

THE HISTORY OF LUNAR BRECCIA 15015,
The European Consortium and friends*

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Rock 15015 was a tough 4770g breccia collected from the surface 20m west of the Apollo 15 lunar module. It has an extensive dark glass coating, which is thick and frothy on the upper surfaces but is thin and smoother on the lower portions of the rock. The polarization properties of the upper surface are consistent with it being highly vitreous and complex in structure. The change of polarization phase angle conforms with previously measured rough breccia surfaces and lunar fines. Electron microscopy suggests that a glass coat is ubiquitous and reveals the presence of microcraters and mounds. Some of the latter are possibly metallic features produced by reduction.

The bulk chemical composition of 15015 is %SiO₂ 47.11, TiO₂ 1.90, Al₂O₃ 14.46, Cr₂O₃ 0.40, FeO 14.38, MnO 0.19, MgO 9.93, CaO 10.49, Na₂O 0.31, K₂O 1.28, P₂O₅ 0.22. This composition is intermediate between Fra Mauro and Mare material and comparable to the local soil (Fig.1). The breccia is packed with fine mineral clasts; the grade is low in Warner group 2. The larger (0.5mm) clasts include 10% rock fragments, 19% pyroxene, 8% plagioclase, 10% glass fragments, 1.3% metal oxides and sulphides, together with 51% matrix. Among the rock fragments mare basalts, plagioclase basalts, Fra Mauro basalts and subordinate metaclastics were recognised mineralogically. The glass, often partially devitrified, occurs as spheres, ropey twists, angular fragments, etc. Fra Mauro types predominate (Fig. 1) with Mare types being subordinate. Also present are broken devitrified fawn spheres which are close in composition to the Apollo 15 green glass. The coating glass is close to the bulk composition of 15015 and was probably formed by melting of constituents of the rock rather than as splashed material. // ⁴⁰Ar/³⁹Ar measurements have been made on samples of matrix, a dark variolitic basalt clast, bubbly glass from the upper surface and a clast of pale, mesostasis-rich, Fra Mauro type basalt. Both clasts show effects of extreme radiogenic argon loss (75%) and precise ⁴⁰Ar/³⁹Ar age determination is not possible. The Fra Mauro type basalt probably crystallized 3.8-0.1by ago, or earlier and represents

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highland material. The variolitic basalt probably crystallized 3.5 ± 0.2 by ago, but because of its low K content and extreme argon loss it is not possible to determine whether it represents pre-mare material or a later extrusion into the Imbrium basin. Argon in the matrix and the glass is dominated by a trapped component; however, a correlation between $^{40}\text{Ar}/^{36}\text{Ar}$ and $^{39}\text{Ar}/^{36}\text{Ar}$ for surface glass appears to indicate an 'isochron age' of 1.2 by. This possibly represents an upper limit for the age of the glass but could also be a manifestation of partially outgassed older inclusions. // Combined high voltage and scanning electron microscopy have revealed radiation damage features which suggest that at least some of the constituent grains have been exposed to cosmic rays prior to brecciation, which may indicate a mixture of mature and immature components. About 30% of the grains have microcrystallites of appearance similar to, but larger in size than, those reported previously in Apollo 11 and Warner group 1 and 2 Apollo 14 breccias. The density of etched tracks extends over almost three orders of magnitude from 10^7 to 10^{10} tracks/cm²; the low track densities suggest a recent exposure for the glass coating.

Gas release patterns show high temperature $^{38}\text{Ar}/^{37}\text{Ar}$ plateaux and indicate that different clasts have quite distinct exposure ages. Thus, ^{38}Ar ages (based on a production rate of 1.4×10^{-8} cc STP/ 10^6 y/gCa) of 490 my for the Fra Mauro basalt fragment and 1290 my for the variolitic basalt clast indicate a prebrecciation irradiation history of at least 800 my for the latter. The low temperature $^{38}\text{Ar}/^{37}\text{Ar}$ ratios, like the $^{40}\text{Ar}/^{39}\text{Ar}$ ratios, are depressed by diffusion and indicate an overall loss of 25% cosmogenic argon in both samples. The loss of radiogenic and cosmogenic argon may have resulted from shock-induced heating although the ease with which argon is evolved from rocks in the laboratory suggests that recent solar heating cannot be discounted.

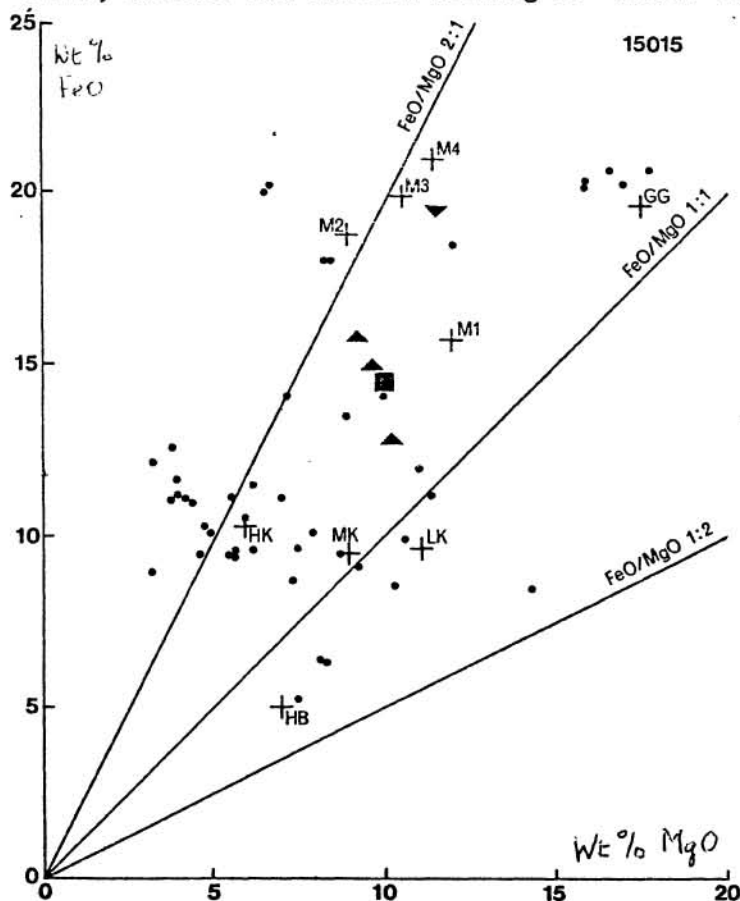
^{21}Ne exposure ages for the matrix and for the Fra Mauro basalt clast lie between 250 and 310 my. A consideration of the loss of ^{21}Ne , which must have occurred, should render these ages consistent with the ^{38}Ar age calculated for the same clast. ^3He exposures ages for all samples measured are less than 100 my.

No amorphous coatings or high densities of latent tracks are observable by electron microscopy; however, solar wind implantation is indicated by the abundance of carbon and nitrogen species and solar wind rare gases. The average total C, N and S values for the rock are 121, 54, and 630 ppm, respectively. The carbon and nitrogen concentrations are respectively ca. 20 and 50% lower than observed for the same elements in 15012 fines from the same sampling station. The sulphur measurements for the rocks and fines are not substantially different. All three elements measured for the rock are depleted in the heavier isotopes. Laboratory heat treatment at 800° C of 15012 fines reduces the total C and N by 20 and 45% respectively; sulphur shows negligible loss. The gaseous carbon and nitrogen species released by the pyrolysis are enriched in ^{13}C and ^{15}N . The data suggests that 15015 has been heated to 800°C

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during or subsequent to its formation from local fines. This thermal event however, may not have resulted in uniform heating of the rock. The CD_4/CH_4 ratios measured for the gases released by DC1 dissolution from various sections of 15015 (bottom 7.3, middle 26 and top ∞), suggest preferential loss of CH_4 relative to less volatile carbide from the uppermost portions of the rock. The ratio observed for the bottom is approximately similar to that normally encountered for grade 0 or 1 soil breccias and microbreccias. The high ratios for the middle and top sections suggest that the material in these areas had experienced a more violent process (greater temperatures or longer times) than brecciation. High CD_4/CH_4 ratios have previously been observed in glassy agglutinate samples (2). The light rare gases and nitrogen are also depleted in the upper portions of 15015. The consortium investigations allow the following conclusions concerning the history of rock 15015: The breccia (metamorphic grade 2) was formed from diverse well-mixed local soil of varying exposure age and maturity. Lithification could not have occurred very tentatively before 2.7 ± 0.2 by; however, the age of the frothy vesicular surface glass suggests aggregation occurred 1.2 by ago. The process responsible for the consolidation of the rock or a subsequent thermal event, induced non-uniform heating to about 800°C at the bottom and higher (or longer) at the top.



fractionating trapped solar wind components present in the constituent soil grains. After formation, 15015 was buried at a depth greater than 2 metres until it was ejected onto the lunar surface possibly around 30 my ago.

15015 Glass fragments and coatings FeO-MgO.

- + Averages of Apollo 15 glass types.
- Three analyses of rock 15015
- ▲ Bubbly coating glass on 15015
- ▼ Glass seam in 15015, probably splash glass
- Individual glass fragments.

References:

- (1) Chang et al., Apollo 15 Lunar Samples, 291 (1972)
- (2) Cadogan et al., Proc. Fourth Lunar Sci. Conf. in press.