OSCILLATORY ZONING IN NAKHLITES AND KINETIC INFERENCES.

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Oscillatory zoning is a characteristics of silicate crystals grown under conditions of rapid magmatic cooling. This feature however has not been considered as it deserves for a number of reasons: it corresponds to faint chemical variations which require high analytical accuracy and a large number of data points to document zoning with a sufficient space resolution on one hand and despite qualitative theoretical interpretations [1] it could not provide useful information of petrogenetic interest. For the present purpose it suffices to notice that the wavelength of chemical oscillations is scaled by D/V, where D is the diffusivity in the magmatic melt of the element of interest and V is the growth rate of the studied crystal. Considerable improvement in the knowledge of chemical diffusion has been achieved over the last decades so that quantitative values can now be obtained for basaltic melts with a reasonable accuracy. Growth rates however are poorly documented mostly because of untractable experimental difficulties: it depends on the extent of supercooling and for the same crystals in the same melt may vary by orders of magnitude. In this work we try to derive growth rates from the wavelength of chemical oscillations in both olivine and augites of three nakhlites, which exhibit a significant fraction of mesostasis: NWA 817, MIL 03346 and NWA 5790. The presence of glass in the mesostasis indicates that cooling after crystallization was fast enough to prevent annealing of growth features. This inference is supported in NWA 5790, which shows irregular zoning due to the partial resorption of augites.

In NWA 5790, textural evidences indicate that olivine and augite grew simultaneously. Olivine (Fo33 in the core) exhibits chemical oscillations for Fe, Mg, Ca and Mn from the core to the rim, superimposed on the more general core to rim zoning already described in nakhlites [2]. Loose correlations between the different chemical variations are observed as is expected for the cristallochemical interplay between more than two elements. The wavelength is nearly constant at about 3 μm. Comparable chemical oscillations are recorded in augites from core to rim for Si, Mg, Fe, Ca, Al, Ti, Mn, Na and Cr with a wavelength of about 15 μm. Chemical oscillations of similar amplitude and wavelength are observed in both NWA 817 and MIL 03346.

The presence of oscillatory zoning clearly indicates that subsolidus exchange, if any, was extremely limited. Assuming a diffusivity in the melt during growth on the order of $5\ 10^{-13}$ m^2/s [3] we obtain growth rates of $2\ 10^{-7}$ m/s and $5\ 10^{-8}$ m/s for olivine and augite respectively. This corresponds to crystallization for about one hour in order to obtain crystals of 2 and 0.5 mm for olivine and augite respectively.

[1] Provost (1982) Thesis IPGP [2] Sautter et al. (2002) Earth Planet. Sci. Lett. 195, 223-238. Day et al. (2006) Meteoritics Planet. Sci. 41, 581-606. [3] Zhang Y. (1993) J. Geophys. Res., 98 11,901-11,920.