PRODUCTION OF COSMOGENIC NUCLIDES IN SNC METEORITES IN THE MARTIAN SURFACE.* J. Masarik and R. C. Reedy, Astrophysics & Radiation Measurements Group, Mail Stop D436, Los Alamos National Laboratory, Los Alamos, NM 87545.

Depth-dependent production rates of ^{3}He, ^{10}Be, ^{21}Ne, ^{22}Ne, ^{26}Al, ^{38}Ar, and ^{53}Mn were calculated for Shergotty, Nakhla, and Chassigny (the "SNC" meteorites, believed to have come from Mars) for spherical geometries in space and also in the martian surface for cases of no and a 15-g/cm^2-thick atmosphere. The calculations were done with the well-tested LAHET Code System. The martian atmosphere does not seriously affect production rates and profiles, and thus the apparent absence of complex cosmic-ray exposure histories in SNC meteorites, in contrast to frequent complex histories for lunar meteorites, is not due to unusual production rates in the martian surface. Relative nuclide production rates in Mars and SNC meteoroids depend on the nuclide and the meteorite's composition but only slightly on the martian atmosphere's thickness.

The SNC meteorite family is one of two sets of "planetary" meteorites, the other being the lunar meteorites. One major difference in the cosmic-ray records of these two sets is that many lunar meteorites show good indications of complex exposure histories [e.g., 1,2], with nuclides made both in space and in the lunar surface, while the SNC meteorites show no indication [e.g., 3,4] of production in the SNC parent body, which was very large and believed to be Mars. Thus SNCs are like most stony asteroidal meteorites in not having complex exposure histories.

The nuclear processes involved in the interaction of GCR particles with the SNC meteoroids and Mars were simulated with the LAHET Code System (LCS), which is a system of 3-D, coupled Monte Carlo codes that treat the relevant physical processes of particle production and transport. LCS and its adaptation to meteorite applications are described in [5]. Production rates calculated for meteorites and lunar cores using LCS-calculated fluxes have agreed well with various measurements [e.g., 5–7]. LCS also has been used to calculate production rates of neutrons and gamma rays in Mars [8].

We simulated the irradiation of spheres or the martian surface with an isotropic GCR-particle flux of 4.8 nucleons/cm^2/s with an energy distribution corresponding to the GCR primary particle flux averaged over a solar cycle [5,6]. The density used for the meteoroids was 3.2 g/cm^3, and that for the martian surface was 1 g/cm^3. Production rates were calculated for a series of depths in each irradiated object. The composition of the meteoroids were those of the 3 SNC meteorites, and that for Mars was one estimated from Viking and SNC measurements [8]. Having calculated the particle fluxes with LCS, the production rates of cosmogenic nuclides were calculated by integrating over energy the product of these fluxes and cross sections for the nuclear reactions making the investigated nuclide [5]. These cross sections were those evaluated for the study of radionuclides or noble gases [e.g., 5–7].

The calculated production profiles for ^{10}Be, ^{21}Ne, ^{26}Al, ^{38}Ar, and ^{53}Mn in Shergotty and ^{21}Ne in Chassigny are shown in Figs. 1–6. Most other profiles for Shergotty, Nakhla, and Chassigny are similar to those shown here. The results for the spherical SNC meteoroids have trends that are similar to those calculated for other meteorites [e.g., 6,9], with production rates increasing with depth and with increasing radius up to radii of ~150 g/cm^2.

The calculated production rates in the martian surface in Figs. 1–6 show the effect of the average thickness of the martian atmosphere (15 g/cm^2) on production rates and allows for direct comparisons with production rates in space. The cosmogenic-nuclide production rates for Mars with 5–25 g/cm^2-thick atmospheres, the range of atmospheric thicknesses now observed at Mars, are higher near the very surface (top ~10 g/cm^2) compared to the case of no atmosphere because the cascade of GCR particles has started in the atmosphere and the atmosphere scatters particles leaking from the surface back into the surface. As low-energy particles can be back-scattered better than high-energy ones, this scattering effect is greatest for nuclides like ^{21}Ne (see Figs. 3–4) that are made by low-energy particles. Below ~10–20 g/cm^2, production rates for no atmosphere are slightly higher than those for an atmosphere. The atmospheric thickness would need to be much thicker than it is now at Mars for production rates to be much lower than the case with no atmosphere, and such thick atmospheres probably were not present at Mars over the last few million years when the SNC meteorites probably were ejected. Thus the martian atmosphere (~15 g/cm^2 thick) is not the explanation for the lack of complex exposure histories in SNC meteorites.

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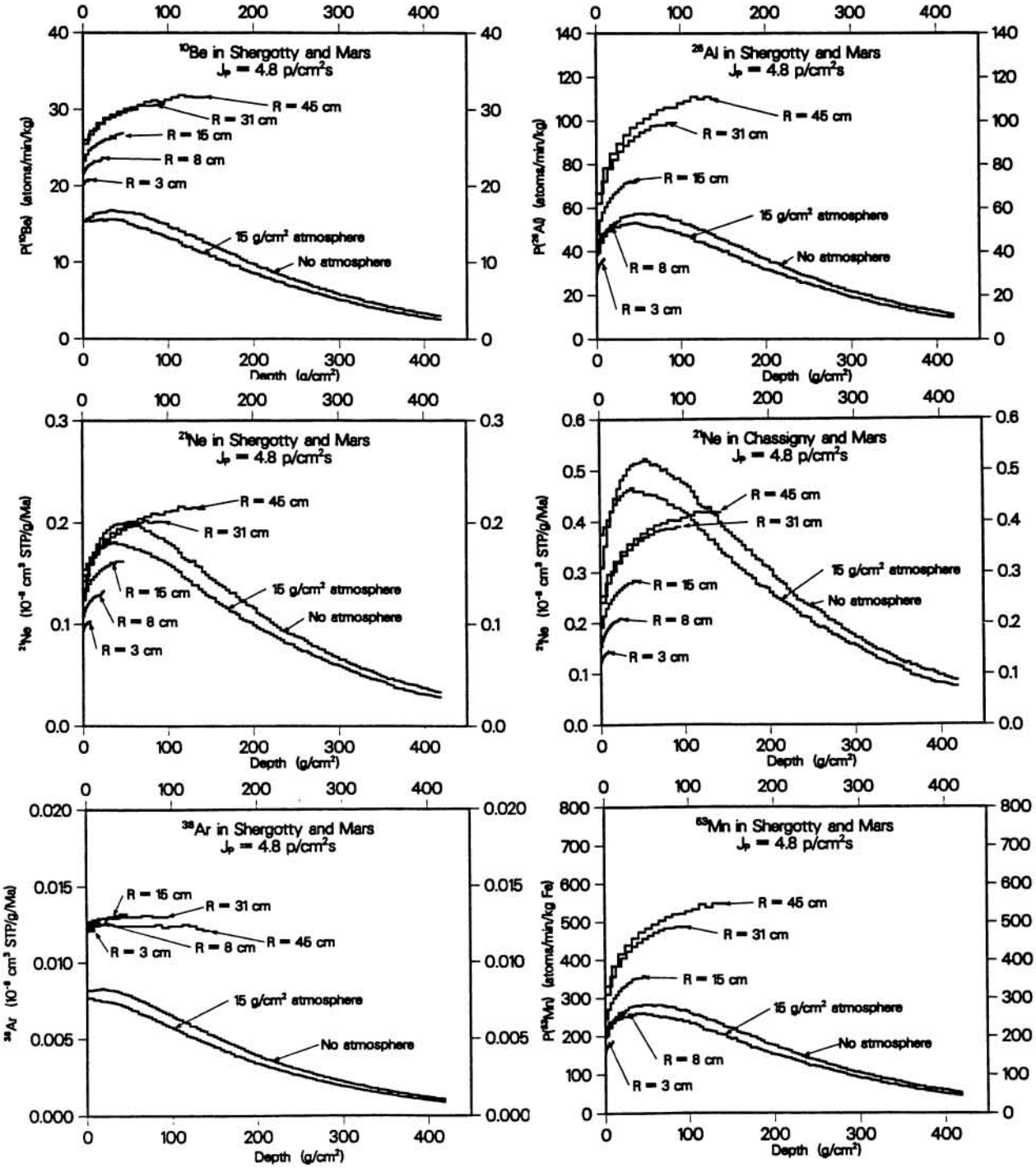

Figs. 1–6. Calculated cosmogenic-nuclide production rates versus depth in meteoroids of various radii and in the martian surface for the cases of no atmosphere and a 15-g/cm^2-thick atmosphere.