PRODUCTION RATES OF COSMOGENIC NUCLIDES AND GALACTIC-COSMIC-RAY SPECTRA.

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Introduction: The best models for making cosmogenic nuclides are needed for good interpretations of concentrations of these nuclides measured in samples of solar-system matter. Theoretical calculations are usually used to get production rates to compare with measurements. An important input to these theoretical calculations is the spectrum of the incident cosmic-ray particles.

Early models often used only one spectrum that included both primary and secondary particles [e.g., 1]. More recently, production rates of cosmogenic nuclides are calculated using spectra of particles that are calculated using Monte Carlo particle production and transport codes. There have been several codes used to calculate these spectra, including the LAHET Code System [e.g., 2], HERMES [e.g., 3], and MCNPX [e.g., 4,5]. All of these cited papers used the same input for the spectrum of protons in the galactic cosmic rays (GCRs), which was from Castagnoli and Lal (1980) [6] with a minor correction [7]. There are a number of spectra that could be used for GCR particles [e.g., 7]. Recently, new ones were reported by Webber and Higbie (2003) [8] and by Clem et al. (2004) [9].

We want to see if the input GCR spectrum affects calculated production rates. Reported here are production rates for several cosmogenic nuclides using the GCR spectra of Castagnoli and Lal (CL) [6] and of Webber and Higbie (WH) [8].

Calculations of Production Rates: Production rates for making ^{10}Be, ^{21}Ne, ^{22}Ne, and ^{26}Al were calculated using existing cross sections [e.g., 2,4] and spectra calculated using the LAHET Code System [2]. These nuclides are made by particles with different energies, with Ne isotopes being readily made by low-energy particles and ^{10}Be being made by higher-energy particles. The composition was that of a typical L-chondrite. Depth profiles were calculated for spherical L-chondrites with a range of radii using a density of 3.55 g/cm^3.

Input GCR spectra. The GCR input spectra were those of CL [6] and WH [8] for an average solar-system modulation of 550 MeV [2]. These input GCR spectra are plotted in Fig. 1. Although they look similar, there are differences in their shapes, such as the flux ratios for ~100-10^3 MeV being lower than those at the lowest and highest energies. For the calculations, both fluxes were normalized to the same total flux.

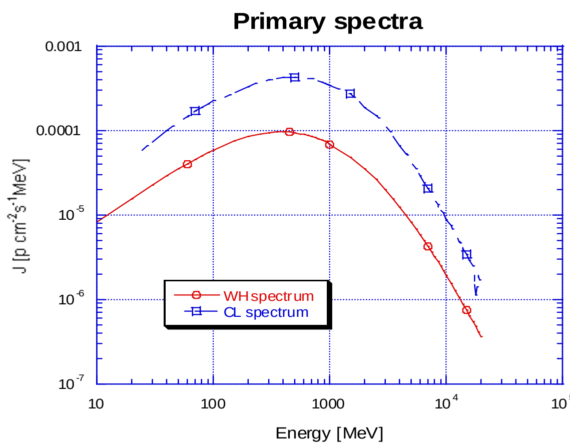

Fig 1. GCR proton fluxes (J[protons cm^{-2} s^{-1} MeV^{-1}]) from the CL [6] (top) and WH [8] (bottom) models for a modulation parameter of 550 MeV are plotted as a function of energy from 10 to 10^5 MeV.

Results: The ratios of the production rates calculated for these 4 nuclides for 3 radii (10, 50, and 100 cm) are plotted in Fig. 2 as a function of depth. The ratios scatter about unity but occasionally reach values of 1.2 and higher.

Summary: Production ratios calculated for cosmogenic nuclides using two different input spectra for the GCR protons vary by up to ~1.2. The ratios tend to be further from unity for large objects where secondary particles are more important, although the trends for radii of 50 and 100 cm go in different directions with depth, which could be because GCR particles are most effective at depths that depend on their energies, as higher energy protons are more penetrating.

Further work will be done with other nuclides and with other input GCR spectra to get a better understanding of how the spectra of the incident GCR particles affect production rates of cosmogenic nuclides.

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[6] Castagnoli G. C. and Lal D. (1980) *Radiocarbon, 22*. 133-158. [7] Reedy R. C. (1987) *PLPSC17, JGR, 92*, E697-E702. [8] Webber W. R. and Higbie P. R. (2003) *JGR, 108(A9)*, 1355. [9] Clem J. M. et al (2004) *Radiation Protection Dosimetry, 110*, 423-428.

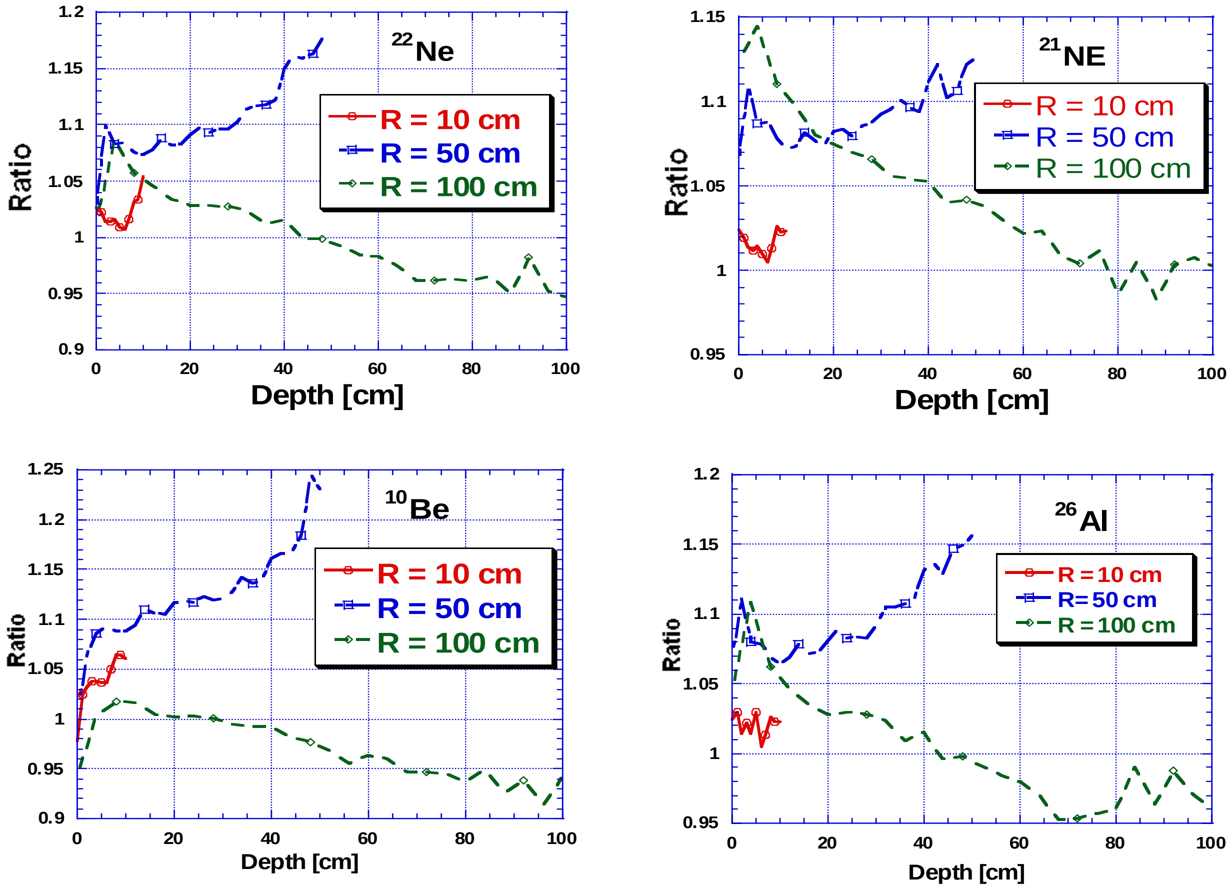

Fig. 2. Calculated ratios (CL/WH) of production rates for making cosmogenic nuclides by incident protons with the spectra from Castagnoli and Lal (1980) [6] (CL) to those from Webber and Higbie (2003) [8] (WH) are plotted as a function of depth for three radii.