EFFECTS OF METEOROID SHAPE ON COSMOGENIC-NUCLIDE PRODUCTION RATES*; J. Masarik and R. C. Reedy, Astrophysics and Radiation Measurement Group, Mail Stop D436, Los Alamos National Laboratory, Los Alamos, NM 87545, USA.

The shape of the meteoroid irradiated in space can be one of the factors influencing cosmogenic-nuclide production. Numerical simulations with Los Alamos 3-D Monte Carlo codes for particle production and transport were done for spherical and ellipsoidal meteoroid geometries. There are statistically important differences in particle fluxes that depend on the irradiated-object's shape and the sample's location. Comparisons of our production-rate calculations with experimental cosmogenic-nuclide data for St. Séverin, which was ellipsoidal in the space, show better agreement for modeling the parent-body's geometry with an ellipsoid than with a sphere.

Nuclides produced by the interaction of cosmic-ray particles with a meteoroid are sources of valuable information about both the meteorite and the cosmic rays. The accurate modeling of the production processes is prerequisite for the interpretation of measurements. The incident particle fluxes, the meteoroid's preatmospheric shape and size, and its bulk chemical composition all determine the production rates of nuclides. As much work have been done on size effects and some done on bulk chemical composition effects [1,2], we concentrated on effects of the shape of the parent body on the production of cosmogenic nuclides.

The production depth profiles are calculated in the framework of a pure physical model [1] that describes, without free parameters, the interaction of cosmic-ray particles with a meteoroid and the subsequent production and transport of secondary particles. In this model, the nucleon spectra are calculated by Monte Carlo simulations using the LAHET Code System (LCS). Having calculated neutron and proton fluxes, the production rates of cosmogenic nuclides are calculated by integrating over energy the product of these fluxes with experimental and theoretical cross sections for the nuclear reactions producing each nuclide [1]. Similar calculations were done by [3,4].

LCS has a very powerful generalized-geometry input module based on the MCNP code [5] that can model different shapes of irradiated objects with a mesh-like geometry structure suitable for the simulation of the energy and spatial distribution of particle fluxes inside the object. The two geometries investigated in this work were an ellipsoid with semiaxes of 40, 20, and 25 cm (the preatmospheric shape of the St. Séverin LL6 chondrite inferred by [6,7]) and a sphere with radius 27 cm, which has the same volume as the ellipsoid. We used a density of 3.55 g/cm^3. As the particle production spectra and fluxes are strongly depth dependent, our model objects were divided into concentric shells with thickness 2.5 cm. In all shells, proton and neutron fluxes were calculated. For the sphere, particle fluxes were averaged over the whole volume of the shell. In the case of the ellipsoid, the fluxes were calculated in two ways: by averaging over the whole ellipsoidal shell and by averaging only over the shaded volume elements in Fig. 1. The last division of the ellipsoid was motivated by the actual location of measured samples [8–10]. Both objects were irradiated by an isotropic galactic-cosmic-ray (GCR) flux of 4.8 protons/cm^2/s, corresponding to the GCR primary particle spectrum averaged over a typical solar cycle. Our model with this GCR flux reproduced very well cosmogenic-nuclide profiles in the Knyahinya L5 chondrite [11]. Statistical uncertainties using our geometrical models and running 100,000 incident GCR particles were $\sim$3–4%.

Our simulations confirm the importance of effects caused by parent-body shape on nucleon fluxes within the meteorite and consequently on production rates of cosmogenic nuclides. At first, we compared particle fluxes inside sphere and ellipsoid averaged over whole concentric shells. No differences in these fluxes were found. The explanation of this fact can be given in the framework of simple geometric considerations. It has been shown [e.g., 3,4] that even in small objects, the substantial contribution to the cosmogenic nuclide production comes from secondary particles. The shape of the irradiated body influences the number of particles (primary and secondary) escaping from the investigated body without participating in particle cascade development. This can lead to a change in the absolute value and the shape of the differential particle fluxes. This effect contributes to increased production rates in larger spheres up to a given radius. For the ellipsoid, there are some regions with larger and smaller curvature than the curvature of the equivalent sphere, and there are also different numbers of escaping particles in these regions. After averaging the fluxes over the whole volume of each shell, the effects caused by differences in the escape of particles are compensated and this leads to the equivalence of observed fluxes.

Many samples measured in St. Séverin were taken from core AIII going through the geometric center of the chondrite in the direction of the minor semiaxes. This is the region of the meteorite where the smallest number of escaping particles is expected, as in a larger sphere. and therefore an increase in particle fluxes and production rates in comparison with those in sphere is natural consequence. The depth-profile shape for all investigated nuclides remained unchanged. An increase of about 5–10% has been found for our calculated ^{53}Mn, ^{10}Be, and ^{21}Ne production rates (Figs. 2–4), which agree well with the measurements for neon [8] and ^{53}Mn [9] (corrected to saturation) but not as well with the shape of the ^{10}Be profile measured by [10].

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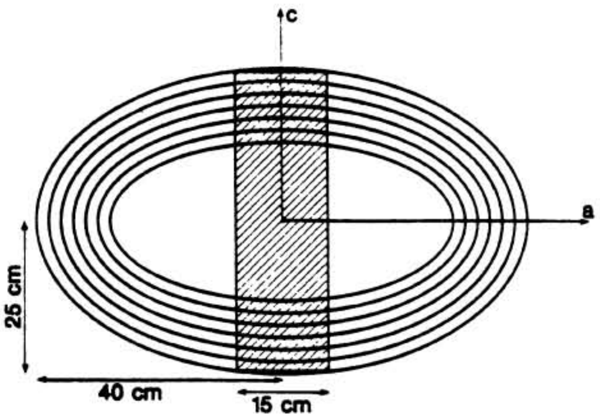
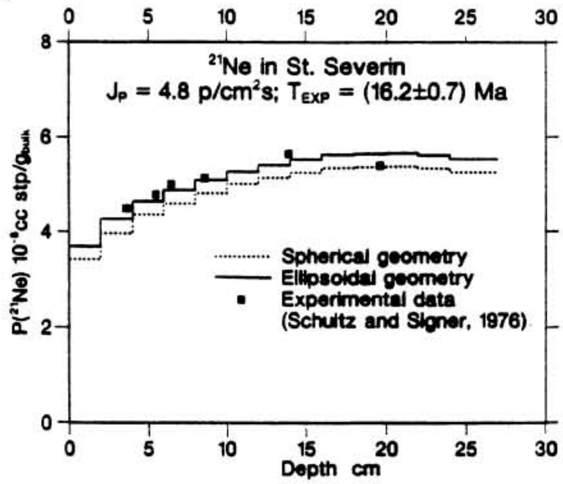
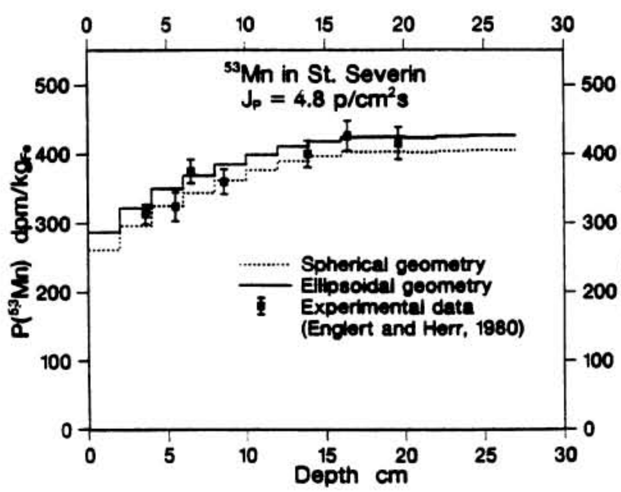
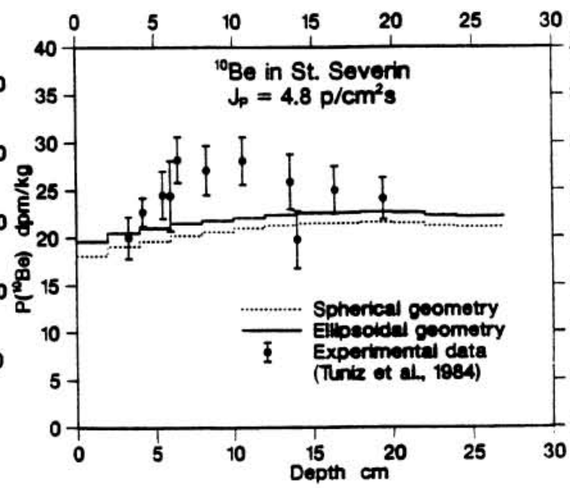


Fig. 1. The geometry used for the St. Séverin ellipsoid in these calculations. The shaded area is 15-cm×15-cm in the *ab* plane and is the region shown for the ellipsoid curves in Figs. 2–4, corresponding to core AIII.







Figs. 2–4. Calculated (sphere and the 25-cm minor semiaxis of ellipsoid) and measured nuclide concentrations of ^{21}Ne (top right), ^{53}Mn (lower left), and ^{10}Be (lower right) in St. Séverin.