ALHA81005: A METEORITE FROM THE MOON -- BUT CAN WE RULE OUT MERCURY?

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There seems to be a clear consensus that ALHA81005 came from the Moon [1-6], but before assessing the implications, the remote possibility that it came from some other body should be addressed. Even if it is not lunar, the rock is profoundly important. The parent body would have to be remarkably similar to the Moon. It would have to have the same oxygen isotope ratios [1], the same FeO/MnO ratios [2-5], and the same anorthositc type of crust, as the Moon; and it must be atmosphereless, with a regolith containing approximately the same amounts of solar wind rare gases as that of the Moon [6]. It may well be that some planet or asteroid has several of these properties in common with the Moon, but it is extremely unlikely that any other body has all four. The only other plausible source would appear to be Mercury.

Earth, the Moon, and the enstatite chondrite/aubrite parent body, all have oxygen isotope ratios along a single mass fractionation line [7]. Because of their exceedingly low FeO/MgO ratios, it has been suggested that the enstatite chondrites formed in a high-temperature zone <<1 AU from the Sun [8]. Thus, it is conceivable that the entire inner solar system was homogenized with respect to oxygen isotopes. Presumably, the Moon became depleted in MnO relative to FeO (compared to similarly FeO-rich chondrites) due to the higher volatility of MnO. Among atmosphereless bodies, this too may be a function of distance from the Sun, for the eucrite parent body (presumably an asteroid) has a higher MnO/FeO than the Moon. But planet size (i.e., escape velocity) and other factors surely must also play a role. A MnO/FeO coincidence between Mercury and the Moon is unlikely, but not impossible.

Anorthositic crusts like that of the Moon probably only form on planets of roughly lunar size. If the planet is too large (i.e., has internal pressures that are too high), its aluminum does not form buoyant plagioclase during the early intense magmatism phase (the magma "ocean"), but instead forms dense mantle phase(s) such as garnet -- this is what probably took place on Earth [9]. Moreover, its early crust is liable to be made over by ongoing geologic activity. If it is too small (i.e., asteroid-sized), it can never form sufficiently large intrusions to lead to global elutriation of plagioclase -- this is probably why anorthosites are only a very minor component from the eucrite parent body [10]. Mercury is 4.6 x more massive than the Moon, but its large core (60-70 wt.%) would have displaced all its aluminum towards the surface. The pressure at the base of Mercury's mantle is roughly 100 kb. For comparison, the lunar central pressure is ~47 kb, and the pressure at the base of Earth's mantle is ~1370 kb. Mercury is probably the right size to have produced an anorthositic crust, provided it was melted extensively like the Moon. Indeed, the visible reflectance spectrum of Mercury is sufficiently similar to spectra from lunar highlands soils to suggest [11] that Mercury's crust is similarly anorthositic, with roughly 5.5 wt% FeO, mainly as orthopyroxene.

Being only 39% as far from the Sun as the Moon, Mercury's surface is exposed to 6.7 x as much solar wind as the Moon's. A regolith breccia from Mercury will not necessarily have 7 x higher solar gas contents than one from the Moon, however. Another factor, the mean surface residence time (i.e., reciprocal cratering rate), differs between Mercury and the Moon. The cratering rate on Mercury is most likely ~2 x, but possibly 5 x, that on the Moon

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[12], so an avg. regolith breccia from Mercury probably, but not necessarily, has significantly higher solar gas contents than one from the Moon. ALHA81005 has noble gas concentrations that are low even for a lunar soil [6], and most regolith breccias have 2-4 x higher concentrations than soils [13]. If the noble gas data are an obstacle to accepting the lunar origin of ALHA81005, it is because they are too low, not too high. The explanation is probably that ALHA81005 is atypically poor in surficial "fines" material, for a regolith breccia. We have observed that it appears to contain considerably less of the swirly brown glass associated with such materials, too.

In summary, the possiblity should not be completely overlooked that ALHA81005 is from some body other than the Moon; Mercury is the most plausible alternative. But a powerful combination of circumstantial evidence is overwhelmingly in favor of its being from the Moon.

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