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SOLAR PROTON PRODUCED NEON IN SHERGOTTITE METEORITES

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Cosmogenic radionuclides produced by near-surface, nuclear interactions of energetic solar protons (~10-100 MeV) have been reported in several lunar rocks and a very few small meteorites. We recently documented the existence and isotopic compositions of solar-produced, or SCR Ne in two lunar rocks [1, 2]. Here we present the first documented evidence for SCR Ne in a meteorite, ALH77005, which was reported to contain SCR radionuclides [3]. Examination of literature data for other shergottites suggest that they may also contain a SCR Ne component. Existence of SCR Ne in shergottites may be related to a martian origin.

Solar-Produced Ne in ALH77005: To resolve SCR Ne produced near the surface of ALH77005 from galactic (GCR) Ne expected to dominate at depths below a few cm, we made temperature extractions of 7 samples from different shielding depths. A three-isotope Ne correlation plot (Fig. 1) indicates that most of the Ne is cosmogenic in composition; only the first (350°C) extractions, releasing a small fraction of the total Ne, plot outside of Fig. 1 and along the trend lines that connect with atmospheric composition. The cosmogenic $^{21}Ne/^{22}Ne$ ratio in ALH77005 appears variable, however, and gives values of 0.71-0.78 (for $^{20}Ne/^{22}Ne < 1.0$). These ratios are less than those shown by typical chondrites, e.g., the 31 H-chondrites plotted on the same $^{21}Ne/^{22}Ne$ scale in Fig. 1 [4]. The range of $^{21}Ne/^{22}Ne$ ratios shown by 30 of these chondrites (0.82-0.94) spans much of the range that is predicted to occur from significant variations in GCR shielding depths [5]. High $^{3}He/^{21}Ne$ ratios (ALH77005 is ~8) and $^{21}Ne/^{22}Ne$ ratios below ~0.8 are very difficult to obtain in chondrites from GCR shielding alone [5].

We conclude that ALH77005 contains, in addition to a GCR component, a SCR Ne component having the calculated composition (Fig. 1) for energetic solar protons over a shielding range of 0.5-10 g/cm^2 [6]. This is the first description of SCR Ne in a meteorite. In addition to having lower $^{21}Ne/^{22}Ne$ ratios, those ALH77005 samples believed to have resided nearer the meteorite surface also tend to have somewhat larger concentrations of total cosmogenic ^{21}Ne compared to more interior samples. This observation is consistent with an extra SCR component but not with GCR production as a function of depth. Because the predicted SCR/GCR production ratio for Ne varies ~1-0.1 over shielding depths of ~0.7-8 g/cm^2 (6), $^{21}Ne/^{22}Ne$ in ALH77005 is expected to vary ~0.70-0.80 over the same shielding range, in agreement with measured data. We recently showed very systematic correlations in cosmogenic ^{21}Ne concentrations, $^{21}Ne/^{22}Ne$ ratios, and subsurface depths for samples from lunar rock 61016; these were attributed to a depth-variable SCR component [1]. One H-chondrite (Fig. 1) gave $^{21}Ne/^{22}Ne = 0.74$ and high $^{3}He/^{21}Ne = 9$ indicative of irradiation under low GCR shielding [4]; we suggest that this chondrite also contains a SCR Ne component.

SCR Ne in Other Shergottites: Literature data [7, 8, 9, 10, 11, 12, 13, 14,15 16, 17] of Ne released during temperature extractions of shergottites EET79001, LEW88516, Shergotty, and Zagami also show $^{21}Ne/^{22}Ne$ lower than that for typical chondrites and suggest the presence of SCR Ne. A least squares fit to the EET79001 data (Fig. 2) defines cosmogenic $^{21}Ne/^{22}Ne = 0.76$ at $^{20}Ne/^{22}Ne = 0.85$ and passes near the atmospheric composition. Data for the other shergottites (Fig. 2 inset with the same $^{21}Ne/^{22}Ne$ scale) show a more cosmogenic composition and indicate $^{21}Ne/^{22}Ne$ of ~0.73-0.83. (One temperature extraction of Shergotty shows a chondrite-like $^{21}Ne/^{22}Ne$ of 0.88 but an unexplainably low $^{20}Ne/^{22}Ne$.) Measurements of cosmogenic radionuclides and tracks in shergottites suggest that they were irradiated as small objects and suffered low ablation losses averaging 1-3 cm [3, 18]. The cosmogenic $^{3}He/^{21}Ne$ ratio for ALH77005 and LEW88516 (~7-8) suggests that shielding was less than for the other three shergottites ($^{3}He/^{21}Ne = 4$-6) [17], and thus a larger SCR component might be expected in ALH77005.

Effects of Composition: Because ALH77005 and LEW88516 have chemical compositions similar to ordinary chondrites, observed differences in $^{21}Ne/^{22}Ne$ (Fig. 1) cannot be caused by target element effects. However, because other shergottites show considerable compositional differences compared to chondrites, we examined the compositional effects on cosmogenic $^{21}Ne/^{22}Ne$ in more detail (Fig. 3). Mg yields a considerably lower $^{21}Ne/^{22}Ne$ than do Al and Si, and the Mg/Mg+Si+Al parameter has been previously used to examine the effects of sample composition on cosmogenic $^{21}Ne/^{22}Ne$ [19, 20]. The oval field labeled "chondrites" shows analyses of silicate mineral separates from two chondrites [see 19], whereas the dashed line represents the variations in GCR shielding for the H-chondrite data shown in Fig. 1. Also plotted are data for three eucrites [21] and multiple depth samples of lunar rocks 68815 and 61016 [1, 2], the latter being pure anorthosite with essentially no Mg. All samples of the two lunar rocks except those with the highest $^{21}Ne/^{22}Ne$ were shown to contain significant SCR Ne. These data suggest that GCR $^{21}Ne/^{22}Ne$ tends to correlate with Mg in silicates, but that even extreme compositional variations ranging from olivine to anorthosite cannot explain the ALH77005 data (labeled A in Fig. 3). We conclude that GCR Ne compositions generally would be limited to the shaded area of Fig. 3, and that increasing amounts of SCR Ne would move compositions to the left.

Literature data for other shergottites (L, E, Z, and S) as well as Nakhla (N) and Chassigny (C) are also shown in Fig. 3. The L and Z points are individual analyses, whereas the E and S points show the median values and total ranges of temperature extractions (Fig. 2). Although Chassigny and Nakhla give no evidence of SCR Ne, such a component appears to be present in LEW88516, EET79001, and possibly in some samples of Zagami and Shergotty.

It appears that all known shergottites, in contrast to chondrites, contain a cosmogenic Ne component with low $^{21}Ne/^{22}Ne$ that cannot be explained by shielding or composition; this suggests a Mars-related factor. Some evidence exists that the GCR $^{21}Ne/^{22}Ne$ ratio produced from pure Na is as low as 0.4-0.5. These shocked shergottites might contain such a cosmogenic component produced from Na-rich salts on the martian surface and shock-implanted by the process that has been invoked to implant Martian atmospheric gases into shergottites [22]. One sample of EET79001 showed variations in cosmogenic $^{21}Ne/^{22}Ne$ of 0.74-0.79 during temperature extractions [8, and Fig. 2], which might suggest separate release of cosmogenic Ne produced from Na compared to that produced within the silicate. Alternatively, orbital parameters of the shergottites during transit to earth may have produced more favorable conditions for SCR Ne production. Among the various possibilities are lower eccentricities or different inclinations of shergottites compared to chondrites to enhance the SCR/GCR production ratio, or smaller entry velocities into the earth's atmosphere to cause lower surface ablation of shergottites [H. Zook, pers. comm.]. In the latter case, the longer exposure ages of nakhlites and Chassigny compared to shergottites [7] may explain the absence of this SCR Ne in the former.

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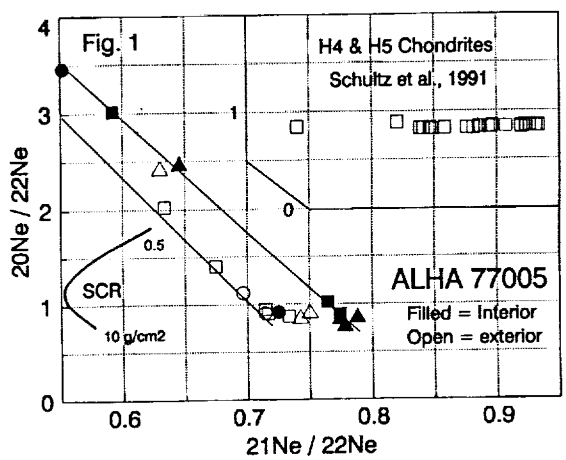

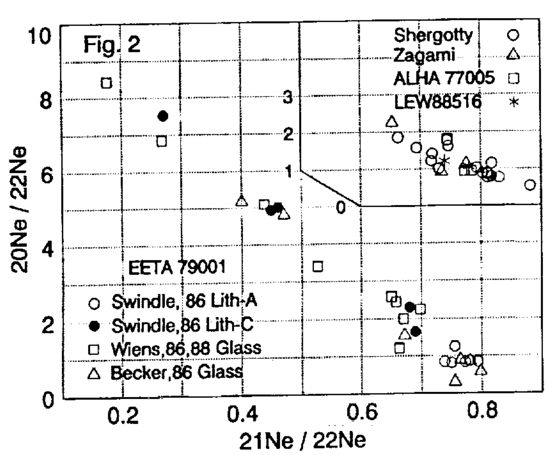

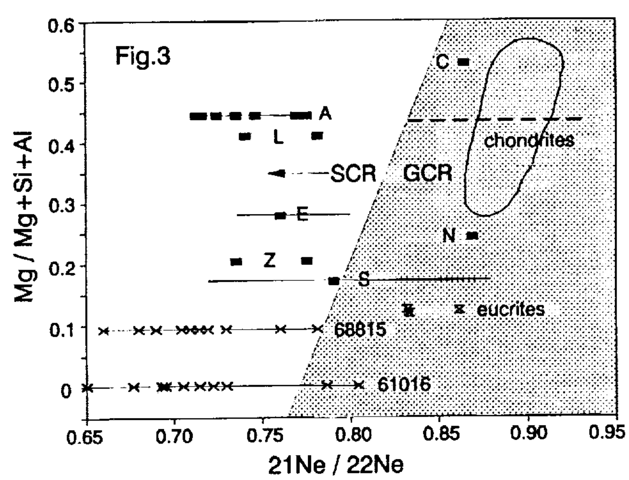

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