ANGRITES AS SAMPLES OF MERCURY?: A SPECTRAL PERSPECTIVE. D. T. Blewett[1] and T. H. Burbine[2]. [1]NovaSol, 733 Bishop St., 28th Floor, Honolulu, Hawaii 96813 USA (dave.blewett@nova-sol.com); [2]Dept. of Astronomy, Mount Holyoke College, South Hadley, Massachusetts 01075 USA (tburbine@mtholyoke.edu).

Introduction: There has been recent speculation [1, 2] that angrite meteorites could be samples of Mercury because of their lack of the volatile Na, oxygen isotope composition, and textural and cosmic ray exposure evidence that is consistent with a large parent body that formed near the Sun. We perform a comparison between laboratory spectra of angrites and telescopic spectra of Mercury, and discuss geologic considerations that bear on the question of a mercurian origin for angrites.

Meteorites From Mercury: Meteorites are known to have originated on the Moon and Mars. It is in principle possible for impact-ejected material ejected from Mercury to reach the Earth, but at greatly reduced efficiency compared to delivery from Mars [3]. An attempt to forecast the characteristics of mercurian meteorites suggested the following [4]: potentially unusual isotopic composition, low in volatiles, enriched in refractory elements, and low FeO content. Surface rocks should show high solar-to-galactic cosmic ray damage ratio, and regolith breccias are expected to be rich in impact vapor deposits, agglutinates and exogenic chondritic material, and may show implanted solar wind abundances that indicate fractionation caused by Mercury's magnetic field.

Angrite Meteorites: Angrites are commonly believed to be derived from a basalt-covered parent body. The angrites are composed predominantly of anorthite, Al-Ti diopside-hedenbergite, and Ca-rich olivine (including sub-calcic kirschsteinite) [5]. Angrites formed under markedly different oxygen fugacities than the eucrites, another type of common meteoritic basalt. Partial melts of carbonaceous chondritic material resemble either angrites or eucrites, depending on the oxygen fugacity during melting [6]. Relatively oxidizing conditions produced partial melts similar to angrites while relatively reducing conditions produced partial melts similar to eucrites.

Remote Sensing Studies of Mercury: Telescopic observation of Mercury is complicated by the planet's small angular separation from the Sun as seen from Earth. As a result, the composition of the mercurian surface is not well known.

Thermal Emission Spectroscopy. Thermal-infrared emission studies provide evidence for compositional variety from place to place on Mercury. Reported compositions include intermediate or mafic lithologies resembling terrestrial basalt and anorthite [7], feldspars and feldspar-pyroxene mixtures [8], feldspathic/feldspathoidal minerals and olivine [9], bronzite, picrite, and sodalite [10], and intermediate to ultramafic rock types [11]. At longer wavelengths, microwave emissions [12] reveal that the surface is much more transparent at centimeter wavelengths than the lunar highlands, attributed to lower Fe and Ti on Mercury.

Reflectance Spectroscopy. Reflectance spectra of the Moon and some asteroids show an absorption near 1 µm caused by ferrous iron (Fe^{2+}) in silicate minerals and glasses. Most visible-to-near-infared (VNIR) spectra of Mercury are featureless [13-15] (Fig. 1), though a recent study reported a weak absorption at 1.1 µm, attributed to calcic clinopyroxene [16]. Telescopic images of Mercury in VNIR wavelengths at ~300 km/pixel found no evidence of the Fe^{2+} absorbtion feature [17]. The lack of a clear 1 µm band on Mercury implies that the regolith is very low in Fe^{2+}, probably even lower than areas of pure anorthosite in the lunar highlands that contain <~3 wt.% FeO [18].

Spectral Properties of Angrites: Angrite silicates have FeO in the range ~10-20 wt.%. FeO content this high produces strong mineralogical absorption bands. Indeed, measured laboratory spectra of four angrites all have clear 1 µm pyroxene features, with some also displaying weak 2 µm pyroxene bands [19] (Figure 2). The weak to absent 2 µm pyroxene bands are characteristic of some high-Ca pyroxenes [20] where Fe^{2+} is located almost entirely in the M1 crystallographic site.

Discussion: Destruction of crystalline regolith components through repeated melting/vaporization by the elevated micrometeorite flux at Mercury has been considered as a means by which mineralogical absorption bands could be masked [21]. Such a process could conceivably hide the weak bands in a glassy regolith derived from low-FeO precursor minerals. However, it seems unlikely that agglutinates with 10-20 wt.% FeO, as would be produced in a regolith derived from angritic material, would exhibit the near total lack of a Fe^{2+} band characteristic of Mercury spectra.

Mariner 10 Color Images. Mariner 10 images of Mercury in two colors, ultraviolet (UV) and orange, have been recalibrated and allow some compositional inferences to be made [22]. Mercury's "incoming" hemisphere lacks large regions that are dark and "bluish" similar to the basaltic lunar maria. "Blue" color, corresponding to high UV/orange ratio, is consistent with a high abundance of opaque phases such as ilmenite, the main carrier of Ti in lunar materials. With the Mariner 10 spectral bands, two parameter images can be constructed: one related to the abundance of opaque phases, and one sensitive to the combined effects of maturity and Fe^{2+} content [22, 23]. Most of the surface seen in the Mariner 10 spectral parameter images is of intermediate opaque abundance. Several impact craters, such as Kuiper and Lermontov, appear to have exposed low-opaque material from beneath the medium-opaque surface material. Plains units with intermediate opaque abundance and likely low ferrous iron content have embayed margins indicative of emplacement as lava flows [22].

Features that are dark and have a relatively high abundance of opaque phases have been identified in the Mariner 10 spectral parameter images. These features could represent mafic volcanic material. Some of the dark, high-opaque features have morphology consistent with pyroclastic deposits [22]. Another feature could be similar to a lunar dark halo impact crater (DHC) [23]. DHCs on the Moon are formed when mare basalt buried beneath a highlands-rich unit is excavated and deposited around an impact crater.

Angrites from Mercury? Earth-based remote sensing of Mercury has led to the consensus that the planet's surface is globally low in FeO. This is inconsisent with the iron-rich basaltic composition of angrites. Local units identified in Mariner 10 images of Mercury may have a mafic character. Therefore, a source crater in such a unit could conceivably have launched the material that eventually fell to Earth as an angrite. However, the type specimen, Angra dos Reis, is a cumulate and differs in mineralogy from the other angrites [23, 19]. This suggests that more than a single impact is needed to deliver material to Earth. It seems unlikely that our putative mercurian samples would all come from multiple impacts in the small, localized deposits suspected to have a mafic composition rather than the low-iron, low-to-medium-opaque units that dominate the surface. Thus the current evidence argues against a mercurian origin for the angrites. This same conclusion has been reached by others [4, 25].

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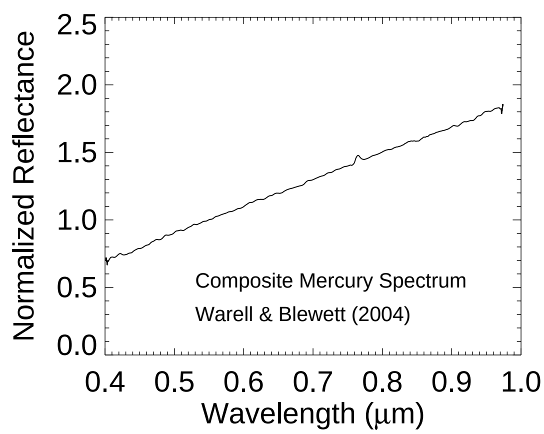

Figure 1. Composite spectrum of Mercury normalized to 1.0 at 0.55 µm [15]. The reflectance is remarkably linear, with a strong "reddish" spectral slope.

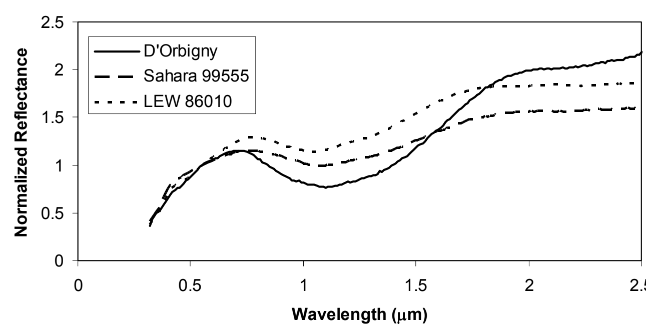

Figure 2. Laboratory spectra normalized to 1.0 at 0.55 µm of three angrite meteorite powders [19]. All spectra display clear Fe^{2+} absorptions centered near 1 µm.