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To accompany Preliminary Geologic Map of the Geminus Quadrangle of the Moon

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Geologic Setting

The Geminus quadrangle is in the northeast quadrant of the earthside hemisphere of the Moon, about 250 km north-northwest of Mare Crisium, 300 to 480 km north of Mare Tranquillitatis, and only 160 km east of Mare Serenitatis. Highlands predominate in the southeastern part of the map area, whereas lowlands make up the western and northern thirds. The most conspicuous feature is the crater doublet Atlas and Hercules, two craters having dark interiors, long associated with transient phenomena (Middlehurst and Moore, 1967, p. 450).

The area is close to the circular troughs and highland belts that alternately ring some of the large lunar basins (Hartmann and Kuiper, 1962), yet stratigraphic units cannot readily be shown to be related to the formation of these basins, or are unrelated to them. However, the part of Lacus Somniorum that extends into the southwestern part of the quadrangle succeeds outward a ring of terra materials that discontinuously encircles Mare Serenitatis along its east margin. Thus, the Somniorum trough and some basin ejecta, perhaps present under the mare material that fills Lacus Somniorum, may be structurally and genetically related to the Serenitatis basin. The Somniorum trough does not appear to be the southeast extension of the Frigoris trough, one of the structural rings around the Imbrium basin, although the two troughs are located approximately the same distance from Mare Imbrium. Therefore, a structural and genetic relation of the Somniorum trough to the Imbrium basin is less likely than to the Serenitatis basin.

The structural evidence relating large physiographic features in the Geminus quadrangle to the formation of the Crisium and Humboldtianum basins is even more fragmentary than for features related to the Serenitatis and Imbrium basins. In the southeastern part of the quadrangle, the V-shaped trough that forms the eastern part of the pseudo-craters Geminus E and EA appears to be an offshoot of the third outer trough that rings Mare Crisium on the northwest side. It resembles the grabens of the Imbrian sculpture which are radial to the Imbrium basin, and it probably was formed by faulting at the time the Crisium basin was formed. Similarly in the northeastern part of the map area, northeast-trending ridges in the terra (pIu) are radial to Mare Humboldtianum, and may be the surface expressions of fault blocks related to the formation by impact of the Humboldtianum basin.

Stratigraphy

The stratigraphic units mapped in the quadrangle are subdivisions of highland or terra (hilly, and smooth), plateau, lowland (mare and plains), and crater materials. Ages are based partly on cross-cutting relationships and albedo differences as discussed in earlier work for units elsewhere on the Moon (Shoemaker, 1962; Shoemaker and Hackman, 1962; McCauley, 1967; Wilhelms, 1970). The relative ages of craters are determined from the apparent gradual degradation of crater morphology with time; the model suggested by Pohn and Offield (1970) for dating craters larger than 8 km in diameter on Lunar Orbiter photographs has been adhered to.

Pre-Imbrian materials.--The oldest rocks in the quadrangle are highland, plateau, and crater materials of pre-Imbrian age. The highland materials (pIth, pIts, pIr and pIu) form bright terrain whose relief is rugged and high (pIth), intermediate and smooth (pIts), and hummocky (pIr). In the southern part of the map area, mountainous blocks of hilly terra (pIth) occur interspersed with smoother terra (pIts). Plateau materials (pIp) occur in the western part of the map; they are brighter and more densely cratered than Imbrian plains materials (Ip), and they are slightly hummocky and faintly lineated whereas Imbrian plains materials are not. Materials of extremely degraded, barely recognizable craters excavated in terra materials, and the materials of craters with subdued cratered rims and walls, embayed and partly filled by plains material (Ip), are considered pre-Imbrian in age. Some of these craters are elliptical, which suggests deformation by compression or a volcanic origin. The pre-Imbrian age of hilly and smooth terra is arrived at from the pre-Imbrian craters superposed on or included in these two units. Additionally, hilly terra commonly is embayed by, and therefore is older than plains and mare materials of Imbrian age.

The materials of hilly terra (pIth) are not very densely cratered by small craters, presumably because craters formed on steep slopes are destroyed by creep and slumping faster than on more level units. Smooth terra (pIts) is more densely cratered. Commonly, it is surrounded by hilly terra, and locally, appears to be blanketed with colluvium derived from hilly terra nearby.

In the northwest part of the map area, hummocks appear to be superposed on two types of terrain: rounded terra (pIr) and plateau materials (pIp). The hummocks become fewer and smaller eastward, and grade into smooth, discontinuous materials that blanket units pIp and pIr near the crater Williams. A few kilometers south and southwest of the Imbrian crater Hercules C, they are similar in form and albedo to the hummocks on the hummocky facies of the Fra Mauro Formation, and well within the radial occurrence of that facies, 1,000 km (Wilhelms, 1970) beyond the Caucasus Mountains and the Alps, which form the outer rim of the Imbrium basin west and northwest of the Geminus quadrangle. It is likely, therefore, that a thin blanket of basin ejecta mantles pre-Imbrian terra and plateau materials in the northwest part of the map area. These ejecta are not mapped on this preliminary map of the quadrangle, because the pre-existing topography of the terra under them can be distinguished. Rounded terra probably is smooth terra (pIts) blanketed with basin ejecta. Materials of hilly terra, however, do not appear to be mantled by basin ejecta, either because the blanket of ejecta is so old that is has been eroded away, or it is too thin and consists of particles too fine to be detected.

The source and the age of the basin ejecta are in doubt. An early Imbrian age cannot be ruled out, if the hummocks and other blanketing materials can be shown to have been ejected from the Imbrium basin. A pre-Imbrian age would be more logical, if the shorter distance to the rim of the old Serenitatis basin could be taken as a criterion of origin for the elusive and much older ejecta from the Serenitatis basin.

Imbrian System

Materials of Imbrian age exposed in the quadrangle consist of light plains materials (Ip), dark plains materials (Im_1 and Im_2), and crater materials.

Plains-forming materials.--Materials with smooth, relatively flat surfaces partly fill depressions between blocks of hilly terra or within the rims of some craters. These plains-forming materials are divided into stratigraphic units on the basis of differences in albedo and crater density. The older unit is the lighter and more densely cratered; it consists of plains materials (Ip), which probably are correlative with the Cayley Formation exposed north and south of Ariadaeus rille (Morris and Wilhelms, 1967). Like the Cayley Formation, the light plains materials lack ridges, and, if rilles are present, they are ill-defined. The unit occurs on benches marginal to Lacus Somniorum and in depressions between blocks of terra, and it forms the cratered floors of many pre-Imbrian craters.

The younger and darker units of Imbrian plains-forming materials consist of mare materials, located primarily in Lacus Somniorum and in the depressions that extend south of the craters Hercules and Atlas and that border the highlands in the northeastern part of the map area. In albedo, crater density, and mode of occurrence, the mare materials resembles those of the Procellarum Group as originally defined by Hackman (1966, p. 4) in Oceanus Procellarum near the crater Kepler and at least some of the unrayed mare materials in Mare Imbrium, east of the crater Copernicus. This Imbrian mare material is divided into two subunits (Im_1 and Im_2) on the basis of decreasing albedo and crater density. The darker, least cratered subunit (Im_2) occurs in only a few patches within Lacus Somniorum. The albedo contact between the two subunits is gradational and relief is not sufficient to determine the relative age of the two subunits from superposition. Mare subunit Im_2 probably is the younger, on the basis of the lower crater density and the general observation elsewhere on the Moon that plains-forming materials become lighter with increasing age; possibly the increase in albedo with age is related to the number of slopes and fragments of all sizes exposed through cratering. On the basis of similarities in albedo (Pohn and Wildey, 1970), mare subunits Im_1 and Im_2 in the Geminus quadrangle may be synchronous with mare subunits Ipm_1 and Ipm_2 in Mare Serenitatis (Carr, 1966). Unlike the peripheral occurrence of darker mare material in Mare Tranquillitatis (Wilhelms, 1968) and Mare Serenitatis (Carr, 1966), the darker mare material (Im_2) in the Geminus quadrangle occurs in the center of the mare (Lacus Somniorum), not along the edge.

Crater materials.--Materials of Imbrian age also include the floor, central peak, wall and rim materials of impact craters dated according to the criteria outlined by Pohn and Offield (1970). The reflectivity of 70-cm radar (Thompson and Dyce, 1966, p. 4843; and unpublished maps) is enhanced greatly by materials of Copernican, Eratosthenian and Imbrian craters and by materials in the highlands. Polarized backscattering of radar is reportedly enhanced about twofold by materials in the Imbrian craters Atlas and Hercules; depolarized enhancement is even greater (Thompson, unpublished maps). A surface roughness caused by blocks about 1-meter in diameter is adequate to explain the enhancements of radar reflectivity (Thompson and Dyce, 1966, p. 4849-4852, table 4).

Eratosthenian and Copernican Systems

Dark-plains materials.--Mare materials of low to intermediate albedo (Em) underlie parts of the floors of the late Imbrian crater Hercules and the Eratosthenian crater Geminus. Mare material of similar albedo and apparently uncratered by ejecta from Hercules and Atlas extends over small areas south of Hercules and is mapped as being younger than Atlas and Hercules rim materials. Some mare material in Berzelius E is not blanketed by ejecta from Geminus and is also considered as Eratosthenian in age.

Crater materials.--Materials of impact craters fresher than those of Imbrian age are assigned to the Eratosthenian and Copernican Systems according to topographic sharpness and albedo. The materials of some unusually fresh rayless craters are dated as Copernican rather than Eratosthenian, on the belief that the absence of rays radiating from some craters, besides being time dependent, may also depend on the composition of the crater ejecta.

Large infrared anomalies have been observed at eclipse (Shorthill and Saari, 1969, p. 11, fig. 5) in some impact craters of Eratosthenian and Copernican age. The largest of these in the Geminus quadrangle are in Cepheus A, Atlas A, one small crater southwest of Hercules, and Hooke D. Cepheus A was the site of the 27th most conspicuous infrared anomaly on the eclipsed Moon of December 19, 1964 (Shorthill and Saari, 1965, p. 211). Smaller infrared anomalies are present in the craters Maury, Maury A, Geminus and Schuckburg C.

Dark materials of fissure craters.--Small elongate, flaring craters are alined on narrow rilles or fractures in the floors of the Imbrian craters Atlas and Franklin. Dark material not only has accumulated along part of the rille to form a crater, but it also extends as a thin mantle over the floors and the slump blocks along the walls of Atlas and Franklin. The obvious structural control of these small craters along rilles, and the extension of the dark crater material as a nearly continuous, but thin, blanket over morphologically different materials belonging to the host craters suggests that the dark material is volcanic ejecta, thinning rapidly outward from a central vent. The dark material has accumulated within Imbrian craters, and at least part of it could be Imbrian in age, if volcanic activity began soon after the formation of the host craters. It could be as young as Copernican, if reported transient phenomena in Atlas (Williams, 1898; Haas and others, 1949; Roques and others, 1950; Sidran, 1968) are related to volcanic activity there. Accordingly, the dark materials around the fissure craters are assigned an Imbrian to Copernican age.

Slope materials.--Slope material (Cs) brighter than the materials of an adjacent unit is assigned a Copernican age. The albedo of the slope materials is highest on the steepest and freshest slopes, which suggests that it is a function of the amount of fresh material exposed, either bedrock or talus. Unit Cs therefore is a morphologic rather than a rock-stratigraphic unit (Wilhelms, 1970); it may include bedrock, talus, and regolith, separately or together.

Geologic History

After extrusion or agglomeration of the terra material, the oldest events recorded on the lunar surface in the Geminus quadrangle are the events, presumably impacts, that formed the pre-Imbrian craters, many of which are now deformed. Still in pre-Imbrian time came the impact that formed the Serenitatis basin, and at the beginning of the Imbrian Period, the one that formed the Imbrium basin. Blocks ejected from either of these basins or both occur in the terra in the northwestern part of the Geminus quadrangle but not on the steepest slopes. The trough occupied by Lacus Somniorum perhaps is structurally and genetically related to the Serenitatis of Imbrium basins. The northward-trending V-shaped trough in the eastern half of Geminus E may be related to the formation of the Crisium basin. The event that generated the Humboldtianum basin may have occurred in late pre-Imbrian time, as sculpturing has affected relatively smooth and low parts of the terra (pIu) in the northeastern part of the map.

Depressions, craters, and troughs were filled with plains material and mare material during a relatively short period extending from early to late Imbrian time, while cratering was still a very active process leading to the formation of craters as large as Atlas, Hercules, and Franklin.

In late Imbrian or early Eratosthenian time, a network of tension cracks, probably due to cooling of a thin crust of mare material, gave rise to rilled floors within the craters Atlas and Franklin. Subsequent volcanic activity, evidenced by the fissure cones and the dark mantling material around them, may have continued to the present. The fissure cones probably are the sites of the transient phenomena reported in the crater Atlas at least twice during the last 75 years.

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