (1975) may be valid, the natural refining process is unnecessary to explain the compositional range of Fe–Ni alloys in the north-west Otago–south-Westland region, since a considerable range is represented in the source serpentinites of the Red Mountain area. This range probably reflects the Fe–Ni range of bulk compositions during hydrothermal alteration.

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Volborthite in Liguria, Northern Italy

VOLBORTHITE $Cu_3(VO_4)_2.3H_2O$, so far described in few localities (Guillemin, 1956; Witkind, 1961; Leonardsen and Petersen, 1974), has been found in two parts of Liguria. In the Cassagna Mine (Eastern Liguria), where Mn-ores occur within the M. Alpe Chert Formation (Passerini, 1965) that lies on the top of ophiolite sequences volborthite is mainly associated with the Cu-bearing minerals chalcosine, cuprite, malachite, azurite, and native copper, in a mineralization related to fossil araucaria trunks (Cortesogno and Galli, 1974). In the upper Neva Valley (Albenga, Western