COSMOGENIC NEON FROM PRE-COMPACTION IRRADIATION OF MURCHISON AND KAPOETA. M.W. Caffee, J.N. Goswami[1], C.M. Hohenberg, and T.D. Swindle, McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130. [1]Also Physical Research Laboratory, Ahmedabad - 380 009, India.

Since the realization that the individual grains of certain primitive and gas-rich meteorites may provide information on conditions prior to final compaction (1,2,3), efforts have been made to delineate pre-compaction features and to establish some characteristics of the pre-compaction history of these objects. Of particular interest in this study are comparisons of neon isotopic records between grains showing solar flare particle tracks (which indicate exposure to energetic particle irradiation prior to compaction) and those which do not show such effects.

Individual interior grains were hand-picked from Murchison (olivines) and Kapoeta (pyroxenes). Mineral confirmation and target chemistry were obtained by electron microprobe analyses. Each set of grains was further divided into irradiated and unirradiated subsets, packaged in platinum foil boats (typically 15 milligrams), and loaded into the side arm of a low-blank extraction bottle for mass spectrometric analysis as described by Hudson, et al. (4). Neon was extracted by two-step heating at 800°C and 1900°C with the amounts, compositions, and appropriate procedural blanks given in the table.

As is evident from the data, there are large differences between irradiated and unirradiated grains in both meteorites. This is especially true in the concentrations of ^{21}Ne, due almost exclusively to spallation reactions by energetic particles. For instance, irradiated olivine grains from Murchison contain 30 times more cosmogenic ^{21}Ne and irradiated pyroxene grains from Kapoeta contain two orders of magnitude more cosmogenic ^{21}Ne than their unirradiated counterparts. These differences clearly show that spallation effects in the irradiated grains are dominated by exposure to energetic particles prior to compaction and hence can provide records of pre-compaction history.

From the observed quantity of cosmogenic ^{21}Ne and the measured target abundances, exposure ages of 0.8 and 0.5 m.y. for unirradiated grains from Murchison and Kapoeta, respectively, are found (using ^{21}Ne production rates of Reedy (5)). The Murchison value is in good agreement with previous determinations (6). The Kapoeta exposure age seems considerably lower than previous values (7,8).

If the cosmogenic ^{21}Ne in the irradiated grains is due to galactic cosmic rays, pre-compaction exposure periods of 28 and 56 m.y. are obtained for Murchison and Kapoeta, respectively. However, before these numbers can be taken seriously one must determine whether the cosmogenic neon observed in the irradiated grains of both meteorites is indeed due to galactic cosmic ray spallation reactions. If not, use of the usual GCR production rates is incorrect, yielding incorrect pre-compaction ages. As an alternative, we consider the effects of spallation reactions due to irradiation by energetic solar flare particles under 1) present conditions and 2) conditions possibly unique to the early solar system.

Solar Cosmic Ray Spallation Reactions Under Present Conditions: In assessing the probability of significant solar cosmic ray spallation effects under present conditions we first examine lunar regolith samples. Although solar cosmic ray effects have been predicted, given the average particle flux, cross sections, and target chemistry (9, 10), and have been observed in certain near-surface samples (11), spallation reactions in lunar material are normally dominated by galactic, rather than solar, cosmic rays. Moreover, it is usually difficult to even observe spallation effects in lunar regolith grains since the rare gas inventory is so dominated by solar wind gases. However, the irradiated Murchison and Kapoeta grains are enriched in spallation neon relative to solar wind gases when compared with the unirradiated grains. Indeed, for the irradiated Murchison grains there is little observable solar neon, indicating more or less complete shielding from the solar wind. It would be difficult to obtain solar flare effects without accompanying solar wind effects under present solar conditions unless there were a uniform shielding of a few mg/cm^2. Furthermore the isotopic composition of the cosmogenic neon in these samples does not resemble that expected from the relatively soft solar cosmic ray spectrum. SCR-produced neon under low shielding conditions should be characterized by a ^{20}Ne/^{21}Ne ratio of 2-4 (7, 8). The measured ratio of 1.6 for irradiated Murchison is clearly an upper limit for the cosmogenic ^{20}Ne/^{21}Ne ratio since some trapped neon is obviously present. One must conclude that the composition of the cosmogenic neon in these particles resembles that produced by GCR irradiation (^{20}Ne/^{21}Ne 1) rather than that produced by present SCR. Therefore, on the basis of both quantity (relative to the solar wind) and composition it seems difficult to

account for the observed cosmogenic neon by solar cosmic ray interactions under conditions now present in the solar system.

Solar Cosmic Ray Spallation Reactions Under Unusual Solar/Solar Nebula Conditions: If conditions in the primitive solar nebular were substantially different, comparisons with present lunar regolith material may not be valid. Recent observations (12) in fact raise the possibility of enhanced flare activity early in the history of the solar system and higher energy solar particles could produce cosmogenic neon indistinguishable from that produced by galactic cosmic rays. Since many models for chondrule formation require substantial gas pressures, it is at least plausible that gas pressures may once have been high enough to stand off the solar wind but perhaps not energetic solar flare particles, and at the same time, account for the lack of track gradients in irradiated Murchison grains. Also, an increase in solar flare activity might not be accompanied by a proportionate increase in solar wind. Although these ideas are clearly speculative, some combination of these factors could lead to the effects we see. However, it seems unlikely that ancient solar flare tracks and solar wind and spallation gases could be preserved through the differentiation Kapoeta has apparently experienced.

In summary, we observe large enhancements of cosmogenic neon in irradiated Kapoeta and Murchison grains when compared with similar but unirradiated grains. This component must consequently have been produced prior to the final compaction of the parent body. If the conditions which existed at that time were similar to present conditions, substantial pre-compaction exposure times of 56 and 28 m.y., respectively, are required. The possibility of irradiation of these grains by energetic solar particles from an active early sun should not be dismissed.

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Table 1. Blank Corrected Neon Isotopic Data

Sample	Weight $g \times 10^{-6}$	Temp. °C	$[^{21}Ne]$ $cm^3STP/g \times 10^{-9}$	$^{20}Ne/^{21}Ne$	$^{22}Ne/^{21}Ne$
Murchison olivines					
Unirradiated	87	800	BL	–	–
(11 grains)		1900	4.7	(2.45)[1]	1.25(.40)[2]
Irradiated	71	800	0.4	103(38)[2]	11(8)
(11 grains)		1900	141.	1.60(.17)	1.22(.02)
Kapoeta pyroxenes					
Unirradiated	463	800	BL	–	–
(10 grains)		1900	1.6	8.2(1.7)	1.9(.2)
Irradiated	164	800	1.1	259(17)	20.4(1.7)
(6 grains)		1900	179.	3.01(.02)	1.27(.01)
Procedural blank					
(inc. Pt. foil)		1900	1.7[3]	182(24)	38(5)

1. Uncertainty in value is comparable to value itself.
2. Errors include statistical errors and 25% uncertainty in blank correction.
3. $cm^3STP \times 10^{-14}$
BL - Measured ^{21}Ne comparable to blank level.