SELENOLOGY

Collapse Craters?

from our Geomagnetism Correspondent

LUNAR craters are, as every schoolboy knows, the result of meteoritic impact. But are all craters on the Moon impact craters? After all, the nature of the Apollo samples has been taken as evidence for the existence of lava flows on the Moon; and certain terrestrial lava flows contain craters of a different sort—volcanic collapse craters. Is it possible then that some lunar craters are caused by collapse rather than impact?

Terrestrial collapse craters are usually caused by deformation of partly cooled surfaces following withdrawal of fluid lava from beneath the crust during extrusion, or to drainage of surface material into subsurface cavities. If longitudinal structures such as fractures or lava tubes are present, the collapse craters produced are elongated and tend to form chains. If, on the other hand, there are no distorting structures the craters are circular and apparently distributed randomly. In other words, viewed from a distance they would probably be indistinguishable from impact craters. And so if there really are lava flows on the Moon it is reasonable to suppose that they, too, are liable to undergo collapse.

But short of close examination of the craters, how could such a hypothesis be tested? Greeley and Gault (*Science*, **171**, 477; 1971) have done it simply by comparing size-frequency distributions of lunar craters with those of known terrestrial collapse craters obtained under similar conditions. Thus, because the lunar counts were made from photographs of areas in and near Copernicus taken during Lunar Orbiter missions, terrestrial collapse craters in basalt at Modoc (California), Wapi Field (Idaho) and Laguna (New Mexico) were photographed at similar scales and under similar light conditions. The three terrestrial size-frequency distributions which resulted were similar and possessed two obvious characteristics—the maximum crater density is caused by craters in the range 8–12 m in diameter, and the slope of the cumulative crater density curve for craters of diameter greater than 10 m is about -3.

The first thing to be said about the lunar size-frequency distributions is that most of them are quite different from those on Earth. Distributions from the continuous ejecta blanket, the flat dark fissured portion of the floor, the smooth inner wall and the smooth terraces on the rim flanks of Copernicus are similar to each other, but the cumulative crater density curve for each has a slope of about -2. Distributions from the interior terraces ("flat, dark, smooth often fissured terraces which appear to fill low regions between slump blocks of the inner crater wall") and a floor fissure flow ("a small, smooth, relatively uncratered unit associated with fissures on the floor") are quite different, however. They are, in fact, very similar to the terrestrial collapse crater distributions; and have, in particular, cumulative curve slopes of about -3 and a maximum number of craters in the range 11–16 m diameter.

The conclusion to be drawn from all this, according to Greeley and Gault, is that many of the craters on the interior terraces and the floor fissure flow are collapse craters—a hypothesis put forward by Kuiper *et al.* some five years ago (*Calif. Inst. Tech. Jet Propul. Lab. Tech. Rep.*, 32–800; 1966). This could, of course, affect some indirect determinations of the age of the lunar surface. If lunar craters are caused by meteoritic impact, older surfaces will presumably have more craters than younger ones—a fact which can be used to assign relative ages to different parts of the lunar surface. But if a surface contains collapse craters in addition to impact craters, it will seem to be relatively too old.

Piecing Together the Life Stories of Meteorites

Two articles in Monday's *Nature Physical Science* may be signposts to the way in which a few of the holes in what is known about the immediate past history of meteorites will be filled in. The article by J. F. Lovering and his colleagues describes one of the few meteorites which has come near to doing anybody an injury—on the face of it meteorites have a surprisingly unimpeachable record considering that they are lobbed into the atmosphere at speeds of tens of kilometres per second. But on September 28, 1969, a meteorite fragment tore through the corrugated roof of a hay shed near Murchison, in Victoria, Australia, fortunately without striking anybody. The weight of meteorite fragments collected from the vicinity of Murchison after September 28, 1969, that have found their way into museums or the University of Melbourne adds up to 82.7 kg, but "a considerable quantity" is thought to have found its way into private hands, underlining the necessity for measures like that which has been laid before the British House of Lords to make all meteorites which fall in Great Britain crown property (see *Nature*, **229**, 446; 1971).

As well as giving a preliminary account of the Murchison meteorite, which seems to be a type II carbonaceous chondrite, the article by Lovering *et al.* raises the hope that an examination of the fragments will give details of how the parent body was shattered by the pulse of frictional heat as it struck the atmosphere. Apart from the intrinsic interest, the problem is significant because for determinations of meteorite age it is important to use fragments that have not been too much affected by heat. Most of the Murchison fragments have complete fusion crusts indicating that break-up took place while the meteorite was still moving fast enough to cause ablation. Some fragments have crusts of two thicknesses, the thicker presumably formed at an earlier stage in the fragmentation process.

In the second article knowledge of the effect of the heat pulse is carried a stage further by an examination of the Ucera chondrite which fell in Venezuela on January 16, 1970. The intensity of the thermoluminescence from samples of meteorite depends on the heating that the samples received in the atmosphere, samples taken from near the fusion crust showing weaker thermoluminescence than deeper material. J. E. Vaz reports a systematic examination of the thermoluminescence along two axes through the Ucera meteorite, from which it is inferred that the temperature at 4 mm inside the final surface exceeded 120° C but did not reach 240° C, and that deeper than 1.5 cm the temperature cannot have been more than 120° C. This seems to confirm laboratory studies of the transformation in the metals and silicates of meteorites which also indicate a depth of penetration of the heat pulse a centimetre or so.

As well as showing that the thermoluminescence output has not been affected by the heat pulse other than in the outer 1.5 cm of the Ucera meteorite, the thermoluminescence measurements along one axis show a slight asymmetry about the centre. For parent bodies that were originally less than 2 m across, which would include the Ucera meteoroid, thermoluminescence is induced chiefly by cosmic radiation. Thus it rather looks as if the asymmetry in the thermoluminescence distribution means that the meteorite was shielded non-uniformly while it was exposed to cosmic rays in space. Non-uniformity of the heating in the atmosphere cannot be the answer because the meteorite is well rounded, and because of the similarity of the thermoluminescence output from samples adjacent to the fusion crust on different sides. A shielding effect is also indicated by the comparatively low ^{14}C activity measured for the Ucera meteorite.

Oddly enough, for an old science that was under way in the last century, the study of meteorites is having a revival just now. Part of the story is a renewed interest in the determination of meteorite ages, but meteorites should also provide some kind of record of the past history of the cosmic ray flux.