MINERALOGICAL INVESTIGATIONS OF LUNAR SAMPLES AND METEORITES

Grant NAG 9-29

Semiannual Progress Report No. 1
1 February 1983 to 31 July 1983

Principal Investigator
Dr. Ursula B. Marvin

November 1983

Prepared for
National Aeronautics and Space Administration
Johnson Space Center
Houston, TX 77058

Smithsonian Institution
Astrophysical Observatory
Cambridge, MA 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this grant is
Dr. John Dietrich, Code SN2, NASA Johnson Space Center
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Projects included in this progress report, which represents the first six-month period of grant NAG 9-29 fall into three categories: (1) some research is ongoing, begun under the funding of NASA grant NGL 09-015-150 to John A. Wood, with whom P.I. Ursula Marvin has been a Co-Investigator for many years; (2) some research (notably investigations of the lunar meteorite ALHA81005) has been begun under and entirely supported by grant NAG 9-29; and (3) preliminary preparations have been made for research proposed for the first year of NAG 9-29, but substantive study has not begun. Marvin and Wood continue to share laboratory facilities and instrumentation, and administrative and support services.

Apollo 16 breccia 67015. Marvin continues as leader of a consortium studying the clast and matrix compositions and accumualtion history of 67015, a feldspathic fragmental breccia from North Ray Crater. This sample is expected to follow the precedent of other consortiu. samples, providing in this case information about the subsurface geology of the Apollo 16 site. A second round of clast samples was allocated for thin sections, chemical analyses, and $Ar^{40/39}$ determinations. Marvin analyzed the sections by microprobe, and Marilyn M. Lindstrom analyzed splits of the same clasts by INAA. Argon dating is underway. Two specimens were sent to David Strangway for tests of the intensity and stability of magnetization. Initial results indicate intense enough magnetization to require the study of individual oriented clasts; Strangway will attempt to determine whether the breccia is a conglomerate of randomely magnetized materials or a rock that was uniformly magnetized after aggregation.

Breccia 67015 contains clasts of dark, vesicular KREEP-rich melt rock of VHA composition, contradicting the prevailing belief that feldspathic fragmental breccias are KREEPless. This finding, with similar, recent, observations by other petrographers studying this class of rocks, overrules a hypothesis proposed by Stoffler et al. [1981, Proceedings of the Twelfth Lunar and Planetary Science Conference, pp. 185-207], that the feldspathic fragmental breccias and dark KREEPy melt rocks at the Apollo 16 site were derived from different areas of the moon in separate impact events.

We have discovered a new type of clast that has characterisics of pristine feldspathic breccias in 67015,310. This clast has a medium-graired diabasic texture and consists of 75% plagiocalse (An_{90-92}), 15% pyroxene ($En_{76}Fs_{20}Wo_4$ and

$En_{49}Fs_{11}Wo_{40}$), 2% opaques (chiefly ilmenite with traces of troilite and metal) and 8% glassy mesostasis containing cristrobalite, potash feldspar, apatite, and ilmenite. Melt rocks could duplicate the igneous-looking texture, but Lindstrom's INAA analyses show no trace of iridium, a key evidende of meteoritic contamination, and the Ni and Co values lie withing the endogenous lunar range. The bulk content, on the other hand, differs from any previously classified pristine lithology. Clast 310 has an unusually high Ti content (3% TiO_2), and is significantly richer in REE than most igneous lunar rocks; it contains only half the average REE range of VHA melt rocks. Additional microprobe analyses and argon dating will be performed before we begin to draw conclusions about the provenance of this material.

Some preliminary findings for 67015 have been published [Lindstrom and Salpas, 1983, Lunar and Planetary Science XIV, pp. 442-443; Marvin and Lindstrom, 1983, Proceedings of the Thirteenth Lunar and Planetary Science Conference, pp. A659-A670], but a final consortium publication is planned for the detailed description and assessment of this sample.

Lunar meteorite Allan Hills 81005. This study was a real-time response to the discovery that one of the specimens collected in the 1981 Antarctic field season strongly resembled a lunar highlands breccia. Marvin received thin section 81005,22 during the first round of sample allocations from this rock (in January 1982). Marvin analyzed 81005,22 and library section 81005,3 by electron microprobe. Her analyses generally agreed with those of other investigators, and helped to characterize ALHA 81005 as a glass-welded soil breccia, plagioclase-rich and KREEP-poor, from the lunar highlands.

The most abundant constituent of ALHA 81005 clasts and glasses is plagioclase (An_{94-97}). Glasses are present in many forms, including colorless, yellow, and orange spherules, felty devitrified masses, and brown partially flow-banded matrix material. MnO/FeO partitioning is typically lunar and differs from that found in achondritic meteorites (Marvin, 1983a).

Two clasts appear to be mare basalts (Marvin, 1983b). One consists of a single 430-μm lath of unzoned plagioclase (An_{95}) attached to a mass of black, Ti-rich glass containing minute crystallites, chiefly armalcolite and ulvospinel. There is only trace Zr, a common lunar highland armalcolite component. The absence of mafic silicates makes identification of the clast uncertain, but the

glass composition, atypical of highlands lithologies, suggests derivation from a Ti-rich mare basalt.

A second clast has a diabasic texture and consists of 86% bytownite ($An_{85}Ab_{12}Or_1$), 7% pyroxene (mainly augite, $En_{45}Fs_{13}Wo_{42}$), and 7% mesostasis (containing normative silica, K-feldspar, ferroaugite, and ilmenite). This clast could be a highlands sodic ferrogabbro, except that the 1-2 wt.% Cr_2O_3 found in the pyroxene suggests mare derivation. The An content of the plagioclase suggests an origin among the low-K mare basalts.

If these two clast types can be confirmed as mare products they will, along with the VLT mare basalt clasts found by Ryder and Ostertag [1983, Lunar and Planetary Science Conference XIV, Abstracts from Session on Meteorites from the Earth's Moon, pp. 29-30] and Treiman and Drake [1983, Geophysical Research Letters, in press], they will constain the search for the highlands source region of ALHA 81005 to some area of the highlands crust that lies within a reasonable distance of at least three different varieties of mare material and is anorthositic but KREEPless.

The circumstances of the discovery of 81005 and its handling, and the significance of this find to planetary sample research, are outlined in Marvin (in press), to be included in a special issue of Geophysical Research Letters. Descriptions of the two possible mare clasts are included, but other pretrographic data will be published in a manuscript in preparation. This will include a description of a 3-mm cataclastic anorthosite containing pyroxenes that extend the range of Fe-rich compositions previously observed in the ferroan anothosites. In addition, 81005 contains a 2-mm clast with an anorthositic gabbro composition, but a quasi-cumulate texture dominated by chains of pyroxenes and olivines lying in granulitic plagioclase. The olivine is Fo_{40}, by far the most Fe-rich mafic mineral reported in 81005.

Antarctic meteorite pairing and the concentration mechanism. Marvin has begun a detailed examination of meteorite distributions in the Allan Hills region to add information to the criteria for pairing specimens and to test the current concentration model, which postulates that meteorites falling on large Antarctic catchment basins are carried within the ice for long distances before surfacing behind mountain barriers. She spent part of February 1983 at the

U.S. Museum of Natural History in Washington, examining the library of Antarctic thin sections and plotting specimen locations on the detailed field map of the 1981-82 Antarctic season. Specimens are color-coded to identify meteorite type on the map. It is possible to make such a detailed record for the first time, since the 1981-82 season was the first in which meteorite finds were actually surveyed relative to fixed points, and distances measured by snowmobile. Supporting plots of the 1976, 1977, and 1978 finds have been produced using distribution maps and field notes compiled by K. Yanai.

Some of the plotted specimen groupings reinforce Marvin's intuitive belief that some of the Antarctic meteorite specimens represent primary strewnfields rather than ice transport mechanisms. The most striking example occurs near the south end of the main Allan Hills ice field, where 18 fragments were found within an elogate area of 490 x 170 m, at some distance from any other meteorites. Sixteen of the specimens have been classified as L6; Marvin predicts that the two remaining unclassified specimens will also be L6. The clustering suggests a strewnfield — surely these specimens were not concentrated via random falls over a large catchment area. Comparisons of terrestrial residence times and ice ages for meteorites and their locii are necessary to determine whether the stones were found at or near their impact site(s) or travelled as a discrete group from a distant site.

In contrast, a group of eucrites distributed like shower fragments was shown by the thin sections to include members of distinct falls.

This study is yielding important information about meteorite distributions, but is hampered by the fact that fewer than half of the Allan Hills meteorites have been sectioned and classified. Many plotted classified meteorites were surrounded by unclassified specimens. This situation results from the long-standing policy of sectioning only fragments <100 g. Results are beginning to be available for several sets of pebble-sized specimens allocated for study, and this project will continue as new classifications are made. Publication of preliminary conclusions will probably occur in grant year 1984.

Meteoritic zircon. Marvin has dissolved the metal from a 15-g specimen of the Vaca Muerta mesosiderite to obtain an aliquot of silicate minerals that have been fractioned on the basis of grain size and magnetism. She is currently searching these fractions for zircon.

Other activities. A third publication in the Smithsonian Contributions to Earth Sciences series has been completed (Marvin and Mason, in press). Marvin (1983c) was written in the interests of disseminating information on the Antarctic meteorite program to a broad scientific community and interested lay readers. The wider spread of information is one of the priorities of the Meteorite Working Group, of which Marvin was a member between 1977 and April 1983. Marvin's membership on the Universities Space Research Association, of which she was Chair from March 1982 to June 1983, continues through March 1984.

Publications during this period:

Marvin, U.B. (1983a). Some petrologic comparisons between ALHA 81005 and lunar highland soil breccias. Lunar and Planetary Science XIV, Abstracts from the Session on Meteorites from Earth's Moon, Lunar and Planetary Institute, Houston, 18-19.

Marvin, U.B. (1983b). The discovery and initial characterization of Allan Hills 81005: The first lunar meteorite. Geophysical Research Letters, special issue, in press.

Marvin, U.B. (1983c). Extraterrestrials have landed in Antarctica. New Scientist 97, 710-715.

Marvin, U.B. and Mason, B. (1983). Field and laboratory investigations of meteorites from Victoria Land, Antarctica. Smithsonian Contributions to the Earth Sciences, in press.