COMPOSITIONAL CHARACTERISTICS AND PETROGENETIC RELATIONSHIPS AMONG THE NWA 773 CLAN OF LUNAR METEORITES. B. L. Jolliff, R. A. Zeigler, and R. L. Korotev, Department of Earth and Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130 (blj@wustl.edu)

Introduction and background: Lunar meteorites continue to provide new and diverse samples from the Moon. Among those that differ significantly from known rocks of the Apollo collection are Northwest Africa (NWA) 773 and other recent finds that are likely paired with it, including NWA 2700, NWA 2727, NWA 2977, NWA 3160, and probably another recently recovered but as yet unnamed NWA stone [1-4]. This group, which we refer to herein as the NWA 773 clan, contains a distinctive olivine-gabbro cumulate (OGC) lithology as well as an olivine-phyric basalt (OPB), immature, mafic regolith and fragmental breccia, and other less abundant lithic components, including one with lower FeO and one with high FeO and significantly elevated incompatible-element concentrations.

The olivine-gabbro cumulate of NWA 773 has been studied extensively [e.g., 5,6] and bears additional significance as one of the youngest lunar igneous rocks (~2.8 Ga) whose crystallization age is well determined [7,8]. From our analysis of the cumulate in NWA 773, we concluded that the OGC formed in a shallow intrusive setting from olivine accumulation. Its unusual chemistry, including very low Ti (VLT) and high Mg, coupled with very low Eu and na, and relatively enriched LREE [9,6], indicated a petrogenetic relationship with green volcanic glass as sampled at the Apollo 14 site, specifically green glass B, type 1 [6], which has an extremely low Eu concentration and a relative enrichment of the LREE [10]. These characteristics are uncommon among lunar VLT compositions. We previously called attention to the apparent petrogenetic association between the OGC and KREEP [9,6], and isotopic characteristics further confirm this connection [11].

We have also argued that the breccia that accompanies NWA 773 OGC, which shares these compositional traits but is enriched in somewhat more fractionated components, could be regolith developed from basalt related to the OGC that erupted to the surface, plus clasts of the underlying OGC, i.e., guilt by association (in addition to compositional arguments). The new paired stones provide another potentially key piece of the puzzle; in addition to OGC and breccia, they also contain large and well preserved clasts of olivine-phyric basalt [12]. Again, guilt by association and compositional similarities suggest a petrogenetic relationship. Here, we test the hypothesis that a petrogenetic relationship exists between OGC, OPB, and the breccia that occurs in the NWA 773 clan. We can only say if a petrogenetic relationship is possible; an age determination on the OPB is needed for confirmation (see [13]).

Compositional systematics: All of the individual sample splits that we have analyzed and the inferred average lithology compositions have high Fe concentrations (18-23 wt% FeO), including the breccia (Fig. 1). Concentrations of TiO_2 in OGC and OPB, and in most of the breccia subsamples are <1 wt%. Ni and Co concentrations are high, owing to the abundance of Ni- and Co-rich olivine. What really sets these lithologic components apart from other lunar basalts, however, is their relative LREE enrichment and high Sm/Eu (Fig. 2). Sm

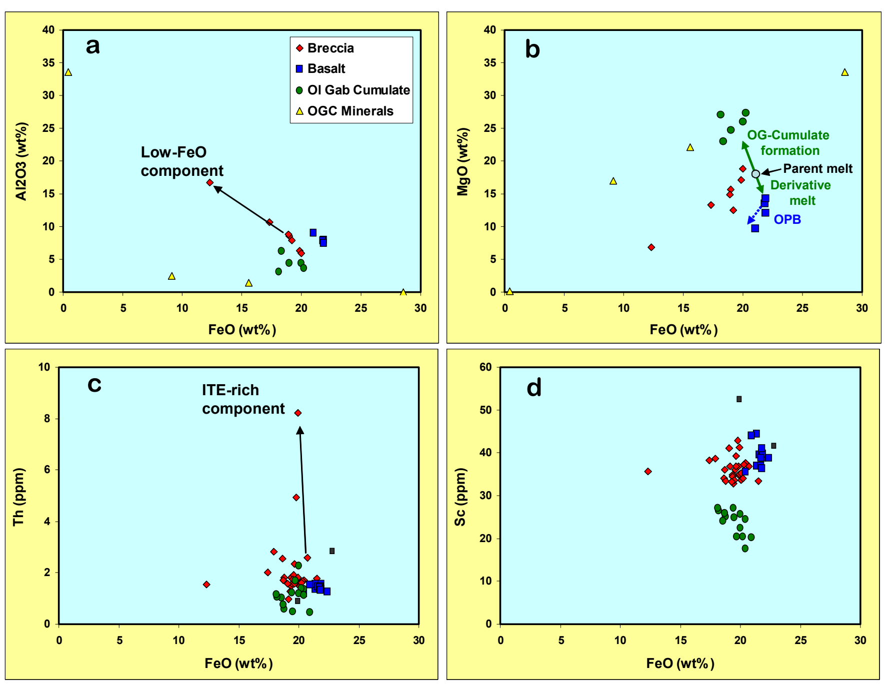

Figure 1. Compositional plots for the NWA 773 "clan" of lunar meteorites. (b) shows inferred petrogenetic relationship between OGC and OPB (as a derivative melt). Blue arrow shows the effect of olivine crystallization on basalt composition. OGC minerals in (a) and (b) are averages for plagioclase, augite, pigeonite, and olivine, for reference.

and Eu concentrations lie more-or-less along a line between Apollo 14 Green glass type B and KREEP.

From compositional variability among subsamples of the NWA 773 clan, we can address the compositions of the main endmember components in the breccia. The two main components are the OGC and OPB. There is also a lower-FeO component (modeled as FeO ~12.3 wt%, Al_2O_3 ~16.7 wt%,) and an FeO- and incompatible-element-rich component (modeled as FeO ~19.9 wt%, Th ~8 ppm) (see Fig. 1). Using these as compositional mixing components, a linear least-squares mixing model suggests that the breccia consists of some 60% OPB, 26% OGC, and about 7% each of the other two components, on average. The lower FeO component has a gabbroic normative composition (CPx-rich), and the incompatible-element-rich component has a basaltic (or ferrogabbro) composition. Both of these share the compositional traits that distinguish the NWA 773 clan.

Petrogenetic relationships: The scenario proposed by [6] for petrogenesis of NWA 773 OGC involved a parent melt similar to Apollo 14 green glass B1, incorporation of an additional but small proportion of a KREEP component, intrusion to near the surface, and shallow, slow crystallization, beginning with olivine accumulation. The major- and trace-element composition of OPB is consistent with extraction of the same or a similar melt to the one that gave rise to OGC, following some 20% crystallization of olivine and eruption to the surface. The olivine phenocrysts in OPB are very similar in composition to the OGC cumulus olivine.

The low FeO component, sampled in one of the splits of NWA 773, is plausible as a plagioclase-rich fraction (excess plagioclase) of the contemporary melt of OGC and OPB because it has significantly higher Al_2O_3 than expected for a derivative melt. It has an almost identical REE pattern to OPB; however, it does not exhibit elevated Eu or sufficiently elevated Na as expected for a plagioclase-rich fraction from this melt. Thus, it may be related to a separate lithologic component, but it must be one with plagioclase that is low in Na and Eu.

The ITE-rich breccia subsamples have major- and trace-element compositions that are approximately consistent with intercumulus melt, whose composition is determined as the complement of 85% of cumulus minerals, mostly olivine and pyroxene, of OGC. This component appears to be present in subsamples of NWA 3160 as a coarse-grained breccia that occurred on one side of our sample, but it may be present as a finely brecciated and cryptic component in subsamples of NWA 773 that are also slightly enriched in incompatible elements relative to OGC and OPB. This ITE-rich lithology occurs separately from OGC, thus it may have formed as a significant accumulation or segregation of trapped melt within the OGC intrusive body or one like it.

Conclusions: On the basis of geochemical and mineral-chemical similarities, we conclude that a petrologic relationship is plausible between the olivine-gabbro cumulate and olivine-phyric basalt in the NWA 773 clan. Both of these are plausibly related to Apollo-14-like green glass as a parent melt. That association and the young age of the cumulate (and of the basalt [13]) are consistent with an origin in the Procellarum KREEP Terrane, which experienced an extended period of volcanism compared to the rest of the Moon.

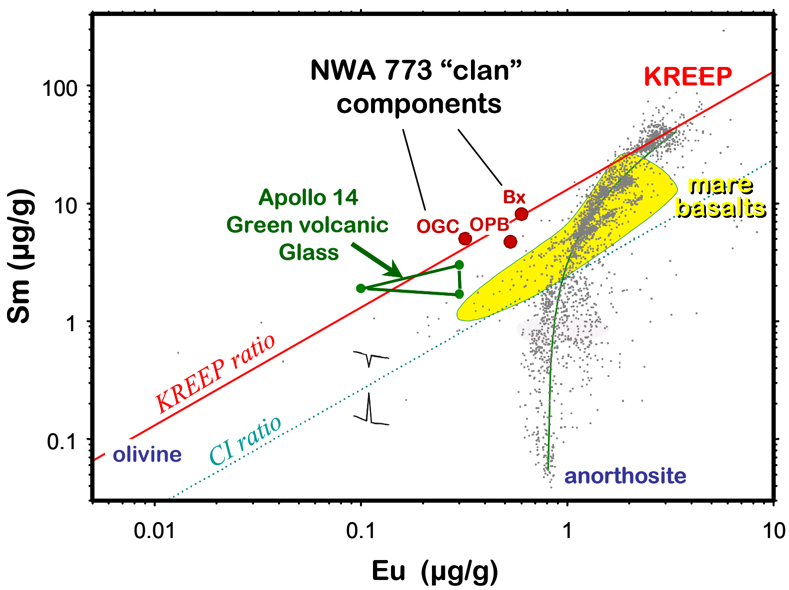

Figure 2. Geochemical relationship between OGC, OPB, and breccia in NWA 773- clan components and inferred relationship to Apollo 14 green-glass source and KREEP. Most lunar mare basalt compositions plot within the yellow field.

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References: [1] Bunch et al., 2006, *LPS* **37**, #1375; [2] Zeigler et al., 2006, *Ant. Met.* **30**, 125-126, NIPR; [3] Zeigler et al., 2006, *MAPS* **41**, A197, #5235; [4] Zeigler et al., 2007, *LPS* **38** (this vol.); [5] Fagan et al., 2003, *MAPS* **38**, 529-554; [6] Jolliff et al., 2003, *GCA* **67**, 4857-4879; [7] Fernandes et al., 2003, *MAPS* **38**, 555-564; [8] Borg et al., 2004, *Nature* **432**, 209–211; [9] Korotev et al., 2002, *MAPS* **37**, #5259 ; [10] Shearer and Papike, 1993, *GCA* **57**, 4785-4812; [11] Borg et al., 2005, *LPS* **36**, #1026; [12] Zeigler et al., 2006, LPS **37**, #1804; [13] Fernandes et al., 2007, *LPS* 38 (this vol.).