ZONING OF MINERALS IN MAFIC CLASTS FROM BASALTIC

ACHONDrites

JEREMY S. DELANEY,1 O'NEILL C.1,2 NEHRU C.E.1,2 PRINZ M.1. (1) Amer. Mus. Natural Hist., New York, NY 10024; (2) Brooklyn College, CUNY, Brooklyn, NY 11210.

INTRODUCTION. Zoned minerals provide useful data about the crystallization histories of igneous rocks. Until recently, Pasamonte (1) was the only eucrite having unequilibrated pyx and plag. The factors controlling mineral zoning in mafic achondrites could not be adequately tested for lack of samples. Identification of numerous unequilibrated mafic clasts in polymict eucrites and howardites (2,3) has greatly increased the number of available samples with zoned minerals so that comparative study within the basaltic achondrites is now possible. Pyroxene and plagioclase in mafic clasts from Pasamonte, ALHA78040, EETA79004 and 79005 have been analyzed and zoning profiles constructed. These are used to examine the relationships among several factors influencing mineral composition. Factors include (a) bulk rock composition; (b) cooling rate; (c) crystallization sequence; (d) subsolidus reheating; (e) variation of intracrystalline diffusion rates; (f) crystal orientation; (g) fS2 may influence Fe concentration; (h) competition from other growing crystals.

PYROXENE. Profiles of pyx from Pasamonte (4,5) show smooth increases of Fe/(Fe+Mg) and CaO from core to rim. There may be crystallographic controls (6) but the profiles may be explained by crystal-liquid fractionation with Fe and Ca enrichment in the late liquid. Variations in edge CaO are controlled by the textural setting. Pyroxenes that grew into interstitial melt may have edges as calcic as Wo40 whereas those that butt against feldspar were isolated from the late liquid may show little or no enrichment (4). The CaO of the liquid from which the latter grew was probably taken up by growing plag. Profiles from Pasamonte are the simplest (lines 1 in Fig. 1). Pasamonte pyx differs from most samples as exsolution is rare or absent indicating quick cooling. Very fine exsolution in clasts from polymict eucrites implies slower cooling and the effect of intracrystalline diffusion may be superimposed on the profiles (7). In equilibrated eucrites (1), slow cooling or reheating has obliterated zoning by intracrystalline diffusion). Profiles from mafic clasts in the polymict eucrites (Fig. 1) are between 200 and 300 microns long but are normalized to the same length for comparison. These pyx have similar unzoned cores. The edges are Fe-augite with variation of CaO (Wo20-40) depending on the crystallization environment. The outer parts of the profiles vary, however, with complex profiles in ALHA78040,37B1 (4), EETA79005,37B1 (2) and ALHA78040,53B (3B). The similar core compositions imply that crystals began growth in magmas of similar (eucritic) composition. Annealing of the clasts, while sufficient to cause some exsolution, did not cause enough intracrystalline diffusion to obliterate fine detail in the complex profiles. Possible explanations of the observed profiles are: (a) The step in the Wo% profiles 2, 3b and 4 may be explained by the crystallization sequence. Initially only pigeonite or subophitic pigeonite+plag crystallized and the CaO of the melt increased slowly. Eventually, the pyx was forced to accept more diopside and rapidly became augitic as seen in all the Wo profiles. In some, however, the pyx stabilized at Wo20-30, probably because of discrete augite crystallization in the late liquids. Cecrystallizing augite would remove CaO that would otherwise precipitate in the rims of early crystallized pigeonites.

(b) The importance of orientation (8) and (c) growth environment is illustrated by the two nearly orthogonal traverses 3a and 3b from a pyx in ALHA78040,53. The traverse 3a ended against a large feldspar, while 3b ended in fine grained SiO2 rich interstitial material. The observed regions of Wo enrichment are contemporaneous and the wider core of 3a suggests that the two directions grew at different rates. The flat rim of 3b was caused by continued crystallization in this direction until the growing crystal was forced to compete with newly crystallizing augite.
ZONING IN MAFIC CLASTS

Delaney, J. S. et al.

(d) The $f_{52}$ influenced pyx growth in Elephant Moraine A79005, a howardite. Profile 2 has a minimum En content 40-50 microns from its edge against feldspar. In this rim the unusual increase of En with Wo is caused by reaction of the growing pyx with a S phase. The rim is packed with tiny troilite inclusions and large SiO$_2$ inclusions. This texture and reversal of the Fe enrichment trend reveal that the pyx reacted with S to form troilite and SiO$_2$.

PLAGIOCLASE. Feldspar in mafic clasts also shows compositional zoning. Variations from An$_{90}$ to An$_{75}$ are observed but the zoning may be normal, reversed or complex. Extraction of information about the fractionation history and crystallization sequence of the basaltic achondrites is difficult because the observed profiles are caused by the cooling history (10) and growth morphology (11) rather than igneous fractionation. Complex 'W' shaped profiles are common in tabular and euhedral crystals and result from both inward and outward growth of hollow crystals (11). Their cores often contain Ca-pyroxene that is typical of late stage liquids in these meteorites.

CONCLUSIONS. (1) Zoning of pyroxene in mafic clasts from basaltic achondrites reveals the crystallization sequence of achondritic magmas. Late crystallization of augite, although noted in a few eucrites, is not well documented but is consistent with the trend of increasing calcic pyroxene in howardite mafic clasts (3) with fractionation. Since this feature is seen in the polymict eucrte mafic clasts, which appear to be more closely related to howardites than to the eucrites (2), the zoning in pyroxene provides a succinct summary of the crystallization history of howardite mafic rocks. (2) Zoning of feldspar is complex, but with further study will provide useful constraints on the cooling of magma bodies. Such information will provide a useful complement to cooling rate estimates of other types (e.g. 7).


---

Fig. 1 Zoning profiles for pyroxenes from achondrites.
1 = Pasamonte,
2 = EETA 79005,37B1,
3 = ALHA 78040,53,
4 = ALHA 78040,37B1