NEUTRON CAPTURE PRODUCTION RATES OF COSMOGENIC ^{60}Co, ^{59}Ni AND ^{36}Cl IN STONY METEORITES;

M. S. Spergel, York College of CUNY, Jamaica, New York, 11451, USA; R. C. Reedy, Los Alamos National Laboratory, Los Alamos, New Mexico, 87545, USA; O. W. Lazareth and P. W. Levy, Brookhaven National Laboratory, Upton, New York 11973 USA

To unfold the cosmic-ray exposure history of a meteorite, it is best to use a variety of cosmogenic products (tracks and nuclides) with different production profiles. Neutron-capture reactions have production rates which vary considerably with sample depth and meteorite size[1]. Their production profiles differ appreciably from those for tracks or nuclides created by energetic cosmic ray particle spallation reactions. In large meteorites neutron-capture reactions are the main sources of cosmic-ray produced nuclides such as ^{59}Ni and ^{60}Co.[1] The cosmogenic radionuclide ^{60}Co, from the $^{59}Co(n,\gamma)$ ^{60}Co reaction, has been a very useful tool for unfolding the cosmic-ray exposure record of the large Jilin (Kirin) chondrite[2,3].

The neutron-capture reaction rates producing ^{36}Cl, ^{59}Ni, and ^{60}Co in meteorites were calculated by Eberhardt, et al.[1] using neutron slowing-down theory. Lingenfelter et al.[4] used neutron-transport theory to calculate the low-energy neutron flux and neutron-capture induced isotopic anomalies in the moon. Previously we reported neutron-transport theory calculation of the low-energy neutron, as a function of depth, in spherical meteoroids[5] and preliminary results for ^{59}Ni and ^{60}Co production rates.[6-7] Reported here are complete results for neutron flux calculations in stony meteoroids, of various radii and compositions, and production rates for ^{36}Cl, ^{59}Ni, and ^{60}Co.

New neutron source strengths have been calculated that increase our calculated production rates by about 30% in larger meteorites.[11] The $^{59}Ni/^{60}Co$ production ratio in spherical L-chondrites with radii >150 g/cm^2 is usually within agreement with measurements on various large meteorites; but higher than the ratio as calculated by Eberhardt, et al.[1] Neutron-capture calculations for a C3-chrondrite with 100-ppm hydrogen and for an aubrite (≈1% Fe) provide neutron-capture systematics that differ considerably from those obtained with L-chondrites. Measured neutron-capture radionuclides in the Allende meteorite agree better with calculation for a dry chondrite than for one with 100-ppm H; indicating that Allende had a low H content. Our lunar claculations agree with the calculation of Lingenfelter et al.[4], Kornblum et al.[9], and with the lunar neutron measurements.[8] Both the absolute values and the activity-versus-depth profiles calculated for ^{60}Co formation in the Moon agree with the measurements of Wahlen et al.[10] For large spheres the calculated results converge to those obtained for the Moon, but there are significant differences between the lunar results and those predicted for a meteorite with a radius of 1000 g/cm^2. The calculated neutron fluxes and nuclide production rates for small spheres are quite different from those for large meteorites.

The $^{59}Ni/^{60}Co$ ratio is nearly constant with depth in most meteorites: this effect is consistent with the neutron flux and capture cross section properties. The shape of the neutron flux energy spectrum, varies little with depth in a meteorite. The size of the parent meteorite can be determined from one of its fragments, using the $^{59}Ni/^{60}Co$ ratios, if the parent meteorite was less than 75 g/cm^2 in radius. If the parent meteorite was larger, a lower limit on the size of the parent meteorite can be determined from a fragment. In C3 chondrites this is not possible.

In stony meteorites with $R < 50$ g/cm^2 the calculated ^{60}Co production rates (mass < 4 kg), are below 1 atom/min g-Co. The highest ^{60}Co production rates occur in stony meteorites with radius about 250 g/cm^2 (1.4 m across). In meteorites with radii greater than 400 g/cm^2, the maximum ^{60}Co production rate occurs at a depth of about 175 g/cm^2 in L-chondrite, 125 g/cm^2 in C3 chrondrite, and 190 g/cm^2 in aubrites. Production results for ^{60}Co and ^{59}Ni in meteorites of radius 300 g/cm^2 (≈86 cm) are shown in Fig. 1 and Fig. 2 respectively. The figures contain results for L Chondrite and C3 type meteorites.

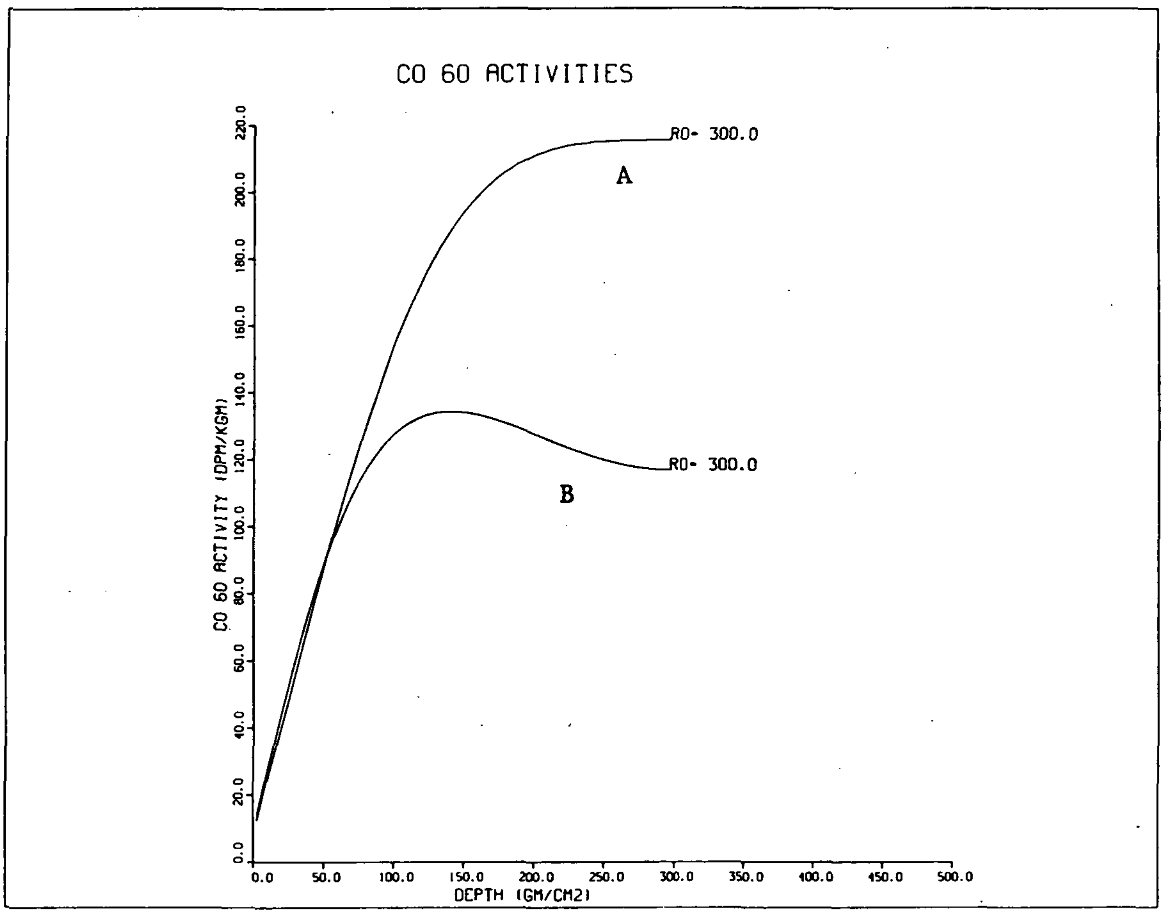

FIG. 1. ^{60}Co production (DPM/Kg) curves in a L Chondrite (A) and a C3 (B). Peak activity occurs closer to the surface in the C3 Chondrite. Cobalt activity levels are effected by the different hydrogen abundances in the meteorites.

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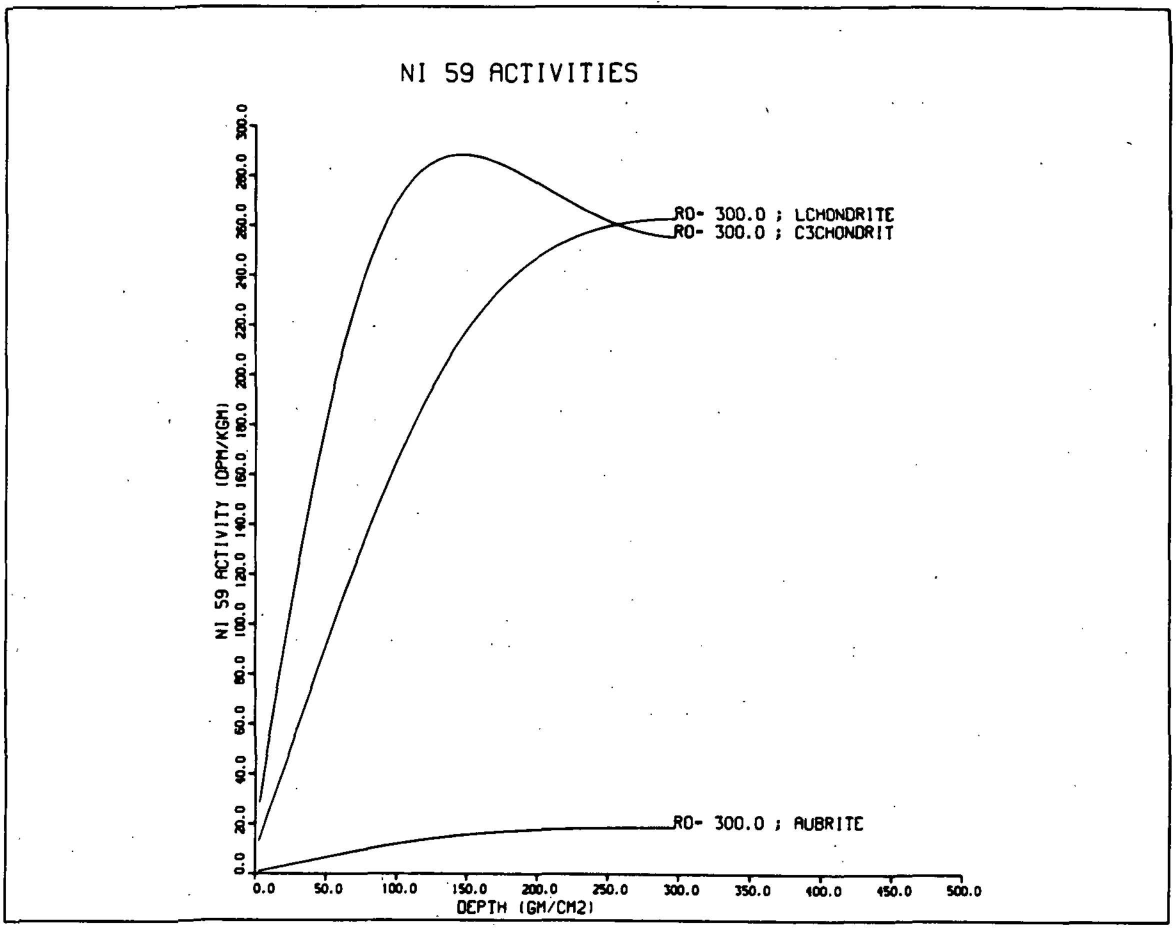

FIG. 2. ^{59}Ni production (DPM/Kg) curves in L Chondrite, C3 Chondrite and Aubrite type meteorites. Peak activity occurs closest to the surface with the C3 Chondrite.

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