LEW 87051, A NEW ANGRITE: ORIGIN IN A CA-AL-ENRICHED EUCRITIC PLANETESIMAL? M. Prinz[1], M.K Weisberg[1,2], C.E. Nehru[1,2].
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Angra dos Reis (ADOR) was recovered in 1869, LEW86010 in 1986, and now a third angrite, LEW87051, has been found in 1987. A related clast has also been found in the N. Haig polymict ureilite [1,2]. LEW87051 is very small (0.6g), and only a small thin section was available for study (2.2 x 0.8 mm). LEW87051 is an igneous rock, but contains abundant xenocrysts of olivine (up to 1mm). Comparison of this meteorite with the other angrites offers an opportunity to reevaluate the origin and history of these remarkable rocks.

TEXTURES AND MODES. LEW87051 is mainly a fine-grained melt rock consisting of subparallel laths of anorthite (400 μm), intergrown with subhedral Fe-rich fassaite and olivine (400 μm) which extend across the laths. The laths contain irregularly shaped voids (up to 5 μm). The texture is close to that of a quench melt. Plag laths and titanian magnetite (up to 20 μm) are the earliest phases, followed shortly by pyx and ol; crystallization is near-simultaneous. Ti magnetite is euhedral and included within ol and pyx. Incorporated throughout the melt are sharply defined subhedral xenocrysts of Mg-rich olivine; crystals range from 150-1000 μm. Xenocryst margins are sharply bounded by the melt rock which crystallized on the margins of the crystals. The xenocrysts constitute 25 vol. % of the meteorite. Modally, the melt rock portion (75% of the meteorite) consists mainly of fassaite, olivine and anorthite, with traces of spinel, merrillite, titanian magnetite, metallic FeNi and troilite, as shown in Table 1. LEW87051 is the most anorthite-rich of the angrites.

MINERAL CHEMISTRY. Mineral data for the melt rock portion of LEW87051 are presented in Table 1. Fassaite and olivine are more Fe-rich than those in other angrites. Fassaite is strongly zoned, with FeO and $TiO_2$ increasing from core to rim, resulting in strong pleochroism on the outer portions. In addition, MnO increases from 0.1-0.3%, and MgO decreases from 10-0.5%, from core to rim. $Al_2O_3$ generally increases, but remains near-constant in some cases. The ranges noted are a composite from all grains studied. Olivine compositions are difficult to determine precisely because it exhibits fine, submicron-sized, kirschsteinite exsolution. These exsolution patterns are complex and beyond the resolution of a 1-2 μm electron microprobe beam. Thus, it is not possible to precisely determine olivine-kirschsteinite equilibration temperatures [5], as was done for LEW86010 and ADOR [6]. Plag is $An_{100}$, and $TiO_2$ in Ti magnetite in higher than in other angrites (Table 1). The olivine xenocrysts differ sharply from melt rock olivine. Xenocrysts are fairly uniform in composition, but have some FeO enrichment near the margins, probably due to exchange with the surrounding melt. The core compositions of 12 xenocrysts range from $Fo_{73-90}$, with the largest xenocryst (about 1mm across) being $Fo_{90}$. CaO in these olivines is 0.5-0.6%, and no kirschsteinite is present.

BULK COMPOSITIONS. The bulk compositions of the melt rock portion, olivine xenocrysts, and whole rock were determined by broad beam microprobe analysis. Results are presented in Table 2. The olivine xenocrysts have an average mg # of 81.5, and the melt portion is 36.6, lower than any of the other angrites. The melt rock also has the highest $Al_2O_3$ and lowest MgO of all the angrites.

DISCUSSION AND CONCLUSIONS. The origin of angrites is problematic, and LEW87051 provides new aspects to the evolving data base. Some of the more important aspects added thus far include: (1) Angrites can be melt rocks which cool very rapidly, as compared to previously known coarse-grained or recrystallized samples. (2) Angrites can have a lower mg #, and have a higher anorthite component than previously known. (3) Angrites can contain Mg-rich olivine xenocrysts representing older or unmelted material. Overall, angrites have Fe-enriched CAI-like compositions, are extremely depleted in volatiles and siderophiles, and have oxygen isoptopes and initial Sr ratios that are compatible with basaltic achondrites. On the basis of the new data from LEW87051, and previous data from the other angrites, two general hypotheses for LEW87051 emerge. HYPOTHESIS 1 is that the Mg-rich olivine xenocrysts are portions of a dunitic or mantle sample incorporated into an ascending Ca-Al-enriched melt. HYPOTHESIS 2 is that the olivine xenocrysts are unmelted isolated olivine crystals (chondritic relicts) incorporated into melted CAI-like material. Hypothesis 1 implies a differentiated planetesimal with a parent body composition capable of producing mantle rocks with olivine similar to that of the basaltic achondrite planet. This would satisfy the oxygen and Sr isotopic constraints, but there are problems. Angrites are critically undersaturated in silica and from a phase equilibria, as well as from a bulk compositional, point of view it does not appear to be possible to derive angrites from the eucritic parent body. The angrites are also about 20x more depleted in volatiles than the eucrites. No angrite-like material has ever been found in eucrites, diogenites, howardites or mesosiderites, nor in the Earth or Moon. Hypothesis 2 has problems in that it implies a CAI-rich planetesimal, requires Fe-enrichment by nebular processes (such as gas-solid exchange) or mechanical mixing of an Fe-rich component, requires loss of volatiles and siderophiles, requires crystallization of LEW86010 at a depth of about 60m in a solid rock planet [7], and angrites have no isotopic anomalies [8]. It is also unclear if the olivine xenocrysts would remain unmelted in the Ca-Al-Fe-rich LEW87051 melt.

The presence of the olivine xenocrysts and the known characteristics of the angrites make both hypotheses difficult to accept without modification. However, one possibility is a compromise between the two hypotheses. That is, the angrites may form in a eucritic-like body which has additional Ca-Al component added to it. The extreme volatile-depletion of the planetesimal remains puzzling, but may be the result of the higher temperature melting required to melt a Ca-Al-enriched parent body composition.

REFERENCES. [1] Prinz, M. et al., 1986, LPSC XVII, 681-682. [2] Davis, A. M. et al., 1988, LPSC XVIII, 251-252. [3] McKay, G. et al., 1987, LPSC XIX, 762-763. [4] Kallemeyn, G.W. and P.H. Warren, 1988, LPSC XX, 496-497. [5] Davidson, P.M. and D.K. Mukhopadhyay, 1984, Cont. Min. Pet. 86, 256-263. [6] Prinz, M. et al., 1987, LPSC XIX, 949-950. [7] McKay, G. et al., 1989, Meteoritics (abs.) 24, in press. [8] Lugmair, G.W. et al., 1988, LPSC XX, 604-605.

Table 1. Textures, Modes, Mineral Comp. of LEW87051 and other angrites

| | LEW 87051 | LEW 86010 | ADOR | N. Haig Clast |
|---|---|---|---|---|
| Texture | Fine | Coarse | Rextal | Rextal |
| Xenocrysts | 25% | None | None | None |
| Mode | | | | |
| Fassaite | 45.5 | *43.3 | 95 | 70 |
| Ol + Kst | 12.8 | 23.5 | 5 | 10 |
| Anorthite | 41.7 | 31.8 | trace | 20 |
| Spinel | trace | 0.1 | trace | - |
| Merrillite | trace | 0.3 | trace | - |
| Ti magnetite | trace | trace | trace | - |
| Fe Ni | trace | trace | trace | - |
| Troilite | trace | 0.7 | trace | - |
| Min. Comp. | | | | |
| Fassaite | | | | |
| FeO | 11-26 | 7-11 | 6.7 | 8-11 |
| $TiO_2$ | 1-5.5 | 1-3 | 2.2 | 1.3-2.5 |
| $Al_2O_3$ | 4-8 | 6-12 | 10.0 | 5.5-7.7 |
| Olivine (melt) | | | | |
| % Fo | 15-20 | 33 | 53 | 48-61 |
| %CaO | 2.5 | 1.5-2 | 1.3 | 1.2-1.8 |
| % Anorthite | 100 | 100 | 86 | 98 |
| Ti in magnetite | 30 | 22 | 21.9 | - |
| % Ni in FeNi | 6 | 4.5-6.5 | 2-4 | - |
| Olivine (xeno.) | | | | |
| % Fo | 73-90 | - | - | - |

*Modal data for LEW86010 from G. McKay et al. [3].

Table 2. Bulk Comp. of LEW87051 and other Angrites

| | 1 LEW 87051 | 2 LEW 87051 | 3 LEW 87051 | 4 LEW 86010 | 5 ADOR | 6 N. Haig Clast |
|---|---|---|---|---|---|---|
| $SiO_2$ | 41.3 | 38.8 | 42.1 | (38.0) | (43.5) | 45.9 |
| $TiO_2$ | 0.60 | <0.01 | 0.79 | 1.59 | 2.9 | 0.84 |
| $Al_2O_3$ | 15.3 | <0.01 | 20.3 | 14.2 | 9.8 | 11.6 |
| $Cr_2O_3$ | 0.14 | 0.14 | 0.14 | 0.13 | 0.28 | 0.63 |
| FeO | 14.9 | 17.0 | 14.2 | 20.2 | 9.3 | 8.8 |
| MnO | 0.34 | 0.33 | 0.34 | 0.22 | 0.08 | 0.12 |
| MgO | 14.0 | 42.1 | 4.6 | 7.1 | 11.2 | 10.9 |
| CaO | 13.3 | 0.56 | 17.6 | 18.5 | 23.7 | 20.5 |
| $Na_2O$ | <0.01 | <0.01 | <0.01 | 0.03 | 0.04 | 0.05 |
| $K_2O$ | <0.01 | <0.01 | <0.01 | 0.03 | <0.01 | <0.01 |
| $P_2O_5$ | 0.24 | ≤0.01 | 0.31 | - | - | - |
| Total | 100.12 | 99.00 | 99.88 | 99.97 | 100.0 | 99.34 |
| mg # | 62.6 | 81.5 | 36.6 | 51.3 | 67.0 | 68.8 |

1. Whole rock, with 75% melt portion, 25% xenocrysts.
2. Broad beam analysis of 12 olivine xenocrysts.
3. Broad beam analysis of melt rock portion.
4,5. From Kallemeyn and Warren [4].
6. Reconstituted from modal analysis.