

A TRACE OF PRESOLAR NE IN CHROMITE FROM EQUILIBRATED ORDINARY CHONDRITES? M. M. Meier¹, M. E. I. Riebe^{2,1}, C. Alwmark³, C. Maden¹, H. Busemann¹, and R. Wieler¹. ¹ETH Zurich, Institute of Geochemistry and Petrology, Clausiusstrasse 25, 8092 Zurich, Switzerland (matthias.meier@erdw.ethz.ch). ²Carnegie Institution of Washington, Department of Terrestrial Magnetism, 5241 Broad Branch Road, NW, Washington DC 20015-1305, USA. ³Lund University, Department of Geology, Sölvegatan 12, 22353 Lund, Sweden.

Introduction: At a mass fraction of 0.3%, chromite is the most abundant oxide in equilibrated ordinary chondrites, and a metamorphic product of parent body heating [1]. Grain sizes can reach a few 100 μm [1]. Chromite also exists in other types of chondrites (and some achondrites [2]), although these grains are often much smaller. Besides its uses as a tool in meteorite classification [1], mineralogic thermometer [3] and shock indicator [4], the extreme durability and weathering-resistance of chromite has also led to another application: Chromite is the only major meteoritic mineral that survives nearly unaltered for at least 0.5 Ga in terrestrial sediments [5], as exemplified by chromite grains from fossil meteorites and micrometeorites which fell in the Ordovician period [6,7]. These chromites have not only retained their original $\Delta^{17}\text{O}$ [8] and $\epsilon^{54}\text{Cr}$ [9], but even He and Ne from the solar wind and from cosmic-ray spallation [10-14]. Hundreds of extraterrestrial chromite grains (from fossil meteorites [10-12], fossil micrometeoritic dust [12-14], and from recent meteorites [12]) have since been analyzed for He and Ne. These studies have shown that in a Ne three isotope plot (Fig. 1), extraterrestrial chromite grains free of solar wind are found preferentially along a line which could be interpreted as connecting a cosmic-ray spallation end-member (GCR) with a so far unknown trapped component, with a $^{20}\text{Ne}/^{22}\text{Ne}$ ratio of ~ 7 [14,15]. This component (which could also be a mix of known components) was tentatively named “Ne-HL+E” by [15] because it plots between Ne-HL and Ne-E. All Ne components in this part of the diagram (e.g., Ne-HL, Ne-E) are thought to be presolar [16], suggesting that Ne-HL+E (if confirmed) might be presolar too. But how would presolar Ne survive parent body heating? Here we investigate this hypothesis and report He and Ne concentrations and isotopic compositions of chromite grains from a suite of meteorites with known (short) cosmic-ray exposure (CRE) ages.

Methods: Chromite grains were extracted by hydrochloric/hydrofluoric acid dissolution of seven different ordinary chondrites: Farmington (abbreviated “F” in Figs.; L5), Appley Bridge (“A”; LL6), McKinney (“M”; L4), Ochansk (“O”; H4), Saratov (“R”; L4), Holbrook (“H”; L/LL6) and Saint-Séverin (“S”; LL6), and picked under an optical microscope (15-20 grains per meteorite). The largest and “cleanest” grains (minimal residual silicate minerals attached) were set apart for future Xe analysis. The remaining grains were

grouped in batches of 3-5 grains, imaged to determine their volumes (and masses, via density) using an empirical relationship between cross-sectional area and volume [14], loaded into the sample chamber of a custom-built “compressor source” noble gas mass spectrometer [17] at ETH Zurich, and pumped down to 10^{-9} mbar. Gases were then extracted from the grain batches by heating them with a Nd:YAG laser ($\lambda=1064$ nm) for 60 s. Then, ^3He , $^{20,21,22}\text{Ne}$ and background gases (H_2O , Ar, CO_2) were measured using a protocol from [18].

Results & Discussion: Except for one grain batch from Appley Bridge (see Fig. 1), the Ne isotopic ratios of all grain batches plot (within 2σ uncertainties) on the trend line found by [14,15]. The main motivation for including Appley Bridge and Farmington in this study was their very low CRE ages, of ca. 1.2 Ma [19] and 0.025 Ma [20], respectively. This should have resulted in a very low concentration of cosmogenic ^{21}Ne ($^{21}\text{Ne}_{\text{cos}}$), thereby allowing us to better resolve the $^{20}\text{Ne}/^{22}\text{Ne}$ ratio of the putative Ne-HL+E. However, as shown in Fig. 1, one Appley Bridge chromite batch seems to contain a trapped component with a $^{20}\text{Ne}/^{22}\text{Ne}$ ratio far above Ne-HL+E, which could be terrestrial air, Q gases or (fractionated) solar wind. Also, the chromite grains from Farmington contain much more

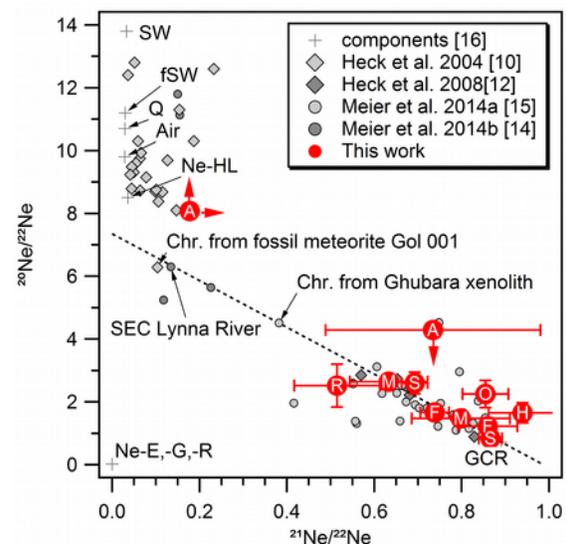


Fig. 1: Ne-three isotope diagram with previous studies of Ne in extraterrestrial chromite (the dashed trend-line is forced through the GCR point) and this work. All error bars are 1σ , arrows (e.g., Appley Bridge) indicate lower or upper limits. Components see [16].

$^{21}\text{Ne}_{\text{cos}}$ than would be expected from the published CRE age of their host meteorite, 0.025 Ma [20]. The concentration of $^{21}\text{Ne}_{\text{cos}}$ rather suggests a CRE age of ca. 15-25 Ma (Fig. 2) for Farmington. These grains might retain $^{21}\text{Ne}_{\text{cos}}$ from an earlier GCR irradiation episode which was later erased (e.g., by a strong impact shock ca. 0.5 Ga ago [21]). This confirms again their strong retentivity for noble gases, which might also help explain the potential survival of presolar noble gases in chromite. For all other grain batches, the concentrations of $^{21}\text{Ne}_{\text{cos}}$ correlate with the CRE ages of the respective meteorite (Fig. 2). They plot close to the correlation line determined by [12] from Ne in chromite batches from the ordinary chondrites Eva (“E”; H5), Harleton (“Q”; L6), Hessle (“L”; H5), Mount Tazerzait (“T”; L5), and St. Severin (“S”; LL6). Because the two meteorites with the shortest CRE ages in our suite have turned out to be special cases, the $^{20}\text{Ne}/^{22}\text{Ne}$ ratio of Ne-HL+E could so far not be better constrained. Three sediment-dispersed extraterrestrial chromite (SEC) grains from the Lynna River site (Russia) [14], and one chromite grain batch from fossil meteorite Gol 001 (Sweden) [10] are still plotting closest to Ne-HL+E. Also, a chromite grain from a xenolith in the shocked L5 chondrite Ghubara [15] plots in-between the Ne-HL+E point and the data points from other recent meteorites (Fig. 1). After subtraction of the cosmogenic component, the trapped (Ne-HL+E) ^{22}Ne shows an average concentration (in $10^{-8} \text{ cm}^3 \text{ STP/g}$) of 0.14 and a range of 0.00078–0.51, comparable to the concentrations of ^{22}Ne -HL+E found in Ghubara chromite grains [15]. Combining He and Ne isotopes can potentially further constrain the origin

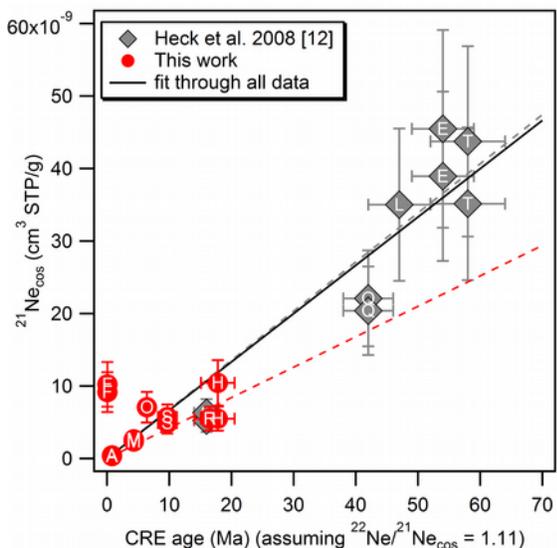


Fig. 2: Measured concentration of $^{21}\text{Ne}_{\text{cos}}$ in chromite vs. CRE age of the meteorite. The dashed lines are the linear regression lines of the two data sets, forced through the origin, the black solid line fits all data.

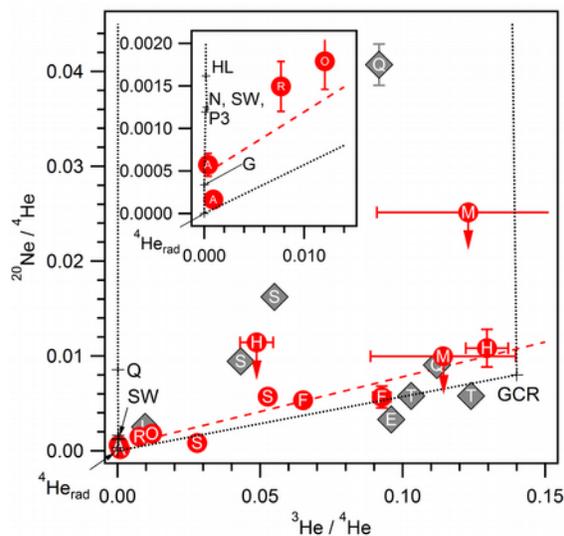


Fig. 3: Data from [12] (gray) and this work (red). For a few grains, the $^{20}\text{Ne}/^4\text{He}$ ratio is not well-constrained, but the remaining grains from this work fall on a mixing line between cosmogenic He, Ne and either radiogenic ^4He , or a presolar component, which could be “He-HL+E” (i.e., a combination of HL and G in Fig. 3, and possibly some $^4\text{He}_{\text{rad}}$). A GCR-air mix can be excluded from Fig. 3 ($^{20}\text{Ne}/^4\text{He}_{\text{air}}=3.5$). Additional constraints will be gained from the detection or non-detection of ^{132}Xe (and, possibly, other Xe isotopes) with the RELAX instrument at Manchester University, and the comparison with the average ^{20}Ne , ^4He in chromite grains. We also plan additional experiments to further exclude any instrumental (or data reduction) artifacts.

References: [1] Bunch T. E. et al. (1967) *GCA* 31, 1569-1582. [2] Bunch T. E. and Keil K. (1971) *The American Mineralogist* 56, 146-147. [3] Wlotzka, F. (2005) *M&PS* 40, 1673-1702. [4] Rubin A. E. (2003) *GCA* 67, 2695-2709. [5] Schmitz B. (2013), *Chemie der Erde* 73, 117-145. [6] Schmitz B. et al. (2001) *EPSL* 194, 1-15. [7] Schmitz B. et al. (2003) *Science* 300, 961-964. [8] Heck P. R. et al. (2010) *GCA* 74, 497-509. [9] Schmitz B. et al. (2016) *Nat. Commun.* 7:11851. [10] Heck P. R. et al. (2004) *Nature* 430, 323-325. [11] Schmitz B. et al. (2014) *EPSL* 400, 145-152. [12] Heck P. R. et al. (2008) *M&PS* 43, 517-528. [13] Meier M. M. M. et al. (2010) *EPSL* 290, 54-63. [14] Meier M. M. M. et al. (2014) *GCA* 125, 338-350. [15] Meier M. M. M. et al. (2014) *M&PS* 49, 576-594. [16] Ott U. (2014) *Chemie der Erde* 74, 519-544. [17] Baur H. (1999) *EOS Trans. AGU* 46, #F1118. [18] Heck P. R. et al. (2007) *APJ* 656, 1208-1222. [19] Heymann D. (1965) *JGR* 70, 3735-3743. [20] Levin B. J. et al. (1976) *Icarus* 28, 307-324. [21] Bogard D. D., Hirsch W. C. (1980) *GCA* 44, 1667-1682.