# SOLAR WIND-DERIVED HELIUM AND NEON IN SEDIMENT-DISPERSED EXTRATERRESTRIAL CHROMITE GRAINS FROM THE MID-ORDOVICIAN LYNNA RIVER SECTION, RUSSIA.

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**Introduction:** Mid-Ordovician (~470 Ma) sediments contain traces of the break-up of the L chondrite parent body (LCPB) asteroid, predominantly in the form of sediment-dispersed extraterrestrial chromite (SEC) grains having an element composition [1], as well as an O-isotopic composition [2] compatible with an L chondritic origin. Chromite ($FeCr_2O_4$) is the only abundant meteoritic mineral that survives diagenesis and weathering. Just as the fossil meteorites identified in the same beds in Sweden [3], these SEC grains probably derive from the break-up of the LCPB (e.g. [4] [5]). The break-up event is marked in the sediments by a dramatic ~two-orders of magnitude jump of SEC grain abundance within a layer of the lower Darriwilian [1], after which an abundance of several grains (>63 µm) per kg of slowly deposited limestone was maintained over at least a few million years [6]. These SEC grains, and the corresponding abundance jump, have so far been identified at several places worldwide: at several locations in Sweden [1], at Puxi river in China [7] and most recently at Lynna river in Russia [8][9]. Almost all SEC grains from Sweden [10][11] and China [6] contain He and Ne of solar wind (SW) isotopic and elemental composition, confirming their extraterrestrial origin. The SW-derived noble gases also indicate that these grains were delivered to Earth in the form of micrometeorites, with at least one side exposed directly to the SW, and that they survived transfer through the Earth's atmosphere without strong heating [11][6]. For this project, we have measured the concentrations and isotopic composition of He and Ne in SEC grains from two sediment layers from the Lynna river section in Russia. The sediments collected at this locality contain the highest known concentrations of SEC grains, up to 10 SEC grains >63 µm per kg of sediment [9], which are also exceptionally well preserved compared to SEC grains from other localities (e.g., minimal replacement of Fe by Zn [9]).

**Samples and Methods**: We studied 34 and 17 grains from layers Ly3 and Ly4, respectively (see [9] for stratigraphy). These layers are just below and above the tentative boundary between the *Lenodus variabilis* and *Yangtzeplacognathus crassus* conodont stratigraphic zones, identified before in Sweden [1] and China [7]. Both layers are above the layer where the abundance of SEC grains markedly increases. The SEC grains were extracted from the limestone using concentrated HCl and HF, as described in detail in [9], and subsequently had their elemental composition in Cr, Fe, Mg, Al, Ti and V (semi-quantitatively) determined using SEM (Hitachi S-3400N) with an attached EDS (Oxford Instruments Inca X-sight) on unpolished grain surfaces. Their mass was then measured on a microbalance with a typical accuracy of ~0.4 µg (~1 – 100% of the grain masses). The grains were then mounted for He, Ne analysis and the extraction cell pumped to UHV for 48 h. Helium and Ne were extracted by melting each grain with a 1024 nm IR laser. Active gases were removed by ZrO/TiO getters and cold traps (liquid $N_2$). He and Ne were then analyzed using a custom-built compressor-source noble gas mass spec-

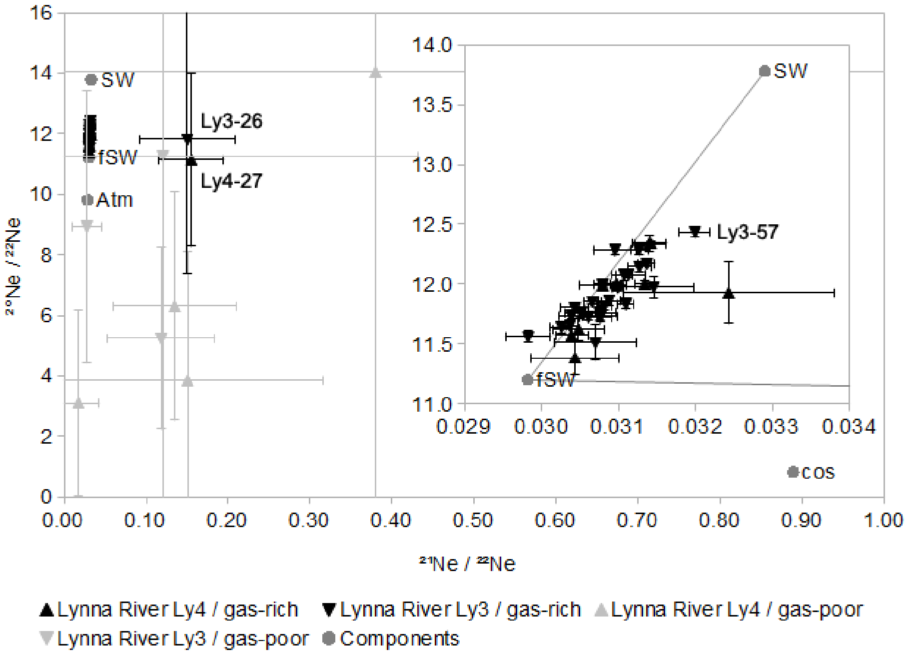

*Figure 1: Grains with significant cosmogenic Ne excess are labeled. SW = solar wind, fSW = fractionated SW, Atm = Earth's atmosphere, cos = cosmogenic (GCR)*

trometer with very high sensitivity [12]. Signals were calibrated with known amounts of pure He and Ne as in [11]. Interfering species ($H_2{}^{18}O^+$, $CO_2{}^{++}$, $Ar^{++}$) contributed less than 1% to the $^{20,22}$Ne signals.

**Results**: Two grains from Ly3 were lost during heating. Of the remaining 32 grains, 28 were gas-rich, i.e. contained He and Ne in high concentrations (on the order of $10^{-2}$ and ~$10^{-4}$ ccSTP/g, respectively) and an isotopic composition plotting between SW and fractionated SW (fSW) in the Ne-three-isotope-diagram (Fig. 1) as well as $^3$He/$^4$He-ratios close to fSW values of $2\times10^{-4}$. The remaining Ly3 grains showed very low He and Ne concentrations (<$10^{-8}$ ccSTP/g in $^{20}$Ne). Of the 17 grains from Ly4, 10 were gas-rich as defined above. Most of the grains plot somewhat to the right of the line connecting SW and fSW, indicating the presence of cosmogenic $^{21}$Ne ($^{21}$Ne$_{cos}$), although for most grains not beyond their individual uncertainties. A similar observation was made by [11] for SEC grains from Sweden. Three grains (Ly3-26, Ly3-57 and Ly4-27) reveal an unambiguous $^{21}$Ne$_{cos}$ excess. We calculate a combined galactic (GCR) and solar cosmic ray (SCR) production rate of $^{21}$Ne in chromite of about $9.2\times10^{-10}$ ccSTP/gMa as in [11], but using the model from [13] for production from SCR. The resulting GCR+SCR exposure ages for Ly3-26, Ly3-57 and Ly4-27 are 0.17±0.03, 4.95±1.65 and 0.25±0.03 Ma, respectively (errors include mass uncertainties). Ne-21$_{cos}$ plotted against total $^{20}$Ne concentration (Fig. 2) shows a positive trend for most grains, as observed before by [11].

**Discussion**: The presence of high concentrations of SW-derived He and Ne, as well as $^{21}$Ne$_{cos}$, in sediment-dispersed chromite grains of L chondritic composition derived from two different layers of the mid-Ordovician Lynna river section further corroborates their extraterrestrial origin, and implies that they were delivered to Earth as micrometeorites. The maximum concentration of SW-derived $^{20}$Ne of ~$6\times10^{-4}$ ccSTP/g observed in some of the Lynna river grains is a factor of ~2 higher than the maximum concentration found at other localities [11][6], suggesting that the Lynna river grains are exceptionally well-preserved.

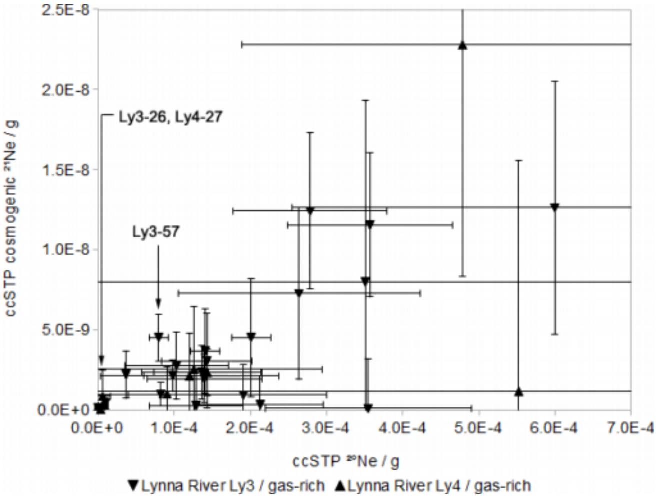

*Figure 2: Correlation between cosmogenic and SW-derived Ne. Four grains with "negative" cosmogenic Ne omitted.*

This is the first time that GCR+SCR exposure ages compatible with Poynting-Robertson timescales (for Ly3-26 and Ly4-27) have been determined in SEC grains from Ordovician sediments. So far, this has only been achieved using chromite grains from (cm-sized) fossil meteorites [14], where the cosmogenic signal is not swamped by SW gases. The exposure ages of these two grains can also be used to correlate the Ly3 and Ly4 beds roughly with the upper part of the "Arkeologen" bed in the Hällekis quarry in Sweden [14], and determine a deposition age difference between Ly3 and Ly4 of about 0.08±0.04 Ma. The second grain from Ly3 with a resolvable $^{21}$Ne$_{cos}$ excess, Ly3-57, has a higher exposure age of 4.95±1.65 Ma, clearly exceeding the Poynting-Robertson decay time for micrometeoritic grains [11]. Therefore, this grain was probably pre-exposed to GCR in the regolith layer prior to the break-up of the LCPB. There, the grain is exposed to $2\pi$ irradiation (GCR only, SCR is shielded), where the production rate was lower, and thus the true pre-exposure age has to be longer. Assuming it was exposed for 0.17±0.03 Ma to GCR+SCR during transfer to Earth (as was grain Ly3-26 from the same bed), and applying a "meteoritic" ($4\pi$) production rate of $7.04\times10^{-10}$ ccSTP/gMa [14][10] divided by 2 (roughly correcting for $2\pi$ exposure), the resulting pre-exposure time in the regolith is 13.0±4.3 Ma. The co-existence of grains of different exposure ages within the same sediment bed thus confirms the suggestion by [11] that regolith-derived grains are present in mid-Ordovician sediments.

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