On the origin of translation lamellae in olivine

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[Taken as read 7 November 1968]

Summary. Translation lamellae in olivine crystals are generally considered to be a result of mechanical deformation of pre-existing crystals but a recent hypothesis suggests that they may be formed during the latter stages of olivine crystallization in olivine-rich rocks due to the stresses imposed by mutual interference. Olivine crystals showing well-developed translation lamellae occur in the ultrabasic dykes of south-west Skye and it is demonstrated that these lamellae are unlikely to have been formed by mutual interference. Possible origins of the lamellae are considered and it is concluded that they are most likely to have been formed by tectonic deformation at elevated temperatures prior to the intrusion of the dykes.

A BANDED structure, visible between crossed nicols, has been recorded from olivine crystals in a variety of basic and ultrabasic rocks. These bands or lamellae have been investigated by a number of authors (for detailed accounts see Turner (1942), Chudoba and Frechen (1950), and Challis (1967)) and it is generally agreed that they are of deformational origin. However, some doubt exists concerning the precise nature of the deformation and the purpose of this contribution is to present some additional evidence and discuss briefly its genetic significance.

The principal point of contention appears to be whether the deformation affected pre-existing crystals or occurred during the growth of the crystals. Several writers, e.g. Chudoba and Frechen (1950), Hamilton (1957), Voll (1960), and Raleigh (1965), have suggested that the lamellae arise during the deformation of previously formed crystals and Chudoba and Frechen have advanced the hypothesis that the amount of disorientation of adjacent lamellae is proportional to the plasticity of the crystals, which in turn depends on the temperature at which the deformation occurred and hence the depth of origin. In the most recent work on translation lamellae, however, Challis (1967) concluded that they are formed during crystal growth due to stresses imposed by mutual interference of the olivine crystals. This conclusion was based partly on the observation that the lamellae often extend right to the edges of crystals displaying marginal zoning, which, according to Challis (1967, p. 200), proves 'that the deformation lamellae were produced after most of the rock had crystallized'.

Olivine crystals showing well-developed translation lamellae are abundant in the Tertiary ultrabasic dykes of south-west Skye that have been examined by the writer. Most of the olivine in these dykes was introduced in crystalline form (Gibb, 1968) but there is little doubt that the narrow zoned margins that occur on the crystals grew mainly after the intrusion of the dykes. The translation lamellae in these crystals could not have been formed by mutual interference during the crystallization of the zoned margins since olivine crystals showing lamellae occur in the marginal parts of some of the dykes where the olivine content is less than 20 %, i.e. much less than the concentrations necessary for appreciable mutual interference (Challis, 1967, p. 202).

The lamellae also seem unlikely to have been formed by mechanical deformation of the rock after the solidification of the dykes since the pyroxene and plagioclase crystals exhibit no evidence of such deformation and it can only be concluded that the lamellae were not formed *in situ* but were present in the cores of the olivine crystals, which were suspended in the magma during its intrusion. The lamellae extend right to the edges of many of these crystals and therefore it appears that this does not necessarily imply that they were formed after the zoned margins crystallized. Indeed, it does not seem improbable that subsequent growth on previously deformed crystal cores would be in continuity with the part of the crystal on which it was taking place, thus extending the translation lamellae right to the edges of the crystals (cf. the extension of plagioclase twinning into mantling anorthoclase (Muir, 1962, p. 483)). This would also account for the fact that translation lamellae in olivine xenocrysts from basalts (e.g. Hamilton, 1957) extend to the edges of crystals with strongly zoned margins. Consequently, the extension of translation lamellae into the zoned margins of olivine crystals can not be regarded as proof that they were formed during or after the crystallization of the zoned margins as Challis suggests.

The ultimate origin of the translation lamellae in the introduced cores of the olivine crystals in the Skye dykes is open to speculation and three possibilities may be considered: mechanical deformation in a parent cumulate due to superincumbent load pressures; deformation due to mutual interference of olivine crystals during the latter stages of olivine crystallization in a parent cumulate; and tectonic deformation at elevated temperatures of the olivine crystals (possibly while in a rock of which the olivine represents the refractory residuum after partial fusion).

Superincumbent load pressure alone seems an unlikely possibility in general since, as Challis points out, there are many examples of olivine cumulate rocks in which lamellae are not present.

A large proportion of the olivine crystals in the Skye dykes, including many of those with lamellae, exhibit a strong tendency towards idiomorphism and, since the marginal zones on the idiomorphic crystals are narrow, the introduced cores must have been more or less euhedral. It is difficult to envisage the attainment of such good crystal form under conditions of mutual interference. In addition, the average olivine contents of the dykes are less than 60 % and it seems unlikely that the parent cumulate (if such it was) contained much more olivine than this. Such an olivine content seems, as Challis suggests, rather low for mutual interference to have been effective. Consequently, mutual interference appears an unlikely origin in this particular case.

No valid objection to the third of the above possibilities is apparent in the case of the dykes but a general objection is that some strongly deformed ultramafic complexes show very little development of translation lamellae (Challis, 1967, and personal communication). However, it may be that, as Chudoba and Frechen (1950) and Raleigh (1965) suggest, relatively high temperatures are required to produce the lamellae and that tectonic deformation at temperatures below the critical value would not give rise to translation lamellae in the olivine crystals whereas excessively high temperatures might promote complete recrystallization.

It appears, therefore, that although mutual interference during crystal growth may give rise to translation lamellae in olivine, particularly in cumulates, it can not account for all instances of lamellae. Some other mechanism must therefore be found and, of the existing hypotheses, that proposed by Chudoba and Frechen is, in the writers' opinion, the most satisfactory.

Acknowledgements. The writer would like to thank Dr. G. A. Challis for her invaluable discussions and Mr. R. Johnston for his suggestions and constructive criticism of the manuscript.

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[*Manuscript received 12 February 1968*]