Ar-Ar DATING OF SHOCK-MELTED ORDINARY CHONDRITES: CHRONOLOGY OF ASTEROIDAL IMPACTS.
T. D. Swindle, D. A. Kring, E. K. Olson and C. E. Isachsen, Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson AZ 85721-0092. (tswindle@u.arizona.edu)

Abstract: ^{40}Ar-^{39}Ar dating of 13 samples from 5 shock-melted ordinary chondrites is used to determine the timing of impacts in the Main Asteroid Belt. Three samples of the H impact melt LAP 02240 have well-defined plateaus at ~3900 Ma, consistent with the "lunar cataclysm" and many other meteorite impact ages. The LL impact melt breccia NWA 1701 records an impact at ~1000 Ma, in which melt was more thoroughly degassed than clasts, unlike the case in at least two other well-studied chondrites. Single samples of three other meteorites appear to record impacts less than 1000 Ma ago.

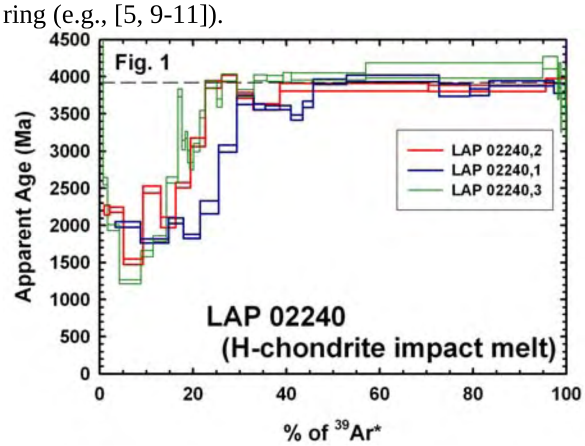
Introduction: Although chondritic meteorites are prized for providing a window into the formation and early evolution of the first solids in the Solar System, they also have witnessed the subsequent evolution of the planetary system, including impacts. Any inner Solar System-wide event should have left its mark on the asteroids as well as the planets. Additionally, even impacts that are simply random collisions of asteroids can have consequences throughout the inner Solar System. We have studied several shocked ordinary chondrites [1-3] in recent years. We are currently studying five more meteorites that are impact melts, impact melt breccias, or contain large impact melt veins, both to understand the chronology of asteroidal impacts, and to understand how such impacts affect the petrology and ^{40}Ar-^{39}Ar systems of the meteorites. Our procedure is to study multiple samples whenever possible, since shock effects, including degassing, can vary on very localized scales. In this abstract, we focus on two meteorites from which we have analyzed a total of 10 samples, and briefly discuss preliminary results from three other meteorites from which we have so far analyzed one sample each.

Procedure: After petrographic characterization, 10-20 mg samples of melt and (if possible) unmelted clasts were separated. Samples were irradiated at the University of Missouri Research Reactor, with a J-factor of 0.02. Samples of standard hornblende MMhb-1 were included as a flux monitor, while samples of CaF_2 and K_2SO_4 were included to monitor production of Ar isotopes from Ca and K, respectively. Samples were analyzed on the University of Arizona VG-5400. After corrections for blanks and interfering reactions, all samples still included measurable ^{36}Ar in low- and high-temperature extractions. We have assumed the low-temperature ^{36}Ar is terrestrial contamination and have subtracted a commensurate amount of ^{40}Ar. Without this correction, there would be no plateaus at low temperatures.

Results and Discussion: Figs. 1-4 are "plateau plots" of apparent age vs. fraction of ^{39}Ar released.

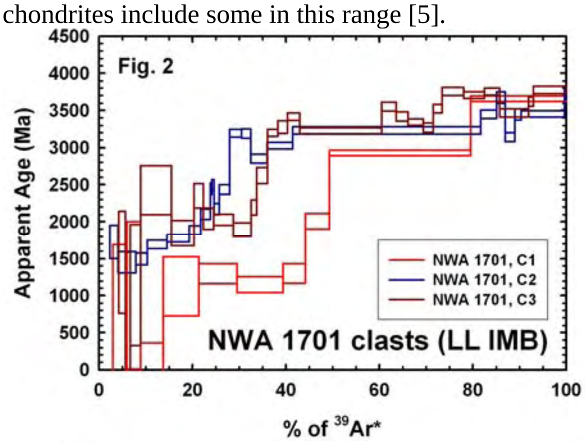
LAP 02240. Perhaps the most interesting results come from this impact melt (or impact melt breccia) with H-chondrite affinities. Petrographically, it is similar to the L chondrite Cat Mountain [1]. It is dominantly melt, with 1-50 µm silicates and 40-100 µm metallic orbs. We also identified one fragment of a radial pyroxene chondrule. The edge of our sample contains a shock-metamorphosed chondritic fragment with shock-disseminated metal.

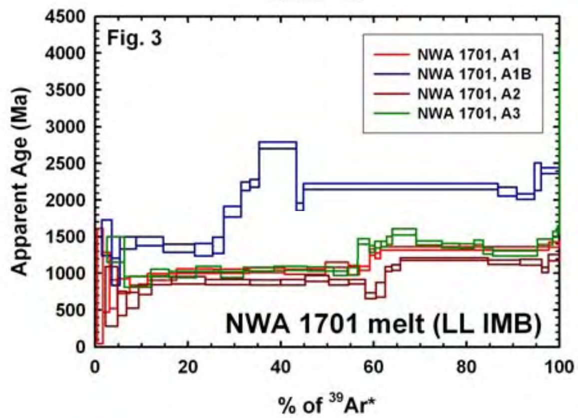
We analyzed three samples of the melt (no clasts could be extracted), and the Ar results were consistent (Fig. 1). All yield plateaus of between 3850 and 4010 Ma over the last 55-75% of the gas released. Our best estimate of the impact age comes from summing all the gas involved in all three plateaus, 3914±36 Ma (1σ), given by the dashed line. Although there is also evidence for some later degassing, it is most likely that the event that melted this rock occurred at ~3900 Ma. As well as being the age of the dated basins on the Moon [4], ages of 3500-4000 Ma have also been measured in other H chondrites [5, 6], HED meteorites [7] and IIE irons [8]. It thus seems likely that an event that affected the entire inner Solar System was occurring (e.g., [5, 9-11]).



NWA 1701. This LL chondrite is a melt-matrix breccia. The melt is dominated by 10-30 µm olivine and pyroxene crystals. It also contains relict silicates and 30-50 µm metallic orbs rimmed with sulfide. In addition, there are multi-cm sized shock-metamorphosed clasts. We analyzed three samples of clasts and four of melt (Figs. 2, 3).

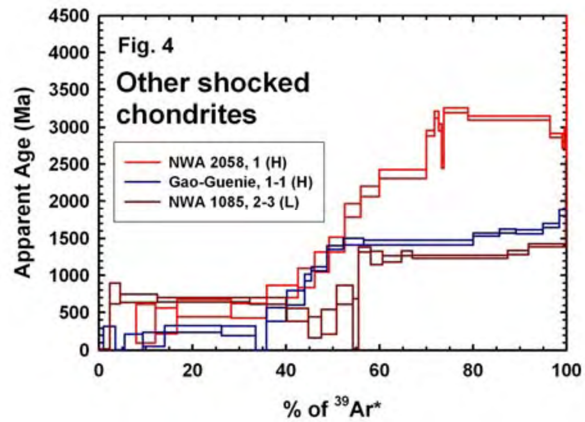
In every case, the clast samples were clearly only partially degassed, retaining apparent ages of 3000 Ma or more at high temperatures. The melt samples, on the other hand, were more completely degassed (although A1B, a 3.7 mg fragment that broke off our A1 sample, is intermediate). However, the melt samples do not tell a completely straightforward story. In every case, there appears to be two plateaus, each containing 40-50% of the total ^{39}Ar released, with the higher-temperature plateau giving an age ~150 Ma younger. The total spread in plateau ages (excluding A1B) is only from 892 Ma to 1216 Ma, but establishing the exact age within that range is difficult. Two or more closely spaced impacts is a possibility, but a single event that caused incomplete resetting in some phases is more likely. In any case, this appears to represent a major impact on the LL chondrite parent body within the last ~1000 Ma. The few impact ages available on LL chondrites include some in this range [5].





From an Ar-Ar geochronology point of view, there are two significant things about the NWA 1701 results. First, it is significant that slightly different plateau ages are obtained on different samples, as in Chico [12], emphasizing the benefit of multiple samples. Second, the melt appears to be more degassed than the clasts, the opposite of what has been observed in Orvinio [3] and Peace River [13]. In those meteorites, the quenched melt apparently ended up with a much longer effective diffusion domain size that made it harder to degas. In this case, it may be that the melt stayed hot long enough to degas before solidifying.

Other chondrites. There are three other meteorites that will be a part of this study for which we have only analyzed a single melt sample each (Fig. 4). Going from the example of NWA 1701, it is possible that any single sample will not be completely degassed, but some conclusions are possible. NWA 2058 (H) has a complicated apparent age pattern, but a relatively recent degassing event that caused only partial resetting is suggested. Gao-Guenie (also H), gives some very young ages, and may have been involved in an impact in the last 300-500 Ma [3,11]. Finally, NWA 1085 (L) may have a plateau at 1100-1300 Ma, but the lower apparent ages at lower temperatures may mean that it was involved with the ~500 Ma L chondrite event [11]. More samples of each of these meteorites were included in the same irradiation and are scheduled to be analyzed.



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