

A comment on 'Formation of the hour-glass structure in augite' by D. F. Strong

IN his interesting paper on the origin of hour-glass zoning in augite, Strong (1969) suggests that we have misinterpreted the zoning we observed in clinopyroxene and have thereby drawn erroneous petrogenetic conclusions. As only a brief abstract (Frisch and Schmincke, 1968) of our work had been published, Strong's argument rests on very little data and we believe that more complete details—not all of which appear in our recent paper full (Frisch and Schmincke, 1969)—support our interpretation.

During a study of mafic inclusions in alkalic basalts of the Roque Nublo Volcanics, Gran Canaria, we noted small, patchy zones of brownish sahlite in green sahlite of an inclusion (no. 630 in Frisch and Schmincke, 1969). These zones are generally completely surrounded (as far as can be determined from the two-dimensional view of the thin section) by the green pyroxene, with which they share optically diffuse but chemically sharp borders. The green pyroxene is depleted in Fe, Al, Ti, and Na, and enriched in Si and Mg relative to the brown pyroxene. Complete analyses are given by Frisch and Schmincke (1969).

The pyroxene forming microphenocrysts in the basalt that is host to the inclusion shows better-developed zoning with a similar chemical trend. We analysed three zoned microphenocrysts with the electron probe. Two are sketched in fig. 1, the third is physically and chemically similar to *b* of fig. 1. Note that crystal *a* in fig. 1 is the reverse of crystal no. 5 in Strong's fig. 4. Iron progressively diminishes and magnesium increases from the brown patches ($\text{Ca}_{48}\text{Mg}_{35}\text{Fe}_{17}$) in the green inclusion pyroxene to the greenish or greenish-brown borders ($\text{Ca}_{44}\text{Mg}_{45}\text{Fe}_{11}$) of the microphenocryst pyroxene. Other elements also vary, as above. We

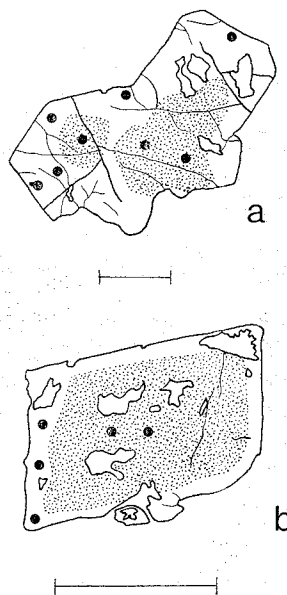


FIG. 1. Two clinopyroxene microphenocrysts in the basalt that is host to Inclusion no. 630 (Frisch and Schmincke, 1969). The stippled areas (generally brownish) are enriched in Fe, Ti, Al, and Na and depleted in Mg, Si, and Cr, relative to the surrounding blank areas (greenish). The filled circles indicate the spots at and near which electron probe analyses were made.

Scale bar: 0.5 mm.

contend that this trend represents true 'reverse' Fe-Mg zoning, due to Mg-enrichment in the melt as crystallization proceeded.

On various grounds (Frisch and Schmincke, 1969), we concluded that the inclusions are composed of early crystallization products of their host basalts, i.e., they are cognate.

Strong (1969, p. 478) suggests that the 'patchy core zones' of the inclusion pyroxene are from a late, rather than an early, stage of crystallization, being due to the 'filling of "embayments"', which were caused by adsorption of foreign material'. Admittedly, it is difficult, if not impossible, to prove in a thin section that the central parts of a crystal had no connection with the outside and must therefore have formed prior to the outer parts. However, we consider this possibility remote for grains of the type shown in fig. 1. Furthermore, the *consistency* of the zoning trend in the microphenocryst pyroxene appears to us to be strong evidence that enrichment of magnesium did actually occur during crystallization. By analogy, we believe that the patchy zones in the inclusion pyroxene are true, early formed core zones.

Reports of reverse Fe-Mg zoning in pyroxene have become increasingly frequent as use of the electron probe microanalyser has become more widespread, e.g. Smith and Carmichael (1968, p. 222); Nicholls and Carmichael (1969, p. 56); Borley, Suddaby, and Scott (1969). We have observed it in another alkalic basalt from Gran Canaria (but have found normal zoning in all other rocks so far studied). Thus, reverse Fe-Mg zoning in pyroxene is probably a not uncommon phenomenon but we agree with Strong that caution must be exercised in its identification.

Acknowledgements. We thank D. F. Strong for his comments on this note and acknowledge that he does not necessarily agree with all our conclusions.

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[Manuscript received 23 March 1970]