THE CHICO, NM, L-6 CHONDRITE: A LARGE, 500 My-OLD IMPACT MELT WITH A LONG COSMIC RAY EXPOSURE; D.D. Bogard, D.H. Garrison (NASA-JSC, Houston, TX), E.R.D. Scott, K. Keil, G.J.Taylor (Univ. New Mexico, Albuquerque), S. Vogt, G.F. Herzog (Rutgers Univ., New Brunswick, NJ), and J. Klein (Univ. Pennsylvania, Philadelphia).

The L-chondrites Chico (105kg) and Point of Rocks (0.9kg) consist very largely of material melted by impact, and along with Ramsdorf (L), Yamato-790964, -74160 (LL) and paired specimens [1-4], they are the only chondrites known to consist mainly of impact melt. Their geographic proximity, along with our petrographic and noble gas studies, indicate that Chico and Point of Rocks are almost certainly paired. Samples from six sides of the Chico mass (~35x37x30 cm) suggest that over 80% consists of impact melt. This melt shows diverse, very fine-grained textures and contains few unmelted clasts (<5 vol.%). Metal and sulfide have aggregated into 1-10mm-sized nodules, which have been severely weathered. One shows a dendritic structure with a cell width of 50æm, indicating cooling during crystallization at $5^{o}C/sec$. The remainder of Chico (<20 vol.%) consists of heavily shocked "chondritic" regions that may be 5cm or more in size and contain 5-30 vol.% of silicate impact melt pockets. These regions have remnants of chondritic structure, and metal and sulfide have not aggregated into large nodules. Olivines that crystallized in chondrules and impact melts have similar compositions of Fa 25 ± 1; low-Ca pyroxene in chondritic regions is Fs 21 ± 0.5. In Point of Rocks, both chondritic and impact melt silicates are typically poorer in FeO, Fa 24 ± 1, Fs 19 ± 1 [4], although their compositions are still largely within the range of equilibrated L chondrites.

Melt and chondritic samples from Chico and a melt sample from Point of Rocks were irradiated with fast neutrons, and 39Ar-40Ar ages were determined as a function of temperature during stepwise degassing of argon (Figs. 1 & 2). The Chico chondritic sample shows 39Ar-40Ar ages as low as 490My (million years) at lower extraction temperatures, but these apparent ages rise to ~2,200My at high extract temperatures. The melt samples show greater degrees of argon degassing; the lowest apparent age seen in the melt samples of Chico and Point of Rocks are ~525My and ~500My, respectively, and their total ages are ~550My and ~590My. Several shocked L and H-chondrites have determined 39Ar-40Ar degassing ages of ~500My, and a large fraction of L-6 chondrites show major loss of radiogenic argon and helium. Thus, it seems reasonable to conclude that formation of melt glass in Chico and Point of Rocks was caused by a major shock event ~500My ago. A comparison of ages and extraction temperatures required to degass Ar from Chico melt and chondritic samples would seem to preclude the explanation that these ages were produced by heating the meteorite uniformly long after the glass phase was produced. Nakamura et al (this volume) have determined a 87Rb-87Sr isochron age of 461My for a Point of Rocks melt sample adjacent to the sample used for 39Ar-40Ar analysis. If this age is the actual time of the shock event, then at that time the melt glass phases of these two chondrites would have retained approximately 0.6-1% of the total radiogenic 40Ar present. A small percentage retention of 40Ar is perhaps explained by rapid thermal quenching of the glass after the shock event.

To determine whether Chico and Point of Rocks had the same cosmic ray exposure age, we analyzed an ~30mg sample of each meteorite for cosmogenic He, Ne, and Ar. To better control chemical heterogeneity, two additional, near-surface samples (10c & 12e) were taken from the main mass of Chico, ~250mg of each was coarsely crushed, and ~50mg of each was analyzed. Concentrations of these cosmogenic gases, summarized in Table 1, are unusually large for chondrites, and the 22Ne/21Ne ratios, which tend to decrease with increased shielding during cosmic ray exposure, are unusually small. Some models for production of cosmogenic Ne [e.g. 5, 6] predict minimum values of 22Ne/21Ne at high shielding that are similar to, or slightly lower than, measured ratios in Chico and Point of Rocks, and would correspond to much lower than typical production rates of cosmogenic gases. Therefore, it seemed conceivable that Chico and Point of Rocks might have very long exposure ages for a chondrite, conceivably as old as the 39Ar-40Ar shock age. Cosmic ray produced radionuclides 10Be and 26Al were measured in two samples of Chico by Accelerator Mass Spectrometry to check this possibility. These data (Table 1) show that the cosmogenic production rates for Chico, at least during the past few My, were only slightly lower than those for other large chondrites extensively studied [e.g.6]. The calculated single-stage exposure age for Chico is then ~85My.

No meteorite (apparently including Chico) has shown similar exposure age and shock-heating age, although both ages are initiated by major collisional events involving the parent object. Is it possible that a large impact crater on a chondrite parent body shock-heated part of the eject sufficiently to reset 39Ar-40Ar ages and also initiated exposure to cosmic rays? With the above question in mind, an examination of literature data of cosmogenic noble gases in chondrites [7] revealed approximately 10 chondrites having both high

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cosmogenic gas concentrations (i.e. 21Ne >15x10^{-8}cc/g) and low 22Ne/21Ne (<1.07) such that a very long exposure age could be possible. Seven of these give direct or indirect evidence of shock or shock heating, and two are already known to have partially re-set 39Ar-40Ar ages. Unfortunately, noble gas determinations on 4 of these chondrites are old and possibly suspect [L. Schutz, pers.comm.]. Thus, we have begun analyses of cosmogenic noble gases, radionuclides 10Be & 26Al, and possibly 39Ar-40Ar ages for several of these chondrites to further test the possibility that shock-ages and exposure ages might be produced by a common, large shock event. In addition, data in Table 1 show small variations in 22Ne/21Ne among the samples of Chico and large differences in cosmogenic gas concentrations between Chico samples 10c and 12e, taken ~37 cm apart from opposite sides of the meteorite. If these concentration differences in Ne are due to shielding variations, they are not consistent with the similar 10Be and 26Al values for samples 10c and 12e. Given the weathered state of the surface of Chico, it is quite possible that sample 12e, taken from the surface, has experienced gas loss due to weathering or due to heating during atmospheric ablation. Because Chico indicates a greater level of shielding than other large chondrites whose cosmogenic products have been studied in detail (e.g. Keyes, St. Severin, Alh-78084), it would be informative to document in Chico any variations of cosmogenic products as a function of location and depth. Thus, we plan to acquire depth-documented samples from Chico, analyze these for cosomogenic noble gases and radionuclides, and compare the results against various model predictions.

References: [1] F.Begemann & F.Wlotzka (1969), G.C.A. 33, 1351; [2] M.Miyamoto, H.Takeda, & T.Ishii (1984), J.Geophys.Res. 89, 11581; [3] H.Takeda, T.Hudson, & M.Lipschutz (1984), Earth Planet. Sci. Lett 71, 329; [4] E.Scott, P.Maggiore, J.Taylor, D.Keil, & D.Szuwalski (1986), Lunar Planet. Sci. XVII, 785; [5] A.McDowell & L.Nyquist (1986) Lunar Planet.Sci. XVII, 528; [6] T.Graf, H.Baur, & P.Signer (1989) submitted to G.C.A.; [7] L.Schult & H. Kruse (1978) Nucl. Track Detection 2, 65;

Table 1. Noble gas concentrations in 10^{-8}ccSTP/g, radionuclides in dpm/kg

Sample	3He	4He	21Ne	22Ne	40Ar	38Ar	10Be	26Al
Pt. Rocks	80	457	17.0	17.8	510	1.52	-	-
Chico #1	94	616	22.3	23.4	472	2.49	-	-
Chico 10c	83	660	21.6	23.3	135	1.47	19	58
Chico 12e	48	511	14.0	15.0	659	1.26	21	61

(38Ar is the calculated spallation; others gases are measured values)