THE LYNCH 002 LUNAR METEORITE REVISITED. K. L. Robinson[1*], C. L. Smith[2], A T. Kearsley[2], A. W. R. Bevan[3], and M. Anand[1,2]. [1] Department of Physical Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA UK. [2]Department of Mineralogy, The Natural History Museum, Cromwell Road, London, SW7 5BD UK. [3]Department of Earth and Planetary Sciences, Western Australian Museum, Locked Bag 49, Welshpool DC, Western Australia 6986, Australia. *katie.robinson@open.ac.uk.

Introduction: Lunar meteorite Lynch 002 was discovered in Western Australia in 2010 [1]. Only two abstracts providing general petrography and bulk O isotope data [1] and bulk/trace element neutron activation data [2] have been published to date about this sample. Here, we present preliminary data from a more comprehensive study of Lynch 002.

Lynch 002 is a fine-grained, complex regolith breccia that has experienced some terrestrial alteration [1,2]. Based on the fine grain size and the presence of glass spherules and agglutinates [1], it likely formed from relatively mature regolith. Korotev [2] noted that it is rich in Fe for a brecciated meteorite (~9 wt.%) and unusually rich in light rare earth elements.

Lynch 002 contains many lithic fragments including mare basalts, KREEP-rich material, and feldspathic material, as well as remnants of pyroxferroite [1]. Other important features of Lynch 002 include melt veins cutting through the sample, and cracks infilled by terrestrial carbonate [1]. For this work we focus primarily on the basaltic clasts, but mineral fragments are also abundant [1].

Mare basalt clasts: Lynch 002 contains several basalt fragments with a variety of sizes and textures. All are small (< ~500 μm). We report preliminary mineralogical data from eight mare basalt clasts (Lithics 1, 4, 5, 8, 11, 12, 20, and 33) here. These basalts range in size from ~100 to ~500 μm. Most have subophitic textures with strongly zoned pyroxenes, although another fragment (Lithic 12, Fig. 1B) has an olivine phyric texture (though this could be a recrystallized impact melt). Grain sizes vary from 100+ μm long in Lithic 1 and 11 (Fig. 1C, D), to < 20 μm in Lithics 5 and 12. Lithic 1 is unusual in that about ~20 % of the clast consists of elongate silica grains (Fig. 1C), though silica is found in several of the other basalt fragments. High Z phases include ilmenite and FeS.

Mare basalt chemistry. All basaltic clasts found in Lynch 002 so far contain strongly zoned pyroxenes (e.g. $En_{72}Fs_{22}Wo_{6}$ to $En_{20}Fs_{59}Wo_{21}$ in Lithic 4). Fig. 2 shows the compositions of pyroxene from 7 basaltic clasts on the pyroxene quadrilateral. Lithic 5 is the most magnesian and has a more limited range of Fe than the other clasts. Olivine in Lithic 12 is Mg-rich (Fo_{82-86}), but data are lacking for the Fe-rich rims.

Lunar basalts are classified by bulk TiO_2 abundance. We can classify the basalts found in Lynch 002 by comparing the molar Fe/(Mg+Fe) versus molar Ti/(Ti+Cr) of their pyroxenes with similar data from Apollo basalts, after [3-5]. The results are shown on Fig. 3. All of the basaltic clasts identified so far in Lynch 002 plot in the low-Ti field or between the low-Ti and very low Ti (VLT) fields.

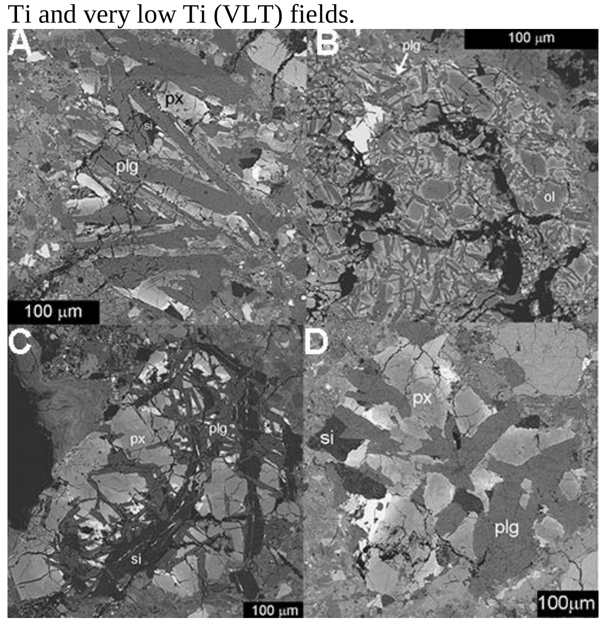

Fig. 1. Textural diversity of basalt clasts in Lynch 002. ol=olivine, px=pyroxene, plg=plagioclase, si=silica. Scale bars are all 100 μm. (A) Lithic 4. This is the most common basalt texture observed in Lynch 002. (B) Olivine-phyric lithic 12. (C) Silica-rich basalt Lithic 1. (D). Lithic 11 is the coarsest grained basalt in Lynch 002.

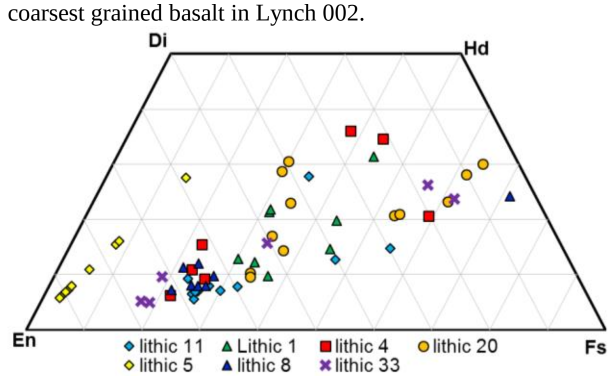

Fig. 2. Pyroxene composition in 7 basaltic clasts in Lynch 002.

TiO_2 abundance of parental lava flows. With the distribution coefficient D(TiO_2)(px/bas) and the TiO_2 abundance of the earliest formed (most magnesian) pyroxene, we can model the bulk TiO_2 content of the parental magma of the basaltic fragments [3]. The equation used (defined in [3]) is:

$$D(TiO_2)(px/bas) = [0.0148 \times (CaO_{pyx}) + 0.09 \pm 0.05\ (2\sigma)$$

The TiO_2 contents of our inferred parent magmas for Lynch 002 mare basaltic clasts range from ~1.5 to ~4 wt. %. The magmas sampled by Lithics 5, 8, and 33 have similar TiO_2 content of ~1.5 wt. %. Lithics 1, 11, and 20 have TiO_2 contents between 2-3 wt. %, while the source of Lithic 4 has the highest inferred TiO_2 abundance at ~4 wt. %. This variation could show that multiple lava flows with diverse TiO_2 contents were sampled by Lynch 002. There are still several basaltic fragments we have not yet analyzed, so even more flows may have been sampled.

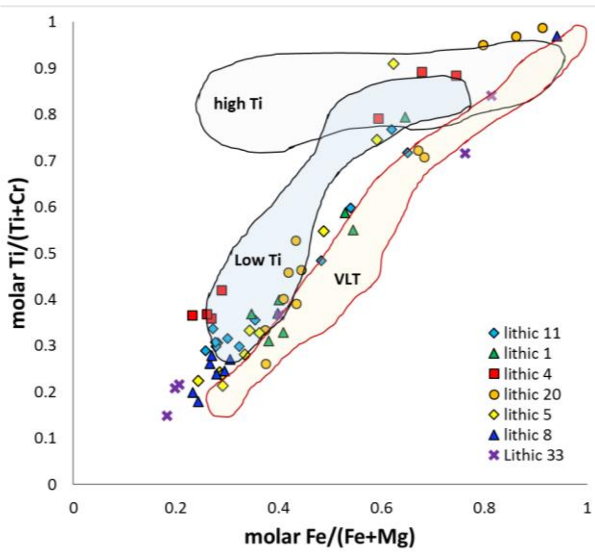

Fig. 3. Molar Ti/(Ti+Cr) vs. molar Fe/(Fe+Mg) plot for 7 basalts in Lynch 002. Apollo data [6-8] is denoted by fields. All the basalts identified in Lynch 002 thus far are low-Ti basalts.

Possible chondrule fragment: Meteoric fragments have previously been reported in lunar samples [9]. Lithic 38 was noted as unusual during the initial characterization of Lynch 002 by C. Smith and A. Kearsley (Fig. 4). Texturally, this clast resembles a fragment of a porphyritic olivine chondrule with glassy mesostasis. The large bright grain consists of FeS, with several small blebs of FeNi near one edge. Initial electron microprobe analysis of the cores of the olivine shows that it has an average composition of Fa_{15}. The preservation of zoning in the olivines and the presence of the glassy mesostasis suggest that *if* Lithic 38 is a chondrule fragment, its potential source is an unequilibrated ordinary chondrite.

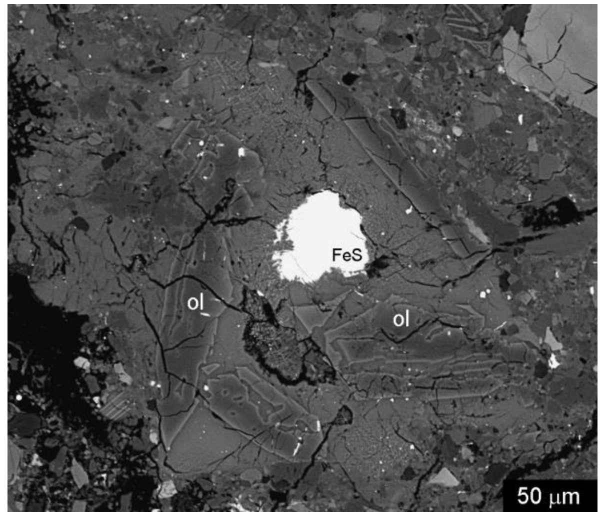

Fig. 4. BSE of Lithic 38, a potential chondrule fragment. The zoning of the skeletal olivines suggests that *if* it is non-lunar it may come from an unequilibrated ordinary chondrite.

Preliminary Conclusions: Lynch 002 is a very complex breccia. The mare basalt fragments studied thus far are all low-Ti basalts, likely originating from multiple lava flows containing ~1.5 to 4 wt. % TiO_2. However, the presence of KREEP-rich clasts [1] indicates that Lynch 002 probably originated from the near side, somewhere within the Procellarum KREEP Terrane. Lynch 002 may also contain a fragment of a porphyritic olivine chondrule, but this remains to be confirmed.

References: [1] Smith C.L. et al. (2012) *75th Met. Soc.*, Abstract #5137. [2] Korotev R.L. (2013) *76th Met. Soc.*, Abstract #5021. [3] Robinson K.L. et al. (2012) *Meteor. Planet. Sci. 47*, 387-399. [4] Nielsen R.L. & Drake M.J. (1978) in *Mare Crisium: The View from Luna 24*, 419-428. [5] Arai T. et al. (1996) *GCA 70*, 877-892. [6] Bence A.E. & Papike J.J. (1972) *Proc. LS III*, 431-469. [7] Dymek R.F. et al. (1975) *Proc. LS VI*, 49-77. [8] Vaniman D.T. & Papike J.J. (1977) *Proc. LS VIII*, 1443-1471. [9] Joy K.H. et al. (2012) *Science* 336, 1426-1429.

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