Lunar Meteorite EET96008: Paired with EET87521, but Rich in Diverse Clasts.

Paul H. Warren and Finn Ulff-Møller, Institute of Geophysics, UCLA, Los Angeles, CA 90095 (pwarren@ucla.edu)

We have studied the bulk composition and petrology of the EET96008 lunar meteorite [1]. This fragmental breccia consists of nearly pure Ti-poor (VLT) mare basalt, and all signs indicate pairing with EET87521 [2]. However, the studied thin section is rich in diverse clasts, including a highland impact melt breccia.

We divided our original allocation of two chips into numerous smaller ones, and have thus far analyzed, using INAA, five chips with masses of 76-103 mg. All five have bulk compositions remarkably similar to EET87521 [2,3]. The resemblance to EET87521 extends to mineralogy and texture, including unusually extensive (by mare standards) exsolution of the pyroxenes. Fig. 1 is a BSE view of some especially coarse lamellae. The minerals show EET87521-like minor element trends, such as low Ti# ($\equiv$ molar Ti/[Ti+Cr]) in pyroxenes (Fig. 2). The "generic" pyroxene Ti# trend indicates the parent basalt was a Ti-poor (VLT) type with only about 0.8 wt% TiO_2 (calibration of [4]).

Our new data allow us to further test the hypothesis (tentatively rejected by [4]) that EET87521/96008 is launch paired with the Y793274 and QUE94281 (YQ) lunar regolith breccia meteorites. The YQ meteorites, albeit probably not paired in the conventional (entry) sense, are very probably a launch pair, based on general compositional-mineralogical similarity [4,5], and especially because they contain the same two mare pyroclastic glass types [4]. Like the EET lunaites (lunar meteorites), the YQ meteorites are dominated by Ti-poor mare basalt with unusually extensive pyroxene exsolution. Previous work has noted, however, that compared to the YQ mare component EET87521 has lower contents of V and to a lesser degree Cr [4]. Our new data manifest some additional differences between the EET and YQ lunaites. Figs. 3 and 4 include literature data for EET87521 and the YQ meteorites from a variety of sources [2-5 and many references in 4]. In Fig. 3, Na concentration appears higher (wtd. mean 2.9 mg/g) in EET than in the extrapolated (18% FeO) YQ mare component, which has only about 2.15 mg/g [4]. Fig. 4 shows a positive Sc vs. Eu correlation among EET analyses, and significantly higher Eu in EET (wtd. mean 0.89 µg/g) than in the extrapolated (42 µg/g Sc) YQ mare component, which has only about 0.63 mg/g [4].

Clast 96h (Fig. 5; the fine-grained clast's shape resembles a filled-in "∞") is of highland impact melt origin, much like clast H of EET87521 [2]. Like EET87521, EET96008 is nearly pure mare material. Nonetheless, the mode of 96h, determined with the aid of digital processing of BSE images, features 73 vol% feldspar (dark grey in Fig. 5), 26% mafic silicates (pyroxene + possibly minor olivine), 1% silica, and <<1% opaques, including ilmenite, Cr-spinel, kamacite and FeS; cf. clast H, 74% feldspar, 25% mafic silicates (pyroxene) and 1% opaques. In 96h, feldspar compositions are $An_{88.9-95.6}$, olivines cluster at Fo_{67}, and pyroxenes mainly cluster at $En_{61-70}Wo_{3.5-9}$. The highland affinity of these clasts is confirmed by high Ti# in their pyroxenes (Fig. 2; cf. Fig. 7 of [3]).

Clasts 96g1 and 96g2 are very similar to one another. Fig. 6 is a BSE view of 96g1; 96g2 is bigger (1.1 mm across, despite truncation by an edge of the PTS) with

slightly more diverse grain sizes. In both cases, the mode has about 40 vol% pyroxene, 40% olivine, 20% silica, and a trace of FeTi-oxide. Feldspar is completely absent, even though several hundred individual small silicate grains are sampled in each clast. The textures are fine grained and granular, with polygonal, equant grains.

Clasts 96g1 and g2 are enigmatic, but they probably originated as pyroxferroite, which is metastable at pressures of <1 GPa [6]. Among Apollo mare basalts, pyroxferroite occurs mainly as a late-stage mineral, finely intergrown with other phases including feldspar and opaques, and/or mantling extensively zoned pyroxenes [7]. In contrast, 96g1 and g2 seem to be isolated large equant masses. However, relatively slow cooling apparently can lead to larger pyroxferroites, as in 12021. Cooling to 900°C must occur in less than about three days if metastable pyroxferroite is to survive [6]. Slower cooling causes pyroxferroite to break down into an olivine:pyroxene:silica assemblage, in volume proportionality $\approx$ 40:40:20. This scenario probably applies to 96g1 and g2. However, slow cooling was not necessarily the immediate aftermath of igneous crystallization. Break-down of the pyroxferroite was conceivably a shock-metamorphic reaction, or else a more indirect impact product, caused by annealing of the EET lunaites within a cryptomare (as tentatively suggested, to engender the pyroxene exsolution in EET87521 and/or YQ, by [4]).

Clast 96e is an extraordinarily evolved lithology. It outcrops only as a 1.8 mm long selvage along an edge of EET96008,37. Its mode has 97 vol% plagioclase (An_{76-86}), 1.4% extremely ferroan pyroxene ($En_{1.1-3.9}Wo_{39-44}$), 1.2% silica, 0.4% olivine ($Fa_{98.8}$), 0.2% phosphate (mainly a single 55 µm long lath), with minor K-feldspar (average $Or_{76}Ab_{18}An_6$, in a fine-scale intergrowth with silica) and traces of ulvöspinel, zircon and FeS. The significance of this mode is severely compromised by the limited outcrop. Moderate shock effects further complicate matters, but the original texture appears to have been medium grained, and the number of separate plagioclase crystals sampled appears to be ≥4 and probably <7, with largest dimension (truncated at edge of the PTS) >0.6 mm.

At face value, the mode of clast 96e implies a highland origin, possibly as an extreme variant of the ferroan anorthositic suite, or a variant of the alkalic suite. But it seems about equally likely that the mode is unrepresentative, and 96e is a derivative of mare basalt, perhaps the same Ti-poor mare basalt that dominates the EET lunaite bulk composition. The EET lunaites have uncommonly high bulk-rock Fe# ($\equiv$ molar Fe/[Fe+Mg]), even by mare standards, and the parent mare magma may have undergone an unusual degree of differentiation. Possibly the thermal evolution was disturbed by involvement in a cryptomare, as tentatively inferred for YQ [4], but the slow subsolidus cooling implied by the extensive pyroxene exsolution (also suggested by the decomposed pyroxferroites in 96g1 and 96g2) might reflect origin in a thickly ponded flow or even a shallow intrusive. In such a setting, slow igneous cooling would enhance the potential for extreme differentiation. However, to reconcile this mare-origin hypothesis with the mode of 96e, it must be assumed that the mode is *grossly* unrepresentative, and/or that the parent mare magma man-

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aged even in its late-stage evolution to locally accumulate (float?) plagioclase.

Together, the typical coarse pyroxene exsolution, the two decomposed coarse pyroxferroite clasts, and the extremely evolved composition of clast 96e, all hint (yet only hint) at origin of the dominant mare component of the EET87521/96008 breccia in either a shallow intrusion or else an unusually deep-ponded flow.

References: [1] McBride K. & Mason B. (1998) *AMN* **21**, 12. [2] Warren P. H. & Kallemeyn G. W. (1989) *GCA* **53**, 3323-3330. [3] Warren P. H. & Kallemeyn G. W. (1991) *PSAM* **4**, 91-117. [4] Arai T. & Warren P. H. (1999) *MPS*, in press. [5] Jolliff B. L. et al. (1998) *MPS* **33**, 581-601. [6] Lindsley D. H. et al. (1972) *LS* **III**, 483-485. [7] Frondel J. W. (1974) *Lunar Mineralogy*.

Fig. 1 BSE image of unusually coarse exsolution in EET96008 pyroxene.

Fig. 2 EET96008,37 pyroxenes

Fig. 3

Fig. 4

Fig. 5

Fig. 6