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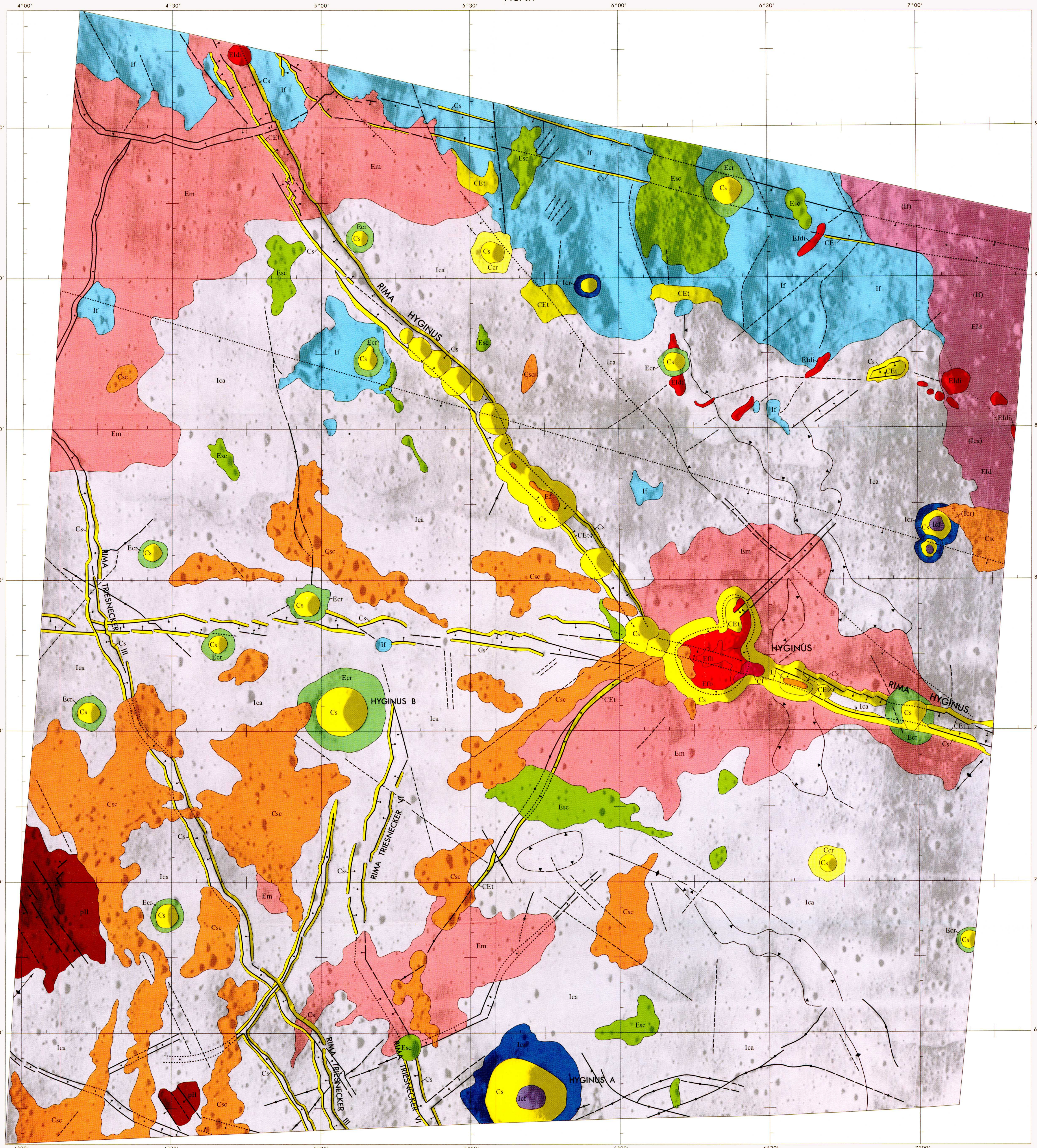

Interior—Geological Survey, Reston, Va.—1976—G75292

Lunar photomap base Orbiter V, Site 23.1. 1st edition, 1969, the U.S. Army Topographic Command
Base compiled from Lunar Orbiter V photographs. The horizontal control was established by photogrammetric triangulation using orbit constraints and is based on Lunar Orbiter V ephemeris data dated 15 Oct. 1968. Relative horizontal accuracy is ±591 metres expressed at 90 percent probability

SCALE 1:250 000
TRANSVERSE MERCATOR PROJECTION

5 0 5 10 STATUTE MILES
5 0 5 10 KILOMETRES

Mapped 1972. Principal sources of geologic information: Lunar Orbiter high-resolution photographs IV H97, 102, V H95, 96, 97; Lunar Orbiter medium-resolution photographs III M73, V M94, 95, 96, 97; Apollo 10 photographs AS-10-31-4648, 4649, 4650, 4651, 4652; AS-10-32-4809, 4810, 4811, 4812, 4813, 4814; high-illumination photograph 5818, 61-inch reflector, U.S. Naval Observatory; low-illumination photographs 1527, 1843, 1900, 2668, 3362, 3904, 61-inch reflector, Catalina Observatory, University of Arizona (Kuiper and others, 1967)
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GEOLOGIC MAP OF THE RIMA HYGINUS REGION OF THE MOON

By
Richard J. Pike

1976

CORRELATION OF MAP UNITS

COPERNICAN
ERATOSTHENIAN
IMBRIAN
PRE-IMBRIAN

DESCRIPTION OF MAP UNITS

Cs BRIGHT SLOPE MATERIAL — *Characteristics:* Occurs on steepest slopes, typically on inner crater walls and sides of grabens. Very bright. Very low crater density; superposed craters subdued and distorted. Numerous large blocks and boulder tracks in crater Hyginus and neighboring chain craters. Rugged bedrock ledges in Rima Hyginus. Horizontal stratification not evident. In smaller grabens includes exposures of unit CEt too narrow to map separately. *Interpretation:* Actively mass-wasting slopes developed on any rock unit. Fresh, steep rock outcrops or talus material, and often both in narrow exposures

Ccr CRATER RIM MATERIAL — *Characteristics:* Materials with concave surface surrounding craters. Texture grades from rough at sharp crater rim crest to topographically subdued at bright halo or rays. Much brighter than surrounding terrain. Low density of superposed craters. *Interpretation:* Ejecta from fresh primary impact craters

Csc SATELLITIC CRATER MATERIAL — *Characteristics:* Shallow, somewhat asymmetric, small craters with low raised rims. Typically associated with bright ray material. Usually clustered, in places single. Birdsfoot patterns or elongate chains locally evident. Some thick deposits bury parts of shallow grabens. Discontinuous, thin (unmapped) deposits and accompanying ray material cover much of western map quadrant. *Interpretation:* Secondary craters excavated by impact of ejecta from primary impact crater Triesnecker south of map area

Cfd CRATER FLOOR MATERIAL, DARK — *Characteristics:* Smooth, dark material on floor and eastern wall of crater Hyginus; west-sloping surface, convex-upward in western half of exposure. Few superposed craters; numerous blocks of lighter material from higher slopes in unit Cs. Overlies unit Efb; contact with unit Efb obscured by craters. *Interpretation:* Possibly volcanic material, perhaps lava; possibly a landslide scar (eastern half of exposure) and accompanying deposit (western half of exposure). Youngest floor unit within crater Hyginus

CEt TALUS — *Characteristics:* Material forming elongate, continuous slopes of constant width at foot of grabens walls below exposures of unit Cs. Breaks in slope at contacts with cliffs above and graben floor below. Coalesced from opposing walls of narrower grabens to form V-shaped troughs. Also broader, and more irregular slopes at terra-plains contacts and within some craters. Typically smooth-appearing with low crater density. Forms gentler slopes than unit Cs. *Interpretation:* Talus aprons, accumulated debris usually mass-wasted from steeper slopes above

Ecr CRATER RIM MATERIAL — *Characteristics:* Material with concave-upward surface beyond moderately subdued crater rim crest. About as bright as surrounding terrain. Break in outer slope imperceptible in smaller craters. Moderate density of superposed craters. Conspicuous hummocky texture in largest exposure mapped (Hyginus B). *Interpretation:* Ejecta from primary impact crater

Esc SATELLITIC CRATER MATERIAL — *Characteristics:* Similar to unit Csc, but no accompanying bright ray material or birds-foot patterns. Craters somewhat more subdued topographically. *Interpretation:* Secondary craters excavated by ejecta from primary impact crater Agrippa to southeast or possibly Manilius to northeast

Efh CRATER FLOOR MATERIAL, HUMMOCKY — *Characteristics:* Material with hummocky, but grossly horizontal, surface. Individual hummocks average about 100 m across. Darker and slightly less heavily cratered than unit Efb; lighter and much more heavily cratered than unit Cf. Much of unit lies within irregular depression in unit Efb that is roughly aligned with east leg of Rima Hyginus. Margin of exposure locally lobate. Very sharp contacts embay unit Efb. Brighter, smoother, and less heavily cratered in eastern third of exposure. Some irregular low-rimmed depressions 75–250 m across contain light material. *Interpretation:* Probably volcanic lava. Intermediate-age floor unit in crater Hyginus. May partially occupy shallow structural depression in earlier floor unit (Efb). May comprise two distinct subunits of slightly differing age; eastern subunit the younger. Light material may represent stratification within unit

Efb CRATER FLOOR MATERIAL, BULBOUS — *Characteristics:* Material with undulating, but grossly horizontal surface characterized by bulbous protuberances. Separated from topographically lower unit Efh by low, irregular scarp. Surface undulations and protuberances average 500 m across. Density of superposed craters moderate, lower than that of unit Ica, but greater than that of crater floor units Cf and Efh. About as bright as unit Ica. Protuberances bear minute concentric markings. Overlapped by units Cs, including numerous blocks. *Interpretation:* Irregular, low-rimmed depressions 100–400 m across contain light material. *Interpretation:* Possibly volcanic material, perhaps lava. Oldest floor unit within crater Hyginus. Protuberances may be small laccoliths or lava domes that have been mass-wasted. Undulating surface may at least partially reflect degraded blocks of slumped Cayley Formation. Light material may represent stratification within unit

Ef CHAIN-CRATER FLOOR MATERIAL — *Characteristics:* Flat, smooth material in bottoms of four largest chain craters along Rima Hyginus. Density of superposed craters somewhat lower than that of units Ica and Efb. Similar in brightness to unit Ica. Overlapped by unit Cs, including numerous blocks. *Interpretation:* Debris eroded from walls of large collapse craters by mass-wasting, slumping, and meteorite bombardment. May veneer large collapse blocks of Cayley Formation

Em MARE MATERIAL — *Characteristics:* Flat, smooth, and dark plains-forming material. Low density of superposed craters. Embays upland terrain. Variable brightness. Sharp to indistinct contacts; brighter near contacts with unit Ica, where it apparently subdues but does not bury subjacent craters. Obscured by ray material and swarms of accompanying ray material of the primary impact crater Triesnecker. D_L about 220. *Interpretation:* Thin volcanic material, probably basalt lava flows, possibly pyroclastic material. Eruptive centers may lie outside map area, but also may include crater Hyginus

Eld DARK MANTLING MATERIAL — *Characteristics:* Very dark. Typically subdues, but does not obliterate, forms and textures of subjacent uplands and plains topography. Lateral changes in brightness and subjacent terrain textures. Sharp to indistinct contacts. *Interpretation:* Pyroclastic volcanic material. Thin mantle in map area; thickens to north and east. Eruptive centers may lie outside the map area

Eid MATERIAL OF IRREGULAR DEPRESSIONS — *Characteristics:* Irregular to elongate, usually rimless depressions along structural lineaments. May occur in chains. *Interpretation:* Materials of non-impact and probably noneruptive depressions, possibly formed by collapse of unconsolidated surface rocks into cavities opened along structural faults or fracture zones

Icr CRATER RIM MATERIAL — *Characteristics:* Material with smooth to irregular surface beyond subdued and irregular rim crest of crater with low planimetric symmetry. Not markedly concave. As bright as surrounding terrain. Highly cratered. Suggestion of coarse hummocky texture in largest exposure mapped (Hyginus A). *Interpretation:* Ejecta from primary impact crater

Icf CRATER FLOOR MATERIAL — *Characteristics:* Smooth, essentially level material centered in crater bottoms. Topography somewhat irregular in largest exposure mapped (Hyginus A). *Interpretation:* Debris eroded from walls of older primary impact craters by mass-wasting and meteorite bombardment. May include small slump blocks

Ica CAYLEY FORMATION — *Characteristics:* Flat and light plains-forming material. Heavily cratered; more superposed craters than on mare materials; crater density variable. Embays upland terrain. Contacts with mare gradational. Horizontal stratification not evident; even on walls of deepest chain crater. Extension cracks present along edge of northwest leg of Rima Hyginus. Maybe highest topographically in east central part of region, east of northwest-trending ridges. Slightly lower crater density where exposed as floors of large grabens. D_L about 450. *Interpretation:* Probably impact ejecta from Orientale (possibly Imbrium) basin; in some localities possibly volcanic material similar to mare materials, but older. A uniform deposit at least 850 m thick in center of map area. Apparent brightness differences due to extensive superposed ray material and possibly to thin dark mantling material. Numerous secondary impact craters produce variable crater density. In wider grabens, veneered with materials mass-wasted from walls

If FRA MAURO FORMATION, SMOOTH MEMBER — *Characteristics:* Gently rolling, hummocky material of moderate relief. Topographically higher than other terrain in map area. Embayed by light and dark plains units; contacts obscured by talus and mantling material. Conspicuous lineaments radial to Imbrium basin to northwest. Superposed impact craters well preserved on level terrain, but muted and distorted on slopes. Unusually dark in northeast corner of map. Forms isolated hills in plains units. D_L about 1,200. *Interpretation:* Outer facies of debris blanket ejected from Imbrium basin. Coalesced ejecta clots subsequently faulted and mass-wasted. In places, mantled by thin, dark material (unit Eld)

pIl LINEATED MATERIAL — *Characteristics:* Material forming strongly lineated ridges and troughs. Ridges range from steep to gentle; smoother slopes predominate. Lineaments radial to Imbrium basin. Level troughs much more highly cratered than sloping ridges. *Interpretation:* Pre-Imbrian material block-faulted by Imbrium impact or gouged by impact debris. Probably reworked pre-Imbrium basin ejecta, perhaps veneered with other materials

(If)
Contact — Dotted where buried. Buried units indicated in parentheses

Fault — Solid line at base of scarp (bar and ball on downthrown side); double lines enclosing ball, graben; ball on line, narrow graben. Dashed where inferred and exposed; dotted where inferred and buried

Lineament — Narrow, shallow, and linear groove or discontinuous chain of small depressions on plains material; broad and irregular cleft in Fra Mauro Formation. *Interpretation:* Single fault or joint; on plains material, also buried, narrow graben

Low ridge — Line marks crest. Arrow indicates tapered nose. *Interpretation:* Low anticline reflecting compaction of planar impact ejecta over elongate protuberance in subjacent topography of the Fra Mauro Formation; in some localities possibly an igneous intrusion or narrow lava flow ridge

Low scarp — Line at foot of scarp. Dashed where very low. *Interpretation:* Fault scarp or fault-line scarp, possibly buried by compacted Cayley Formation; in some localities possibly a flow front

GEOLOGIC SETTING

The Rima Hyginus region lies within the Mare Vaporum quadrangle (LAC 59), 7° from the center of the lunar earthside hemisphere, near several large impact basins. The Rima Hyginus region occupies a broad structural trough concentric with the Imbrium basin, which has greatly controlled the geology of the area. Plains-forming materials cover most of the region, except for a belt of hilly terrain with about 600 m of relief, to the north, and some isolated hills to the west. Numerous linear grabens and a chain of endogenic craters are the prominent structures; the region includes only three craters larger than 5 km in diameter.

STRATIGRAPHY

Pre-Imbrian materials

The oldest rocks in the Rima Hyginus region formed at an unknown time before the Imbrium basin impact. The proximity of the pre-Imbrian Tranquillitatis, Serenitatis, and Vaporum basins suggests that most of these rocks originated as impact ejecta. The present lineated character of the unit was imprinted during formation of the Imbrium basin either by intricate fracturing or by gouging by ejected debris (Baldwin, 1963). Conspicuous scarps in the lineated material are radial to Imbrium. The unit lies immediately beneath the Fra Mauro Formation, a relation not observed in the two mapped exposures, but evident in the Riphaeus Mountains region to the southwest (Eggleton, 1965).

Fra Mauro Formation

Ejecta from the Imbrium basin occurs most conspicuously in the map area as the smooth member of the Fra Mauro Formation (Eggleton, 1965). Plains materials probably overlie the Fra Mauro Formation in all but the northern edge of the map area, where the unit has been faulted, evidently along Imbrium radials. Some isolated remnants of the Fra Mauro protruding through the later plains may be fault blocks. Exposures of the Fra Mauro Formation have been considerably rounded and subdued. Its uncharacteristic darkness in this area may reflect a wider distribution of thin dark-mantling materials than mapped.

Plains-forming materials

The Cayley Formation dominates the surficial stratigraphy of the Rima Hyginus region. These level, light, and highly cratered plains materials were deposited on the lineated material and on the Fra Mauro Formation after formation of the Imbrium basin. Absence of Fra Mauro in all but the northern part of the region suggests that the Cayley Formation thickens significantly to the south, possibly owing to faulting of pre-Cayley rocks along the buried westward extension of Rima Ariadaeus. The origin of the Cayley Formation is somewhat uncertain; it may be ejecta from the Orientale basin (Chao and others, 1973), or from the Imbrium basin (Eggleton and Schaber, 1973), or perhaps volcanic materials (Wilhelms, 1968). Relative ages of lunar geologic units are inferred from D_L, the diameter of a crater eroded to a 1° slope by the impact flux that has accumulated on various surfaces (Soderblom and Lebofsky, 1972). Because the Fra Mauro Formation (D_L about 1,200) is significantly older than the Cayley Formation (D_L about 450), the Cayley may not be Imbrium ejecta, although it may overlie planar Imbrium ejecta. Superposed dark mare material, bright rays, and large numbers of bright-walled satellitic impact craters have extensively modified the original, probably intermediate and uniform, brightness of the Cayley Formation.

The darker plains unit, mare material, occurs as a thin southerly extension of a much larger, thicker deposit in Mare Vaporum, and as isolated exposures on the plains. The largest of the latter occurrences may have erupted from the crater Hyginus, but it also could have originated elsewhere and may have been ponded in a broad topographic low before the crater or the rille formed. Although Eratosthenian mare material appears on the floor of the northwest leg of Rima Hyginus, it is not evident whether all of it was emplaced before or after the principal subsidence of this part of the graben. The relative age of the mare material (D_L about 220) suggests that it was deposited well after the light plains, perhaps even after formation of the younger grabens.

Dark mantling materials

Thin, dark materials subdue, but do not necessarily bury, upland units in the map area. The mapped exposure marks the southern margin of the Sulpicius Gallus Formation (Carr, 1966; Wilhelms, 1968). Even thinner deposits of these materials, presumably pyroclastic, may have darkened the Fra Mauro Formation throughout the region.

Materials of impact craters

Craters in the region were formed by excavation (primary or secondary impact) and by collapse. The different origins are recognized on the basis of gross crater morphology, particularly the presence or absence of a raised rim (Gilbert, 1893). Primary impact craters, such as Hyginus A and Hyginus B, belong to a morphologic continuum of craters characterized initially by bright rays, radial symmetry, high rims, absence of a flat floor, interiors lower than the surrounding terrain, and concave-upward, hummocky-textured deposits beyond a sharp rim crest. Some fresh impact craters smaller than about 1 km have a low central mound probably related to thickness of the regolith (Oberbeck and Quaide, 1967). The diagnostic characteristics are subdued in progressively older impact craters by mass-wasting, ballistic sedimentation, and erosion by subsequent small impacts. Hyginus A and two other Imbrian-age impact craters have acquired shallow flat floors and irregular rim crest outlines and profiles. Younger impact craters in the area have been less severely modified. Small impact craters formed on sloping upland surfaces have been degraded more rapidly than craters formed on the level plains.

The Rima Hyginus region has been heavily cratered by secondary impacts. Secondary impact craters and swarms of secondary impact craters from the primary impact crater Triesnecker, much of the southwestern map quadrant and probably account for over 80 percent of the secondary craters in the entire area. Older-appearing secondary craters, probably of Agrippa and Manilius, also are present.

Materials of endogenic craters

Subsidence craters, which are characterized primarily by the absence of a raised rim, are the outstanding features of the region. They include the crater Hyginus and at least 13 chain craters along the northwest leg of Rima Hyginus, the most conspicuous graben rille. Hyginus comprises a main crater about 9 km across and at least one smaller subsidiary crater on its north side and is situated at the intersection of two major and one minor rille systems. The main crater is about 700 m deep (thin and ensuing measurements from shadow lengths on Lunar Orbiter V photographs), has no raised rim, and is moderately circular in plan. The crater wall, probably composed of fragments, slopes at about 28° down to its juncture with the nearly horizontal floor, which is about 5.5 km across. The floor of the subsidiary crater lies about 200 m above that of the main crater and comprises a gently sloping debris apron and what may be a fault block of more cohesive floor material.

The Cayley Formation may have formed by eruption as well as by subsidence. The main and the subsidiary craters evidently collapsed into a cavity created initially by crustal extension and normal faulting along the three intersecting grabens and possibly by evacuation of erupted mare material surrounding Hyginus. The high circularity of the crater lip suggests further subsidence along ring faults. Sizes of the three intersecting rilles indicate that rille subsidence could have accounted for no more than 13 km³ of the 34 km³ contained in the present crater. Some small fraction of the remaining 21 km³, less a substantial (unknown) volume representing collapse along ring faults, may have been deposited around the crater as at least 500 km² of dark mare material. The average thickness of the mare material here cannot exceed 40 m (neglecting both vesiculation and compaction) and almost certainly is much less. If the mare material is lava, then Hyginus could be a very large pit crater, somewhat similar to the much smaller depressions aligned along the southwest rift zone on the terrestrial shield volcano Mauna Loa (MacDonald, 1972). The absence of a broad, raised rim flank precludes interpretation as a caldera (Wilhelms, 1968). Alternatively, a pyroclastic origin for the mare material suggests that Hyginus may be a large maar (Shoemaker, 1962) with ejecta deposited as a thin, dispersed blanket rather than as a raised rim (Schumm, 1970), but Hyginus would be a most atypical maar. Terrestrial maars form only in the presence of abundant surface water or shallow ground water (Waters and Fisher, 1970; Lorenz, 1973), a highly unlikely occurrence on the Moon. Moreover, the low depth-diameter ratio of Hyginus (1:13) and apparent high proportion of crater volume to ejecta volume indicate a subsidence basin rather than a true maar (Noll, 1967; Lorenz, 1973). Subsidence could have occurred within Hyginus during several endogenic phases, as it did in the remarkably similar-appearing and similar-sized terrestrial crater Trou au Natron (Vincent, 1963). Explosive eruption of material was far less important than collapse in the formation of Trou au Natron, where the thin fragmental deposits that surround the depression are not necessarily related to its origin (Roland, 1974). If the deposit of mare material surrounding Hyginus was emplaced before the crater formed, then Hyginus probably originated entirely by collapse.

The morphology of the floor within the main crater, which comprises three units (bulbous, hummocky, and dark crater floor material), is consistent with any of these interpretations of Hyginus. Differences in brightness and crater density among the three possibly endogenic floor units suggest a prolonged infilling history after formation of Hyginus. If these units are volcanic (Grudewicz, 1971), then the high relief of bulbous dome material and the dark material may imply relatively viscous lava. The west-northwest alinement of the hummocky and dark materials within the older bulbous material suggests that the most recent floor-forming activity was localized in Hyginus along the N. 75° W. structural trend, in possible analogy to structural-eruptive relations observed in the floor of the terrestrial caldera Mokuaweoweo (MacDonald, 1971). Bright materials occur in walls and in bottoms of simple and chained low-rimmed depressions on the two older floor units. This material may be an older regolith or possibly thin layers of bright volcanic deposits, perhaps mare-type basalts, interbedded within the darker floor deposits and exposed by subsequent cratering or sagging. Alternatively, the bright materials may be volcanic sublimates (Grudewicz, 1971). However, all three of the floor units within Hyginus conceivably could have been emplaced by noneruptive mechanisms that involved slumping, settling, and mantling of the collapsed Cayley Formation.

The rimless, coalescing craters along the northwest leg of Rima Hyginus are the most conspicuous nonimpact chain craters on the Moon. The 13 subcircular craters, which mostly share common septa and do not overlap, range in size from 1.5 km across and 200 m deep to 5.0 km across and 850 m deep. None possesses any trace of a raised rim, and none appears to be accompanied by dispersed ejecta deposits. Although most of the craters are conical in profile, four of the larger ones have small flat floors. Most of the craters intersect both the floor and the walls of the enclosing graben. Lack of medial crater rows wholly within smaller grabens implies that the lunar rilles did not form by subsidence of crater chains, as have somewhat similar-appearing linear grabens associated with chains of volcanic craters in the rift zone of northern Iceland (Thorarinsson, 1966). Instead, the craters formed after the rille, evidently by collapse and accompanied by little or no ejection of solid volcanic material. In fact, the chain craters along Rima Hyginus probably are totally noneruptive. They may have developed much like the small, alined collapse craters that are found in glacial outwash deposits in the dry valleys of Antarctica (Morris and others, 1972). The opening of tension faults in consolidated lunar rocks at depth may have allowed particulate material of the overlying Cayley Formation to sift down into them at discrete points along the rille, forming the collapse craters of Rima Hyginus. A variant of this mechanism was considered much earlier (Gilbert, 1893). All subsidence craters along this rille probably are Eratosthenian, the age of the dark material evidently erupted from the much larger (and originally, perhaps much deeper) crater Hyginus.

Slope materials

The freshest materials are very bright, irrespective of their topographic attitude. The consistent brightness of steep bedrock or debris slopes in older materials suggests the presence of freshly exposed surfaces, presumably created by continuous removal of weathered debris by mass-wasting. The bright slope material is a true rock unit where it is entirely talus but locally may indicate fresh exposures of other rock units still in place. Distinct aprons of talus, as well as numerous boulder tracks, occur below exposures of bright slope material in the larger rilles, at some plains-uplands contacts, and in some craters.

STRUCTURE

Linear rilles in the Rima Hyginus region parallel six different and unequally conspicuous directional trends, approximately northeast, northwest, north-northeast, north-northwest, east-northeast, and west-northwest. The rilles range in size and morphology from discontinuous, narrow, V-shaped clefts less than 200 m wide and 20 m deep to steep-sided, flat-bottomed grabens 5 km wide and up to 350 m deep, and traceable for 200 km beyond the map area. Some rilles branch, some exhibit en echelon and stepped patterns, and others pinch out on the plains material. Larger grabens probably are bounded by high-angle normal faults (McGill, 1971) and are floored by material similar to that bordering the faults. The largest rille is associated with endogenic craters. Superposition relations and moderate to light impact cratering of the rille floors suggest that movement along all grabens occurred between deposition of the Cayley Formation and late Eratosthenian time, but no systematic sequence among the various grabens or structural trends is evident (Offield, 1966). Recurrent and simultaneous faulting obscure crosscutting relations; some apparent morphologic contrasts reflect varying coherence of materials rather than relative age (Smith, 1966).

The major structural trend, which bears about N. 35° W., is radial to Imbrium and Nectaris and concentric with Serenitatis (Wilhelms, 1964; DeHon, 1970). It includes the northwest leg of Rima Hyginus, major structures in the Fra Mauro Formation and in the lineated material, low mare ridges, and some segments of the Triesnecker rille system. A much less conspicuous trend, concentric with Imbrium and radial to Serenitatis at about N. 45° E., includes the Sinus Medii trough, some elements of the Triesnecker rille system, and minor structures in the lineated material and smooth member of the Fra Mauro Formation. The third and fourth trends, which comprise elements of the Triesnecker rille system bearing about N. 15°–25° W. and N. 15° E., respectively, may be related to old Tranquillitatis concentric features and Vaporum radial features. The fifth trend, about N. 71°–78° W., includes the eastern and western legs of Rima Hyginus, a rille crossing the southwest corner of the map area, a wide, shallow graben in the Fra Mauro Formation, and the buried segment of a 400-km extension of Rima Ariadaeus (east of the map area). This trend could reflect Serenitatis concentric structures and Fecunditatis radial structures but more likely has a nonbasin origin. The Ariadaeus extension appears as a lineament in the Fra Mauro Formation about 60 km north of the crater Ukert, west of the map area, where it parallels Rima Bode II 10 km farther north before ending at Sinus Aestuum. The wide, shallow upland graben is the easterly part of a continuous, nearly 350-km system of grabens and lineaments. Just north of the map area, the northwest-trending segment of this graben cuts the northwest leg of Rima Hyginus and then resumes its west-northwest strike for another 200 km, west of 2° E. as an inconspicuous upland lineament. The sixth structural trend, about N. 64°–70° E., includes only a few rille segments west and east of the crater Hyginus A. It could be related in part to Vaporum concentric structures and Tranquillitatis radial structures.

Rilles in the Rima Hyginus region are consistent with at least two interpretations. All six structural directions follow local trends radial to and concentric with the impact foci of six mare basins (Baldwin, 1963): Imbrium, Serenitatis, Tranquillitatis, Fecunditatis, Nectaris, and Vaporum. Commensurate with size, age, and distance from Rima Hyginus, the six impacts probably created a local network of intersecting fracture zones that prefigured many structures in the region (Offield, 1966; DeHon, 1970). The relation between rilles and mare-basin trends is strong in the northeast and northwest directions, less certain in the north-northeast and north-northwest directions, and equivocal in the east-northeast and west-northwest directions.

Structures in the Rima Hyginus region also coincide with six trends of a purported moonwide tectonic network, or grid system (Fielder, 1963; Strom, 1964), possibly similar to trends evident in the oldest terrestrial basement rocks (Hills, 1963; Badgley, 1965). Approximate symmetry of the six lunar directions about the north-south axis is consistent with three sets of conjugate shear fractures generated by global north-south compression or torsion. In particular, the east-northeast- and west-northwest-trending lunar rilles (most are outside the map area) may belong to such a system because they are very long, relate but slightly to impact basins, and cluster about the lunar equator. The four other tectonic trends may approximately parallel stronger trends related to mare basins (Offield, 1966); stepped, en echelon graben walls could reflect near coincidence of at least two structural trends. Grabens bearing N. 75° W. and N. 40° W. may be larger than those developed in other directions because coincident basin-oriented fractures reinforced trends of the grid system.

Rilles of the Rima Hyginus region probably formed in direct response to crustal tension (Baldwin, 1963), regardless of the ultimate genesis of their patterns. The presence of grabens along all six trends indicates that tension was applied to the lunar crust simultaneously in more than one horizontal direction. The stepped and en echelon patterns of Rima Hyginus suggest that shear stress, resulting from tension radial to Mare Serenitatis, could have predominated. The absence of horizontal offsets, of significant crustal extension, and of widespread volcanism indicates that the tension was not persistent; the Rima Hyginus region probably was not a center of crustal spreading on the Moon. The rilles evidently formed during a single major episode of regional uplift or subsidence (Baldwin, 1963) that reactivated primordial grid system and earlier mare basin fractures, possibly in response to the filling of Mare Imbrium and accompanying widespread adjustments of mass disequilibria and related crustal stresses. Localized volcanism, which often accompanies grabens and associated areas of crustal tension on Earth (Thorarinsson, 1966; MacDonald, 1972), is not conspicuous in the Rima Hyginus region. With perhaps one exception (unit Efh), none of the rocks associated with the rilles are both undisputedly eruptive and necessarily the direct result of rille development. Moreover, the remarkable endogenic craters along Rima Hyginus probably qualify only as collapse depressions and not as true volcanoes (MacDonald, 1972). Vertical tectonics and consequent endogenic activity in the Rima Hyginus region may have been assisted by tidal flexing, which generates its maximum stress at the center of the lunar earthside hemisphere.

GEOLOGIC HISTORY

The pre-Imbrian Tranquillitatis, Serenitatis, and Vaporum impact basins all contributed material to the oldest rocks underlying the Rima Hyginus region. About 3.9×10^9 years ago (Papanastassiou and Wasserburg, 1971), the Imbrium basin formed 1,000 km to the northwest, pervasively fracturing preexisting rocks along radial and concentric trends and depositing impact ejecta, the Fra Mauro Formation. The later Orientale impact may have deposited the Cayley Formation. A period of widespread extrusive volcanism followed, during which the mare rocks were deposited; this activity may have persisted on a reduced scale throughout the Eratosthenian Period. Thin pyroclastic materials appear to have blanketed the uplands. After the Cayley Formation and perhaps some of the darker plains were deposited, linear rilles formed along six different structural trends. Opening of the largest and youngest graben, Rima Hyginus, was accompanied by formation of subsidence craters and perhaps deposition of some of the darker plains. Although all grabens probably had opened by the end of the Eratosthenian Period, floor-forming activity within the crater Hyginus may have persisted into the Copernican Period. Impact cratering, which has continued throughout the history of the region, extended into Copernican time with formation of rays and secondary impact craters of the crater Triesnecker. Ejecta from the Eratosthenian impact craters Manilius and Agrippa formed earlier secondary craters. Mass-wasting and impact cratering have subdued the steeper slopes and scarps, generated a regolith, and deposited extensive aprons of talus, particularly in the larger grabens. Scattered blocks and boulder tracks on the surface of the youngest floor unit in the crater Hyginus suggest that active slope wastage persists in recent lunar history.

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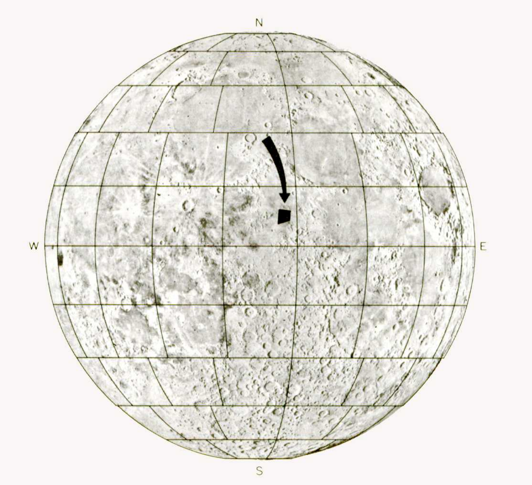

INDEX MAP OF THE EARTHSIDE HEMISPHERE OF THE MOON
Arrow indicates region of this report

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