LEW 86010, A SECOND ANGRITE: RELATIONSHIP TO CAI'S AND OPAQUE MATRIX.

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Angra dos Reis (ADOR) was found in 1869 and has been considered a unique achondrite since then. It consists primarily of fassaitic pyroxene with minor ol, kirschsteinite (kst), spinel, metal, troilite and a trace of calcic plag [1]. It has notably high Ca, Al and Ti (as in CAI's), combined with unusually high Fe. The only other related material ever found was reported by Prinz et al. [2] as a clast in the N. Haig polymict ureilite; a similar clast was noted in the Nilpena polymict ureilite [3]. Now, a second angrite (LEW 86010), first described by Mason [4], has been found. This new, remarkable igneous rock, clearly related to ADOR, offers an opportunity to reevaluate the origin of this meteorite group.

Texture and Mode. LEW 86010 is coarse-grained, unshocked, igneous, with a subophitic to poikiltic texture and variable grain size. The texture is dominated by large (0.4-2.6mm) zoned fassaite crystals, with light colored cores and reddish brown (pleochroic) outer zones. These are intergrown with coarse (0.1-2.6mm) ol crystals with exsolution lamallae of kst about 15 microns wide; lamellae in a single direction are parallel to (001), those in two directions are parallel to (011) or (031). Large (0.14-1.4mm) laths of plag are also present. Inclusions of each of these major phases are found in large crystals of the other two phases. Minor greenish spinel, and traces of troilite and FeNi are also found. Modally, LEW 86010,7 contains: 58.3% fassaite, 20.3% ol, 21.0% plag, 0.2% spinel, 0.2% troilite, trace of FeNi.

Mineral Chemistry. Fassaite has a striking zoning pattern. From core to rim, there is increasing TiO_2 (1-3%), Al_2O_3 (6-12%), FeO (7-11%), and decreasing MgO (12-8%) and Cr_2O_3 (0.7-0.1%); CaO is constant at 24%. There is a sharp interface between the inner and outer fassaite portions, and each portion is zoned in the same direction. Large ol crystals are Fo_{33}, and have exsolved kst, whereas ol inclusions (in plag) are Fo_{47-55}. Differing compositions of ol inclusions coexist in a single host plag crystal. CaO in ol ranges from 1.5-2.2%, a larnite (La, Ca_2SiO_4) component of 2-3.7%; thus, large ol crystals are $La_{3.7}Fo_{31.8}Fa_{64.5}$. Kst has 28.0% CaO, and a composition of $La_{45.6}Fo_{12.7}Fa_{41.7}$. Plag is An_{100}, with 0.2-0.5% FeO; ol inclusions in plag have higher FeO. Spinel is hercynitic, with high FeO (37%) and Al_2O_3 (55%). FeNi has 4.5-6.8% Ni, 0.8-1.2% Co, and undetectable Si, Cr and P.

Bulk Composition. The bulk composition of LEW 86010,7 was calculated from the mode of this thin section, using average mineral compositions. It is estimated to be: SiO_2, 43.3%; TiO_2, 0.42%; Al_2O_3, 12.1%; Cr_2O_3, 0.37%; FeO, 15.9%; MnO, 0.30%; MgO, 9.4%; CaO, 15.2%; Na_2O and K_2O are <0.01%; the mg# is 49.1.

Discussion and Conclusions. (1) LEW 86010 has an igneous texture, indicative of a molten state, although this does not necessarily imply it is an achondrite. It may be igneous in the sense of a Type B CAI [e.g. 5]. ADOR has a recrystallized texture, whereas the N. Haig ADOR clast has an igneous texture. (2) 86010 is enriched in ol and plag, and is more FeO-rich than ADOR, but is similarly volatile-depleted. The N. Haig clast is also enriched in ol (Fo_{48-60}) and plag (An_{98}), but has the same Fe-enrichment as ADOR. (3) Ol and kst in angrites are plotted in an olivine quadrilateral [6] in Fig.1. This indicates ol crystallization at about 1075° C, and exsolution at about 775°C. Zoned fassaites in 86010 indicate fairly rapid crystallization, and the presence of FeNi grains indicates an oxidation state near the iron-wustite buffer. (4) The crystallization sequence of 86010 is early spinel and FeNi, followed shortly by ol and plag, and soon thereafter by fassaite. Ol, plag and fassaite nucleate near-simultaneously for most of the crystallization history indicating a bulk composition close to a three phase boundary. Projection of the bulk comp. onto the Fo-An-Gehlenite system, used for Type B CAI's [7], is consistent with this type of crystallization, although an Fe-bearing system is needed. (5) 86010, ADOR, and polymict ureilite ADOR clasts reveal a remarkably refractory (Ca, Al) and Fe-rich composition that is not indicative of derivation from a planet with a chondritic composition similar to that of the Earth, SNC, or Eucritic planets. Instead, it strongly resembles Type B CAI's (although not as Ca-Al rich), except for the extreme Fe-enrichment (with very low Ni). Type B CAI's are primitive, have gone through a molten stage [7, 8], and represent materials formed early in the solar condensation sequence. However, they are essentially Fe-free. The only other early-formed primitive Fe-rich (with low Ni) material available for mixing with the CAI component is the opaque matrix component in chondritic meteorites. It contains mainly FeO-rich ol and opx, sulfides, metal, and magnetite, and is thought to be closely related to the material from which Mg-Fe chondrules formed [9]. (6) We propose an origin for the angrites that includes a starting composition of CAI and opaque matrix, which was then heated and melted. The melting took place in a nebular setting similar to that in which the Type B CAI's melted, perhaps on a larger scale such as in a planetoid. Thus, angrites are not achondrites sensu stricto, but molten mixtures of two well-known primitive meteoritic components.

References. [1] Prinz, M. et al., 1977, EPSL 35, 317-330. [2] Prinz, M. et al., 1986, LPS XVII, 681-682. [3] Jaques, A.L. and M.J. Fitzgerald, 1982, GCA 46, 893-900. [4] Mason, B., 1987, Ant. Newsletter 10, No. 2. [5] MacPherson, G.J. and L. Grossman, 1981, EPSL 52, 16-24. [6] Davidson, P.M. and D.K. Mukhopadhyay, 1984, Cont. Min. Pet. 86, 256-263. [7] Stolper, E., 1982, GCA 46, 2159-2180. [8] Stolper, E. and J.M. Paque, 1986, GCA 50, 1785-1806. [9] Scott, E.R.D., in press, Min., comp. and origin of chondritic matrix material - an overview, in "Meteorites and the Early Solar System," J.F. Kerridge and M.S. Mathews (eds.), Univ. Arizona Press.

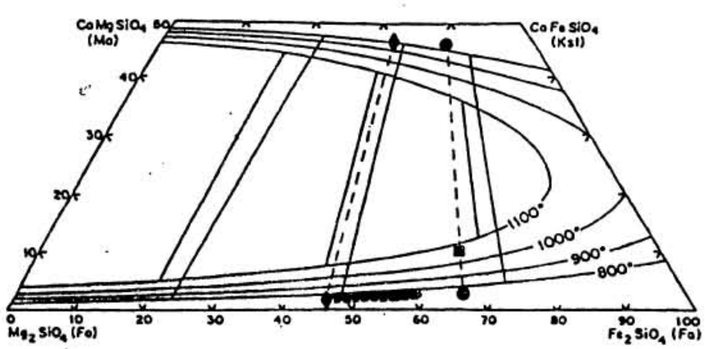

Fig.1 Olivine quadrilateral [6], with LEW 86010 (circles), ADOR (diamonds), N. Haig Clast 1 (hatched area).