^{39}Ar-^{40}Ar AGE OF AN APOLLO 15, KREEP-POOR, IMPACT MELT ROCK

D.D. Bogard, D.H. Garrison*, and M.M. Lindstrom, NASA, Johnson Space Center, Houston, TX 77058 (* also Lockheed-ESC, Houston, TX)

KREEP-poor impact melt rocks (KPIM) were identified by Lindstrom et al (1) as an important new type of impact melt at the Apollo 15 site. They make up approximately one third of the impact melt fragments found as 2-10 mm soil particles or as clasts in regolith breccias at the Apennine Front. They are impact melt rocks, often with poikilitic texture, which have noritic bulk composition. They are distinct from typical Apollo 15 LKFM impact melt rocks in their lower incompatible element concentrations and non-KREEPy REE patterns. Their noritic bulk composition led to suggestion (1) that they may represent a basin-forming impact, but their KREEP-poor character distinguishes them from the KREEPy Imbrium and Serenitatis ejecta common at the Apollo 15 and 17 sites. Lindstrom et al (1) suggested that they represent an older basin and are part of the pre-Serenitatis section at the Apennine Front. Determination of an age of these melt rocks is essential to the interpretation of KPIM.

Regolith breccia 15459 contains a 1 x 3 cm white clast which is the largest identified fragment of KPIM. Lindstrom et al (1) describe it as a plagioclase-rich coarsely poikilitic impact melt and present several analyses of the clast. In order to get a representative sample of this clast they were allocated 2 g of material (15459,414) which was ground in diamonite and homogenized. A 41 mg split of this sample was irradiated with fast neutrons to convert a portion of the ^{39}K to ^{39}Ar. The isotopic composition of the Ar extracted by stepwise heating the sample in an ultra-high vacuum furnace was measured on a mass spectrometer. Corrections were made for system blanks, decay of ^{37}Ar and ^{39}Ar since irradiation, and reactor interferences. The irradiation constant (J) determined from two samples of the NL-25-2 hornblende was 0.0343. The ^{39}Ar-^{40}Ar age was calculated for each temperature extraction, and ages are plotted in Fig. 1 against the cumulative fractional release of ^{39}Ar. The age width of each data box gives the uncertainty calculated from uncertainties in blanks, decay time corrections, reactor corrections, and irradiation constant. The K and Ca concentrations determined on our sample were 0.097% and 8.9%, respectively. This [K] is similar to analyses reported by (1), but our [Ca] is somewhat lower.

Most extractions gave essentially constant ^{39}Ar-^{40}Ar ages. The average age for extractions releasing between 6% and 97% of the ^{39}Ar is 3.85 $\pm$0.05 Ga (decay parameters in 2). The sample shows a small amount of ^{40}Ar loss at low extraction temperatures and may show a slightly higher residual age at the highest (1550^{o}C) extraction.

The Apollo 15 site lies on the rim of the Imbrium basin and within the rings of the Serenitatis basin, and radiometric ages of highland samples at this site could readily have been affected by both impact events. In fact, Rb-Sr and Sm-Nd age determinations on clasts of plutonic noritic composition contained in two other impact melt rocks, 15445 and 15455, indicate primitive ages probably as old as 4.5 Ga (3, 4, 5). The Rb-Sr isochrons of these rocks show disturbance, however, and the ^{39}Ar-^{40}Ar release of plagioclase from a clast in 15455 suggests an original age at least as old as 4.2 Ga that was substantially reset by one of the large basin events (5).

The ages of the Imbrium and Serenitatis basins have been inferred from radiometric ages determined for a considerable number of Apollo rocks (e.g., 6, 7). Among more recent estimates of basin ages, the formation of Serenitatis has been inferred at 3.87 $\pm$0.03 Ga (8, 9). The generally accepted age of Imbrium, a younger basin, has been 3.85 $\pm$0.02 Ga (8); however, recent interpretations are that Imbrium is only 3.75-3.77 Ga old (9, 10). Thus, our ^{39}Ar-^{40}Ar age of 3.85 $\pm$0.05 Ga is in good agreement with either the preferred age of Serenitatis or earlier interpretations of the age of Imbrium, but not apparently with recent interpretations of Imbrium's age.

Breccia 15459 also contained a large mare basalt clast of a magma type apparently independent from typical Apollo 15 basalts (11). The Rb-Sr isochron age for this clast is

3.22 ±0.04 Ga (11), and the ^{39}Ar-^{40}Ar age averaged above ~10% release of ^{39}Ar and adjusted to new K decay parameters (2) gives the same age (12). Clearly the 15459 breccia was formed at a time subsequent to the formation time of the mare clast, and the 3.85 Ga ^{39}Ar-^{40}Ar age of the impact melt clast is unrelated to formation of either the breccia or the mare clast.

The significance of the 3.85 Ga ^{39}Ar-^{40}Ar age of this impact melt is open to some interpretation. The clast is compositionally distinct from both Imbrium and Serenitatis impact melt rocks, but the age may have been reset while the clast resided in a hot ejecta layer formed by the Serenitatis impact, or by the Imbrium impact if this occurred 3.85 Ga ago. The hint of an older age (~4.2 Ga) at the highest extraction temperature may be a residue from the earlier formation time presumed for this clast. Alternatively, 15459,414 may have been maintained at a sufficiently high temperature while in the lower crust to have been an open system for Ar until the Serenitatis event brought it to cooler surface regions. From stepwise temperature release data for ^{39}Ar from the clast we calculated diffusion parameters, D/a^2, and examined these against reciprocal temperature in an Arrhenius plot. This plot is linear at temperatures below ~900°C (where ~75% of the ^{39}Ar is released with an activation energy of ~32 kcal/mole) and suggests values of D/a^2 of ~10^{-9} sec^{-1} at 400°C or ~10^{-6} sec^{-1} at 700°C. To produce significant fractional loss of Ar, the clast would have to be held at 400°C for ~10 years or at 700°C for ~10 days. An ejecta layer ~100 meters in thickness initially at 400°C would cool sufficiently slowly to produce significant loss of Ar (13). Thus, thermal environments expected in ejecta from either the Serenitatis or Imbrium events would seem sufficient to readily have reset 15459,414. Isotopic measurements on other radiometric systems are necessary to determine the true age of KPIM.

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