Sm-Nd AND Rb-Sr AGES FOR MIL 05035: IMPLICATIONS FOR SURFACE AND MANTLE SOURCES.
L. E. Nyquist[1], C-Y. Shih[2], and Y. D. Reese[3], [1]Mail Code KR, NASA Johnson Space Center, Houston, TX 77058, laurence.e.nyquist@nasa.gov, [2]Mail Code JE-23, ESCG/Jacobs Sverdrup, P.O. Box 58477, Houston, TX 77058, chi-yu.shih@nasa.gov, [3]Mail Code JE-23, ESCG/Muniz Engineering, Houston, TX 77058, young.reese@nasa.gov.

Introduction: The Sm-Nd and Rb-Sr ages and also the initial Nd and Sr isotopic compositions of MIL 05035 are the same as those of A-881757 [1]. Comparing the radiometric ages of these meteorites to lunar surface ages as modeled from crater size-frequency distributions [2,3] as well as the TiO_2 abundances and initial Sr-isotopic compositions of other basalts places their likely place of origin as within the Australe or Humboldtianum basins. If so, a fundamental west-east lunar assymmetry in compositional and isotopic parameters that likely is due to the PKT is implied.

Sm-Nd age: The Sm-Nd age ($T_{Sm\text{-}Nd}$) = 3.80±0.05 Ga for MIL 05035 (Fig. 1) and agrees within mutual error limits with $T_{Sm\text{-}Nd}$ = 3.87±0.06 Ga for A-881757 [1]. Initial ε_{Nd} = +7.2±0.4 for MIL 05035 compared to +7.4±0.5 [1] for A-881757.

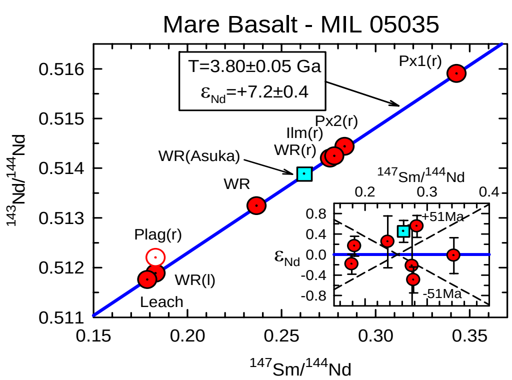

Figure 1. Sm-Nd isochron for MIL 05035, excluding the Plag(r) analysis. A whole rock analysis of A-881757 also lies very close to the MIL 05035 isochron.

Rb-Sr age: The isochron values are $T_{Rb\text{-}Sr}$ = 3.90±0.04 Ga and I_{Sr} (initial $^{87}Sr/^{86}Sr$) = 0.699089±0.000014 (Fig. 2). The Rb-Sr age reported by [1] for A-881757 is 3.89±0.03 Ga when adjusted to $\lambda(^{87}Rb) = 1.402 \times 10^{-11}\ y^{-1}$ in excellent agreement with the MIL 05035 value. I_{Sr} = 0.69910±0.00002 for A-881757 [1] also agrees well with the MIL 05035 value.

Discussion: The Sm-Nd and Rb-Sr data as well as Sm-isotopic data not given here suggest that MIL 05035 and A-881757 are isotopically identical. The internal Pb-Pb isochron age reported by [1] for A-881757 was 3.94±0.03 Ga, whereas the $^{39}Ar\text{-}^{40}Ar$ age was 3.80±0.01 Ga. Recent $^{39}Ar\text{-}^{40}Ar$ age measurements [4] gave younger ages of 3.69±0.07 Ga for A-881757 and 3.71±0.11 Ga for Yamato-793169, thought to be launch-paired with A-881757. Y-

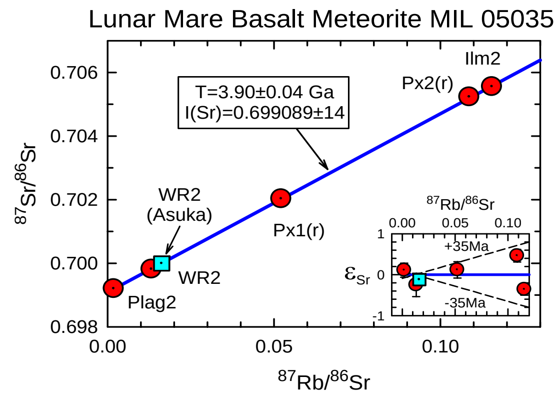

Figure 2. Rb-Sr isochron for MIL 05035. A whole rock analysis of A-881757 falls on the same isochron.

793169 shows strong evidence for Ar degassing in a major impact ~430 Ma ago [4]. We use ~3.80 Ga as the age of MIL 05035 and the other "YAM" (Yamato\Asuka\Miller Range) basalts, but note that the ~3.90 Ga Rb-Sr age, or the ~3.94 Pb-Pb age of A-881757 [1] may more accurately give the crystallization age(s).

Old (~3.7-3.9 Ga) mare basalts are found among the Apollo 11 and 17 Hi-Ti basalts, but the low TiO_2 abundances of the YAMs make a Tranquilitatis or Serenitatis origin unlikely. Crater size-frequency ages [2,3] make the maria Humorum, Humboldtianum, and Australe their most probable places of origin among the nearside maria [4]. We prefer the pre-Nectarian Australe basin, specifically units A1 or A2 (3.80-3.88 Ga) of [2]. Our second preference is for units HU2 and HU3 (~3.77 Ga [2]) in Mare Humboldtianum. An origin within units H6 (3.46/3.75 Ga [2]) or H7 (3.45/3.94 Ga [2]) of Mare Humorum is permitted by

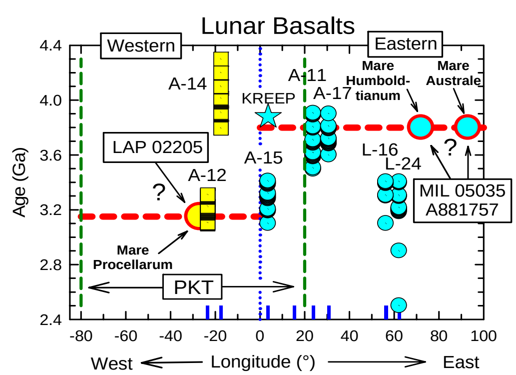

Figure 3. Lunar basalt ages vs. lunar longitude of known or estimated sampling sites.

the age data, but seems less likely for reasons given below.

Lunar basalt ages [5] are plotted vs. the longitude of the known or estimated (YAM, LAP 02205 [6]) sampling sites in Fig. 3. Comparing Fig. 3 to Fig. 12 of [2] summarizing mare basalt ages by the crater size-frequency method shows both similarities and differences. Crater size-frequency ages are lacking for cryptomaria corresponding to some A14 breccia clast ages, and Luna 16 and Luna 24 sampling sites, i.e., the maria Fecunditatis and Crisium, respectively. The sampled L-24 basalts are VLT basalts with TiO_2 abundances about half the TiO_2 abundances of the YAM basalts (Fig. 4.). TiO_2 in Mare Crisium ranges ~1-8% [7]. Candidate surface units for the YAMs in Mare Humorum [2] correspond to spectral units hDSP and mISP of [8] with estimated TiO_2 of ~3.5-5.0 and <~3 wt. %, resp. More recent estimates for the same areas [7] are ~8-9 and ~5-8 wt. %, resp.; higher than TiO_2 ~ 2 wt. % for the YAMs [9]. Also, the Humorum basin lies within the boundaries of the Procellarum KREEP Terrain (PKT) [10], and basalts from the PKT have relatively high I_{Sr} values in contrast to the YAM and L-24 basalts.

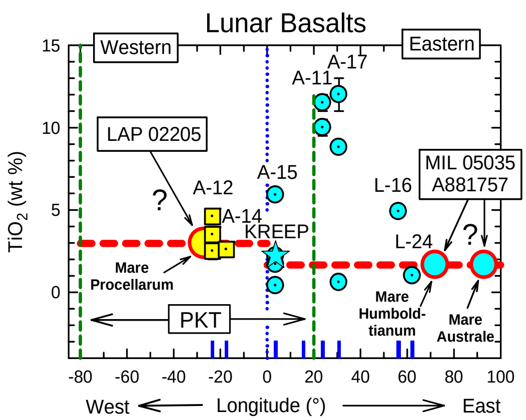

Figure 4. TiO_2 contents of lunar basalts vs. longitude of known or estimated sampling sites.

Fig. 5 summarizes information obtained by converting I_{Sr} values to source region $^{87}Rb/^{86}Sr$ ratios via a 2-stage model. Low I_{Sr} for MIL 05035 and A-881757 shows derivation from a lunar mantle source with a low Rb/Sr ratio compared to the sources of basalts sampled during the Apollo missions. Similarly low source region Rb/Sr ratios were found only for basalts from the eastern maria Fecunditatis and Crisium sampled by the Luna 16 and Luna 24 missions [11, 12].

The YAM basalts differ from the L-24 basalts by having higher ε_{Nd} values. As for the I_{Sr} data, the ε_{Nd} values may be used to estimate 2-stage model source region $^{147}Sm/^{144}Nd$ ratios (Fig. 6). Those data show the mantle source of the YAM basalts to be very LREE-depleted. Thus, the YAM source was deficient in

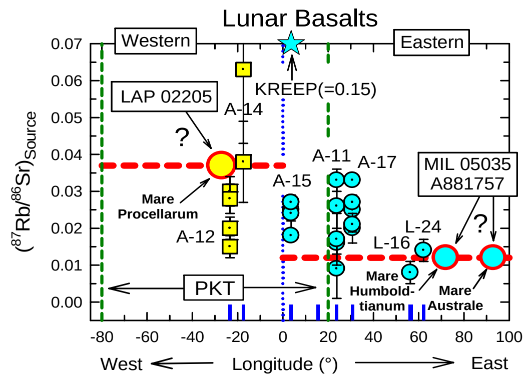

Figure 5. Estimated source $^{87}Rb/^{86}Sr$ for lunar basalts vs. longitude of known or estimated sampling sites.

LREE as well as K-correlated Rb, both characteristic of the urKREEP lunar differentiate. Also, the YAM source is characterized by very low $^{238}U/^{204}Pb$ [1].

Conclusions: The YAM basalts are the products of early melting of sources composed mainly of olivine and orthopyroxene [1], early cumulates in a magma ocean model. The absence of urKREEP from their sources suggests that melting was not due to radiogenic heating. The probable absence of urKREEP-enriched reservoirs beneath the eastern maria suggests an assymmetry in lunar mantle compositions related to the PKT.

References: [1] Misawa K. et al. (1993) *GCA, 57,* 4687-4702. [2] Hiesinger H. et al (2000) *JGR, 105,* 29,239-29,275. [3] Hiesinger H. et al. (2003) *JGR, 108 (E7) 5065,* 1-1 to 1-27. [4] Fernandes V. A. et al. (2005) *LPS XXXVI,* Abstract #1002. [5] Nyquist L. E. et al. (2001) *The Century of Space Science*, Kluwer, 1325-1376. [6] Nyquist L. E. et al. (2005) *LPS XXXVI,* Abstract #1374. [7] Bussey D. B. J. and Spudis P. D. (2000) *JGR 105,* 4235-4243. [8] Pieters C. (1978) *PLPSC9,* 2825-2849. [9] Arai T. (1996) *Meteoritics & Planet. Sci., 31,* 877-892. [10] Jolliff B. L. et al. (2000) *JGR, 105,* 4197-4216. [11] Papanastassiou D. A. and Wasserburg G. J. (1972) *EPSL, 13,* 368-374. [12] Wasserburg G. J. et al. (1978) *Mare Crisium: The View from Luna 24,* 675-678.

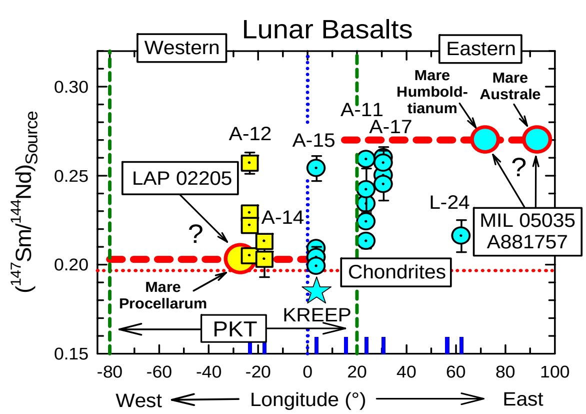

Figure 6. Estimated source region $^{147}Sm/^{144}Nd$ for lunar basalts vs. longitude of known or estimated sampling sites.