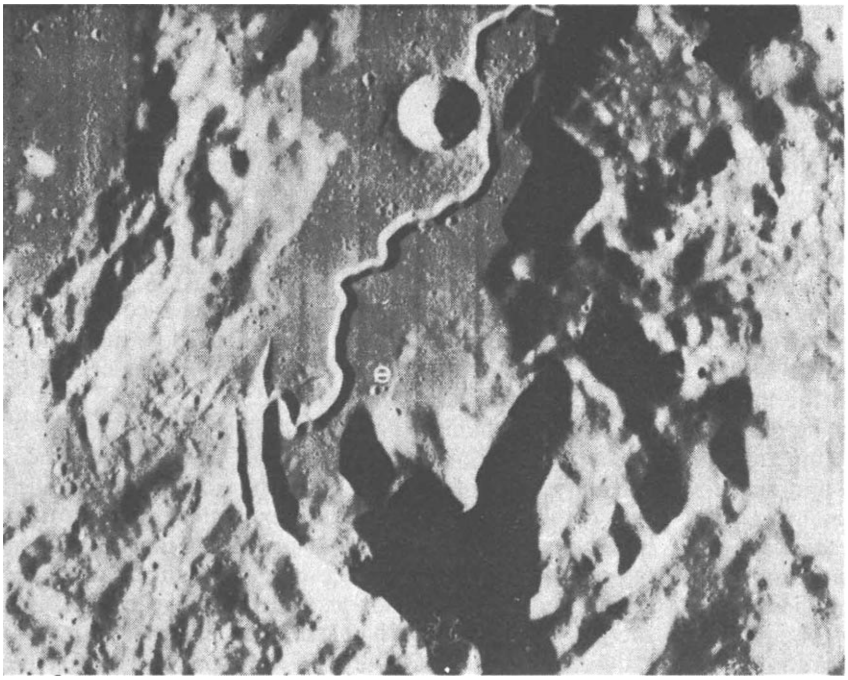
SELENOLOGY

Origin of Hadley Rille

from our Geomagnetism Correspondent



Orbiter photograph of part of the Hadley Rille showing the cleft where the rille originates. The crater, Hadley C, is about 5.5 km across.

SEVERAL different origins have been proposed at one time or another for lunar rilles—the long, narrow, sometimes meandering, but not always continuous, structures that are occasionally reminiscent of river beds. It is by no means clear, of course, that all lunar rilles must have the same origin, and in this sense all, or at least more than one, of the proposed origins may well apply in one situation or another. Thus some rilles may be produced by ash erosion, water erosion, surface collapse arising from intrusive stoping, or fluidization of the lunar regolith by outgassing through fractures, and some may be lava channels, collapsed lava tubes or a combination of the two. There seems to be a consensus among the various investigators that fluid flow is the basic cause in most cases, but agreement breaks down when it comes to deciding what the fluid is.

The Hadley Rille, which lies in a valley of the Apennine Mountains east of Mare Imbrium, is of particular interest because it is planned that Apollo 15 shall land close by. If the mission is successful the Apollo 15 astronauts will presumably bring back some evidence for the origin of the rille, but in the meantime Greeley (*Science*, **172**, 722 ; 1971) has courageously set out the available evidence for the origin and nature of this rille in particular, and concludes that it is, in fact, a lava channel.

On average the Hadley Rille is about 1.2 kilometres wide, 370 metres deep, and about 135 kilometres long. More important than these physical statistics, however, are the characteristics which the rille shares with some others. Thus the Hadley Rille belongs to a class of rilles which appear to originate in craters or depressions of irregular shape, generally trend downslope, possess discontinuous channels and non-joining branches, are quite uniform in width apart from a tendency to taper near the end, are limited to mare surfaces, appear to be controlled by highland topography, and form topographic highs along the rille axes. Most of these characteristics happen to be typical effects of the flow of lava in channels, and all are consistent with it. By contrast, some of the features are not consistent with rille formation by some of the other proposed processes.

As is so often the case, Greeley's strongest evidence comes from the terrestrial analogue. It is well known, for example, that particularly fluid terrestrial lavas can flow not only in open channels but, where the crust has solidified, in tubes. A crust is especially likely to form where channel flow is slow. So, depending upon such factors as gradient and the viscosity of the lava, a lava channel is likely to have both roofed and unroofed sections. Viewed from the air such a formation appears discontinuous—just like the Hadley Rille—although, of course, the constituent lava is continuous in reality. Experiments on lunar basalts have already shown that the lunar lava flows must have been very fluid, permitting the formation of tubes. Moreover, the experiments show that the lavas were probably of low thermal conductivity, so that long channel-tube systems would have been formed. The existence of lava channels in the mare provinces of the Moon is thus not entirely unexpected.

The terrestrial analogy may be taken further. On Earth, lava tubes and channels usually originate in vent craters or depressions related to tectonic features such as fissures, faults and fracture systems around calderas. The Hadley Rille originates on the boundary between mare and highland areas in a "cleft-shaped structure", which appears to be of internal rather than external origin. By contrast the theory proposed by Lingenfelter *et al.* (*Science*, **161**, 266 ; 1968), in which rilles are the product of erosion by water released from subsurface reservoirs by meteorite impact, is less consistent with an irregular structure. There are also other arguments against water erosion. The quantity of water required to produce such a large rille would surely have produced an alluvial fan or outwash plain at the terminus—but no such effect is visible. Moreover, the rille narrows as it reaches its end rather than widens as a river does, and there seem to be no tributaries into the rille anywhere along its length. Finally, water would not, in contrast to lava, be expected to produce the "discontinuity" effect.

The other important piece of evidence adduced by Greeley to support a lava flow origin for the Hadley Rille is topographic. The rille lies on the crest of a topographic high, and it is highly unlikely that erosion, whether by water or ash, would produce a channel along a ridge. It is much more feasible to suppose that the ridge and channel were formed at the same time as part of the same tectonic process. Fluidization of the lunar regolith by outgassing through fractures could also produce channels, of course, but fractures are comparatively independent of topography. The Hadley Rille, on the other hand, is limited to the mare between highland provinces. Basaltic flows are mainly controlled by the topography obtaining prior to the flow.

Perhaps the results from Apollo 15 this July will go some way towards either confirming or refuting Greeley's analysis. Greeley himself, however, is far more optimistic. "Geologic observations, returned samples from the rille region, and improved photographs and topographic maps from the Apollo 15 mission will undoubtedly enable refinement of this interpretation."