GEOCHEMISTRY OF LEW86010 AND ANGRA DOS RIES AND CONSTRAINTS ON THE GENESIS OF THE ANGRITES

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We have performed INAA and electron microprobe-fused bead analyses on samples from LEW86010 (LEW) and Angra dos Ries (ADOR) for a suite of major and trace elements. These studies are being conducted as part of a broader consortium effort on LEW86010 led by G. McKay and directed toward unraveling the petrogenesis of these unusual achondrites. We report here the results of our analyses and provide some preliminary constraints on the petrogenesis of the angrites. We will assume that LEW and ADOR represent liquid compositions, as experimental petrologic investigations have indicated that this is nearly true (1,2).

LEW and ADOR were suspected of being closely related based on preliminary petrologic work by Mason (3), and this relationship was strengthened by further petrologic and geochemical study by numerous researchers (4-7). Although broadly similar, there are enough differences between LEW and ADOR that they cannot be samples from a single magmatic unit. In particular, the major and trace element concentrations in LEW and ADOR pyroxenes do not support an interpretation as a single fractionation sequence (4,5). This observation is supported by the whole rock compositions as well. Whole rock mg# for LEW and ADOR are 40 and 67 respectively, yet in spite of a more primitive major element composition, ADOR contains ~1.9x the REE that LEW does (Fig. 1). The highly charged incompatible elements (Hf, Ta and Th) are less enriched than REE in ADOR relative to LEW with a mean enrichment factor of 1.3 (Fig. 1).

Both LEW and ADOR are highly depleted in Na with CI normalized abundances of 0.032 and 0.045 respectively. These low abundances are difficult to reconcile with the abundant FeO in the angrites. In the solar nebula, Fe metal was significantly oxidized and incorporated in silicates only at temperatures below the condensation temperatures of Na and Mn (8,9). With falling nebular temperature, the FeO/MnO ratio of the silicates increases from 0. The high FeO/MnO ratios for LEW and ADOR (89 and 94) indicate that the source regions for the angrite magmas were quite oxidized. This suggests that the low Na content of the angrites may be due to parent body outgassing of an initially more Na (and other volatile) rich asteroid as has been suggested for the eucrites (10).

In figure 2 we show LEW and ADOR normalized to mean basaltic eucrite (MBE) and Al for major elements. Eucrites were formed by low pressure magmatic processes on their parent body (e.g. 11,12) and their major element compositions may reflect a pattern that is typical for melts produced by low P petrogenesis on an approximately chondritic parent body. ADOR, and to lesser extent LEW, have high Ti/Al and especially Ca/Al ratios compared to MBE. One possible means of fractionating Ca from Al in low P processes is with plagioclase as a major Al sink. However, LEW plagioclase has a MBE normalized Ca/Al ratio of ~0.7 (4) and cannot cause large Ca/Al fractionations as are observed for LEW and especially ADOR. In addition, the relatively modest to negligible Eu depletion in the ADOR and LEW REE patterns (Fig. 1) suggests that there has been only minor plagioclase fractionation. Treiman et al. (13) have suggested either melilite or hibonite fractionation might have occurred during ADOR petrogenesis. Melilite fractionation will <u>decrease</u> the Ca/Al ratio in the melt and cannot therefore explain the high Ca/Al ratios in LEW and ADOR. Hibonite fractionation could possible induce high Ca/Al ratios in the angrite parent magmas, but as noted by (13), hibonite is not observed in experiments on ADOR compositions. High pressure fractionation involving a Ca-poor garnet in the source region (or early cumulates) can be ruled out because of the lack of LREE/HREE fractionation that would be predicted to be caused by the garnet.

Two remaining possibilities are 1. that both angrites contain substantial amounts of cumulate fassaitic clinopyroxene (and LEW may contain significant other cumulus minerals as well), or 2. the source region of the angrite parent magmas was distinctly non-chondritic. As noted above, petrologic experiments (1,2) suggest that both LEW and ADOR are nearly isochemical with their parent melts and might indicate that option 1 above is not correct. A non-chondritic parent with a high Ca/Al ratio could be formed if the highest temperature condensates were lost prior to accretion. The earliest condensates, either corundum or hibonite, have very low Ca/Al ratios and their removal from the region where the angrite parent body was formed could deplete the parent body in Al. However, hibonites which appear to be the highest temperature grains in Murchison are rich in REE and show fractionated REE patterns with extreme Yb depletions (14). If these grains are typical of high temperature condensates, then their removal from the formation location of the angrite parent body would result in unusual fractionations in the angrite REEs which are not observed.

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The angrites have experienced an unusual and complex petrogenetic history and further multidisciplinary study and much cogitation are needed before these meteorites will be understood.

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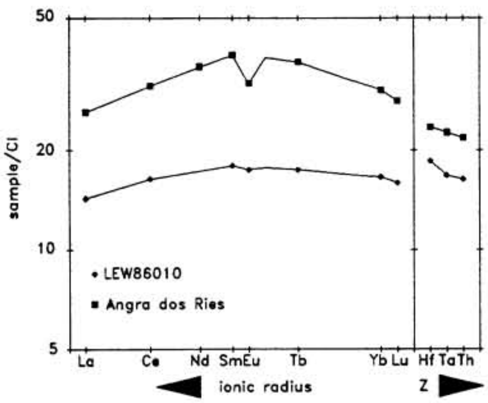

Fig. 1 Refractory trace element patterns in ADOR and LEW are similar, but abundances in ADOR are greater in spite of a more "primitive" major element composition.

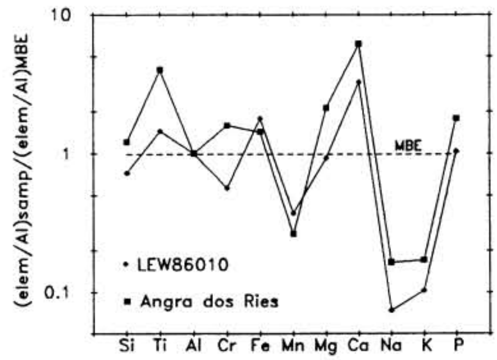

Fig. 2 Major elements normalized to mean basaltic eucrite (MBE) and Al show similar patterns for ADOR and LEW. Calcium and Ti are enriched and Mn, Na and K are depleted relative to eucritic basalts.