LETTERS TO THE EDITORS

PHYSICAL SCIENCES

Calculation of Erosion in Space from the Cosmic-Ray Exposure Ages of Meteorites

VERY little is known about erosion in space—the action of dust, gas, ions and electrons in wearing away material from exposed surfaces in interplanetary space. A cosmic-ray exposure age is obtained from the measurement of one radioactive and one stable spallation isotope produced in a meteorite by cosmic rays. A new interpretation of this age indicates that it sets an upper limit to the erosion-rate of a meteorite in space. The more obvious interpretations in terms of meteoritic break-up and planetary perturbational effects may remain valid.

The cosmic-ray exposure age is determined from the spallation isotope content of a meteorite, with the assumption that the spallation-rate does not vary with time. If erosion occurs in space, however, the spallation-rate in the distant past would have been smaller than in recent times because of the greater amount of shielding material. Hence, due to erosion in space, the measured cosmic-ray exposure age is less than the interval since the meteorite was exposed to cosmic rays. Consequently, the cosmic-ray exposure age gives an upper limit to the rate of erosion in space.

We shall base our discussion on the argon exposure age[1] of the Sikhote–Alin meteorite. The value of 5×10^8 years was obtained[1] from the number of argon-38 atoms (stable isotope) and the decay-rate of argon-39, a radioactive isotope with a half-life of 260 yr. The tritium (helium-3) ages of two iron[2] and one stone[3] meteorite have also been measured; however, the argon exposure age is subject to fewer uncertainties than the tritium (helium-3) age.

We shall assume that the rate of production of argon-38 near the centre of a large iron sphere of radius R obeys the attenuation rule:

$$\mathrm{d}^{38}\mathrm{A}/\mathrm{d}t = C \exp(-R/72) \text{ for } R \geqslant 100 \text{ cm.}$$

where C is a constant determined by the spallation properties of the iron nucleus and the cosmic ray flux.

The Sikhote–Alin meteorite was quite large: the argon-39 radioactivity in the measured sample was about one-ninth the activity expected in a small unshielded body. If the rate of erosion in space is designated by E and if r is the radius of the meteorite just before it struck the atmosphere, then the rate of production of argon-38 at t years ago was $C \exp\{-(r + Et)/72\}$. The present rate of production is $C \exp(-r/72)$. The measured cosmic-ray exposure age, 5×10^8 yr., is given by the expression $\int_0^T (\mathrm{d}^{38}\mathrm{A}/\mathrm{d}t)\mathrm{d}t/C \exp(-r/72)$, where T is the time that the meteorite existed as a body exposed to cosmic rays. If the attenuation rule is substituted into this expression, then the following relation is obtained:

$$5 \times 10^8 \text{ years} = (1 - \exp(-Et/72)/(E/72)$$

where E is the rate of erosion.

Since the time T is greater than the measured exposure age, 5×10^8 years, the upper limit to the rate of erosion E is $1{\cdot}5 \times 10^{-7}$ cm./yr. for an iron meteorite. This rate is somewhat smaller than an estimate made by one of us (F. L. W.)[4].

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[4] Whipple, F. L., Proc. Eighth Internat. Astronaut. Cong., 418 (1957).

Observations of the Lithium Lines in the Twilight Airglow in the Northern Hemisphere

THE recently published discovery of the lithium resonance line in the twilight airglow by Delannoy and Weill[1] and further observations of the emission by Gadsden and Salmon[2] have led to a discussion as to the origin of the lithium atoms in the upper atmosphere. Barbier, Delannoy and Weill[3] have considered the possibility of marine and meteoric origins for the lithium and have favoured the latter hypothesis because the derived abundance ratio lithium/sodium agreed better with the ratio for the meteoric material. Donahue[4] has suggested that the lack of linearity in the relation between sodium brightness and abundance could make ambiguous any conclusions based on the lithium/sodium brightness ratio alone. A third possibility suggested by the U.S.A. International Geophysical Year Committee[5], and supported further by Barber[6], is that the lithium originates from 'hydrogen' bomb tests at high altitude; it is suggested, in particular, that the high-altitude Johnston Island test of August 1, 1958, was responsible for the lithium emissions reported by Gadsden and Salmon from Antarctica and New Zealand. In view of the uncertainty of present knowledge of the behaviour of the lithium emission, an observation from a station in the northern hemisphere should be of interest.

Twilight spectra covering the region 6000–7000 A. have been obtained at Saskatoon regularly since January 1959. An $f/0{\cdot}8$ auroral grating spectrograph[7] was used to photograph the spectrum on Kodak 103 *a–F* plates. During the exposures the spectrograph was guided according to an exposure programme which kept it pointing at the point in the Sun–zenith plane where the geometrical shadow height was 80 km. Following such a programme, a 30-min. exposure may be obtained during a single twilight with a zenith angle range of 0–83°.

A very weak lithium line was obtained in this way on a plate exposed on four occasions during clear twilight during the period January 10–21, 1959. The total exposure time was 115 min. Comparison of this spectrum with the spectrum of a calibrated source of low brightness led to a value of 30 rayleighs for the zenith brightness of the lithium emission for a height of 80 km. of the geometrical shadow.

An estimate of the abundance of lithium in the upper atmosphere can be made from the observed