ALHA 81005: PETROGRAPHY, SHOCK, MOON, MARS, GIORDANO BRUNO, AND COMPOSITION: Rolf Ostertag and Graham Ryder, Institut für Mineralogie, Corrensstraße 24, 4400 Münster.

Summary: ALHA 81005,8 is a glassy, olivine-rich regolith breccia, beyond any reasonable doubt of lunar origin. It is dominated by feldspathic granulitic impactites, contains some cataclastic ferroan anothosites and minor mare basalt components, but lacks detectable KREEP. Its bulk composition (25.1 % Al_2O_3; 8.9 % MgO; 5.6 % FeO) has a higher Mg′ and is poorer in Na and Ti than other lunar soils, a reflection of its large plutonic troctolitic component (olivine fragments) and the poverty of KREEP. We contend that the sample is far more likely to be ejecta from Giordano Bruno than any other lunar crater, hence ALHA 81005 provides information about the Moon's NE limb. The sample was not detectably shocked during ejection from the Moon, although most of its components had already been shocked during regolith formation. Evidently escape of material from planets following impacts does occur without melting, and without the requirements for high indigenous volatiles. If Giordano Bruno is the source, then neither are oblique impacts necessary. The implications for meteorites of possible Martian origin are obvious.

Lunar Origin: The sample came from a planet which produced a feldspathic crust and is also otherwise indistinguishable from the Moon. It is low in volatiles (Na, K low; water absent), and has a low oxidation state (Fe-metal). MnO/FeO ratios in olivines (∼100) and pyroxenes (∼50) are similar to those in all other lunar rocks but not to those in basaltic achondites. Ni in olivines is low (<100 ppm) as in most lunar highlands rocks. ALHA 81005,8 contains lithic clasts similar to those of other lunar highlands breccias except that it lacks KREEP.

Shock: Shock effects in mineral clasts and glass beads in ALHA 81005,8 range from unshocked glass beads and weakly shocked plagioclase with fractures and undulous extinction (≤15 GPa) to fractured olivine, planar elements in pyroxene (30-40 GPa) and diaplectic plagioclase glass (30-40 GPa) all of which is now recrystallized. Lithic clasts are fractured, one clasts shows planar elements in plagioclase. All shock features indicating high shock pressures were developed prior to the event which caused the ejection of the sample from the Moon's surface. The sample itself has not been shocked to more than 15 GPa, if at all, as no mosaicism or unrecrystallized diaplectic plagioclase glass is apparent and most of the glass beads are even unfractured. It is unlikely that the brown matrix glass formed during the ejection event as the sample still contains a high content of solar-wind rare gases (1). The shock pressure experienced by a sample ejected from a body of the size of the Earth's moon may thus be as low as 0-15 GPa. This is consistent with a possible Martian origin of meteorites which have been shocked to only 30-40 GPa, such as Shergotty. Dynamicists have stated that only a shock-melted sample could be accelerated beyond escape velocity upon impact. Not only is this disproved by ALHA 81005, but we now have 10 samples which came from large planetary bodies and not a sinle one of them has been totally shock-melted. The impact melt may have been finely dispersed, nevertheless we have to consider a mechanism which accelerates a low-shocked sample from a planetary body not containing large amounts of indigenous volatiles.

Giordano Bruno: The significance of ALHA 81005 for lunar petrology would be greatly enhanced if we knew from where on the Moon it came. Our petrographic/microprobe investigation requires that the sample has a highland source, far removed from a KREEP supply, but with mare basalts close enough to be components. Furthermore, unless ALHA 81005 has a terrestral age older than all other dated Allan Hills samples, it was ejected from the Moon less than 600,000 years ago, probably less than 200,000 years ago, i.e. very recently. Giordano Bruno is a 20 km crater, very young according to its large ray/crater diameter ratio (greater than the 2 million year old South Ray), and in its size and youth is unequalled as a potential source of ALHA 81005 (presumably, the larger the crater, the more likely to eject material from the planet). Giordano Bruno lies in highlands terrain, but with mare material only 150 km away, filling the areas in and around Maxwell and Lomonosov. The area was not overflown by Apollo, so no data on the possible proximity of KREEP is available; the orbital data taken 30° to the south lack KREEP. We conclude that Giordano Bruno is far more likely than any other lunar crater to be the source of ALHA 81005.

Petrography: ALHA 81005,8 has a brown, commonly vesicular glassy matrix, which encloses glass shards, blebs, and 3 beads, and shocked mineral and lithic clasts. In common with other regolith breccias, lithification destroyed the fragile nature of agglutinates. Much of the glassy matrix has the form of irregular, thin veinlets and blebs, and is evidently multigenerational. Our analytical study was intended to deduce the nature of the components of the rock and compare them with other known lunar materials. More details are given in the accompanying abstract. About 30 % of the lithic clast population (Fig. 1) is feldspathic granulitic impactite (only 2 pyroxene poikiloblastic clasts). These are olivine-rich, and generally have Mg′ ∼80, similar to lunar frontside granulites. Generally distinct from these in both their high plagioclase content and their Fe-rich mafic minerals are cataclastic anortho-

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sites, which are less abundant - there is a distinct hiatus between Mg-rich rocks and cataclastic anorthosites (Fig.2), but no lithic samples are similar to the lunar front-side Mg-suite rocks, many of which are related to KREEP. Feldspathic impact melts ranging from glass and fine-grained glassy breccias to subophitic/poikilitic are common. Some contain minor silica, but lack the abundant mesostasis glass, phosphates, and the opaque oxide materials which characterize KREEP. Two small "cumulate"-textured fragments fall with the anorthosites, one with more Mg-rich group. One 4 mm clast is a polymict breccia, distinct from the rest of the rock in that it lacks granulitic impactites, although it contains one of the poikiloblastic clasts.

Some glasses contain a mare component and some pyroxene fragments and one lithic fragment appear to be of mare basalt deriviation. All analyzed olivine mineral fragments appear to be of plutonic origin (low CaO) and have Ni less than 100 ppm, while pyroxenes include both plutonic and extrusive varieties. The "Mg-gap" apparent among lithic fragments (Fig. 2) is also apparent among single mineral grains. Of 48 mafic mineral fragments larger than 100 microns analyzed, 28 were olivines of plutonic origin, most more magnesian than Fo 77, and most are too large to have come from granulites.

We believe that the bulk composition of the rock is best represented by the clean, vesiculated glass of the fusion crust, away from interference by partly digested clasts. We analysed 6 such points and found them to be homogeneous - the average is presented in the Table and Figure 3.

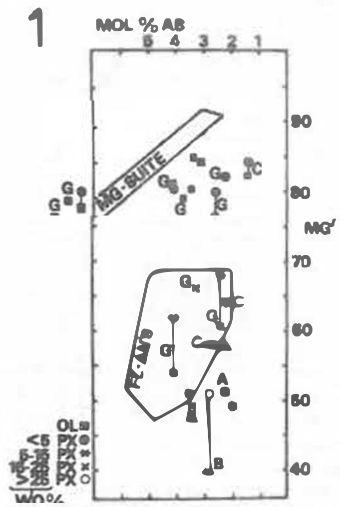
Possibly Na is low cf. bulk rock because of sodium volatilization during fusion but other glasses also have low Na. Analyses of other clear glasses cluster around this composition and support the contention that it represents bulk rock. It apparently agrees reasonably with the matrix analysis of Palme et al. (pers. comm.). The soil in the ALHA 81005 target area is more similar to L 20 soil than other soils but is more aluminous and has a higher Mg'. It is similar to granulites, but is more magnesian because of the olivine component. The anorthosite component is not as great as at Apollo 16. Generally, the composition is similar to the granulitic, anorthosite-poor highlands which can be deduced for the pre-Serenitatis surface at A 17. The low Ti in the sample supports the contention that most of the Ti in lunar frontside breccias is contributed by the KREEP component, which is also lacking in ALHA 81005. Quite likely KREEP is also the dominant source of Na in frontside breccias.

TABLE

ALHA 81005,8 Fusion crust	
SiO_2	45
TiO_2	0.27
Al_2O_3	25.1
FeO	5.6
MgO	8.9
CaO	14.6
Na_2O	0.24
K_2O	0.06

Reference: (1) Bogard, D. and Johnson, P. (1983) Lunar Planetary Science XIV

1



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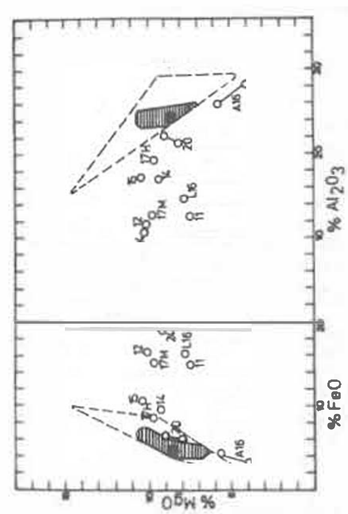

Fig. 1: Ab v. Mg' = (Mg/Mg+Fe) for lithic clasts in ALHA 81005. G = granulites, A = anorthosites, C = "cumulate"-textured clasts. The two granulites off the diagram had no plagioclase analyzed. Fields of front-side ferroan anorthosites and Mg-suite for comparison. Note gap of Mg' values 65 and 75. Fig. 2: Map of thin section ALHA 81005,8. Open = granulites, black = anorthosites and plagioclases, striped = varied impact melts. width 2 cm. Fig. 3: Fusion crust analysis for ALHA 81005 compared with other lunar soils. Black dot = fusion crust, striped = most other clear glasses in ALHA 81005, open = total range of glass in 81005. For its Al and Fe, ALHA 81005 glass is more magnesian than other samples, reflecting its high olivine / pyroxene ratio.