Reports

Interpretation of Ranger Photographs

Abstract. *A dark stripe seen on the Ranger 7 photographs of the moon interrupts the ray patterns and fits a local pattern of lineation. This dark stripe is evidence of recent volcanism, of intermediate or acid type.*

The A-camera photographs taken by Ranger 7 show some details of the moon's surface which suggest strongly that the moon has been subjected to recent intermediate or acid volcanism. Internal origin (and hence volcanism) is inferred from the parallelism of the features; recency is inferred from the fact that one of them is a black mark which seems to interrupt all other markings; and acidity is inferred from the steepness of some ridges which appear to have been extruded.

The alignment and parallelism of the features is well shown on photograph 176, of which Fig. 1 is a copy. There exists a predominant trend in this region from approximately NE by N to SW by S roughly parallel to the trends in the nearby Riphaeus Mountains. This trend is exhibited by some steep and conspicuous ridges which are seen in the central top and bottom of the picture. For these ridges I propose the name "arêtes." It is also shown by the lower, narrower, and less conspicuous wrinkle ridges, especially on later photographs of this series. Baldwin (*1*, Fig. 48) indicates that this region is the site of two of his major families of wrinkle ridges, one of which goes in the direction of the arêtes. Eggleton (*2*) plainly indicates the same two families in this area. The agreement of direction between the arêtes and the wrinkle ridges points to internal causes, since it has never been seriously contended that the wrinkle ridges are due to any exterior cause. It is fortunate that the wrinkle ridges are available as an indication of origin because similar arêtes, especially in the area of Julius Caesar, have been previously classified as debris thrown out of such craters as Mare Imbrium. Fortunately, in this case the arêtes point neither to Mare Imbrium nor to any other mare (such as Tranquillitatis or Serenitatis) which has been suspected of impact origin. A third aligned feature in this region is the row of three craters and the ravine seen in the lower left hand corner. These have been noticed on ground photographs and classified by Eggleton (*2*) as chain craters.

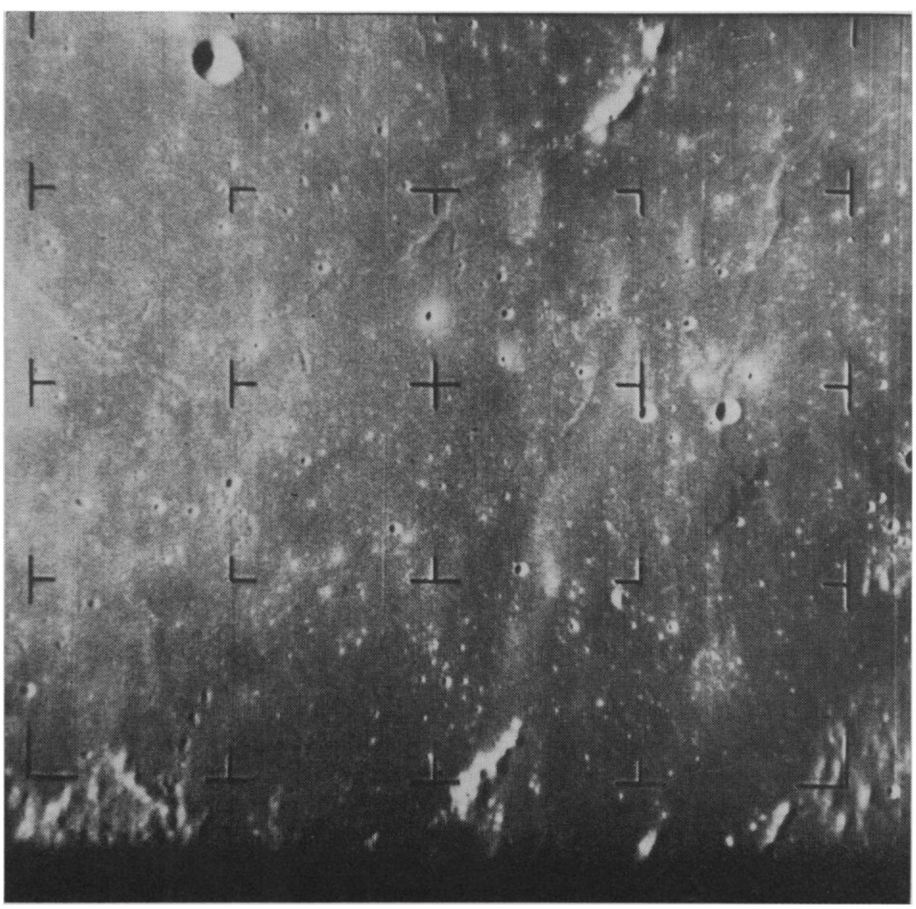

Fig. 1. A-camera photograph No. 176 from Ranger 7. Height above moon's surface, 298 km; width of photograph, 135 km.

The evidence of recency is based on the assumption that the brighter background in these pictures consists of ray material from Tycho with the possible addition of ray material from Copernicus. Several small groups of craters are visible on the Ranger photographs, from each of which a broad whitish marking extends in a northerly direction. On the small scale photographs of the moon the white mark is seen to be a part of a lunar ray. It has long been noted (*1*, p. 358) that the lunar rays, especially those from Copernicus and Tycho, are composed at least in part of markings which spread out from secondary craters on the side away from the primary craters. On this basis we can assign most of the ray material which is seen in the Ranger photographs to the crater Tycho, which is to the south. Rays from Copernicus, to the north, are also seen on some ground photographs to come near this region and may be involved in the general coloration. The net result is a background which is streaky and uneven in its blackness.

On this background, about the middle of the right hand side, will be seen a black marking which parallels the direction of the other lineaments, and which in particular appears to be an extension of the direction of an arête in the lower center of the picture. The significance of the line on which these two lie is further emphasized by a peak which is approximately halfway between the black mark and the prominent ridge, and nearly, though not quite, on the same line. In the later photographs up to No. 188, it is clear that the black marking is in fact a low ridge or group of low mounds. It is very significant that the black marking here discussed appears to cut across ray markings which emanate from a small group of craters to the south. The significance of this fact is that the rays from Tycho and Copernicus are believed to be among the most recent features of the moon. They are generally found superimposed on other craters. Thus the appearance of an internally produced ridge athwart the ray material is an indication of volcanism which is among the most recent of the lunar features and which surely occurred within the last few hundred million years.

The volcanism is probably of the intermediate or acidic kindred. That is to say, the lava is probably high in silica content because it forms steep-sided arêtes. The above-mentioned peak is also a steep feature, the sides of which are at an angle of the order of the height of the sun, which was about 21 degrees in this photograph. Such steep sides are inconsistent with a typical basaltic flow. They suggest strongly the production of viscous lavas. Such an explanation for the arêtes was proposed by Shaler (*3*). On this basis the peak lying between the arête and the black ridge is to be regarded as a tholoid, that is, a type of peak produced on the earth by the gradual extrusion of a viscous lava.

From this point of view it is logical to explain the rounding and blanketing which is seen on craters less than about 200 m across as the effect of an ash flow, such as has been postulated (*4*) to explain the recency of the Rb-Sr dates of tektites. Ash flows are normally associated with steep-sided extrusions of viscous lavas as tholoids or spines.

JOHN A. O'KEEFE
Theoretical Division, Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, Maryland

References and Notes

1. R. B. Baldwin, *The Measure of the Moon* (Univ. of Chicago Press, Chicago, 1963).
2. R. E. Eggleton, "Preliminary geologic map of the Riphaeus region of the moon," *Astrogeol. Studies Ann. Progr. Repts. 25 Aug. 1961–1 July 1963* (U.S. Geol. Survey, Washington, D.C., 1964).
3. N. S. Shaler, "A comparison of the features of the earth and the moon," *Smithsonian Contrib. Knowledge* **34**, Part 1 (1903).
4. J. A. O'Keefe and W. S. Cameron, *Icarus* **1**, 271 (1962); J. A. O'Keefe, in *Tektites*, J. A. O'Keefe, Ed. (Univ. of Chicago Press, Chicago, 1963), chap. 8, p. 186.
5. I thank Dr. E. G. Zies, Geophysical Laboratory, Carnegie Institution of Washington, for a helpful discussion of this problem.

25 September 1964

Carbonate Deposits and Paleoclimatic Implications in the Northeast Pacific Ocean

Abstract. *A narrow carbonate band consisting predominantly of* Globigerina-*rich sediments is present in the deep-sea deposits of the northeast Pacific Ocean extending almost parallel to the coasts of Oregon and Washington. Five radiocarbon dates in the cores from this area suggest that the greatest concentration of* Globigerina-*rich sediments occurred 27,000 to 12,000 years ago. This time interval corresponds roughly to the Vashon (late Wisconsin) glacial times in the Puget Lowland. The results suggest higher carbonate sedimentation in the northeast Pacific during glacial stages.*

It is generally believed that very fine clastic sediments occur in the deep-sea area off the coasts of Oregon and Washington (*1*). A more recent detailed study of cores collected in the area revealed a narrow carbonate band which consists predominantly of *Globigerina*-rich silts, clays, and other biogenic material (*2, 3*).

The submarine topography of the area is shown in Fig. 1. The area is characterized by a broad shelf, a steep irregular slope, the Cascadia Abyssal Plain (*4*) previously described as "Great Trough" (*5, 6*), a north-south trending hilly area, and the east-west Mendocino Escarpment including the hilly area south of the Cascadia Abyssal Plain in the west. A detailed description of the topography has already been presented by Menard (*5*), Gibson (*6*), and Hurley (*4*), and additional data is provided by Nayudu and Enbysk (*3*).

The *Globigerina*-rich sediments in cores 1, 2, 3, 4, 8, 9, 10, 16, and 17 form a narrow band, approximately 160 km wide and about 560 km long, almost parallel to the coasts of Oregon and Washington, 480 km offshore (Fig. 2). The concentration of Foraminifera, both planktonic and benthonic forms, results in a total carbonate content of approximately 30 to 70 percent. Because of variations in the concentration of Foraminifera, these sediments have been designated as *Globigerina*-rich rather than as ooze. In all these samples *Globigerina*-rich sediments extend from the surface to the bottom of the core, reaching a maximum depth of 144 cm in core 16. However, the upper 7 to 12 cm of all these cores shows about a 30 percent decrease in Foraminifera content and a concomitant increase in olive-brown silts and clays. There is also a great increase in number and variety of Radiolaria and diatoms in the northern part of the band. The upper section (of variable thickness) of *Globigerina*-rich silts and clays has been considered as a significant stratigraphic unit. In core 1 the upper 12 cm contain a large amount of olive-brown silts and clays, Radiolaria and diatoms; this core is low in Foraminifera. This section grades into *Globigerina*-rich sediment which in turn changes at about 115 cm into a sediment with very few Foraminifera and without Radiolaria or diatoms (Fig. 3). In core 16, located in the Tufts Abyssal Plain at a depth of 2244 meters, the upper section is 8 cm thick and grades downward into *Globigerina*-rich sediments. At 68 cm the *Globigerina*-rich sediments change with a break into a dark gray silty clay low in Foraminifera (about 30 percent) which extends to 90 cm. From 90 to 104 cm there is a gradual increase in the concentration of Foraminifera (30 to 45 percent) and at 104 cm the sediments are very rich in *Globigerina* (Fig. 4).

Two radiocarbon assays of core 1 have been done. The location of the core and the depth and age of the sample are shown in Fig. 3. The sample (15 to 25 cm) below the low carbonate upper layer is about 12,400 ± 375 years old. Radiocarbon dating of the sample (90 to 100 cm) above the section poor in *Globigerina* indicates that it originated 19,300 ± 950 years ago. Three additional radiocarbon assays were made from core 16 (Fig. 4), which indicate an age of 15,500 ± 600 years for the sample at 10 to 20 cm; 21,950 ± 700 years at 50 to 60 cm; and 26,950 ± 1,000 years at 130 to 140 cm (bottom of the core).

Crandell, Mullineaux, and Waldron (*7*) have shown that the youngest glaciation in the Puget Sound Lowland, the