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**Cr, Mn and Ca Distributions for Olivine in Angritic Systems: Constraints on the Origins of Cr-rich and Ca-poor Core Olivine in Angrite LEW87051;** T. Mikouchi (Mineralogical Inst., Graduate School of Science, University of Tokyo, Hongo, Tokyo 113, JAPAN), G. McKay (SN4 NASA/JSC, Houston, TX77058, USA) and L. Le (C23-C Lockheed ESCO, Houston, TX77058, USA)

## INTRODUCTION

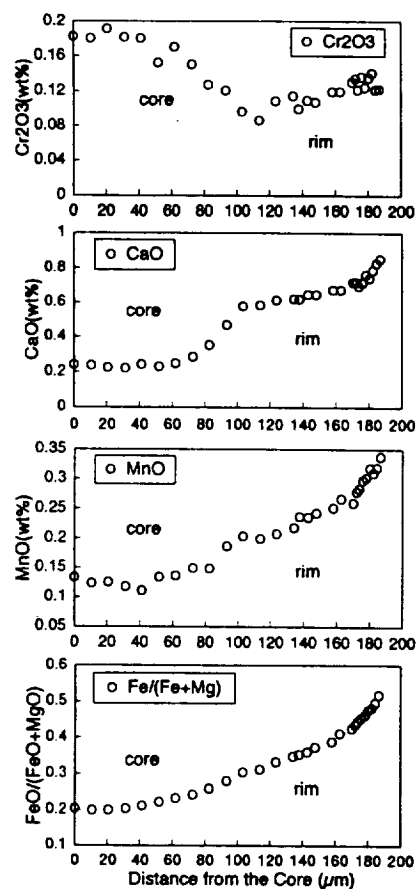
Angrite meteorites are a type of basaltic achondrites that are noted for their very old crystallization ages (4.55b.y.)(1) and unusual chemical and mineralogical properties(2). In spite of great interest, only four angrites have been found yet. LEW87051 is the smallest one which weighs 0.6g. It is a porphyritic rock with coarse subhedral to euhedral olivines (~0.5mm) set in a fine-grained groundmass which clearly represents a crystallized melt(3). The largest uncertainty about the petrogenesis of LEW87051 is the relationship between the large olivine crystals and the groundmass. Prinz *et al.*(4) suggested that olivines are xenocrysts, while McKay *et al.*(5) proposed a fractional crystallization model based on experimental studies. However, the crystals have Cr-rich and Ca-poor cores (Fig.1) which do not match experimental olivines. Although Jurewicz and McKay(6) tried to explain the zoning of the rim by diffusion, some features are not explained. There also exists a definite composition boundary of Fe# and MnO (Fig.1) between the core and the rim. To clarify the origin of these olivines, we have performed experiments using LEW87051 analogs to measure the effects of oxygen fugacity( $f_{O_2}$ ) on distribution coefficients of various elements in angritic system.

## EXPERIMENTAL PROCEDURES

We prepared two different starting materials for the experiments. They are named L7 (bulk LEW87051) and L7A (*ca.* 10% olivine removed from L7). For each experiment, a 125mg pellet was made, placed on a Pt40Rh60 wire loop and suspended in a Deltech furnace for 96 hours at the appropriate temperature and  $f_{O_2}$ . We ran experiments for both compositions from two log. units below the iron-wüstite buffer (I.W. -2) to four log. units above it (I.W.+4). For L7, the pellet was held in the furnace at 1430°C to melt it completely for 48 hours, then quenched to room temperature. After that, it was put back in the furnace for 48 hours at 1400°C to grow olivine crystals. For L7A, the holding times (48 hours and 48 hours) were the same, but the temperature was first 1300°C, then 1225°C. CO/CO<sub>2</sub> flowing gas was used for obtaining the desired  $f_{O_2}$  as measured by a zirconia cell(7). We analyzed the run products by wavelength dispersive analysis (WDS) at 20 kV and 30 nA using a Cameca electron microprobe.

## RESULTS

**Cr Distribution:** Fig.2 shows the distribution coefficient of Cr between olivine and glass ( $D_{Cr}^{Olv/Gl}$ ) at various values of  $f_{O_2}$ .  $D_{Cr}^{Olv/Gl}$  of both L7 and L7A are almost constant against each  $f_{O_2}$ .  $D_{Cr}^{Olv/Gl}$  of L7A is higher than that of L7. The data from L7A experiments have larger error bars than those of L7. Under oxidizing conditions a lot of small spinel grains were formed with



**Fig.1** Observed zoning profiles of LEW87051 olivine

## ORIGINS OF ANGRITE LEW87051 OLIVINE: Mikouchi T. *et al.*

olivine. This might be one major reason why  $D_{Cr}^{Olv/Gl}$  of L7A has large error bars. Our new data are in good agreement with the previous study [5].

**Mn Distribution:** We also pay attention to the Mn distribution, because bulk LEW87051 has as much MnO (0.25wt%) as  $Cr_2O_3$  (0.17wt%). Fig.3 shows the distribution coefficient of Mn vs.  $fO_2$ . Values of  $D_{Mn}^{Olv/Gl}$  are constant over wide range of  $fO_2$  and higher temperature gives lower  $D_{Mn}^{Olv/Gl}$ . The only difference between  $D_{Cr}^{Olv/Gl}$  and  $D_{Mn}^{Olv/Gl}$  is that Mn has a little higher distribution coefficient. The results of this study are in good agreement with [8].

**Ca Distribution:** The extremely low content of CaO in the olivine core is puzzling. Our experimental data for  $D_{Ca}^{Olv/Gl}$  plotted against  $fO_2$  show nice parabola curves.  $D_{Ca}^{Olv/Gl}$  is much lower than  $D_{Cr}^{Olv/Gl}$  and  $D_{Mn}^{Olv/Gl}$ , but shows a similar trend to lower values at higher temperature. However, our experimental olivines have much higher CaO than LEW87051 cores.

## DISCUSSION

This study indicates that  $D_{Cr}^{Olv/Gl}$  and  $D_{Mn}^{Olv/Gl}$  are almost constant from I.W.-2 to +4 for constant temperature. This means  $D_{Cr}^{Olv/Gl}$  and  $D_{Mn}^{Olv/Gl}$  are little affected by  $fO_2$ , precluding changes in  $fO_2$  as the source of the zoning in LEW87051 olivines. Assuming the profiles of  $Cr_2O_3$  and MnO (Fig.1) are mainly a result of fractional crystallization with different distribution coefficients, there would have to exist an area of temperature where  $D_{Cr}^{Olv/Gl}$  is above 1.0 and  $D_{Mn}^{Olv/Gl}$  under 1.0. However, according to our data,  $D_{Mn}^{Olv/Gl}$  is always a little higher than  $D_{Cr}^{Olv/Gl}$  as stated before (Fig.2, 3). We can't explain the zoning profiles of the core only by the difference of the distribution coefficient. The most plausible explanation we think is that first olivine crystallized at some temperature and  $Cr_2O_3$  and MnO zoned normally. Then, it was heated at high temperature and the rim melted. If olivine was kept at high temperature for a long time, the content of  $Cr_2O_3$  would decrease towards the rim by diffusion because the core has higher  $Cr_2O_3$  than that equilibrium with the bulk rock. On the other hand MnO would increase. CaO content wasn't affected very much, because the diffusion rate of  $Ca^{2+}$  will be slower than those of  $Cr^{3+}$  and  $Mn^{2+}$ . After that, the rim crystallized, producing normal zoning by fractional crystallization.

## CONCLUSION

It appears inevitable that LEW87051 olivine experienced two stage crystallization. The zoning in the outer part was primary zoning from fractional crystallization, but zoning in the inner part appears compatible with diffusion. It seems likely that the core olivines are xenocrysts that once crystallized under different conditions, then mixed with the groundmass melt, whereupon the rim grew.

Fig.2  $D_{Cr}^{Olv/Gl}$  vs.  $\log(fO_2/I.W.)$

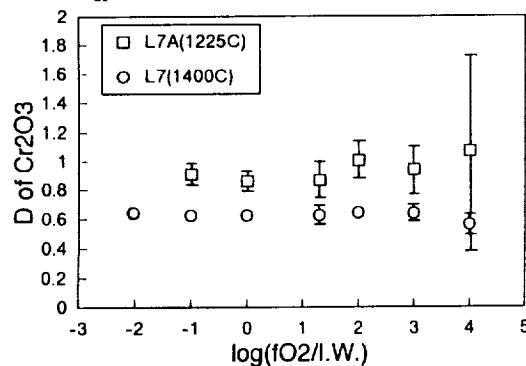
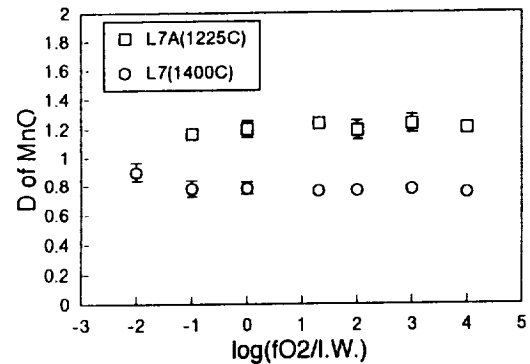


Fig.3  $D_{Mn}^{Olv/Gl}$  vs.  $\log(fO_2/I.W.)$



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