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Occurrence and significance of awaruite in the Dras ultramafics, Kashmir Himalaya, India

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ABSTRACT. A new occurrence of awaruite, from India, is reported in the ultramafic units of the Dras area which form part of the Indus Suture ophiolites in Kashmir Himalaya. Its formation in these rocks suggests a low-temperature process of serpentinization. Ni and Fe released from olivine and/or pyroxene must have formed awaruite peragenetically next to magnetite and pentlandite.

AWARUITE (Ni_2Fe), a nickel-iron alloy, usually occurs in serptentinites and dunites in small quantities that can usually be identified with an ore-microscope. It derives its name from Awarua, North Western New Zealand, where it was first identified (Ulrich, 1890). However, Rodgers and Hey (1980) disputed its type locality stating that it was first found from alluvial sands of Gorge river. The mineral occurs as pseudomorphs after pentlandite, oxidation products of pentlandite, or replacement products of silicates, magnetite, or possibly trevorite. It is reported from more than twenty places but in India, although serpentinites, peridotites, etc. occur in many areas, awaruite has not been studied or reported so far. It is now reported from the Dras ultramafics which form a part of the ophiolite sequence of the Kashmir Himalayas (Radhakrishna, 1980). The characteristics of this mineral and its implications are discussed in the text.

Petrography. About fifteen samples of serpentinite, peridotite, dunite, and pyroxenite were studied under reflected light. In the fresh dunites and peridotites only a chromite-magnetite opaque association is observed. In the serpentinites, magnetite pentlandite, awaruite and chromite are essential opaque minerals in order of predominance. The magnetite observed in the dunites is of the primary character whereas in the serpentinites most of it is of secondary character. This secondary magnetite mostly occurs as veins through the serpentine and, in some cases, represents the original mineral grain boundaries. Awaruite and pentlandite occur in the vicinity of these magnetite veins. Under a microscope it is difficult to distinguish these two minerals. The electron microprobe studies, however, reveal that pentlandite predominates over awaruite and the latter has 59.5% Ni and 39.5% Fe.

The vein magnetite, with which awaruite is associated, is very fine grained. Awaruite does not occur in crystalline form but as globules of less than 0.25 mm size with uneven grain boundaries. The pentlandite grains are fresh and do not show any alteration to awaruite.

Discussion and conclusions. The orthomagmatic origin (Ulrich, 1890) for awaruite has been disputed by the latter studies which suggested that it can form at low temperatures due to reaction between reducing agents and nickel-bearing sulphides and silicates (Nickel, 1959; Krishna Rao, 1964; Chamberlain *et al.*, 1965; Ramdohr, 1950, 1969; Eckstrand, 1975). The pentlandite associated with awaruite in the Dras area is very fresh and does not show any alteration. According to Chamberlain *et al.*, 1965, if pentlandite reacts with hydrogen at about 340 °C the resultant awaruite is associated with pyrhotine; at higher temperatures (i.e. 395 °C) the pyrhotine decomposes to native iron. But an association of awaruite with neither of these minerals precludes the possibility of its formation from pentlandite, probably due to a failure to reach the required temperatures (340 °C). Eckstrand (1975) suggested that awaruite from Dumont may form by replacement of pentlandite if the sulphur is completely lost and the awaruite thus formed in this process associates with the magnetite formed from the excess Fe during the replacement of pentlandite. In the Dras serpentinites the magnetite–awaruite association does not appear to have formed from the above reaction as the pentlandite is very fresh and no traces of alteration are observed.

The absence of partial or complete pseudomorphic replacement textures of sulphides by awaruite, its restricted occurrence in serpentinites, its aphanitic texture (0.25 mm size) globules, and its association only with secondary magnetite veins in serpentine, suggest that it is not formed from sulphides in the Dras area but derived directly from the Fe and Ni released from olivine and pyroxene during serpentinization at temperatures below 350 °C. This is further supported by an absence of formation of native iron from the secondary magnetite (see Chamberlain *et al.*, 1965). Radhakrishna (1980) suggested sea-water involvement in the serpentinization process of the Dras ultramafics. A part of the iron released during this process should have combined with the available oxygen to form magnetite veins. The sulphur supplied from the sea-water with part of the Fe left after the formation of magnetite veins and Ni released during serpentinization could have formed pentlandite. The Ni and Fe left after the formation of magnetite and pentlandite must have parted to form awaruite.

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