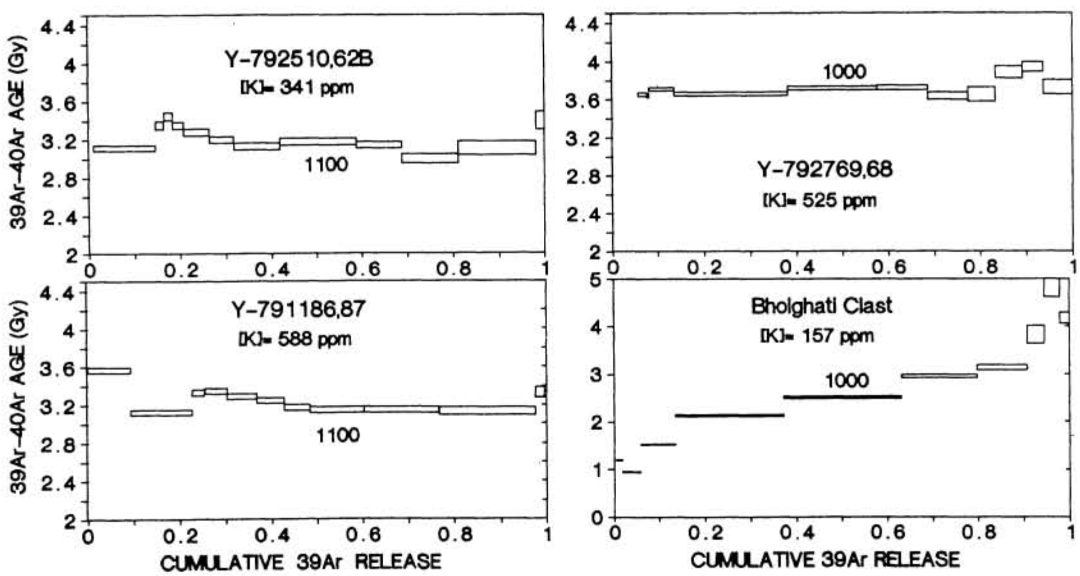
39Ar-40Ar AGES OF EUCRITES: DID THE HED PARENT BODY EXPERIENCE A LONG PERIOD OF THERMAL EVENTS DUE TO MAJOR IMPACTS? D.D. Bogard & D.H. Garrison, NASA, Johnson Space Center, Houston, TX 77058

We are determining 39Ar-40Ar ages of a variety of eucrites for two purposes: (1) Several of these meteorites are objects of collaborative studies, and our 39Ar-40Ar data, along with petrological, chemical, and radiometric studies of other investigators, are intended to provide information on the formation and history of individual eucrites. (2) We wish to compare the 39Ar-40Ar chronology of impact and other thermal events on the HED parent body with that observed for the mesosiderite parent body, chondrites, and the moon to examine similarities and differences in early bombardment histories. We envisaged that reset Ar ages of HED meteorites are the result of their residence times in heated impact ejecta on the parent body, as described by (1). Recent work has concentrated on collaborative studies of individual clasts with the hope that these have had a simpler history compared to the whole-rock breccia. This abstract is a progress report of our studies.

39Ar-40Ar ages of specific eucrites: Chemical and textural characteristics of pyroxenes in a pristine clast from Y-75011 suggested that it could be the least metamorphosed eucritic material ever studied (2). Rb-Sr and Nd-Sm isochron studies on this clast and a matrix sample yielded formation ages of 4.50-4.60 Gy, but some data suggested mild disturbance (1). Our 39Ar-40Ar data show an age for the clast of ~4.05 Gy for the first ~50% of the 39Ar release, followed by an increase in age with increasing extraction temperature to a maximum of ~4.5 Gy. The matrix sample gave an essentially identical 39Ar-40Ar release profile, but with ages lower by ~0.1 Gy for all extractions. In spite of its pristine nature and early Rb-Sr and Sm-Nd formation age, this basaltic clast experienced significant heating and Ar degassing ~4 Gy ago. Pyroxenes in Y-792510 suggest that this eucrite was significantly heated for an extended period. Most temperature releases of a clast from Y-792510 define a 39Ar-40Ar plateau age of ~3.2 Gy, and some separated phases are suggestive of a Rb-Sr age as low as 4.05 Gy (3). A whole rock sample from the Y-792769 eucrite shows a plateau age of ~3.7 Gy. Y-792769 appears to be intermediate between polymict and monomict eucrites, and differs from e.g. Y-75011 in that its pyroxenes show the homogenized trend of the ordinary eucrites, presumably produced by sub-solidus metamorphism (4). A clast from the Y-791186 eucrite shows a significantly younger age of approximately 3.2 Gy. A clast from the Y-790020 eucrite shows a 39Ar-40Ar age of ~3.7 Gy for the first ~50% of gas release, then the age progressively climbs to ~4.4 Gy. Two different clasts from the LEW-85302 eucrite each suggest the presence of a low-temperature phase with an "age" of 1Gy or less, and a high temperature phase with an "age" of 3.0-3.5 Gy. A clast from the LEW-85300 eucrite suggests a high-temperature plateau age of ~3.5 Gy. The Bholghati howardite is the object of a consortium study led by J.C. Laul, and an euctric clast from this meteorite gave a 39Ar-40Ar release pattern suggestive of partial diffusive loss of Ar and rises, with increasing extraction temperature, from an "age" of ~1Gy to >4Gy. 87Rb-87Sr data on Bholghati and Y-792510 are discussed in (5). 39Ar-40Ar data for four of these meteorites are shown below.



Essentially all 39Ar-40Ar ages determined on eucrites, howardites, and diogenites are younger than 4.5 Gy, and presumably reflect impact heating events on the HED parent body. It is informative to compare these HED ages with 39Ar-40Ar and 87Rb-87Sr ages determined for other planetary materials which have experienced significant impact events. Most lunar anorthosite rocks show ages by several radiometric techniques that have been reset by impacts between 3.85 and 4.0 Gy (e.g. 6), whereas several more "pristine" rocks show ages of 4.0-4.45 Gy (e.g., 7). We previously reported 39Ar-40Ar ages on several mesosiderites that suggested a major disruption event or events of the parent body between 3.6 and 3.8 Gy ago, and found no evidence in these samples of K-Ar ages older than 4.0 Gy (8). Interpretation of HED chronology in terms of early bombardment is not straightforward, however. To make this comparison we examined 39Ar-40Ar data from 37 analyses of 23 HED achondrites, from the literature and our own work. Because shapes of the 39/40 release curves often cannot easily be interpreted in terms of well-defined "events", we adopted 24 analyses that gave some indication of an event age (generally interpreted to be more than two extractions releasing significant 39Ar and showing essentially the same age). The "reliability" of these event ages ranges from well-defined by the 39Ar-40Ar data to only moderately indicated by the data.

Rb-Sr ages of a few eucrites are ~4.5 Gy, but other eucrites show varying degrees of radiometric resetting and have lower Rb-Sr "ages" (e.g. 1,9). Sm-Nd ages of eucrites are less common, but show similar trends. All 39Ar-40Ar ages of eucrites and howardites show some degree of resetting relative to 4.5 Gy, and thermal events in eucrites and howardites appear to spread as widely as 3.0-4.4 Gy ago (with one diogenite age of 1.1 Gy). Fig. 5 (below left) contrasts the relatively narrow spread in 39Ar-40Ar ages of mesosiderites with the much larger spread in ages for HED meteorites. The spread in HED ages is also somewhat greater than the typical 3.7-4.1 Gy spread in lunar highland ages. Fig. 6 (below right) shows the much larger spread in 39Ar-40Ar ages for two types of thermal events in chondrites: relatively recent (<1 Gy) events associated with shocked chondrites, and events either <1.5 Gy or 3.3-4.4 Gy that are associated with clasts or melt fragments in chondritic breccias. The "clustering" of lunar highland ages has been attributed to either the tail of a large and rapidly decreasing flux of large impactors in the early solar system, or to a "cataclysmic", short-lived increase in impactors ~3.9-4.1 Gy ago. The observation of apparently younger thermal events in mesosiderites and HED meteorites suggests that large impacts occurred even later on these parent objects. However, it is not yet clearly established whether this larger spread in HED ages compared to lunar highland breccias and mesosiderites is due to a longer period of bombardment resetting of the HED parent body, to a greater sensitivity of HED material to age resetting by less intense events, or to remaining analytical uncertainties in interpreting event ages from radiometric data. Figs. 5 & 6 below suggest, however, that thermal events recorded in the 39Ar-40Ar ages of achondrites, chondrites, and lunar highland rocks are of two types: (1) relatively early events that broadly affected all parent objects and reset or at least disturbed several radiometric systems; and (2) relatively recent events that affected Ar ages of selected meteorites. Intermediate 39Ar-40Ar ages in meteorites (and lunar samples) are almost non-existent.

References: (1) Nyquist et al JGR 91, #B8, p8137, 1986; (2) Takeda et al PLPSC 14, B245, 1983; (3) Nyquist et al, Meteoritics 23, p295, 1988; (4) Aoyama et al Meteoritics 22, p317, 1987; (5) Nyquist et al LPS XX, 1989; (6) Turner & Cadogan PLSC 6, p1509, 1975; (7) Carlson & Lugmair EPSL 90, p119, 1988; (8) Bogard et al LPS XIX, p112, 1988; (9) Birck & Allegre EPSL 39, p37, 1978.