VERY SHORT DELIVERY TIMES OF METEORITES AFTER THE L-CHONDRITE PARENT BODY BREAK-UP 480 MYR AGO. Ph. R. Heck[1], H. Baur[1], B. Schmitz[2] and R. Wieler[1], [1]Isotope Geology, NO C61, ETH, CH-8092 Zürich, Switzerland, heck@erdw.ethz.ch, [2]Marine Geology, Earth Science Centre, P.O. Box 460, SE-405 30 Göteborg, Sweden, birger@gvc.gu.se.

Abstract: Cosmic-ray exposure ages of 480 million year old fossil meteorites found in Southern Sweden constrain delivery times of meteorites from a large collision in the asteroid belt. Chromite grains from seven meteorites from four stratigraphic layers define an exposure age gradient as expected if the meteorites originated from the well-known L-chondrite parent body break-up event. The very short delivery times of a few 10^5 years for the earliest fragments reaching Earth are in the range predicted by dynamical models.

Introduction: Fossil meteorites found in Ordovician sediments in the active Thorsberg quarry in Southern Sweden by Schmitz et al. [1] provide an excellent opportunity to study one of the largest collisions in the asteroid belt in recent solar system history. Abundances of fossil meteorites and sediment-dispersed extraterrestrial chromite grains constrain the lower Ordovician meteorite flux to have been about two orders of magnitude higher than today [2]. Chemical composition of relict chromite grains indicate that the fossil meteorites are L or LL chondrites. Evidence for a break-up event of an L chondrite parent body is mainly given by the fact that many L chondrites have Ar-Ar gas retention ages around 500 Ma [3, 4].

The goal of this study is to determine delivery times of fossil meteorites from different stratigraphic locations in the Thorsberg quarry (~480 Ma). If all fossil meteorites originate from the same parent body disruption event, they should have similar exposure ages. In particular, the ones deposited in older sediments are expected to have had slightly shorter space residence times than the ones found in younger strata. The age difference between the oldest and youngest sediments investigated is about 1 to 2 Myr.

Samples and Experimental: We have analyzed helium and neon isotopes in 20 batches of relict chromite grains from seven fossil meteorites found in four different stratigraphic layers in the Thorsberg quarry. We have shown earlier that relict chromite grains in fossil meteorites retain cosmogenic noble gases [5] since this mineral phase has experienced minimal alteration [1].

After grain extraction from the fossil meteorites [1, 5], batches of a few grains (4-40 µg total sample weight) were melted with an IR-laser in ultra-high vacuum to release noble gases. He and Ne isotopes were measured [5] using an ultra-high-sensitivity noble gas mass spectrometer [6]. Exposure ages are determined using average chromite composition as reported by Schmitz et al. [1] and elemental production rates as published by Leya et al. [7] assuming “average” shielding. Uncertainties of exposure ages are ~30-40% not taking into account uncertainties due to unknown shielding of samples [5].

Results: Cosmogenic ^{3}He and ^{21}Ne are detected in all 20 samples. Terrestrially-produced cosmogenic nuclide contributions ($<10^{-3}$ %) can be safely neglected. Nominal ^{21}Ne exposure ages (T_{21}) of all meteorites are corrected for nucleogenic neon ($^{21}Ne_{nuc}$). Nucleogenic ^{21}Ne (assuming $^{21}Ne_{nuc}/^{4}He_{rad} = 2.8 \cdot 10^{-8}$ [8]) for all but one meteorite account for less than ~3% of the ^{21}Ne excess over atmospheric composition. In one sample of the meteorite Arkeologen (Ark) 007 $^{21}Ne_{nuc}$ nominally comprises about 28% of the excess ^{21}Ne. This samples contains not only relatively large amounts of nucleogenic ^{21}Ne but also has a ^{4}He-concentration at least one order of magnitude higher than the other samples, all of which is assumed to be radiogenic. This implies large U and Th uptake during alteration on Earth. Since we determine $^{21}Ne_{nuc}$ from ^{4}He concentrations, and helium is more readily lost than neon, the corrections for $^{21}Ne_{cos}$ may represent a lower limit. The correction for the Ark 007 samples is very high and their T_{21} is thus probably not real.

T_{21} of different meteorites from the same quarry beds agree within 2σ (Figure 1). T_{21} are a few 10^5 years to ~ 1 Myr and are unusually low compared to ordinary chondrites falling today (cf. [9]). Very remarkably, a T_{21} gradient is observed through the sediment column, meteorites from younger sediments showing higher ages. The T_{21} range of ~1 Myr is in accordance with the biostratigraphically and sedimentologically constrained age range of 1-2 Myr. Nominal ^{3}He exposure ages (T_3) do not show this range nor a gradient. This implies helium from some samples has been lost, thus T_3 are not considered to reflect true space residence times and are therefore not shown.

Discussion: Low nominal exposure ages might be a result of overestimated production rates. This would require that all samples were considerably more heavily shielded than assumed, ie. are fragments of very large meteoroids. This is highly unlikely. The span of exposure ages is within a factor of two of the sediment deposition period. We therefore conclude all $^{21}Ne_{cos}$ has been retained quantitatively or nearly so, possible losses being less than 50%. Our T_{21} for all meteorites (except for Ark 007, see above) thus represent essentially correct exposure ages.

Models by Gladman et al. [10] and Zappala et al. [11] predict that a sizeable fraction of fragments from an asteroid-family-producing collision close to a strong orbital resonance arrives very shortly after the event. In particular, collisions close to the 5:2 and 3:1 Kirkwood gaps should deliver ~10% of their fragments within 0.3 and 1 Myr, respectively. The current data set of exposure ages of Ordovician fossil meteorites is in accordance with these models indicating that several fragments arrived a few 10^5 years after the collision. The finding of slightly longer exposure ages of meteorites from overlying, younger sediment beds than those studied would further substantiate this conclusion. The very short transfer times from the asteroid belt to Earth suggest that the L-chondrite parent-body break-up 480 Myr ago took place in the vicinity of an orbital resonance with Jupiter (eg. 3:1 or 5:2).

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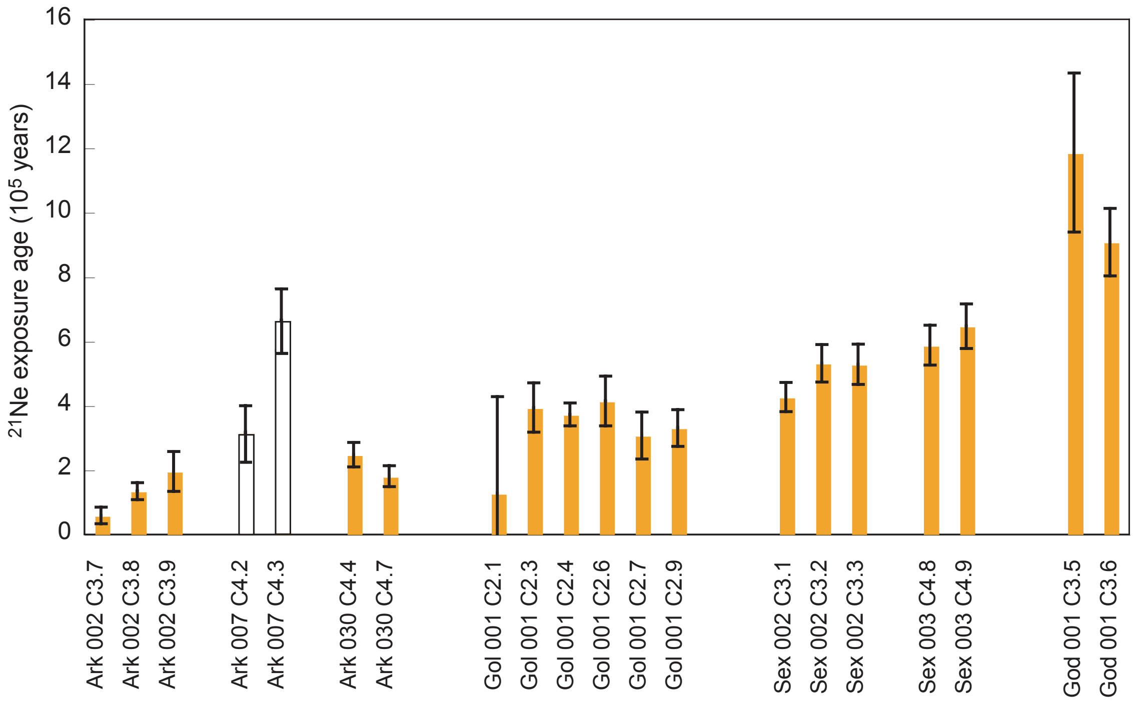

Figure 1: ^{21}Ne exposure ages in 10^5 years. Nucleogenic neon corrections for Ark 007 samples are large and their ages are therefore probably not real. All uncertainties are 1σ. Uncertainties of exposure ages include only analytical errors.