ACAPULCOITE – LODRANITE PETROGENESIS: CLUES FROM TRACE ELEMENT DISTRIBUTIONS IN INDIVIDUAL MINERALS.

Christine Floss. McDonnell Center for the Space Sciences and Dept. of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130, U.S.A.

Introduction: Primitive achondrites have recently received considerable recognition as a potentially important source of information about early differentiation processes in asteroidal bodies [1-3]. The acapulcoites and lodranites are thought to have originated on a common parent body [4,5] that experienced variable degrees of heating, resulting in complex partial melting and melt migration processes. The acapulcoites have experienced primarily Fe,Ni-FeS cotectic melting, whereas lodranites appear to have undergone higher degrees of melting that included the formation and removal of silicate partial melts. I have initiated a detailed study of trace element distributions in the individual minerals from acapulcoites and lodranites in order to provide additional constraints on the origins of these meteorites. Preliminary results are presented here for four primitive achondrites.

Experimental : Trace elements, including the rare earth elements (REE), were measured by ion microprobe in plagioclase, phosphates (apatite and merrillite), clinopyroxene and orthopyroxene from the acapulcoites, Acapulco and ALHA81261, and the lodranite, MAC 88177. Measurements were also made on EET 84302, which was classified as a lodranite by McCoy *et al.* [3], although Mittlefehldt *et al.* [1] noted that it is compositionally similar to the acapulcoites.

Results: REE patterns for the minerals studied are shown in Fig. 1. Plagioclase shows the typical LREE-enriched pattern with a large positive Eu anomaly; abundances of the HREE are below detection limits in all analyses and Y is shown in place of Er, as an analog for the HREE. REE concentrations are higher in EET 84302 than in the acapulcoites. No plagioclase is present in lodranite MAC 88177.

Clinopyroxene and orthopyroxene were both analyzed in all four meteorites, and exhibit similar REE patterns, respectively, in the different samples. The patterns for orthopyroxene are strongly HREE-enriched, with chondrite-normalized Yb/Ce ratios ranging from 20 to 220, and exhibit negative Eu anomalies (Eu is below detection in Acapulco and ALHA81261). REE patterns for clinopyroxene are LREE-depleted with negative Eu anomalies. HREE abundances are similar for the acapulcoites and EET 84302, but LREE abundances differ and are highest for EET 84302. Lodranite MAC 88177 has significantly lower clinopyroxene REE abundances, although one grain (not shown) exhibits a distinctly LREE-enriched pattern relative to the others.

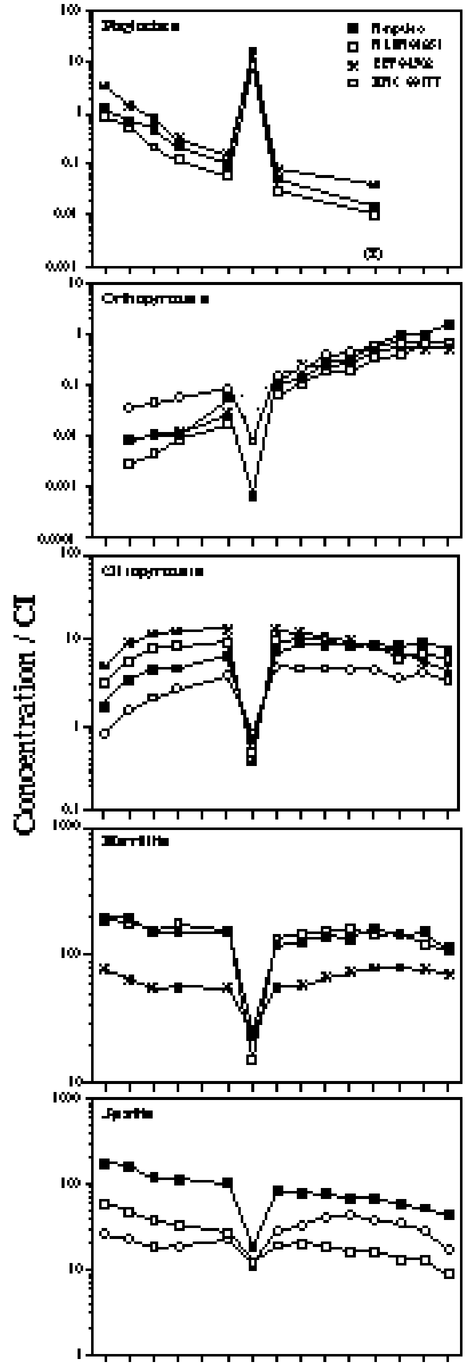

Fig. 1. Average chondrite-normalized REE patterns for minerals from Acapulco, ALHA81261, MAC 88177 and EET 84302. In plagioclase, Sm and Gd abundances are interpolated and Y is shown in place of Er.

REE patterns for merrillite from the acapulcoites and EET 84302 are flat with negative Eu anomalies, but EET 84302 merrillite has lower REE abundances and a smaller Eu anomaly than that from the two acapulcoites. Apatite grains from the acapulcoites have parallel LREE-enriched patterns with negative Eu anomalies, although abundances differ by a factor of four. In contrast, apatite from lodranite MAC 88177 is enriched in the HREE.

REE abundances in silicates and phosphates are generally consistent with those previously reported by Zipfel *et al.* [6] for Acapulco and by Davis *et al.* [7] for Acapulco, ALHA81261 and MAC 88177. However, REE patterns for orthopyroxene and plagioclase from the acapulcoites differ from those reported by McCoy *et al.* [2] for Monument Draw. Silicates from this acapulcoite have similar REE abundances (except for Eu in plagioclase), and patterns that are much flatter than those expected for equilibrium partitioning.

Discussion: Although the details are complex, a simplified scenario for the origin of acapulcoites and lodranites proposed by McCoy *et al.* [2,3,5] suggests that both formed on a common parent body, that underwent variable degrees of local partial melting. Acapulcoites experienced only low degrees of Fe,Ni-FeS cotectic melting and have maintained essentially chondritic troilite and plagioclase abundances, whereas lodranites experienced higher degrees of melting that included partial silicate melting with subsequent loss of troilite and/or plagioclase fractions.

Trace element data from this study are broadly consistent with this scenario. Both clinopyroxene and apatite from lodranite MAC 88177 have lower REE abundances than their counterparts in the acapulcoites, and apatite from MAC 88177 is depleted in the LREE compared to apatite from the acapulcoites. Furthermore, variations of incompatible elements, such as Ti, Zr and Y (Fig. 2), in clinopyroxene and orthopyroxene show that these elements are depleted in MAC 88177 compared to the acapulcoites (however, Y abundances in orthopyroxene are elevated). These characteristics are consistent with removal of a partial silicate melt enriched in incompatible elements and the LREE associated with a feldspathic component. Davis *et al.* [7] made a similar observation on the basis of apatite REE compositions in acapulcoites and lodranites.

McCoy *et al.* [3] considered EET 84302 a lodranite, basing their classification primarily on grain size. However, these authors note that if different criteria are used (e.g., alkali element depletions and/or plagioclase contents) this meteorite would be classified as an acapulcoite, and suggest that it, along with several other 'lodranites' are transitional between the two groups. Mittlefehldt *et al.* [1] noted that EET 84302 is compositionally more similar to acapulcoites than to lodranites: lithophile element systematics are generally similar to those of other acapulcoites, while siderophile element systematics indicate Fe,Ni-FeS melting and melt migration. These authors suggest that EET 84302 should be considered an acapulcoite that has been more severely metamorphosed than most.

The trace element data reported here group EET 84302 together with the acapulcoites: REE abundances in clinopyroxene and orthopyroxene fall within the ranges observed for these minerals in Acapulco and ALHA81261, and in plagioclase are, in fact, slightly higher than in the acapulcoites (Fig. 1). Incompatible element abundances in the pyroxenes from EET 84302 (Fig. 2) also group together with acapulcoite pyroxenes. Although REE abundances in

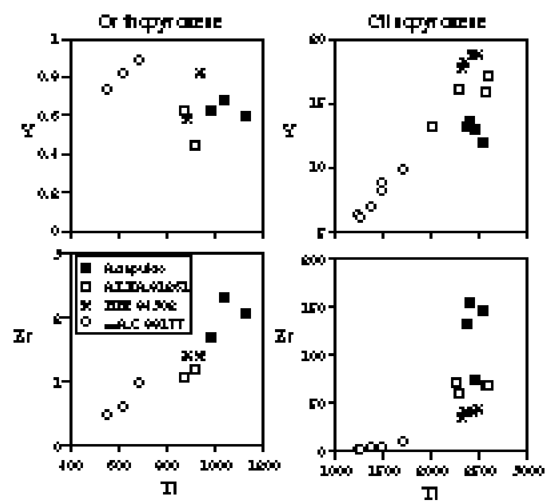

Fig. 2. Abundances of Ti vs. Zr and Y (ppm) in orthopyroxene and clinopyroxene.

merrillite are significantly lower than those from the acapulcoites presented here, they fall only slightly below the range of abundances seen in Acapulco merrillite [6]. Furthermore, the pattern does not exhibit the LREE depletion seen in apatite from lodranite MAC 88177. These data indicate that EET 84302 does indeed seem to be more closely related to the acapulcoites than the lodranites, as suggested by [1].

References: [1] Mittlefehldt *et al.* (1996) *Geochim. Cosmochim. Acta* **60**, 867 [2] McCoy *et al.* (1996) *Geochim. Cosmochim. Acta* **60**, 2681. [3] McCoy *et al.* (1997) *Geochim. Cosmochim. Acta* **61**, 623. [4] Clayton and Mayeda (1996) *Geochim. Cosmochim. Acta* **60**, 1999. [5] McCoy *et al.* (1997) *Geochim. Cosmochim. Acta* **61**, 639. [6] Zipfel *et al.* (1995) *Geochim. Cosmochim. Acta* **59**, 3607. [7] Davis *et al.* (1993) *Lunar Planet. Sci.* **XXIV**, 375.