LaPaz 04841: Comparative Petrology and Textural Study of a New Lunar Mare Basalt Meteorite. E. Hill, L. A. Taylor, Y. Liu. Planetary Geosciences Institute, Department of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN 37996, (EHILL10@utk.edu)

Introduction: Lunar mare basalt meteorites found in Antarctica and the hot deserts of Earth provide samples of the Moon that extend our knowledge beyond that gained during the Apollo and Luna missions. Through their study, we obtain a broader view of lunar magmatism and source rock composition. As impact-excavated samples, meteorites also offer the potential for the study of deeper regions of the Moon. To date, 20 mare basalt finds are catalogued on the List of Lunar Meteorites [1], of which 6 were found on the LaPaz Ice Field in Antarctica. Previous work (e.g., [2,3]) has presented strong arguments for 5 of these (LAP 02205, LAP 02224, LAP 02226, LAP 02436, and LAP 03632) to have originated from the same flow. The 2004 Antarctic search for meteorites season saw the addition of a 6th LaPaz lunar basalt to the collection. This find of LAP 04841 measured 5 x 2.5 x 2.5 cm and weighed 0.06 kg, bringing the total mass of LaPaz lunar basalts to 1.93 kg. Preliminary reports suggest that this new find is paired to the other 5 LaPaz meteorites [4], and is most similar to LAP 02205. We present here the first textural description, mineralogy, and mineral chemistry of LAP 04841 (thin sections LAP 04841,14 & 5, and thick section LAP 04841,18). We also confirm similarities between this meteorite and the other 5 LaPaz lunar basalts.

Petrography and Textures: LAP 04841 is a coarse-grained basalt with subophitic texture. The major mineralogy consists of pyroxene and plagioclase, with interstitial ilmenite. Minor phases include olivine, Ti-chromite, and ulvöspinel. Also present are shock- induced melt veins and a mesostasis, consisting of fayalite, SiO_2, K-rich glass, and with trace amounts of FeNi, troilite, ilmenite, ulvöspinel, phosphates, and baddeleyite. The order of crystallization, inferred from mineral associations, is believed to be Ti-chromite + olivine, pyroxene + ulvöspinel, pyroxene + plagioclase + ilmenite, and mesostasis.

The level of shock-induced deformations varies from slide to slide with the most-intense affected being LAP 04841,14, in which all plagioclases have been fully or partially converted to diaplectic glass, i.e., maskelynite. However, section 18 contains both plagioclase and maskelynite, and section 5 contains no maskelynite, only plagioclase.

Mineralogy: Pyroxene is the most abundant phase and accounts for 56.2 vol% of the samples. Grains are anhedral and range in size up to ~0.5 mm. Pyroxenes have cores of augite, sometimes pigeonite ($Wo_{14\text{-}20}$). Grain compositions grade continuously from core to rim with progressive Fe enrichment to high-Fe augite ($Fs_{59}Wo_{39}$), and pyroxferroite ($Fs_{86}Wo_{13}$).

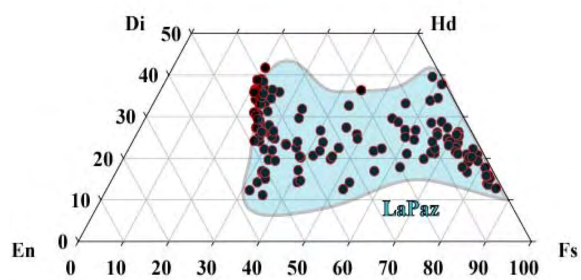

Figure 1. Pyroxene compositions for LAP 04841. The hi-lighted area corresponds to reported values for the other LaPaz basalts [3,7].

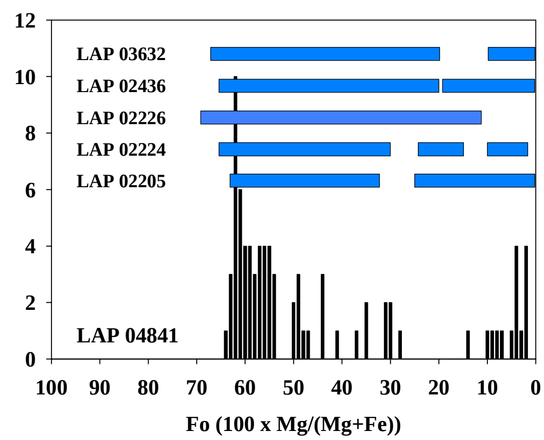

Figure 2. Composition of olivines in LAP 04841. Bars correspond to the range of compositions for olivines in LaPaz meteorites as listed by Day et al. [3]

Plagioclase accounts for 31.9 vol%, is elongated, subhedral, and up to 1.5 mm in length. Compositions are in the range $An_{91\text{-}81}$. Plagioclase transverse analyses reveal complex zoning with FeO increasing towards the rim (up to 1.6 wt%), with a complementary decrease in MgO content. Maskelynite compositions fall within the range of compositions listed for plagioclase and display the same chemical zonations.

Forsteritic olivines account for 1.54 vol%, are anhedral and sub-rounded, and range from 50-200 µm. Olivine is fully within pyroxenes, with which they have resorptive contacts. Compositions are in the range Fo_{64-28}. Olivine grains are zoned with cores of Fo_{64-54} and rims as low as Fo_{28}.

Titaniferous-chromite and ulvöspinel appear in association with olivine and pyroxene and account for 0.19 vol% and 0.81 vol%, resp. The larger proportion of ulvöspinel reflects its presence in association with ilmenite (3.34 vol%) and mesostasis. Chromites appear individually or with ulvöspinel overgrowths. When these phases are related, the boundary between them is sharp, and differs in Cr_2O_3 concentration by as much as 30 wt%. FeNi grains, in association with chromite have compositions $Fe_{93}Ni_6Co_1$. These differ from a FeNi grain found in association with fayalite and phosphate in the mesostasis, with composition $Fe_{85}Ni_{12}Co_3$; exemplifying the incompatibility of these elements in the source melt.

Mesostasis accounts for 5.27 vol% and consists of fayalite Fa_{98-86} (up to ~350 µm), in association with SiO_2, K-rich glass, FeNi grains, troilite, baddaleyite, and phosphates. Ilmenites found in the mesostasis differ from interstitial ilmenites by having lower Al_2O_3 and CaO, and detectable ZrO_2 concentrations.

Lunar Origin and Associations: There are several lines of evidence indicative of the lunar origin of LAP 04841. Analyses of chromite cores provide a V/(Al+Cr) ratio of 1.33 ± 13, translating to a log fO_2 slightly over one log unit below the IW buffer and fall within the lunar average for chromite grains [5]. This value is in accordance with that found by Collins et al. [2] for other LaPaz basaltic meteorites. Pyroxene and olivine Fe/Mn ratios plot along the trends set for lunar basalts [6]. The presence of FeNi metal grains and troilite, the anhydrous nature of the sample, and the anorthositic composition of the plagioclase are further pointers to the lunar origin of LAP 04841.

Initial description of LAP 04841, based on microscope observations, suggests pairing of this meteorite with the other LaPaz lunar basalts [4]. Indeed, our more detailed study has hi-lighted similarities between LAP 04841 and the rest of the LaPaz lunar basalt suite. Previous descriptions of grain-size and texture of LaPaz basalts [3, 7, and 8] match the subophitic, coarse-grained nature of LAP 04841. The ranges of pyroxene and olivine compositions are similar to those determined for the other LaPaz basalts (Figs. 1 and 2); with a closer affinity to LAP 02205, 02436, and 03632.

These meteorites and this new find all display extreme pyroxferroite and fayalite compositions. Mineral modes are close to those reported by Day et al. [3]; with the notable exception of the large volume of mesostasis encountered in LAP 04841; this is evidence for a more fractionated nature of the new find when compared to the other LaPaz basalts.

Further similarities are provided by the petrological evidence uncovered. Ulvöspinel in the mesostasis contains measureable concentrations of ZrO_2. When in association with ilmenite, it is possible to apply the Zr-cooling speedometer [9]. Values obtained provide an estimate of initial temperature of 1217 ºC and a cooling rate of 5.2 ºC/day. This temperature is comparable to that determined by Day et al. [3] (1183 ± 6 ºC) for the LaPaz basalts, and within the range set for low-Ti Apollo basalts by papike et al. [10] (1150 – 1350 ºC). The cooling rate of 5.2 ºC/day matches that found by Collins et al. [2], of between 2.4 and 48 ºC/day, for LaPaz basalts. This is also matched by the cooling estimate of ~6^{o}C/day from olivine zonations in LAP 04841 [11].

Shock Effects

The lack of maskelynite in LAP 04841,5 suggest that in this section, shock has been dissipated by the formation of imbricated melt veins (0.72 vol% of samples studied), displaying evidence of displacement, micro-faulting, and step-faulting of plagioclase, in particular. In all sections, pyroxenes display ondulatory to mosaic extinction, and shock-induced lamellae. Thus, a gradation of shock intensity can be mapped through the meteorite. The presence of both plagioclase and maskelynite in sections 14 and 18 suggests that pressures of deformation involved in the conversion of plagioclase to diaplectic glass are on the border of the 30-45 GPa vitrification range [12]. The mosaicism seen im pyroxenes is supposedly associated with pressures of 30-75 GPa [13]. Shock-melt veins indicate shock levels between 75-80 GPa. Hence, **the different effects observed testify to a range of deformation pressures of <30 GPa, where plagioclase has not been transformed, to >75 GPa, where shock melting has occurred.** The presence of shock-melt veins in LAP 04841,5, which contains no maskelynite, shows the full range of pressures is encountered within a few millimeters, and suggests complex controls on pressure dissipation within the meteorite.

References:

[1]http://meteorites.wustl.edu/lunar/moon_meteorites_list_alumina.htm [2] Collins et al. (2005). *LPS XXXVI*, Abstract # 1141 [3] Day et al. (2006). *GCA*, 70, 1581-1600. [4] *Antarctic Meteorite Newsletter*, vol. 29, No. 2, 2006. [5] Papike et al. (2004) *Am. Min.*, 89, 1557-1560. [6] Papike et al. (2003). *Am. Min*, 88, 469-472. [7] Zeigler et al. (2005). *Met. Plan. Sci.*, 40, 1073-1101. [8] Joy et al. (2005). *LPS XXXVI*, Abstract # 1697. [9] Taylor et al. (1975). *LSC VI*, 181-191. [10] Papike et al. (1998). *Reviews in Min*, 36, 5.1-5.234. [11] Onorato et al. (1978). *LPS XIX*, 613-628. [12] Ostertag et al. (1983) *LPS XXIV, 364-376.* [13] Schaal et al. (1979) *LPS X*, 2547-2571.