COSMIC RAY IRRADIATION HISTORY OF INDIVIDUAL MURCHISON CHONDRULES ANALYZED BY UV-LASER ABLATION. L. Huber[1], K. Metzler[2], C. Maden[1], N. Vogel[1,3], and R. Wieler[1]. [1]Departement of Earth Sciences ETH Zürich, CH-8092 Zürich, Switzerland (liliane.huber@erdw.ethz.ch), [2]Institut für Planetologie, Universität Münster, D-48149 Münster, Germany, [3]Eawag, Water Resources and Drinking Water, CH-8600 Dübendorf, Switzerland

Introduction: Different studies have shown that chondrules within the same meteorite can have different nominal noble gas cosmic ray exposure ages (CREAs) [e.g. 1-3]. There are two interpretations as to the origin of this so-called pre-exposure. First: Chondrules were irradiated prior to parent body accretion while they were still floating as individual objects in space in the early solar system [2]. Second: The pre-exposure happened on a parent body regolith in a 2π irradiation geometry [4]. As chondrules have short survival times as individual objects in space, the first explanation requires a high energetic solar particle flux and therefore would be evidence for an early active sun [2], while in the second case the chondrules would have been exposed to galactic cosmic rays (GCR) over a longer time with presumably present-day flux and energy distribution [4].

Pre-exposure effects can easiest be detected in meteorites which experienced only short recent cosmic ray exposures as meteoroids, such as Murchison and Allende with bulk CREAs of 1.6 Ma [5] and 4.3 Ma [1], respectively. A recent study [1] showed that 26 Allende chondrules had the same cosmic ray exposure ages within uncertainties of a few hundred thousand years, while about 20% of the studied Murchison chondrules showed partly very substantial excesses of cosmic-ray-produced noble gases, corresponding to nominal 4π present day GCR pre-exposure durations of up to several tens of Ma [1].

A different study [6] concentrating on solar flare induced nuclear tracks in CM olivines showed that primary rock fragments (PRFs) did not contain track-rich olivines, while track-rich olivines were found in the clastic matrix surrounding the PRFs. PRFs are aggregates from nebular components like dust-mantled chondrules which subsequently became fragmented and accreted to their final parent body [e.g. 7].

The present study is a combination of [1] and [6], focusing on whether pre-irradiated chondrules are present only in the clastic matrix or also in PRFs of the CM chondrite Murchison. If pre-irradiation happened in the regolith, all chondrules within the same PRF should show no or identical pre-irradiation while the chondrules from the surrounding clastic matrix can have different pre-exposure histories. If pre-irradiation happened prior to parent body accretion different nominal exposure ages are to be expected for chondrules from the same PRF.

Samples: Two slabs of Murchison were carbon coated and mapped by SEM. One sample hosts two small (~3x4 mm and ~3x5 mm) PRFs while the second contains a single large primary rock fragment (~20x30 mm). The maps were then used to locate suitable chondrules within PRFs and the surrounding clastic matrix for *in situ* noble gas analysis.

The first slab was then hand polished to remove the carbon coating. Noble gases were extracted by UV laser ablation using a quintupled Nd:YAG laser (λ = 213 nm). We used a spot size of 160 μm for individual shots on smaller chondrules and a spot size of 60 μm to raster squares of typically the size of 300x300 μm for the larger ones. Resulting pit depths were between 90 μm and 200 μm. To determine the ablated sample masses, hole sizes were measured using a laser scanning microscope and an Alicona infinite focus microscope. Both methods yielded the same volumes within 10 % uncertainties. The masses ablated range between 4 μg to 40 μg. During ablation special attention was paid to not extract noble gases from the accretionary rims of the chondrules which might contain large amounts of primordial noble gases [8].

Until now 10 chondrules have been analyzed, nine from within the clastic matrix and one from a PRF. More data will be presented at the conference.

Results: Fig. 1 shows that all chondrules from the clastic matrix contain a mix of gases of cosmogenic, solar and atmospheric origin. The chondrule from within the PRF contains a mixture cosmogenic and primordial (HL, [9]) Ne. While atmospheric Ne can be attributed to the blank (which is of atmospheric composition and was not deducted from the measured sample signals) the solar wind and HL contributions might indicate that despite our efforts to only extract chondrules, some noble gases from the accretionary rims and clastic matrix were released, too. To determine the concentrations of cosmogenic ^{21}Ne, we performed two- or three-component deconvolutions, respectively, using the endmember compositions as defined by [9, 10].

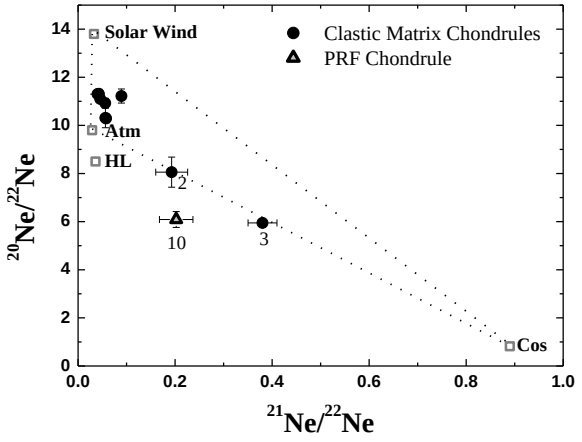

Figure 1: Three isotope plot of neon with the end members Solar Wind, Atmospheric, Cosmogenic and HL [9, 10]. The numbers identify chondrules with high $^{21}Ne/^{22}Ne$. Most chondrules contain a considerable amount of solar wind and/or air contamination.

Based on elemental compositions of [1] who found the production rate of $^{21}Ne_{cos}$ in different Murchison chondrules to be uniform within analytical uncertainties, we used an average ^{21}Ne production rate of 0.43×10^{-8} $cm^3STP/(gMa)$ to determine CREAs of the studied chondrules (Fig. 2). The exposure ages vary considerably for the clastic matrix chondrules.

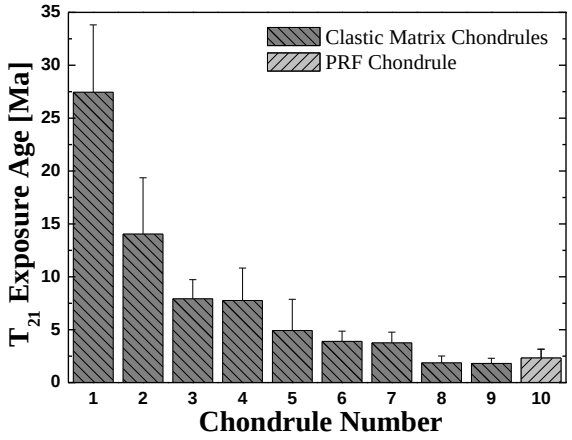

Figure 2: Assuming nominal present-day cosmic ray fluxes the clastic matrix chondrules show different degrees of pre-exposure between 25 and 0 Ma as compared to the bulk Murchison exposure age of 1.6 Ma.

Considering 2 σ uncertainties, three chondrules (Nr. 1, 2, and 3) show an unequivocal cosmic ray pre-exposure while Nr. 4-7 are within 2 σ of the 1.6 Ma meteoroid exposure age [1,5] but might still be considered as pre-exposed. Chondrules Nr. 8-10 show no discernible pre-exposure. The single chondrule measured from the PRF shows no pre-exposure as compared to bulk Murchison.

The ^3He amounts follow the general trend of $^{21}Ne_{cos}$ but for most chondrules it is impossible to determine a reliable cosmogenic ^3He concentration due to contributions of solar wind ^3He.

Discussion: As expected, some chondrules embedded in the clastic matrix show a pre-exposure of substantial length while others have CREAs close to that of the bulk meteoroid of ~1.6 Ma. The pre-exposure duration of the chondrules is up to 25 Ma assuming a 4π irradiation with a current GCR flux. If the pre-irradiation happened on a parent body regolith, the pre-irradiation time increases by at least a factor of two due to the 2π irradiation geometry. The production rate then further depends on the shielding depth which could lengthen the pre-irradiation time even considerably more. The ages obtained here confirm measurements by [1] which reported nominal 4π CREAs of up to 34 Ma. The single chondrule from a PRF shows no pre-irradiation resolvable within uncertainties.

Conclusion and outlook: Our first results, which are consistent with previous studies [e.g., 1] show that in situ UV laser ablation can successfully be applied to chondrules. In situ work not only saves a lot of tedious sample preparation but most importantly allows to control the location of the chondrule within its original lithology. We found that chondrules embedded in clastic matrix experienced different degrees of pre-exposure while the one chondrule analyzed from a PRF shows no sign of pre-irradiation. To further constrain the irradiation history of CM chondrules we will analyze more chondrules from Murchison PRFs and clastic matrix. Furthermore we have started a similar study on another CM chondrite for which the PRFs have already been identified.

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