**MILLER RANGE 05035 AND METEORITE HILLS 01210: TWO BASALTIC LUNAR METEORITES, BOTH LIKELY SOURCE-CRATER PAIRED WITH ASUKA 881757 AND YAMATO 793169.**

R. A. Zeigler, R. L. Korotev, and B. L. Jolliff. Washington University in St. Louis, Campus Box 1169, Saint Louis, MO, 63130. zeigler@levee.wustl.edu.

**Introduction:** The lunar meteorites Miller Range 05035 (MIL) and Meteorite Hills 01210 (MET) were collected during the 2005 and 2001 ANSMET (Antarctic Meteorite Search) field seasons [1,2]. MET is a 22.8 g regolith breccia composed primarily of basaltic material [3-6]. MIL is a 142.2 g coarse-grained basalt [2]. The bulk composition, mineral assemblage, and texture of MIL is similar to lunar meteorites Asuka 881757 (A88) and Yamato 793169 (Y79), as are the reported mineral compositions [1]. The texture, mineral assemblage, and mineral chemistry of the basalt clasts in MET 01210 are also similar to Asuka/Yamato basalts. The bulk composition of MET is consistent with a mixture of Asuka/Yamato basalt and some moderately incompatible-trace-element (ITE) rich feldspathic material. It is likely that MET is also source-crater paired with A88 and Y79 (and MIL).

**Methods:** We determined the bulk composition of meteorites in this study by INAA (trace elements, Fe, Na) and EMPA (major elements) of fused beads made from the INAA samples. We analyzed 240 mg of MET and 423 mg MIL. EMPA (electron microprobe analysis) was also used to determine quantitative mineral compositions for MET.

**Petrography:** MET is a glassy matrix regolith breccia containing lithic clasts of basalt, gabbro, and plagioclase-rich impact-melt breccia, as well as abundant pyroxene, olivine, and minor plagioclase mineral clasts. Mafic mineral compositions in MET clasts are typically ferroan ($Fs_{25\text{-}83}Wo_{6\text{-}41}$; $Fo_{0\text{-}56}$; Figs. 1-2) and plagioclase compositions are moderately Na-rich ($An_{85\text{-}96}Or_{<0.9}$) [for more petrographic detail see 3-6]. MIL is an unbrecciated coarse-grained (2-3 mm) basalt consisting of pyroxene ($Fs_{31\text{-}55}Wo_{15\text{-}42}$), maskelynite ($An_{83\text{-}92}Or_{0\text{-}2}$), Fe-Ti oxide, and symplectite intergrowths [1]. The symplectite is principally composed of fayalite-silica-hedenbergite, with associated K-feldspar and Si-rich glass [1].

**Geochemistry:** MET 01210 has a bulk composition that is relatively rich (for a breccia) in elements associated with ferromagnesian minerals (16 wt% FeO; 54 ppm Sc; 1621 ppm Cr). Concentrations of incompatible trace elements are typical of basaltic samples (3.6 ppm Sm; 0.85 ppm Th). MIL is an Fe-rich basalt (21 wt% FeO) that also has high concentrations of Sc (93 ppm), but relatively low concentrations of Cr (1634 ppm), caused by the high proportion of high-Ca pyroxene and low proportion of olivine in MIL. ITE concentrations in MIL are near the low end of the range of basaltic lunar meteorites (2.8 ppm Sm; 0.45 ppm Th), and are one of the only basaltic lunar meteorites (along with A88, Y79, and NEA 003) that don't have an enrichment in light REEs [7].

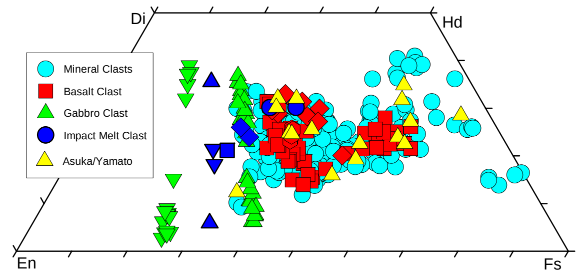


**Figure 1:** Pyroxene quadrilateral showing the composition of lithic and mineral clast pyroxenes in MET. Pyroxene compositions in each type of clast (e.g., basalt) are shown in a single color, whereas analyses from different clasts of the same type are shown as different shapes. For comparison, pyroxene compositions from A88 and Y79 are also shown [10-11].

**Discussion:** There is strong petrographic, geochemical, and isotopic evidence that the A88 and Y79 basaltic lunar meteorites are source crater paired and could be samples of the same lunar basalt flow [8-13]. The texture, mineral assemblage and compositions, and bulk composition of MIL are markedly similar to A88 and Y79, suggesting that MIL could be from the same basalt flow as A88 and Y79, and, thus, all were likely ejected from the Moon by a common impact. The

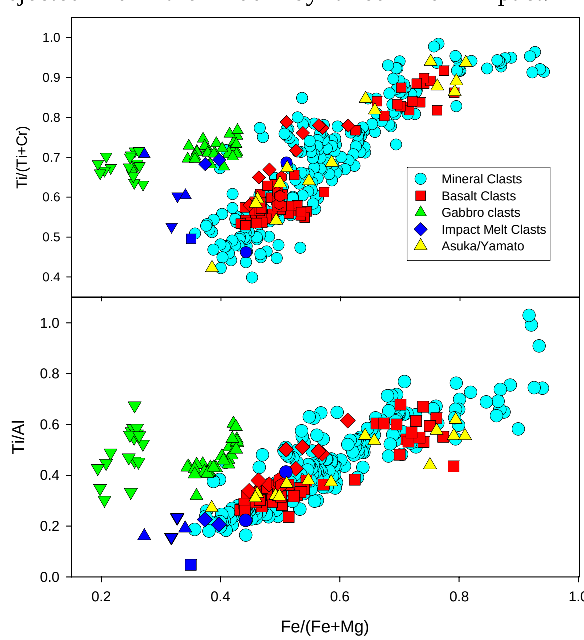


**Figure 2:** Non quadrilateral systematics in MET 01210 pyroxenes compared to A88 and Y79 pyroxenes [10-11]. Pyroxenes in the MET basalt and mineral clasts display nearly identical values as A88 and Y79 pyroxenes. Pyroxene analyses from MET gabbro clasts and many impact-melt clasts do not, however.

unique chemical composition of the MIL, A88, and Y79 basalts compared to other lunar basalts is further evidence that they are source-crater paired. There are four other brecciated basaltic lunar meteorites: NWA 3136, QUE 94281, EET 87521/96008, and Y 793274/981031. A strong case has been made that the latter three (hereafter YQE) are paired [14]. Figure 3 illustrates that despite some similarities, in detail the bulk composition of MET is dissimilar to both NWA 3136 (MgO, CaO, Cr, Th) and YQE (MgO, $TiO_2$, CaO, $Na_2O$, Th, Sc, Co). The bulk composition of MET and the major- and minor-element systematics of MET pyroxenes (both in the basalt clasts and pyroxene mineral clasts) are similar to the A88 and Y79 basalts (Figs. 1-2), an idea first advanced by Arai et al. [4]. The bulk composition of MET is consistent with A88/Y79 basalt that has been diluted by approximately 35% feldspathic material. The feldspathic component in MET has a composition that is intermediate to Apollo 16 soil [15] and the average composition of the feldspathic lunar meteorites [16].

**References:** [1] *Antarctic Meteorite Newsletter*, Vol. 27, No. 1, 2004. [2] *Antarctic Meteorite Newsletter*, Vol. 29, No. 2, 2006. [3] Zeigler R.A. et al. (2005) *LPS 36*, Abstract #2385. [4] Arai T. et al. (2005) *LPS 36*, Abstract #2361. [5] Huber H. and Warren P.H. (2005) *LPS 36*, Abstract #2401. [6] Day J.M.D. et al. (2006) *GCA 70*:5957-89. [7] Korotev R.L. (2007) *LPS 38* (Lunar Meteorites). [8] Jolliff B.L. et al. (1993) *18th NIPR Symp. Ant. Mets.* 214-17. [9] Warren P.H. and Kallemeyn G.W. (1993) *Proc. NIPR Symp. Ant. Met. 6*: 35-57. [10] Takeda H. et al. (1993) *Proc. NIPR Symp. Ant. Met. 6*: 3-13. [11] Koeberl C. et al. (1993) *Proc. NIPR Symp. Ant. Met. 6*: 14-34. [12] Torigoye-Kita N. et al. (1993) *GCA*, **59**:2621-32. [13] Fernandes V.A. (2005) *LPS 36*, Abstract #1002. [14] Korotev R.L. et al (2003) *Ant. Met. Res.16*: 152-75. [15] Korotev R.L. (1997) *MAPS 32*: 447-78. [16] Korotev R.L. et al al. (2003) *GCA 67*: 4895-923. **Acknowledgements:** We would like to thank the Johnson Space Center meteorite curation facility for providing the MET 01210 and MIL 05035 samples and the National Institute of Polar Research, Tokyo for providing the Asuka 881757 and Yamato 793169 samples. This work was supported by NASA grant NNG04GG10G.

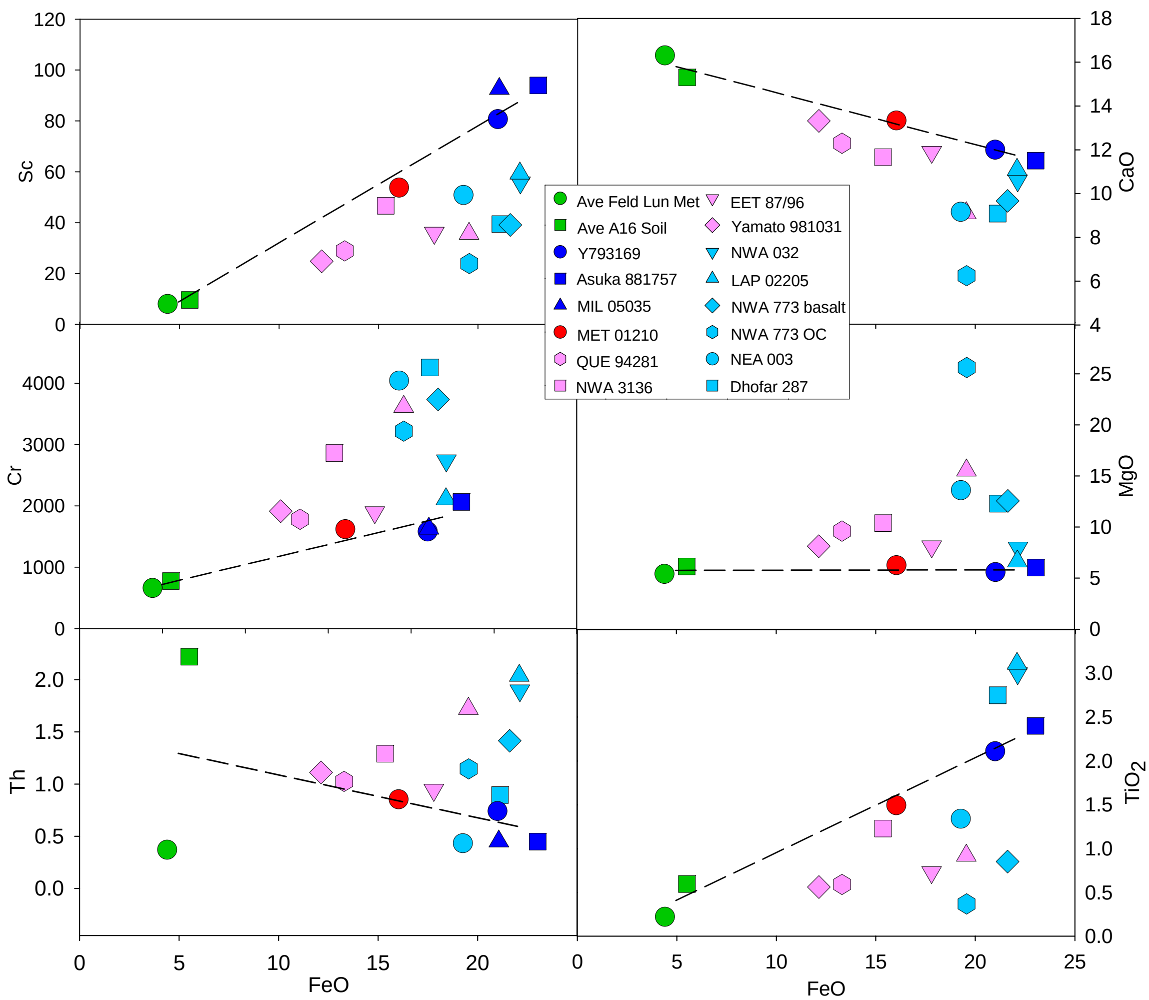


**Figure 3:** Average compositions of 15 basaltic lunar meteorites (all data from this lab) showing the similarity of MIL to A88 and Y79. The dashed line is a mixing line between the average composition of A88 and Y79 and an average of Apollo 16 soils [15] and feldspathic lunar meteorites [16]. In every case, MET falls on or very near this mixing line, suggesting that MET is composed primarily of A88/Y79 basalt (~65%), that has been diluted by some moderately ITE-enriched (relative to feldspathic lunar meteorites) feldspathic component.