CLASSIFICATIONAL PARAMETERS FOR ACAPULCOITES AND LODRANITES: THE CASES OF FRO 90011, EET 84302 AND ALH A81187/84190 T.J. McCoy[1], K. Keil[1], R.N. Clayton[2] and T.K. Mayeda[2] [1]Planetary Geosciences, Department of Geology and Geophysics, SOEST, University of Hawaii at Manoa, Honolulu, HI 96822, USA; [2]Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA.

Abstract. Acapulcoites and lodranites probably sample a common parent body, which has experienced a range of partial melting [1-3]. We present classificational parameters which allow acapulcoites-lodranites to be distinguished from other groups of meteorites, as well as from each other. Petrography can complement oxygen isotopic compositions [4] in separating these meteorites from other groups of stony-irons and primitive achondrites, while petrographic properties alone distinguish acapulcoites from lodranites. Acapulcoites differ from lodranites in having smaller grain sizes, abundant Fe,Ni-FeS as μm-sized veins and plagioclase which escaped melting. We have applied these criteria to three new members of the group. FRO 90011 is a typical lodranite; EET 84302 is intermediate in many properties between acapulcoites and lodranites; and ALH A81187/84190 are paired meteorites and are the first low-FeO acapulcoites. These meteorites provide a wider spectrum of samples from the acapulcoite-lodranite parent body and suggests that this body may have had a complex structure.

Distinguishing Acapulcoites/Lodranites from Other Groups. Acapulcoites and lodranites are rocks consisting of equigranular aggregates of olivine + pyroxene + metal + troilite ± plagioclase. This distinguishes them from stony-iron meteorites such as pallasites and IAB irons: Acapulcoites and lodranites are not stony-iron meteorites with silicate clasts set in a matrix of Fe,Ni metal. This also distinguishes these meteorites from ureilites which contain ubiquitous carbon. Based on mineralogy and petrology, it is almost impossible to distinguish between winonaites and low-FeO acapulcoites and lodranites [5]. However, they can be readily distinguished on the basis of oxygen isotopic compositions.

Distinguishing Acapulcoites from Lodranites. The most important difference between acapulcoites and lodranites is in their thermal history. Acapulcoites experienced partial melting at the Fe,Ni-FeS eutectic [1], while lodranites were heated to somewhat higher temperatures and have also experienced silicate partial melting [2]. While the temperature differences may only have been 50-100°C, it has resulted in dramatic differences in petrologic and compositional properties of the two groups which can be used as distinguishing parameters. We concentrate on three major parameters. Other features (e.g., relict chondrules, evidence for reduction) can be used for classification in some cases.

Grain Size. Lodranites are coarse-grained, with average mafic mineral grain sizes of 538-702 μm. In contrast, acapulcoites are finer-grained, with average grain sizes of 146-173 μm. This is consistent with differences in their thermal and partial melting histories. In acapulcoites, grain growth of the silicates occurred by lattice diffusion in the solid state and, because of the low diffusion rates in solid silicates, grain growth was limited. In contrast, grain growth in lodranites was aided by the existence of silicate partial melts, in which diffusion rates are high, resulting in coarse-grained rocks. This difference in grain size provides a rapid means of initial classification.

Plagioclase Content and Shape. Plagioclase and pyroxene form the first silicate partial melt in a chondritic system. Acapulcoites have 7-15.6 vol.% plagioclase, occurring as small, isolated grains interstitial to mafic silicates. In contrast, lodranites tend to be depleted in plagioclase, although some have up to 10.3 vol.%; many, including Lodran, contain no plagioclase. When present, plagioclase occurs as large, interstitial grains which have been molten.

Metal/Troilite Abundances. Acapulcoites have roughly chondritic troilite abundances (3.6-8.0%), but lodranites are significantly depleted in FeS (0.2-2.7%). Both types have experienced partial melting at the Fe,Ni-FeS eutectic. In acapulcoites, the Fe,Ni-FeS melt is preserved as μm-sized veins which cross-cut plagioclase, indicating that the plagioclase was never molten. In the lodranites, silicate partial melting opened pathways which allowed segregation of the Fe,Ni-FeS eutectic, resulting in a depletion of troilite.

New Acapulcoites and Lodranites. We examined a number of primitive achondrites and found them to belong to the acapulcoite/lodranite clan.

FRO 90011. This meteorite was initially described as an acapulcoite [6]. It is coarse-grained (538 μm) and is depleted in plagioclase (only trace amounts) and troilite (3.0 vol.%). Olivines ($Fa_{9.4}$) and pyroxenes ($Fs_{12.6}$) show reverse FeO zoning. This meteorite is a lodranite.

EET 84302. This rock was thought to be related to silicate inclusions in IAB irons, based on similarities in olivine compositions (Fa_5) [7]. Our oxygen isotopic data ($\delta^{18}O$=+3.31, $\delta^{17}O$=+0.53) and olivine analyses ($Fa_{8.4}$) suggest classification as an acapulcoite or lodranite. This rock is the closest to a transitional member between acapulcoites and lodranites. It is intermediate in grain size (343 μm). Olivine ($Fa_{8.4}$) and pyroxene ($Fs_{8.3}$) compositions are approximately equal, and reverse FeO zoning in olivines is minor. Although plagioclase content is high (11.4 vol.%), individual grains appear to have been molten. Finally, troilite is very low (0.1 vol.%). We conclude that this meteorite has experienced silicate partial melting and should be classified as a lodranite.

ALH A81187/84190. These meteorites are paired and are moderately weathered. Oxygen isotopic compositions (81187, $\delta^{18}O$=+2.79, $\delta^{17}O$=+0.42; 84190, $\delta^{18}O$=+2.54, $\delta^{17}O$=+0.20) suggest that they are members of the acapulcoite/lodranite clan. They are relatively fine-grained (220 μm). Plagioclase contents are chondritic (10.0 vol.%), and individual grains do not appear to have been molten. While troilite contents are low (2.1 vol.%), weathering products (11.3 vol.%) are abundant. Thus, troilite contents are probably not a reliable indicator of classification. Veins of Fe,Ni-FeS cross-cut plagioclase. Olivines ($Fa_{4.2}$) and pyroxene ($Fs_{6.8}$) do not exhibit reverse FeO zoning. These meteorites are classified as acapulcoites.

Discussion. We have shown that acapulcoites and lodranites can be distinguished from other meteorite groups on the basis of petrography and oxygen and mineral compositions. They can also be distinguished from one another, based on mineralogic-petrologic properties that have resulted from differences in their thermal histories.

Our examination of new acapulcoites/lodranites yields two noteworthy new results. First, a meteorite intermediate in properties between acapulcoites and lodranites exists. This is not unexpected, since previously classified lodranites show a wide range of silicate partial melting [2,3]. EET 84302 represents the lowest degree of silicate partial melting of the known lodranites. Second, we discovered a low-FeO acapulcoite, which had been predicted by [2]. Surprisingly, this rock has roughly the same $\Delta^{17}O$ as the higher-FeO acapulcoites, suggesting that acapulcoites come from a reservoir of homogeneous oxygen isotopic compositions, while oxygen isotopic compositions of lodranites are correlated with their FeO content. Either the acapulcoite-lodranite parent body structure must have been very complex or, possibly, these meteorites sample more than one parent body. Discovery of a breccia containing materials of both types would provide definitive evidence for a common parent body.

References: [1] McCoy *et al.* (1992) *LPSC XXIII*, 871-872. [2] McCoy *et al.* (1992) *Meteoritics* **27**, 258-259. [3] Nagahara (1992) *Proc. NIPR Symp. Antarct. Met.* **5**, 191-223. [4] Clayton *et al.* (1992) *LPSC XXIII*, 231-232. [5] Kimura *et al.* (1992) *Proc. NIPR Symp. Antarct. Met.* **5**, 165-190. [6] Folco (1992) *Meteoritics* **27**, 221-222. [7] Mason (1986) *Antarct. Met. News.* **9** No. 3, 18. Samples provided by EUROMET and MWG. Funding in part by NAG 9-454 (K.Keil, P.I.)

Table 1. List of previously classified acapulcoites and lodranites.

Acapulcoites - Acapulco, Monument Draw, Y-74063, ALH A77081, ALH A78230, ALH 81261, ALH 81315
Lodranites - Lodran, Gibson, Y-791491, Y-791493, Y-74357, Y-75274, Y-8002, MAC 88177, LEW 88280