WHAT SHOULD METEORITES FROM MERCURY LOOK LIKE?

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Introduction: Given the existence of meteorites from Mars and the Moon, meteorites from Mercury have long been sought. It is anticipated these should be FeO-poor, with petrology reflecting planetary processes. The achondrite NWA 7325—with a reduced, FeO-poor composition and a high silica content indicative of a tertiary crust not seen on non-planetary bodies—was tentatively associated with Mercury [1]. NWA 7325 has not been identified as Mercurian, though, because its Pb-Pb age (4562.5 ± 4.4 Myr; [2]) and Al-Mg age (≈ 5.4 Myr after CAIs; [3]) indicate formation very early in nebula history. It also records no paleofield (< 1.7 µT), whereas a planetary body is expected to have had a stronger field [4]. Also, its spectrum—dominated by green, Cr-rich diopside—is a poor match to Mercury's surface [5,6], and is only a good spectral match to asteroid 1991 RY_{16} [6].

Here we argue that it is very likely that the mantle-stripping impact Mercury suffered occurred in the first 5-6 Myr of nebular history and created daughter bodies from which meteorites like NWA 7325 could derive. Unlike modern martian or lunar meteorites, NWA 7325 may sample of the surface of proto-Mercury early in its evolution.

Mantle-Stripping Impact: Because of its high core mass fraction (69-77% [7]), Mercury has long been considered to have suffered a giant impact [8,9] that stripped its mantle. A major issue with this model is whether Mercury would simply reaccrete the ejecta. Near-surface material should be ejected as large rocky fragments that will possibly form daughter bodies (e.g., like the ejecta from giant impacts on Mars [10]) but these will mostly be reaccreted. Only material ejected from the deep mantle as droplets (due to decompression vaporization) can be be lost. But Poynting-Robertson drag is inefficient and would allow at least 35% of that ejecta to be reaccreted [9], or even more after considering the optical depth of the cloud [11]. However, [12] argued that a giant impact was likely at 5-6 Myr, when some nebular gas remained and would allow complete loss of droplets by aerodynamic drag. This would lead to loss of olivine (Mg_2SiO_4) only, raising the bulk ratios of Ca, Al and Ti relative to Mg (or Si) on Mercury, but also of Na and K relative to Mg (or Si), consistent with MESSENGER observations [13-15] that Mercury is enriched in both refractory *and* volatile elements relative to Mg. Formation of Mercury by 5 Myr would be completely consistent with models of planetary embryo growth by pebble accretion [16-17] and the early formation of Mars [18]. An impact at 5-6 Myr would be consistent with the timing of other notable impacts in the inner solar system (e.g., the ureilite parent body [19] and the CB/CH parent body [20]).

Meteorites from Proto-Mercury: If Mercury suffered a mantle-stripping giant impact at 5 Myr, ejected crustal material might have reaccreted as rare, small daughter bodies that may reside in the asteroid belt today. These daughter bodies would not cool below their Curie points (780°C) for days, by which point they would be $\sim 10^5$ km from the proto-Mercury, and sample a planetary B field < 0.03 µT (the solar B field also would be << 1 µT, and the nebular field would have largely vanished). 1991 RY_{16} may represent one such daughter body, from which meteorites like NWA 7325 may more recently derive. The daughter bodies and meteorites would sample crustal material on a large, differentiated body, likely to be as chemically reduced and FeO-poor as enstatite chondrites. The age of the samples would reflect the crystallization of the magma ocean on proto-Mercury. This material would not resemble Mercury today, which must reflect the later processes of reaccretion of ejected material, and mantle overturn.

Summary: Whether or not NWA 7325 derives from Mercury itself, one should not reject, on the sole basis of its old age, the possibility of it deriving from the surface materials of a chemically reduced planetary embryo.

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