"NEW" LUNAR REGOLITH BRECCIAS; AN ENIGMATIC FERROAN ANORTHOSITE FROM APOLLO 14

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The recent discoveries of three lunar regolith breccias as meteorites (ALHA81005, Y791197, and Y82192/3; we presume that Y82192 and Y82193 are paired) have sparked renewed interest in this lunar rock type. Regolith breccias account for only about 9% of all rocks from the prime Apollo highlands mission, Apollo 16 [1]. Why then are all three of the lunar meteorites regolith breccias? Were the three lunar meteorites originally a single stone? If not, why should the impact-to-Earth process discriminate in favor of regolith breccias? The lunar meteorites have also dramatically demonstrated that regolith breccias, unlike soils per se, can potentially be found — compositionally unaltered — hundreds of km from the locations where they formed: The same impacts that produce the lunar regolith (by comminuting and mixing mainly local-crustal matter) occasionally blast regolith breccias great distances through space. By investigating previously unstudied Apollo regolith breccias, we can reasonably expect to occasionally find one that originated many km from the relatively tiny areas traversed by the Apollo astronauts (maximum spans of Apollo traverses were, in km: 0.1 for A-11, 0.6 for A-12, 1.6 for A-14, 6.0 for A-16, and 11.5 for A-17; the average separation between an Apollo site and its nearest neighbor is 435 km). These "exotic" regolith breccias will (in general) be significantly different from local regolith samples in composition and/or texture. Thus, we may be able to investigate portions of the lunar regolith never directly sampled by Apollo. At a minimum, expanding the data base for Apollo regolith breccias will help to constrain the nature and origin of the key lunar meteorites.

<u>14076.</u> Based on macroscopic examination, Wilshire and Jackson [2] classified this 2.0 g rocklet as an "F4" (dark-matrix fragmental) breccia. Our studies of 14076 are only just underway (detailed petrography will be coming from mini-consortium colleagues D. T. Vaniman and G. H. Heiken), and we have not yet determined for certain whether it is a regolith breccia. It has a light-brown glassy matrix, and contains spherical objects reminiscent of the "chondrule-like objects" in 14315 [3]. Its I_s/FeO surface exposure index is <0.1, indicating that if it is a regolith breccia it is extraordinarily immature, or else has been severely reheated. In any event, the few compositional data obtained to date (from electron probe analysis of a fused bead) indicate an extraordinary composition. The range for bulk-rock Al_2O_3 content among previously analyzed Apollo-14 rocks of all types other than mare basalt is 13.4-22.0 wt% (14304 [4] and "white rock" 14063 [5-6], respectively). The vast majority (and all of the regolith breccias except 14315) have 16 < wt% Al_2O_3 < 19. We have determined the Al_2O_3 content of 14076,1 to be 30.1 wt% — uncommonly high even by the standards of Apollo 16. The CIPW-normative feldspar content of 14076,1 is 84.1 wt%. The TiO_2 content, 0.34 wt%, is extraordinarily low by Apollo-14 standards, and so are Na_2O (0.42 wt%) and K_2O (roughly 0.10 wt%) (note: Na_2O and K_2O are preliminary!). The bulk-rock <u>mg</u> ratio is a modest 0.62. The main ingredient in 14076 is apparently ferroan anorthosite, a lithology that is the single most abundant pristine rock type from Apollo 16, but has hitherto been extremely rare among Apollo 14 rocks.

<u>14251.</u> Among other suspected regolith breccias from Apollo 14, 14251 is a mature (I_s/FeO = 75) regolith breccia that is unusual for its high (by Apollo-14 regolith standards) <u>mg</u> ratio: 0.67.

<u>Regolith breccias from Apollo 16.</u> Nine suspected regolith breccias from Apollo 16 are surprisingly mature, with I_s/FeO in the range 28-87. For comparison, all but one of 19 Apollo-16 regolith breccias studied by McKay et al. [7] have I_s/FeO $\leq$ 17. The nine "new" regolith breccias are also relatively uniform in composition, and tend to closely resemble Apollo-16 soils. The 20 previous analyses of Apollo-16 regolith breccias suggested a possible bimodality in terms of bulk-rock <u>mg</u> [7,3]. Our new analyses

suggest that the bimodality was actually not significant; the distribution now looks more like a continuum. However, the mean mg of the regolith breccias still appears significantly higher than the mean mg of the local soils [7]. The range in mg ratio among Apollo-16 regolith breccias remains 0.65-0.72. This range is smaller than the contrast between lunar meteorite ALHA81005 (mg = 0.72-0.74, based on analyses at four separate INAA labs [8-11]) and either Y791197 (mg = 0.59-0.66 [12-16] or Y82192 (mg = 0.61-0.63 [17-19]). Considering that the regolith breccias from Apollo 16 were collected during a traverse of 8.5 km across a site specifically chosen to straddle two separate formations (Cayley and Descartes), the mg disparity between ALHA81005 and the other lunar meteorites suggests that ALHA81005 was propelled Earthward by a separate impact [19]. This conclusion is also consistent with isotopic records of cosmic ray exposure histories [e.g., 20].

New data for ALHA81005. We have also obtained a new fused bead analysis for ALHA81005. There were two shortcomings of the previous data base for major elements in ALHA81005: (a) all of the previous data were based on a single technique (INAA), which conceivably could lead to systematic errors; and (b) only a single determination had been made for Si [11]. Our new data are (in wt%): MgO 8.0, Al_2O_3 25.8, SiO_2 44.8, CaO 15.2, TiO_2 0.24, and FeO 5.0. Most of these data are in good agreement with previous analyses of ALHA81005, including our own INAA analysis of the same chip [8]. However, the new TiO_2 and FeO data are lower than the data of Kallemeyn and Warren [8] by factors of 0.81 and 0.92, respectively. The new SiO_2 datum is also significantly lower than the one previously reported (46.46 wt%) [11]. The CIPW norm, based on the new data averaged with our INAA data [8], has 72.3 wt% feldspar, 15.6 wt% pyroxene, and 11.3 wt% olivine. This yields a CIPW pyroxene/(olivine+pyroxene) (hereafter py) ratio of 0.58, whereas the CIPW norm of the Palme et al. [11] analysis has a py ratio of 0.79. For comparison, the only published complete major-element analysis for Y791197 [12] implies a CIPW py ratio of 0.48; analyses of Luna-20 soil imply py = 0.50 [23] to 0.69 [24]; an average of XRF analyses of 10 Apollo-16 soils [25] implies py = 0.64; "exotic" Apollo-14 regolith breccia 14315 has py = 0.90 [5] to 0.94 [3]; and average Apollo-14 regolith [5,3] contains no CIPW-normative olivine, i.e., py = 1. An ALHA81005 py ratio >>0.5 is hard to reconcile with petrographic observations indicating that olivine-rich granulite is one of the most common clast lithologies in ALHA81005 [21-22], and with the observation the ALHA81005 has the most "primitive" mg ratio of any lunar regolith sample.

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Abbreviations: ASAM = Abstracts for Symposium on Antarctic Meteorites (Tokyo)
PLSC, PLPSC = Proceedings of Lunar (and Planetary) Science Conference
PSAM = Proceedings of Symposium on Antarctic Meteorites (Tokyo)