PORPHYRITIC OLIVINE IN ANGRITE LEW87051: COOLING RATE AND EVIDENCE FOR COMPLEX CRYSTALLIZATION HISTORY FROM RELICT CORES AND ZONING PROFILES; T. Mikouchi and M. Miyamoto, Mineralogical Inst., Graduate School of Science, University of Tokyo, Hongo, Tokyo 113, JAPAN., G.A. McKay, SN4, NASA/Johnson Space Center, Houston, TX77058, USA.

Angrites are among the oldest basalts in the solar system and their unique mineral chemistry has stimulated great interest in their controversial origins. LEW86010 and LEW87051 are individual samples discovered in the Antarctic, and classified as angrites with chemical affinities to the first known angrite, Angra dos Reis [e.g. 1-5]. Major constituent minerals of LEW angrites are Ca-rich olivine, fassaitic clinopyroxene, and anorthite. Although fassaites in LEW86010 are zoned, olivines are homogeneous except for exsolution lamellae of kirschsteinite. On the other hand, both fassaites and olivine in LEW87051 show chemical zonings. This evidence suggests that LEW87051 cooled more rapidly than LEW86010. Cooling rate calculations employing Fe/Mg zoning profile of LEW87051 olivine indicate that a cooling rate of at least 1000°C/year cooling rate is necessary to preserve the chemical zoning of Fe/Mg, which is much faster than the previously estimated cooling rate of LEW86010 [6] and in line with the textural evidence of both meteorites. The Fe/Mg zoning profile of LEW87051 olivine also suggests fractional crystallization as a closed system. Several olivines in LEW87051 have been pointed out to have relict cores [7,8]. Microprobe analysis of these olivines reveals that more Mg-rich olivine has larger core area. This fact supports the hypothesis that these are relict grains which survived the melting stage. The outer part of them would simultaneously crystallize with other porphyritic olivines without the relict core, because both show similar zoning profiles and their compositions are nearly identical.

FRACTIONAL CRYSTALLIZATION OF LEW87051 OLIVINE

Olivines in LEW87051 show chemical zoning indicating rapid crystallization. Several grains of LEW87051 olivines have Cr-rich, Ca-poor cores and the grains show two-stage zoning profiles for both major and minor elements [7,8]. We call the Cr-rich cores Type I olivine (cf. Fig. 1), the rims around these cores Type II, and porphyritic olivines with no cores Type III. In the core of Type I CaO increases from 0.3 wt% to 0.6 wt%, and the Fe component increases from 10 to 20 (Table 1). Type II and Type III olivine show zoning profiles similar to each other. The chemical compositions of the center of Type III are nearly identical to those of the edge of Type I and the core of Type II (CaO 0.6 wt%, FeO) (Table 1). Rayleigh fractionation calculation of minor elements of Type I showed that these cores formed through closed-system fractional crystallization [8]. We similarly calculated the atomic Fe/Mg zoning profile of Type III olivine in the hypothetical parent melt by inverting the olivine at the centers. We carried out the fractional crystallization calculation (D_{Fe/Mg}=0.34) until the calculated Fe/Mg ratio was that observed at the edge of the grain, corresponding 22 vol% remaining liquid. We then normalized the distance to the length of the observed profile. The calculated zoning profile well agrees with the observed one (Fig. 2). We also calculated the rim zoning profiles of Fe/Mg for Type II and obtained a good agreement.

CRITICAL COOLING RATE OF LEW87051

We further performed a cooling calculation employing Fe/Mg zoning profiles of LEW87051 olivine (Type III)[9]. To preserve the Fe/Mg zoning formed by fractional crystallization, olivine should cool faster than 1000°C/year. The 200°C/year cooling rate homogenizes the profile within a 150 μm distance from the core to rim. The cooling rate of 1000°C/year corresponds to a burial depth of 2 m of solid rock and 0.1 m of regolith. On the other hand, olivines in LEW86010 are known to show spectacular exsolution lamellae of kirschsteinite [10] indicating slow cooling. A previous calculation of the cooling rate for LEW86010 using this exsolution revealed that 0.1-10 °C/year cooling is required [6]. This cooling rate is much slower than the LEW87051 olivine, although the rate has two orders range due to uncertainty of diffusion rate of Ca in olivine. However, these two cooling rates accord with the textural observation.

RELICT CORES OF LEW87051 OLIVINE

In our previous report [8], we suggested that the core showing two-stage zoning in LEW87051
PORPHYRITIC OLIVINE IN ANGRITE LEW87051: Mikouchi T. et al.

olivine is relict. We have performed additional analyses of porphyritic olivines and examined the relationship between the Fo content of the core showing two-stage zoning and the radius of it (Fig. 3). Although the olivines showing two-stage zoning are not large in number and of course the effect of an off-center cut through the crystal can be considered, we find that more Mg-rich olivines have larger core areas. There is no doubt that more Fe-rich olivine can melt at a lower temperature than Mg-rich olivine. Our observations suggest that these cores are relict surviving the melting stage of the major parts of olivines. More Fe-rich olivines than Fa<sub>15</sub> might completely melt and only Mg-rich olivines could survive. Good accordance of Type II and Type III zoning profiles and their chemical compositions (Table 1) also supports this hypothesis.

CRYSTALLIZATION HISTORIES OF LEW86010 AND LEW87051

The core parts of the olivines (Type I) showing two-stage zoning in LEW87051 would be relict grains surviving the melting stage. After melting, the rim (Type II) and most grains of the porphyritic olivine (Type III) formed under closed system by fractional crystallization. The relation between the area of the core and the Fo component, and the compositional agreement between Type II and Type III support this hypothesis. Rayleigh fractionation calculation of Fe/Mg shows that they formed by closed-system fractional crystallization.

LEW86010 apparently crystallized much more slowly than LEW87051, and numerical simulations of the cooling rates support this idea. According to Yanai [11], the recently identified angrite Asuka881371 shows chemical zonings for both olivine and fassaite. Asuka is ophitic (doleritic) in texture and its grains are larger than those in LEW87051. We suggest its cooling rate was between those of the two LEWs.