^{39}Ar-^{40}Ar Age Dating of Two Angrites and Two Brachinites.

Daniel Garrison[1,2] and Donald Bogard[1], [1]Astromaterials Research, NASA Johnson Space Center, Houston TX 77058; [2]Lockheed Martin Corp, Houston, TX

Introduction. Angrites are a rare group (~7 known) of igneous meteorites with basalt-like composition, which probably derive from a relatively small parent body that differs from those of other igneous meteorites (1,3). Angrites show evidence for extinct ^{53}Mn, ^{146}Sm, and ^{244}Pu, and precise U-Pb, and Pb-Pb ages of 4.558 Gyr for two angrites define the time of early parent body differentiation (2). The ^{147}Sm-^{143}Nd ages of two angrites range between 4.53 ±0.04 and 4.56 ±0.04 Gyr, but no ^{39}Ar-^{40}Ar or Rb-Sr ages have been reported. Most angrites show no evidence for either shock brecciation or metamorphism.

Brachinites are another very rare group of differentiated meteorites consisting primarily of olivine, with minor augite, chromite, Fe-sulfides, and sometimes plagioclase and opx (3). Presence of excess ^{129}Xe and excess ^{53}Cr from decay of ^{53}Mn in some brachinites indicate that they also formed very early. Brachinite petrogenesis is poorly defined. They may be igneous cumulates or metamorphic products of chondritic-like starting material (1,4). If after their formation, angrites and brachinites cooled quickly with minimal subsequent heating, then one might expect them to show uniquely old K-Ar ages, at least in comparison to other differentiated meteorites such as eucrites and mesosiderites.

Most angrites and brachinites contain very little, if any K-feldspar, which has deterred measurements of their Ar-Ar ages. We made ^{39}Ar-^{40}Ar analyses on two angrites, LEW86010 (metamorphosed) and D'Orbigny, and on two brachinites, EET99402 and Brachina. All are finds. Any feldspar in angrites is highly calcic, with expected K concentrations of <100 ppm. We selected LEW86010 and D'Orbigny because they have been the objects of several other studies and because chemical analyses suggested [K] was ~70 ppm in both meteorites (D. Mittlefehldt, pers. comm.). Brachina contains ~9.9% plagioclase of higher K-content than angrites (1), and EET99402 is estimated to contain ~5% K-poor plagioclase (4). Other brachinites contain little to no feldspar (1). We have successfully measured Ar-Ar ages on a few meteorites and lunar anorthosites with [K] <100 ppm.

Brachinites. The ^{39}Ar-^{40}Ar ages and K/Ca ratios as a function of cumulative release of ^{39}Ar for brachinites **EET99402** and **Brachina** are shown in Figs. 1a and 1b. Although [K] in our EET sample was quite low (31 ppm), corrections for Ar blanks and reactor-produced interferences on ^{39}Ar were relatively modest. (Uncertainties in both corrections, along with isotopic measurement errors are included in age uncertainties for individual extractions.) Changes in the K/Ca ratio and rate of release of ^{39}Ar with temperature for EET (Fig. 1a) suggest three distinct K-bearing phases. The lower Ar ages over 0-13% of the ^{39}Ar release were probably produced by Antarctic weathering. Eight extractions (13-49% ^{39}Ar release) show constant K/Ca, have the same age within their respective uncertainties, and define a mean age of 4.13 ±0.06 Gyr. The next three extractions (49-99% ^{39}Ar release) seem to be a different phase and give an average age of 4.265 ±0.025 Gyr. We interpret this age spectrum to indicate different degrees of ^{40}Ar degassing from phases with different Ar degassing properties by a single heating event ~4.13 Gyr ago. Most probably this thermal event was a large impact on the parent asteroid.

The age spectrum for Brachina is more complex, and the rate of Ar release suggests multiple K-bearing phases. The ^{36,37,38}Ar isotopic data indicate that significant amounts of terrestrial Ar were released in the first few extractions (0-17% ^{39}Ar), and terrestrial weathering likely produced these younger ages. Atmospheric ^{36}Ar also seems to have been released over ~17-30% ^{39}Ar release. The average age for 11 extractions releasing 30-100% of the ^{39}Ar is 4.25 ±0.06 Gyr. The reason for the decrease in age at ~55% ^{39}Ar release is not apparent, as the steady decrease in K/Ca seems inconsistent with a ^{39}Ar recoil effect. This age minimum, 4.13 Gyr, is identical to the inferred degassing age of EET99402, and may indicate a common degassing event for both brachinites. The age spectrum over 20-100% ^{39}Ar release may represent separate partial ^{40}Ar diffusion loss profiles from phases with different Ar diffusion properties, as suggested for

EET99402. Interestingly, a ^{40}Ar/^{36}Ar versus ^{39}Ar/^{36}Ar isochron plot of those extractions releasing 30-100% of the ^{39}Ar is highly linear (R^2 =0.9994) and gives an age of 4.28 ±0.02 Gyr and a ^{40}Ar/^{36}Ar intercept of −151 ±179. However, the possible negative intercept suggests that this is a false isochron produced by different degassing rates between ^{39,40}Ar produced from K and cosmogenic ^{36}Ar (5).

Angrites. The ^{39}Ar-^{40}Ar ages and K/Ca ratios as a function of cumulative release of ^{39}Ar for angrites **LEW86010** and **D'Orbigny** are shown in Figs. 2a and 2b. Although LEW86010 contained 80 ppm K, its Ar-Ar age spectrum is highly disturbed. Only the first extraction (0-13% ^{39}Ar) suggests the release of significant amounts of terrestrial Ar. The ^{36}Ar/^{37}Ar and ^{36}Ar/^{38}Ar ratios are relative constant for most other extractions, suggesting the release of only cosmogenic Ar and not atmospheric or trapped ^{36}Ar. The young Ar-Ar ages and higher K/Ca ratios for the first few extractions were most probably produced by terrestrial weathering, and we have observed similar effects in some LEW eucrites. The major decrease in age at ~75% ^{39}Ar release is probably not caused by ^{39}Ar recoil, as K/Ca increases here. It appears that even higher temperature K-bearing sites in LEW have been altered by either Antarctic weathering or impact heating on the parent body. Weathering effects were also observed in the Rb-Sr system in LEW86010 (6). The D'Orbigny sample had very low K (10 ppm) and high Ca, making the reactor correction to ^{39}Ar very large and the Ar ages quite uncertain. Only the first extraction (0-12% ^{39}Ar) released obvious terrestrial Ar, and extractions releasing 29-100% of the ^{39}Ar show constant ^{36}Ar/^{37}Ar and ^{36}Ar/^{38}Ar ratios indicative of only cosmogenic Ar. D'Orbigny suggests a sample ~4 Gyr old which has lost a significant fraction of its ^{40}Ar. Angrites may not be dateable by K-Ar.

References. (1) Mittlefehldt et al., *Reviews in Mineralogy 36*, Planetary Materials, 1998; (2) Carlson & Lugmair, *Origin of Earth & Moon*, 25-44, Univ. AZ Press, 2000; (3) Mittlefehldt et al., *MAPS 37*, 345-369, 2002; (4) Mittlefehldt & Berkley, *XXXIII LPSC* Abst. #1008, 2002; (5) Bogard & Garrison, *MAPS* submitted, 2002; (6) Nyquist et al., *Meteoritics 29*, 872-885.