COSMIC-RAY EXPOSURE AGES OF CHONDRULES

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Introduction: Formation of the parent bodies of iron meteorites predates those of chondrites by few Ma [1] and chondrules formed up to a few Ma later than CAIs [2]. These observations suggest that some chondrules were stored and transported for up to that long prior to accretion. If exposed during that time to energetic particles, chondrules might show an excess of cosmogenic noble gases and/or cosmic ray tracks relative to the rest of the meteorite. Beyersdorf-Kuis et al. [3] recently showed that such noble gas excesses can be detected, provided that the chemical composition for each individual chondrule is precisely known. The irradiation of the samples in a nuclear reactor (INAA), which was necessary to determine the chemical composition, limited their study to a few chondrules and prevented a statistically founded interpretation of the dataset. Here we report our first data for cosmic ray tracks and ^{3}He and ^{21}Ne exposure ages of *numerous* chondrules (several tens per meteorite) from NWA 8007 (L3.2), Bjurböle (L/LL4), NWA 8276 (L3.00), and Shişr 033 (CR2).

Methods: Chondrules were recovered by handpicking after freezethaw disaggregation of a small fragment of the meteorite. Thin sections were prepared using adjacent material for *in-situ* study of tracks in olivine minerals [4]. We developed a novel method using X-ray computed tomography to correct for variable chemical composition. The basic idea is that the X-ray attenuation of a sample can serve as a proxy for the production rate. Chondrules were imaged using a Bruker Skyscan 1173 micro-CT scanner (University of Lausanne). Helium and Ne isotopic concentrations were measured by laser melting at the University of Bern.

Results: We found no track excess for NWA 8007 and Bjurböle and small excesses of up to 5-fold in some chondrules from NWA 8276 and Shişr 033. Chondrules from NWA 8007 (n=28) and Bjurböle (n=24) have ^{20}Ne/^{22}Ne and ^{21}Ne/^{22}Ne ratios that range from 0.8 to 1.4 and from 0.85 to 0.94, respectively. Chondrules from NWA 8007 have mean ^{3}He and ^{21}Ne concentrations (in 10^{-8} cm^{3}STP/g) of 34.4±5.2 and 8.4±1.9 (2 SD), respectively. Chondrules from Bjurböle show lower mean ^{3}He and ^{21}Ne concentrations (in 10^{-8} cm^{3}STP/g) of 18.5±0.8 and 4.9±0.4 (2 SD), respectively. After correction for variable chemical composition, chondrules from NWA 8007 have within uncertainty identical mean ^{3}He and ^{21}Ne exposure ages of 16.6±1.3 and 16.6±1.8 (2 SD) Ma, respectively. Chondrules from Bjurböle also show within uncertainty identical mean ^{3}He and ^{21}Ne exposure ages of 9.1±0.3 and 9.6±0.8 (2 SD) Ma, respectively. All chondrules of the same meteorite have within uncertainty identical ^{3}He and ^{21}Ne exposure ages. The variability in ages is up to 15% lower than that in concentrations, which shows that our estimates of production rates are accurate. The noble gas data for NWA 8276 and Shişr 033 will be presented at the conference.

References: [1] Kruijer T. S. et al. 2012. *Geochimica and Cosmochimica Acta* 99:287–304, [2] Connelly J. N. et al. 2012. *Science* 338:651–655, [3] Beyersdorf-Kuis U. et al. 2015. *Earth and Planetary Science Letters* 423:13–23, [4] Metzler K. 2004. *Meteoritics & Planetary Science* 39:1307–1319.