THE GEOCHEMISTRY OF A NEW LUNAR METEORITE, QUE93069, A BRECCIA WITH HIGHLAND AFFINITIES -- D.A. Kring, D.H. Hill, and W.V. Boynton, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721 USA.

The 1993 ANSMET field team collected a 21.4 g fragment of an ovoid stone, partially covered with a gray-green frothy fusion crust, that has since been classified as an anorthositic breccia or microbreccia of presumed lunar origin [1; also see 2]. Geochemical analyses of a split of this meteorite (#12) indicate that it is indeed of lunar origin. The bulk Fe/Mn ratio in QUE93069 is ~75, which is similar to the values of ~75 ± 5 in Apollo samples [3] and in previously identified lunar meteorites [*e.g.*, 4], and yet distinct from those in all other groups of meteoritic material. Similarly, the sample has bulk K/La (~90), K/U (~2000), and Fe/Sc (~4600) ratios that are characteristic of lunar samples [5] and distinct from those in other groups of meteorites. The K/U ratio also indicates that QUE93069 is not a terrestrial meteorite excavated from an anorthositic crustal region.

Potentially, QUE93069 may represent a previously unsampled portion of the Moon and, because it is a breccia, it could also have components from several different geologic terranes. To unravel the history of the rock, and to determine whether the meteorite is dominated by highland components or mare components, we examined the absolute and relative abundances of several major, minor, and trace elements in an ~200 mg bulk sample.

The relationship between the bulk Ca/Al ratio (~95) and weight percent TiO_2 (~0.5) [6] suggests that the meteorite has a slightly stronger affinity for mare lithologies than highland lithologies, but a mixture of rocks from both terranes seems equally likely. In contrast, the relative abundances of Mg (~3.7 wt. %) and Cr (600 ppm), which are very similar to those in the lunar meteorite Y86032 [7], suggest the meteorite is composed largely of highland components. The relative abundances of Fe and Sc (Fig. 1) are also consistent with a highlands provenance, and imply that any mare component constitutes less than 10% of the breccia [7]. These relationships are substantiated by the abundance of Ir (15 to 20 ppb), which is typical of those in soils, regolith breccias, and polymict breccias, but higher than those found in mare basalts and highland monomict rocks [3].

The bulk REE abundances are ~10 times those in CI chondrites (Fig. 2), are LREE-enriched (La/Lu is 1.9 x CI), and contain a slight positive Eu anomaly. This pattern is typical of highland rocks in the Apollo collection and is similar to those in other lunar meteorites with highland affinities. The pattern is not similar to the convex-upward patterns characteristic of mare basalt regions, although a minor mare basalt component cannot be dismissed.

The absolute REE abundances in QUE93069, which are substantially less than those in the Calcalong Creek lunar meteorite (Fig. 2), indicate that the breccia only contains a small KREEP component, if any. Bulk K abundances of ~300 ppm are too low for KREEP, but are consistent with ferroan anorthosites or Mg-suite lithologies [8]. The relationship between the Ti/Sm weight ratio (~1700) and the Mg/(Mg+Fe) atomic ratio (~0.70) also suggest any KREEP component is small [9]. Instead, these ratios suggest the QUE93069 breccia could be a mixture of anorthosites and the Mg-suite of rocks. The bulk Mg/(Mg+Fe) ratio falls between the values of ferroan anorthosites (0.5 to 0.7) and the Mg-suite (0.7 to 0.9 in norites and troctolites) [9]. Likewise, the

relationship between the Ti/Sm ratio and Sm (~1.6 ppm) suggest the sample could be a mixture of (ferroan) anorthosites and the Mg-suite of rocks [9].

In summary, the geochemistry of QUE93069 indicates it is indeed a lunar meteorite. The bulk composition of the meteorite is also consistent with its classification as an anorthositic breccia, although it appears to be a mixture of anorthositic and Mg-suite lithologies, and at most a small mare component. Because it does not have a large mare or KREEP component, QUE93069 does not appear to have come from the same region of the Moon as the meteorites EET87521, Y793274, Asuka 31, Y93169, and Calcalong Creek. On the other hand, the highland affinities of QUE93069 are similar to those in some of the anorthositic lunar meteorites, particularly MAC88105 and ALHA81005, and while not paired with them, nor in detail the same, QUE93069 appears to have sampled a similar type of geologic terrane.

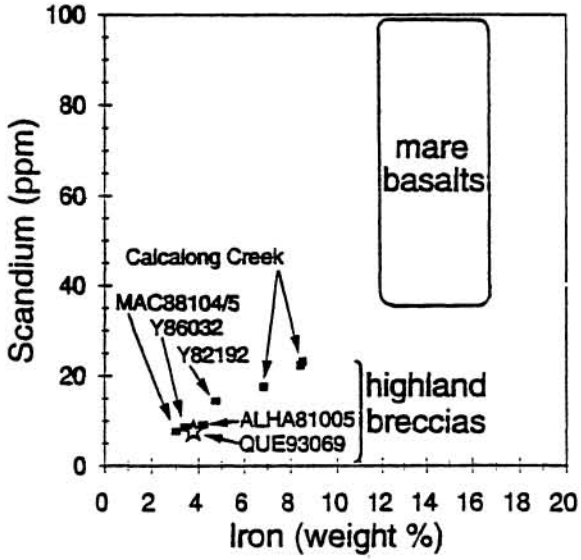

Fig. 1. Relative abundances of Sc and Fe in QUE93069 which plots in the compositional field of highland breccias and lunar meteorites MAC88104/5, Y86032, Y82192, ALHA81005, and Calcalong Creek [4,10,11]. The compositional field of mare basalts is also shown for comparison [after 7].

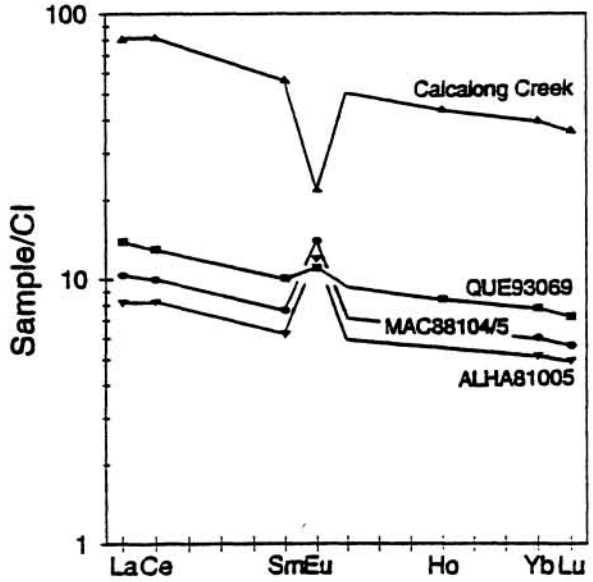

Fig. 2. Preliminary REE abundances, normalized to CI chondrites, in QUE93069. For comparison, the REE abundances in MAC88104/5 and ALHA81005, two lunar meteorites with highland affinities, are shown; MAC88104/5 is said to resemble QUE93069 in thin-section [1]. Also shown are prelimary REE abundances in a split of Calcalong Creek that was analyzed with QUE93069 [see 11] and is representative of a KREEPy lunar meteorite.

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