METEORITE FROM THE MOON: PETROLOGY OF TERRAE CLASTS AND ONE MARE CLAST IN ALHA 81005,9.

Allan H. Treiman and Michael J. Drake. Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721.

INTRODUCTION

ALHA 81005 was first noted to be an unusual meteorite during preliminary examination by R. Score (1). Subsequently Mason examined a polished thin section. He noted that the microbreccia contains clasts which are more feldspathic than those in most eucrites and that they resemble anorthositic clasts from lunar terrae rocks (1). Petrographic and electron microprobe analyses confirm that ALHA 81005,9 originated in the lunar terrae and is the first recognized lunar sample transmitted to Earth by natural processes. A clast of VLT mare basalt in the breccia may restrict the possible source of the meteorite on the lunar surface.

GENERAL DESCRIPTION

ALHA 81005,9 is a microbreccia of lithic and vitric clasts set in a fine-grained matrix with pervasive glass. Lithic clasts include anorthosite, troctolite, spinel troctolite, and norite fragments. A majority of clasts retains igneous textures, but few clasts have not been modified thermally and/or mechanically. The remaining lithic fragments have textures varying from cataclastic to granulitic to variolitic with relict plagioclase. The presence of unmodified vitric clasts and matrix glass suggests that most thermal recrystallization preceded formation of the breccia. Deformational features which post date consolidation of the breccia are not observed.

CONFIRMATION OF LUNAR TERRAE ORIGIN

Pyroxene compositions, particularly molar Mn and Cr contents versus molar Fe/(Fe+Mg) ratios provide sensitive petrochemical criteria for distinguishing between rocks from different planetary bodies. The Mn content of pyroxenes from ALHA 81005,9 (except clast G) all fall within the lunar terrae field (Fig. 1) and indicate that the meteorite is not related to the basaltic achondrites (2). Similarly the Cr contents of the pyroxenes (except clast G) are inconsistent with a terrestrial or eucritic origin, but are consistent with a lunar terrae source (2). Thus, pyroxene chemistry confirms the petrographic observation that ALHA 81005,9 is from the lunar terrae.

TERRAE CLAST PETROLOGY

Compositions of plagioclase and mafic minerals from the anorthositic clasts plot in the field of pristine ferroan anorthosite (3). In other igneous clasts (except clasts I, U and G) plagioclase is An 96-98, and the molar Mg/(Mg+Fe) ratios of the mafic phases range from 0.52 to 0.84. These compositions extend from the pristine anorthosite field to the pristine Mg-suite field, and imply that the basaltic rocks are impact melts of a source containing anorthositic and Mg-suite protoliths. Anorthositic clasts could represent one protolith; a suitable Mg-suite protolith is not present in ALHA 81005,9, and its composition must be inferred. Plagioclase in the Mg-suite protolith must have been An 96-98 because igneous clasts all contain plagioclase of that composition. The presence of abundant magnesian pyroxene in the basalts implies that the Mg-suite protolith was noritic, with low-Ca pyroxenes of Mg/(Mg+Fe)> 0.84. Known pristine norites do not contain such magnesian pyroxene and calcic plagioclase (3), and the Mg-suite protolith may represent an undiscovered lunar rock type.

Two unusual basaltic clasts, I and U, contain plagioclase more sodic than An 96. Clast I is a spinel troctolite with 60% plagioclase laths (An 94), interstitial olivine (Fo 80), and a single crystal of brown spinel ($Mg_{0.64}Fe_{0.37}Al_{1.69}Cr_{0.28}Ti_{0.01}O_4$). Clast U is a norite with plagioclase laths (An 91-An 96) and interstitial low- and high-Ca pyroxene and olivine. Minor phases include troilite, Fe-metal, ilmenite, rutile, and Zr-armalcolite. By mineralogy, clast U is a Mg-norite (4), but I and U are probably both impact melts.

CLAST G: MARE VLT BASALT

Clast G is a unique, small fragment of Fe-rich basalt, consisting of 75% plagioclase laths with interstitial high- and low-Ca pyroxene and a silica polymorph (cristobalite?). Mesostasis areas contain pyroxene, ulvospinel, pyroxferroite, silica, troilite and glass (up to 1.9 wt.% K_2O). Plagioclase composition is relatively constant at An 95, but pyroxene compositions vary widely (Fig. 2). The extreme Fe-enrichment of the clast G pyroxenes is consistent with a lunar mare source and rules out a terrae origin (Fig. 1). This conclusion is reinforced by the Cr content and Ti/(Ti+Cr) ratios (Fig. 3) of the pyroxenes. Note that Ti/(Ti+Cr) ratios of the pyroxenes at a given Fe/(Fe+Mg) ratio are very low and are similar to very low titanium (VLT) basalts of Apollo 17 and Luna 24 (5).

ORIGIN OF ALHA 81005

There is little doubt that ALHA 81005 originated in the lunar terrae. However, the VLT basalt lithology (clast G) is consistent with a source for this meteorite in a terra region adjacent (within 100 km?) to areas of VLT mare basalt. Luna 24 returned VLT basalt from Mare Crisium, and spectral reflectance study (6) indicates that VLT basalts (some unsampled) also occur in Mare Somniorum, Mare Frigoris, Sinus Roris, northern Mare Imbrium, and western Oceanus Procellarum. The source of ALHA 81005 is probably a young crater in the terrae adjacent to one of these regions if the meteorite is from the Earth-facing hemisphere of the Moon.

REFERENCES

(1) Antarctic Meteorite Newsletter 5, No. 4, November, 1982.

(2) Basaltic Volcanism Study Project (1981) Basalt Volcanism on the Terrestrial Planets, p. 348, 361. Pergamon Press.

(3) Norman M.D. and Ryder G. (1979) A summary of the petrology and geochemistry of pristine highland rocks. Proc. Lunar Planet. Sci. Conf. 10th, p. 531-559.

(4) James O.B. and Flohr M.K. (1983) Subdivision of the Mg-suite noritic rocks into Mg-gabbronorites and Mg-norites. J. Geophys. Res. 88, A603-614.

(5) Nielsen R.L. and Drake M.J. (1978) The case for at least three mare basalt magmas at the Luna 24 landing site, p. 419-428 in Merrill R.B. and Papike J.J., eds., Mare Crisium: The View from Luna 24. Pergamon Press.

(6) Pieters C.M. (1978) Mare basalts on the front side of the Moon: a summary of spectral reflectance data. Proc. Lunar Planet. Sci. Conf. 9th, p. 2825-2849.

Supported by NASA grants NAGW 220 and NAG 9-39.

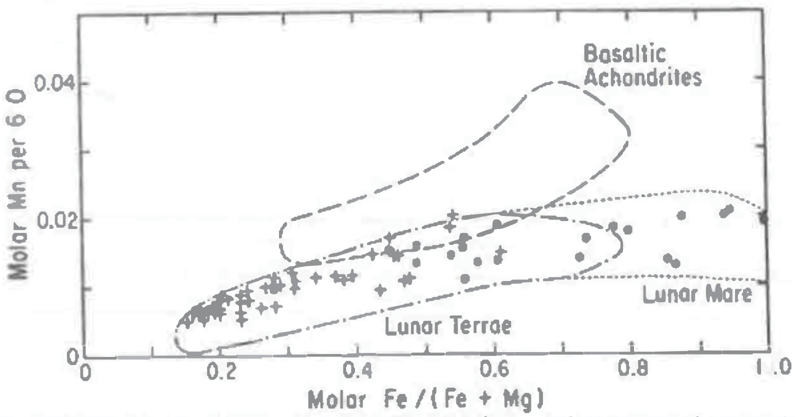

Fig. 1. Molar Mn content of pyroxenes from ALHA 81005,9. Clast G analyses shown as dots; all others as crosses. Fields of lunar terrae, lunar mare and basaltic achondrite compositions from (2).

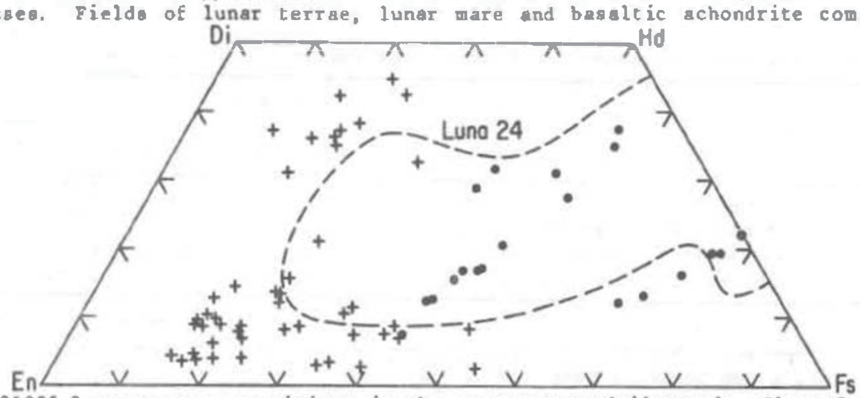

Fig. 2. ALHA 81005,9 pyroxene compositions in the pyroxene quadrilateral. Clast G analyses shown as dots. Field of Luna 24 very low titanium basalt pyroxenes from (5).

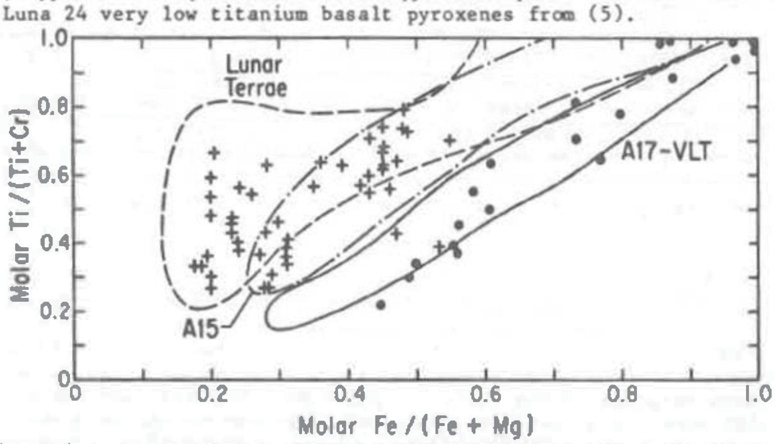

Fig. 3. Molar Ti/(Ti+Cr) content of pyroxenes from ALHA 81005,9. Clast G analyses shown as dots. Lunar terrae field from (2); Apollo 15 and Apollo 17 very low titanium basalt fields from (5).