

**FRAGMENT OF TERRESTRIAL ORIGIN IN REGOLITH BRECCIA  
SAMPLE 14313,108.** Larry A. Haskin, Bradley L. Jolliff, and Randy L. Korotev, Dept. of Earth & Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130

The discovery on Earth of meteorites from the Moon and probably Mars has shown that meteoroid impacts onto bodies of substantial size can blast sizeable chunks of material beyond the gravitational fields of the parent body without melting or even severely shocking them. Consequently, we expect that Earth meteorites are present on the Moon. We may not expect to find an obvious piece of one among the samples collected by the Apollo missions, because terrestrial material is presumably quite scarce relative to indigenous lunar material and non-Earth meteoritic material. However, if found and characterized, terrestrial material exiled to the Moon during the late, heavy bombardment, would provide interesting information about impacts and meteorite-forming processes and would increase our knowledge of the nature of Earth's early Archean crust.

Thus, it should be easy to imagine our excitement on finding a 14 mg fragment of terrestrial material in our survey of several hundred 2-4 mm particles from soil 14161 and Apollo-14 regolith breccias (1). The chemical composition leaves no doubt of the terrestrial origin of fragment 14313,108M. One line of evidence is the high concentrations of elements such as Na, K, Rb, Cs, Zn, As, and Sb, which have low concentrations in lunar materials because they are relatively volatile (Table 1). Another line of evidence is the relative abundances of more refractory elements; the REE are a good example (Figure 1). Note that the REE pattern for 14313,108M is nearly parallel to that of the North American Shale Composite (NASC) and clearly distinct from that of lunar highlands materials.

(Note also how similar the slopes of the diagram for HREE match for both common lunar highland and terrestrial continental materials. Does this arise because the processes of partitioning of HREE are the same for the lunar mantle as for the terrestrial mantle? Does it arise because the Moon and the Earth more or less share a common mantle, as a consequence of the proposed collision of a Mars-sized object with the proto-Earth? Might it result from a modestly non-chondritic REE distribution in the region of the solar nebula where the Earth and Moon formed? The flat HREE distribution of mid-ocean-ridge basalts (MORB) does not support this hypothesis, but since all REE are presumably enriched in MORB's relative to their source regions, the flat distribution does not refute the suggestion strongly.)

Petrographically, the fragment is a chlorite-bearing siltstone with mean grain size  $<30 \mu\text{m}$ . It consists of about 60% quartz, 20% albite, 20% chlorite, and minor K-feldspar and traces of apatite and rutile. It shows no signs of having been subjected to significant shock. Also, its surface is rounded, whereas the surfaces of the other fragments from the lightly crushed sample of 14313,108 (an indurated, coherent regolith breccia) are angular. Its surface has no evident zap pits or strongly adhering material of lunar origin.

Before we would argue that the particular fragment 14313,108M was a meteorite blasted off the Earth and captured by the Moon, we would first have to be confident that the particle was not a contaminant added to the lunar material through human activity. We received sample 14313,108 from the curator in the form of 2-4 mm fragments. We are confident that neither our own laboratory procedures nor curatorial procedures would add a 14 mg fragment to a lunar sample. However, it turns out that the parent sample of 14313,108 was opened and crushed some 18 years ago under "reasonably clean" conditions in the laboratory of another investigator whose results would not have been compromised by a small amount of a common terrestrial contaminant.

In our customary attempt to quantify our observations, we have undertaken a crude mathematical analysis of the "excitement function" (to which we assign the euphonic acronym XTF) relating to the discovery. We did not record the exact moment that excitement over this discovery began, so we arbitrarily take as time zero the moment that we realized fully that one of the Apollo 14 fragments had a terrestrial origin. The value of the XTF remained constant for several hours, then began to diminish with an apparent half-life of  $4.3 \pm 0.8$  days as our suspicions of sample contamination grew.

After further tracking, we recognized that an exponential approaching zero as an asymptote did not properly describe the XTF, which had begun to reach negative values. The XTF value continued to decrease as our skepticism grew with respect to whether the fragment had become part of the sample without human intervention. The rate of development of negative excitement (defined as irritation by some investigators) accelerated as we realized that, even though our interest in the particle was receding beneath background

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level, we were still stuck with an obligation to evaluate more thoroughly the possibility that the particle had been on the lunar surface prior to the Apollo 14 mission. The level of excitement took on rapidly increasing negative values as we realized we had made the task especially difficult by eliminating the possibility of obtaining low limits easily on the duration of possible lunar surface exposure based on observing isotopes or other radiation effects. We had already accomplished this by irradiating the fragment to a neutron fluence of  $6.7 \times 10^{19}$  n/cm<sup>2</sup> for the INAA (which is how we discovered its terrestrial origin in the first place).

We have estimated the limits on the future value of the XTF. It may remain quite low, and even continue to decrease, but it is unlikely to approach  $-\infty$  unless two circumstances obtain: (a) contamination cannot be proven or is eventually proven, but only after extensive further work, and (b) the particle is such a common terrestrial material that its detailed characterization contributes nothing of scientific or human interest. Alternatively, should some new datum support the notion that, indeed, the fragment preceded spacecraft missions to the lunar surface, the value of the XTF would undergo a discontinuous jump to at least its former highest level, where it might remain for some indeterminate time. Obviously, we cannot reasonably estimate the curvature of the function without further observation.

Thus, our effort to characterize the particle is still underway. This is one of those preliminary reports of the type not followed by a final report unless more interesting information appears.

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**Table 1.** Results of instrumental neutron activation analysis for particle 14313,108M (mass=14.2 mg). Values in  $\mu\text{g/g}$ , except oxides in percent (cg/g). Uncertainties are one standard deviation estimates of analytical precision.

Na <sub>2</sub> O	2.40	± 0.03	Rb	26.0	± 1.0	Eu	0.685	± 0.016
K <sub>2</sub> O	0.62	± 0.13	Sr	61.	± 11.	Tb	0.513	± 0.012
CaO	0.20	± 0.06	Zr	153.	± 13.	Yb	1.70	± 0.03
Sc	5.33	± 0.08	Sb	0.359	± 0.012	Lu	0.264	± 0.004
Cr	35.6	± 0.5	Cs	1.37	± 0.03	Hf	3.82	± 0.05
FeO	4.19	± 0.06	Ba	80.	± 5.	Ta	0.72	± 0.02
Co	13.1	± 0.2	La	21.1	± 0.3	W	0.8	± 0.3
Ni	<40.		Ce	45.2	± 0.6	Ir	<0.005	
Zn	100.	± 3.	Nd	18.8	± 1.0	Au	0.0019	± 0.0005
As	4.12	± 0.15	Sm	4.20	± 0.06	Th	6.73	± 0.10
						U	1.57	± 0.05

**Fig. 1.** Chondrite-normalized REE concentrations in 14313,108M, North American Shale Composite (2), and mean values for suites of highlands soils (3).

References: 1) Jolliff et al., LPSC XX, 476; 2) Gromet et al., *Geochim. Cosmochim. Acta* 48, 2469, 1984; 3) Haskin, *Revs. Mineral.* 21, 227, 1989.

