The Occurrence of Olivine Hyperite at Ödegårdens Verk, Bamble, South Norway, by M. Glaveris

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Glaveris (1970) noted the occurrence of olivine in the hyperite at Ödegårdens Verk, thus confirming Brögger's (1934) deduction that olivine was part of the pre-corona magmatic mineral association. We wish, however, to suggest an interpretation of the corona structures in terms of the rock's thermal and tectonic history, which differs somewhat from that given by Glaveris.

Glaveris describes the coronas as consisting of an inner zone of radiate orthopyroxene, an intermediate zone of garnet and a discontinuous outer rim of scapolite. He concludes from his study that 'the second (garnet) corona is of metamorphic origin, while the third one (scapolite) apparently belongs to a magmatic phase . . .' He then postulates a regional metamorphism during a magmatic event of which the scapolitization is a late stage, though he does appear to leave open the possibility that the dolerite intrusion and the scapolitization are completely independent events.

No mention is made of the origin of the first (pyroxene) corona, but its distinction from the second (garnet, 'metamorphic') presumably implies that it is a magmatic reaction rim.

Similar corona structures have been described recently from Lofoten (Griffin & Heier 1969) and Sognefjord (Griffin 1971). In both of these cases it was demonstrated that the coronas formed by a two-stage reaction sequence:

(1) olivine + plagioclase → aluminous pyroxenes + spinel
(2) aluminous pyroxenes + spinel + plagioclase → low-Al pyroxenes + garnet.

In Lofoten and Sognefjord, as well as in numerous other coronites now under investigation by us, reaction (1) has produced a double corona, with an inner zone of orthopyroxene and an outer zone of clinopyroxene plus spinel. The garnet produced by reaction (2) has nucleated first at the interface between these two zones and grown outward, while a new, low-alumina clinopyroxene has grown inward from the same interface. In advanced stages of corona growth, evidence of reaction (1) is preserved in the form of high-Al clinopyroxene inclusions in the garnet shell of the corona. This may also be the case at Ödegården; Glaveris' Fig. 1 shows abundant unidentified birefringent inclusions within the garnet.

Experimental work (Kushiro & Yoder 1966, Green & Ringwood 1967; Irving & Green 1970, Green & Hibberson 1970) has demonstrated that this reaction sequence will occur in a magnesian olivine/calcic plagioclase assemblage as a result of increasing P at a constant T, or during isobaric cooling from magmatic temperatures at moderate P (5–8 KB). Under the same conditions, iron-rich olivine and plagioclase react directly to pyroxenes and garnet.

To produce the described coronas by isothermal burial, P would have to increase from less than 8 to greater than 11 KB at 1000 °C, or from less than 7 to greater than 9 KB at 700 °C (Irving & Green 1970). If T is allowed to increase with P, as it is commonly assumed to do during regional metamorphism, the increase in P must be even greater, since both reactions have positive P–T slopes (cf. Kushiro & Yoder 1966).

The well-preserved magmatic textures of most coronite dolerites (cf. Glaveris 1970, Fig. 2) argue against the extensive deformation needed for such burial, and favor the simpler explanation of isobaric cooling in the middle to lower crust. This explanation is also consistent with the relative JD/Ts ratios of the pyroxenes produced by the two reactions (Griffin 1971) and with the common occurrence of coronas in undeformed dolerites from deep-seated terranes.

It thus seems unlikely that the pyroxene and garnet coronas described by Glaveris are of separate origin, or that the garnet is the product of a 'regional metamorphism'. If the term 'metamorphism' is to be used in reference to such corona structures, it would be more appropriate to speak of *retrograde* metamorphism (cf. Griffin & Heier 1969). It therefore follows that there is no need, from the evidence presented by Glaveris, to postulate a 'regional metamorphism' between the intrusion of the Bamble hyperites and the scapolitization. There may well have been such an event, but the coronas do not record it, and are in fact relicts of a pre-metamorphic assemblage. If Glaveris can indeed demonstrate that the scapolitization postdates the formation of the pyroxene-garnet coronas, he would seem to have good evidence that the metasomatic event occurred after the dolerites had cooled from magmatic T (1200°?) to around 600–700 °C.

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REFERENCES

Brögger, W. C. 1934: On several archean rocks from the South Coast of Norway. The South Norwegian hyperites and their metamorphism. *Vid.-Selsk. Skrifter, 1. Mat.-Nat. Kl. No. 1,* 1–421.

Glaveris, M. 1970: The occurrence of olivine hyperite at Ödegårdens Verk, Bamble, South Norway. *Norsk. geol. tidsskr. 50,* 15–17.

Green, D. H. & Hibberson, W. 1970: The instability of plagioclase in peridotite at high pressure. *Lithos 4,* in press.

Green, D. H. & Ringwood, A. E. 1967: An experimental investigation of the gabbro to eclogite transformation and its petrological implications. *Geochim. et Cosmochim. Acta 31,* 767–883.

Griffin, W. L. 1971: Genesis of coronas in anorthosite of the Upper Jotun Nappe, Indre Sogn, Norway. *Jour. Petrology,* in press.

Griffin, W. L. & Heier, K. S. 1969: Paragenesis of garnet in granulite-facies rocks, Lofoten-Vesteraalen, North Norway. *Contr. Miner. Petrol. 23,* 89–116.

Irving, A. & Green, D. H. 1970: Experimental duplication of mineral assemblages in basic inclusions of the Delagate breccia pipes. *Phys. of the Earth and Plan. Inter. 3,* 385–389.

Kushiro, I. & Yoder, H. S. 1966: Anorthite-forsterite and anorthite-enstatite reactions and their bearing on the basalt-eclogite transformation. *Jour. Petrology 7,* 337–362.