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^{39}Ar-^{40}Ar AGES OF ACHONDRITES: EVIDENCE FOR A LUNAR-LIKE CATACLYSM?.

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The observation that the K-Ar, Pb-Pb, and Rb-Sr ages of a significant number of lunar highland rocks were reset in the interval of 4.1-3.8 Ga ago led to the concept of a cataclysmic bombardment of the moon during this period (e.g. 1,2). Histograms of ^{39}Ar-^{40}Ar ages of highland rocks (2,3) are strongly peaked at 3.8-3.95 Ga, 3.85-4.1 Ga, and 3.9-4.0 Ga for samples from Apollos 14, 16, and 17, respectively. Some disagreement exists as to whether these age clusters represent the termination of an ~0.6 Ga-long period of lunar bombardment or are primarily the result of resetting by a few large basin-forming events. Several lunar plutonic rocks indicate radiometric ages of 4.0-4.6 Ga (3), and some crustal rocks (e.g. anorthosites) show partial evidence of remnant ages older than 4.0 Ga, implying that some rocks either escaped the cataclysm or were incompletely reset by it. Crater densities demonstrate that during the time of formation of large mare ~3.2-3.8 Ga ago the lunar bombardment rate had dramatically decreased.

An important consideration for understanding the early bombardment history of the solar system, including the moon, is whether evidence also exists in meteorites for resetting of radiometric ages by cataclysmic bombardment of their parent bodies. The HED achondrites probably formed on a relatively large, common parent body that is known to have experienced extensive melting and differentiation about 4.5 Ga ago. Although a few HED meteorites show precise Sm-Nd or Rb-Sr isochrons of 4.46-4.56, others show considerable disturbance of radiometric systems, particularly K-Ar, probably caused by early impact metamorphism and brecciation on the parent body. A comparison of ^{39}Ar-^{40}Ar ages of achondritic meteorites with ages of lunar highland rocks should help elucidate the nature of the early bombardment of the solar system.

We are participating in various consortia studies of primarily Antarctic eucrites and howardites for which we have measured ^{39}Ar-^{40}Ar ages of various clasts and matrix samples. Some of these analyses have not been previously reported. Included in these data are ages of 3.9-4.0 Ga for two different clasts from howardite EET 87509 and a clast from polymict eucrite Yamato 790020, and ages of 3.4-3.5 Ga for clasts from polymict eucrite Yamato 791186 and monomict eucrite Yamato 792510. We have classified our data and literature data for ^{39}Ar-^{40}Ar analyses of HED meteorites into three groups: 1) most of the Ar release indicates a single age; 2) a significant fraction of the Ar release gives a common age, but some phases may have lost additional Ar or some phases may not have been completely degassed of Ar; and 3) a specific age is not suggested by the release. A histogram of ^{39}Ar-^{40}Ar ages of eucrites and howardites for the first two groups spreads between 3.4 and 4.4 Ga, but apparent age clusters occur at ~3.5 Ga and ~4.0 Ga. Ages from data group 1 fall in both age clusters. ^{39}Ar-^{40}Ar ages of 14 mesosiderites, another class of differentiated meteorite probably from a different parent body, are strongly clustered at ~3.8-4.1 Ga. Although the data base for impact metamorphic ages of HED meteorites is much smaller than that for the moon, these data suggest that at least two large meteorite parent bodies experienced significant impact metamorphism ~3.8-4.1 Ga ago, the same time period that the moon apparently experienced intense bombardment. Significant, early impact bombardment on meteorite parent bodies coincident with its occurrence on the moon would require that the process was spread across much of the solar system and would strongly imply that many craters observed on the Martian cratered terrain and on Jovian satellites also formed at the same time. The smaller cluster of HED ages at ~3.5 Ga does not have a known lunar counterpart.

It appears from the limited number of Sm-Nd and Rb-Sr isochron data that the ages may not be as completely affected for HED meteorites as for lunar highland rocks, an observation that might be due to the larger size of the moon. Given the same source of impacting objects, the fraction of material heated for a sufficient time/temperature to cause age resetting may be larger on the moon than on asteroids for more than one reason. Recent studies suggest that larger impactors may generate a greater fraction of strongly heated material (4), and larger craters are possible on the moon compared to asteroids before the parent would be disrupted. In addition, strongly heated ejecta may be spread further from the crater on asteroids compared to the moon (5), and this thinner ejecta on asteroids can be expected to cool faster and thus be less likely to experience age resetting.

(1) F.Tera et al, EPSL **22**, 1974; (2) B.V. Project, Ch.7.3, 1981; (3) L.Nyquist & C.Shih, GCA **55**, 1991; (4) M.Cintala & R.Grieve, LPS XXII, 1991; (5) M.Cintali et al, Proc.LPSC 9th, 1978.