Reports

Topographic and Geologic Aspects of a Far-Side Lunar Crater

Abstract. *Important details resolved by Lunar Orbiter photographs have revealed some volcanic aspects in the topography of a crater on the far side of Moon, about 70 kilometers south of Tsiolkovsky.*

The resolution of Lunar Orbiter photographs reveals details that were not previously resolvable. A far-side crater at 128°E,28°S, about 70 km south of Tsiolkovsky, reveals some topography (shown in the approximate cross-sectional profile *A′-B′-C′-D′*, in Fig. 1) on the north and east sides of the crater floor that seems to be slightly different in extrusive or flow nature from that near Flamstead and elsewhere (*1*). The approximate profile between *D′* and *C′* crosses a lobate front, having a thickness of at least 20 m, about 4 km east of *G*. The material at *G*, on top of the flow mass, has a surface texture quite unlike that of Earth lava flows or of apparent lava flows in eastern Oriental (a crater, 700 km in diameter, recorded in Lunar Orbiter IV photograph 33A-M187). Interpretation of the area around *G* as a mudflow can be eliminated because of the lunar condition of vacuum that would remove the liquid water necessary for such a flow. A cushion of air lubricating a landslide, such as the Sherman or Blackhawk landslide (*2*), is also eliminated from consideration by the same conditions of lunar vacuum. The apparent viscosity of the flow in the vicinity of *G*, which flow seems to originate near *X*, appears to be much lower than that of lava flows; it is considerably more like an ash-flow tuff on Earth (*3*).

The number of craters on the lobate front near *G* is considerably less than the number of equal-sized craters on the surface of this flow, or on the crater floor in front of the flow, and this difference does not appear to be caused by the difference between the two surfaces in angle of exposure to sunlight. Several sharp (or fresh), small craters, visible on the lobate-front area, suggest that the material of the flow front is capable of sustaining a crater of this small size. Some mechanism other than impacting meteorites, or their secondaries, must be held to account for the greater number of small craters on the surface of the flow than on the lobate front. Could gas, a common component of ash flows, escaping from the flow material near *G* before its final consolidation, account for at least some of the small craters on top of the flow?

Another apparent flow front (in the vicinity of *B* in Fig. 1) is much thinner than the flow in the vicinity of *G*, and has a very irregular and generally nonlobate front west of *B*, as exposed by Sun at about 20-deg elevation from N80°W. The cratered surface texture is quite similar to that of the northern flow surface, but this flow appears to have a broad-area origin rather than a point source such as *X*. No stress-strain

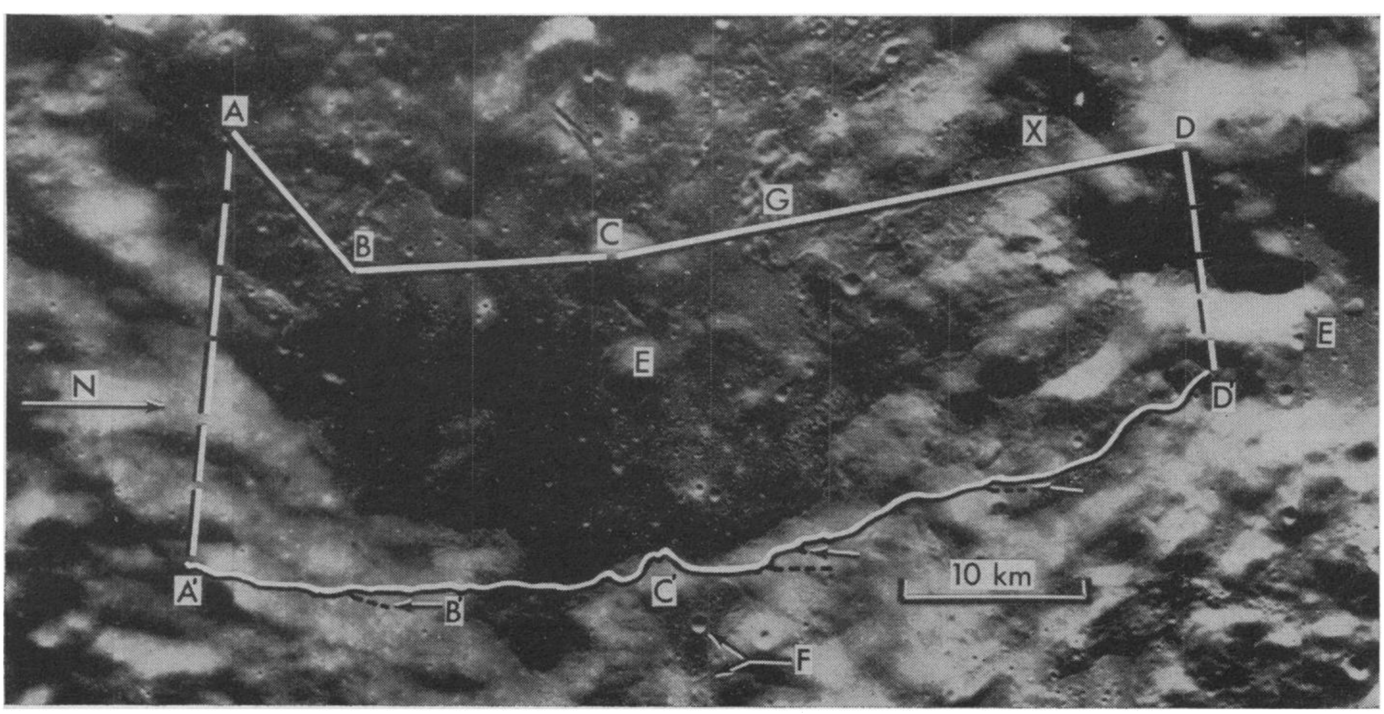

Fig. 1. Crater on the far side of Moon. Approximate topographic profile *A′-B′-C′-D′* appears to the east of the straight delineations *A-B-C-D*. Arrows beneath *A′-B′-C′-D′* suggest approximate directions of the proposed flows. Markings at *F* on the edge of a small "upper lake" resemble lava-lake marks in Hawaiian calderas.

surface cracks or extruded lobate-flow ridges are visible at this resolution on this flow front (nor on the "second" top-flow front 7 km southeast of X). The shadow pattern and ground texture 6 km N50°W of B suggest that this material at the lip of the flow is higher than that 2 km east of this lip.

Apex craters (E and C, Fig. 1) are visible on several conical hills on the edge and floor areas of the crater; these resemble pyroclastic cinder cones and are somewhat smaller than the major conical hills in central Copernicus, which are some 2100 m in height.

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References

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Biologic Effects of Supernovae

Abstract. *Estimates of the probability that nearby explosions of supernovae have occurred during the earth's history and the biologic effects of the radiation therefrom are presented. They suggest that cosmic radiation from supernovae could have caused the extinction of many exposed animals without the simultaneous extinction of plant life. This suggests that supernovae should be considered as one possible mechanism by which fauna become extinct.*

Since supernovae are thought to be an important source of cosmic radiation (*1, 2*), one would expect that a nearby explosion would result in a significant increase in background radiation. One of the most obvious consequences of a large acute dose of cosmic radiation would be the mass extinction of organisms. It has been suggested by several investigators (*3–5*) that the explosion of supernovae might account for the mass extinction of fauna as observed in the geologic record.

Two independent groups (*1, 2*) arrived at a similar estimate for the energy released in the form of cosmic radiation during the explosion of supernovae. In addition, the frequency of nearby explosions can be calculated from the frequency of observed supernova remnants (*6, 7*) and the estimated distribution of supernovae in our galaxy (*6*). We have used these estimates to calculate the cosmic ray flux received here on earth following the explosion of nearby supernovae. This in turn has permitted us to ask several interesting questions, the most pertinent being whether the magnitude and frequency of the doses are plausible and of biologic interest.

Supernovae can be divided into two types (I and II) according to their optical characteristics, the general release of energy, and distribution in space. Supernovae of the first type are basically old stars of comparatively small mass ($\simeq 1$ solar mass), which liberate 10^{48} to 10^{49} ergs upon explosion. Since they are less energetic and occur less frequently than type II supernovae, they are not considered in this report. Supernovae of the second type are massive young stars whose evolution is proceeding rapidly. As a result of detailed hydrodynamical calculations, Colgate and White (*2*) found that 2×10^{51} ergs are released in the form of cosmic rays (E_{cr}) in the explosion of a large type II supernova (10 solar masses). On the basis of general considerations of the distribution of energy in the various modes (cosmic rays, magnetic field, kinetic energy), Ginzburg and Syrovatskii (*1*) arrived at a value close to 10^{51} ergs. We will use $E_{\mathrm{cr}} = 10^{51}$ ergs and $E_{\mathrm{cr}} = 10^{50}$ ergs, values which should approximate fairly accurately the upper and lower limits on E_{cr}.

The cosmic ray flux at the top of the atmosphere, due to an explosion occurring a distance R light-years away, for $E_{\mathrm{cr}} = 10^{51}$ ergs is,

$$F = 9 \times 10^{13}/R^2 \text{ erg cm}^{-2} \qquad (1)$$

Since cosmic rays are charged particles, they will be affected by the interstellar magnetic field to some extent. However, for the nearby explosions that are of importance here this effect is negligible.

The normal cosmic ray flux at the top of the atmosphere is 9×10^4 erg cm^{-2} year^{-1}. It produces a dose of about 0.03 roentgen/yr (*8*), so the dose due to a supernova explosion R light-years away will be, for $E_{\mathrm{cr}} = 10^{51}$ ergs, approximately

$$D = 3 \times 10^7/R^2 \text{ roentgens} \qquad (2)$$

A very important factor is the time over which this dose occurs. Since diffusion effects can be neglected for relativistic particles traveling over comparatively short interstellar distances, such as are of interest here, the relevant time interval is that for the release of the energy in the form of cosmic rays. If the cosmic rays are produced by relativistic shock waves, as in the theory of Colgate and White (*2*), the time scale is of the order of 10^3 or 10^4 seconds, or less. In solar flares, relativistic protons are produced by plasma effects in a time of the order of 10^3 seconds. General considerations of the acceleration of particles by plasma turbulence (*9*) lead to the conclusion that the time scale is not too different from this during or soon after the explosion of a supernova. Therefore, it is safe to say that the dose D is received over a period of, at most, a few days.

From Eq. 2 it follows that R must be less than a few hundred light-years, if an appreciable dose is to result. Of the known supernova remnants, only CTS-1, at a distance of about 400 light-years, is anywhere near this close (*10*). However, it appears to be the remnant of type I outburst and would have a negligible effect. Of course, we have direct information only for events that have occurred in the past 100,000 years. For earlier times we must make estimates on the basis of the probability for the occurrency of a supernova within a distance of R_0 in t years. Type II supernovae are concentrated toward the galactic plane. Both theoretical and observational evidence indicate that their galactic distribution should be similar to that of the neutral hydrogen (*6*). According to Van Woerden (*11*) about 1 percent of the neutral hydrogen in the galaxy is in a disk with a radius of 3000 light-years and a height of 600 light-years centered on the sun. Hence, for R_0 less than 600 light-years the number of type II supernovae within R_0 in t years is

$$N(R\,R_0,\, t) = 2 \times 10^{-12} ftR_0^3 \qquad (3)$$

where f is the frequency of type II supernovae in the galaxy per year. It has been estimated from counts of supernova remnants in our galaxy (*6, 7*) that f is 0.02/yr, corresponding to one type II supernova in the galaxy every 50 years. Using Eqs. 2 and 3 one can easily compute the time needed for one dose greater than or equal to D_0.

Figure 1 shows that, even for the