DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND THE
USAF AERONAUTICAL CHART AND INFORMATION CENTER

NOTES ON BASE

The base chart was produced in consultation with Dr. Gerard P. Kuiper and the staff of the Lunar and Planetary Laboratory, University of Arizona. Photography and trajectory information was supplied by the Jet Propulsion Laboratory. Elevation data was compiled by the University of Manchester under Air Force Contract. The base chart is one of a series of five Ranger IX charts compiled from television records of the six Ranger IX cameras.

CONTROL

The lunar features on this chart are positioned to conform with the selenographic latitude and longitude coordinates based on selenocentric measurements made by ACIC and published in ACIC Technical Paper No. 15, "Coordinates of Lunar Features," March 1965. Supplementary positions are developed in the chart area as an extension of the primary control. The position of the impact point is provisional since it was located in respect to surrounding features.

NAMES

Feature names are adopted from the 1935 International Astronomical Union nomenclature system as amended by Commission 16 of the I.A.U., 1961 and 1964.

Supplementary features are associated with the named features through the addition of identifying letters. Craters are identified by capital letters. Eminences are identified by Greek letters.

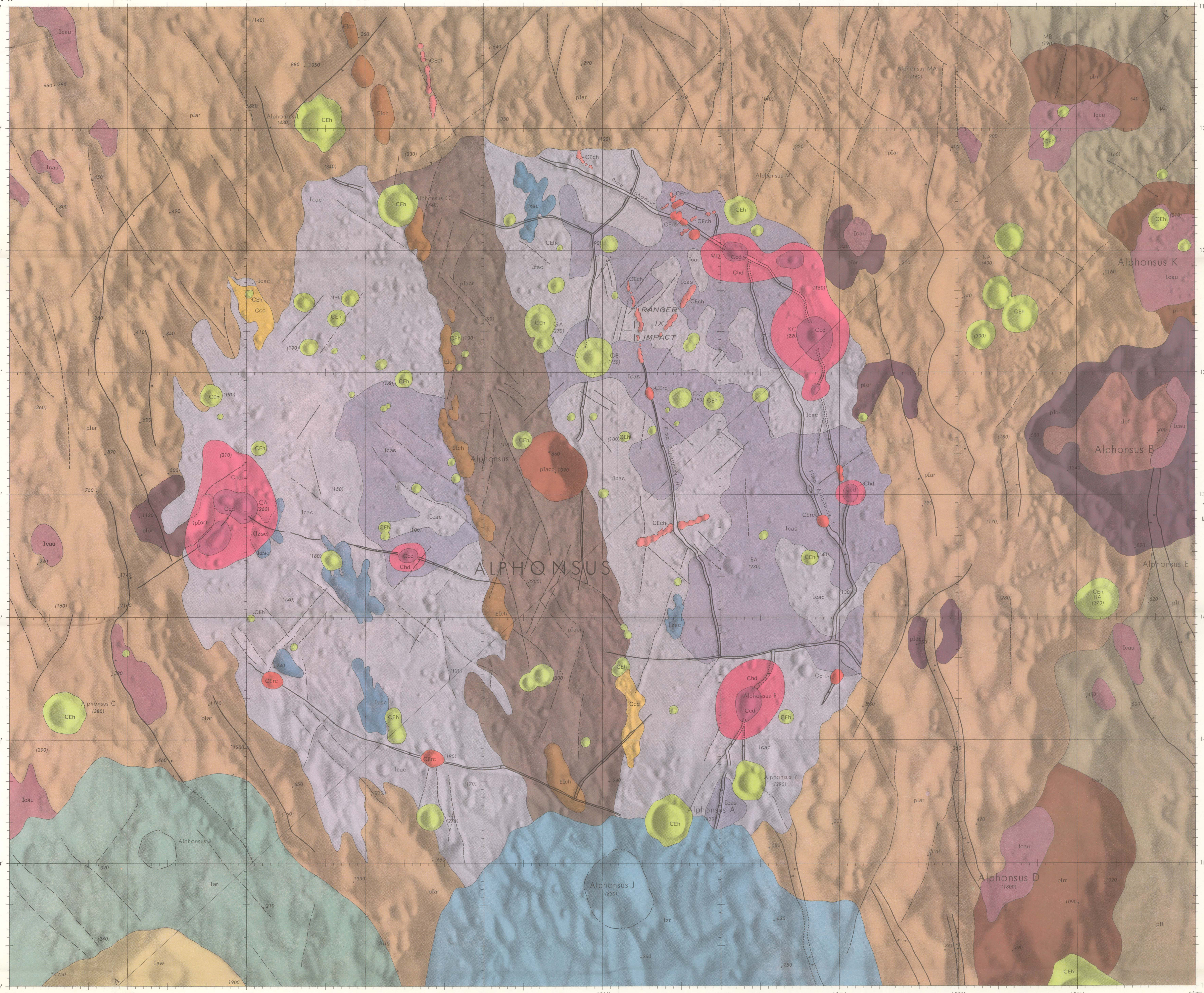
ELEVATIONS

All elevations are shown in meters. The relative heights of crater rims and other prominences above the surroundings and depths of craters were determined by the shadow measuring technique through correlation with data derived from Ranger IX and Earth-based photography. Vertical heights thus established have not been referenced to a vertical datum.

Depth of crater (rim to floor).......................(400)
Relative elevations (referenced to surrounding terrain)..300.

PORTRAYAL

The configuration of the relief features shown on this chart is interpreted from Ranger IX television records. The pictorial portrayal of relief forms is developed using an assumed light source from the west, with the angle of illumination maintained equal to the angle of slope of the features portrayed. Cast shadows are eliminated to enable complete interpretation of relief forms.



Lunar base chart RLC-14 by Aeronautical Chart and Information Center, U.S. Air Force, St. Louis, Missouri 63118

MERCATOR PROJECTION
SCALE 1:250,000

5 0 5 10 15 STATUTE MILES
5 0 5 10 15 KILOMETERS

Principal sources of geologic information: Ranger IX photographs provided by Jet Propulsion Laboratory (reproductions in NASA SP-112). Albedo information from full moon plates 5818 and 5819 taken at U.S. Naval Observatory, Flagstaff, Ariz.

EXPLANATION

Ccc

Crater cluster material

Characteristics
Materials associated with cluster of craters; individual craters mostly 100 to 300 meters in diameter
Interpretation
Clusters of secondary impact craters; parent craters unknown

Ccd | Chd

Dark-halo crater materials

Characteristics
Ccd, *dark crater materials. Has very low albedo and occurs in and around elliptical craters on rilles in the floor of Alphonsus. Partly fills the adjacent rilles. Craters have broad, low convex-upward rims and are elongate along the length of the rille. Less densely cratered than surrounding materials*
Chd, *Dark-halo material. Albedo very low. Forms the dark halos around unit* Ccd. *No discernible relief. Crater density same as for* Ccd
Interpretation
Volcanic pyroclastic material ejected from central crater. Mapped as Ccd *where thick and has observable relief, as* Chd *where thin and no observable relief. Age uncertain, but probably Copernican because both units mask adjacent terrain and have low crater densities*

CEh

High rimmed crater material

Characteristics
Materials associated with fresh-appearing craters. Craters have concave upward rims and are commonly bowl shaped with a slightly rounded rim crest. Blocks sparse either on rim or within crater. Includes both high rim and subdued rim crater materials as mapped by McCauley (1969)
Interpretation
Impact debris in and around young, partly degraded craters

CErc | CEch

Rille crater materials

Characteristics
CErc, *rille crater materials. Materials associated with isolated craters on rilles. Craters elongate along the length of the rille and have rounded convex upward rims. Resemble dark-halo craters except more subdued and have intermediate albedo*
CEch, *rille crater chain material. Materials associated with craters that overlap to form rille-like depressions. Craters are commonly rimless*
Interpretation
CErc, *materials of volcanic craters similar to the dark-halo craters but older; dark halos have been destroyed by mixing with other near surface materials*
CEch, *materials of either volcanic craters or collapse craters along linear structures. Age uncertain. Craters moderately subdued. Probably Eratosthenian but some may be Copernican*

EIch

Chain crater material

Characteristics
Material associated with a chain of craters along the west edge of the central ridge of Alphonsus. The craters are part of a chain of similar craters that extends from the southern end of the central ridge, north across the rim of Alphonsus and along the west edge of the floor of Ptolemaeus, a total length of approximately 170 km. Most of the craters are elongate rimless depressions, but some are circular and have low rims
Interpretation
Materials of a structurally controlled chain of craters trending radially to Mare Imbrium. The craters are interpreted as volcanic but some depressions may have formed by collapse. Age uncertain; designated as Imbrian or Eratosthenian because craters are very subdued

Iar | Iaw

Alpetragius crater materials

Characteristics
Iar, *rim material. Faint ridges on surface radial to Alpetragius. Concentric structures of adjacent Alphonsus rim not visible in area of unit* Iar. *Typical hummocky ejecta pattern absent in map area but present on west part of rim. Grades imperceptibly into surrounding units. Albedo intermediate*
Iaw, *wall and floor material. Forms wall of Alpetragius and low hills on floor. Albedo generally intermediate but high on steepest parts of wall*
Interpretation
Iar, *consists of ejecta reworked by repetitive impact*
Iaw, *includes talus on walls and colluvium and brecciated bedrock on the floor*

Izr | Izsc

Arzachel crater materials

Characteristics
Izr, *rim material. Surface topography characterized by low hills and by shallow depressions and faint ridge radial to Arzachel. Partly fills linear troughs of Imbrian sculpture and previously formed craters such as Alphonsus J. Masks the characteristic rim topography of the southern part of Alphonsus rim. Albedo intermediate*
Izsc, *satellitic crater material. Material associated with shallow, irregularly shaped craters commonly elongate radial to Arzachel. Crater clusters have a plume-like structure with barbs pointing away from Arzachel*
Interpretation
Izr, *consists of impact ejecta reworked by repetitive impact*
Izsc, *materials in and around craters formed by ejecta from Arzachel; craters now almost completely destroyed by erosion*

Icas | Icac | Icau

Cayley Formation

Characteristics
Forms generally level terrain in low-lying upland areas. Albedo intermediate
Icac, *cratered facies, equivalent to cratered basin fill of McCauley (1969). Forms the most densely cratered parts of the floor of Alphonsus. Frequency of craters, 0.3 to 3 km. in diameter, especially high. Most craters are shallow depressions having no rims or very low rounded rims. Blocks extremely sparse compared with typical mare material. Faint northwest- and northeast-trending ridges occur on the surface especially in the west half of the Alphonsus floor*
Icas, *smooth facies, equivalent to smooth basin fill of McCauley (1969). Similar to the cratered facies but less densely cratered*
Icau, *undifferentiated. Mapped locally where* Icac *and* Icas *cannot be distinguished*
Interpretation
Non-cohesive mixture of colluvium, impact ejecta, and volcanic debris. Ridges occur at surface where unit is thin and topography of underlying more cohesive material is apparent at the surface. Sparsely cratered Icas *younger than heavily cratered* Icac

pIor | pIof

Post-Alphonsus crater materials

Characteristics
pIor, *rim material. Forms the rim of craters in Alphonsus rim material. Craters cut by north-northwest-trending fractures. Albedo intermediate*
pIof, *floor material. Occurs only in the floor of Alphonsus B. Low hills and north-northwest-trending fractures*
Interpretation
Materials associated with impact craters that formed after Alphonsus but before the Imbrium basin

pIar | pIacp | pIacr

Alphonsus crater materials

Characteristics
pIar, *rim and wall material. Forms the rim of Alphonsus. Grades imperceptibly into the surrounding regional terra material. Steep inward-facing scarps on east and west walls. North and south parts of rim transected by north-northwest-trending troughs and fractures. Northeast- and northwest-trending low ridges and shallow depressions on most of rim. Sparsely cratered except for level areas. Albedo generally intermediate but high on steepest slopes*
pIacp, *central peak material. Forms the steep central peak of Alphonsus. Albedo high*
pIacr, *central ridge material. Forms the central ridge of Alphonsus. Low to moderate relief. Albedo intermediate. Shallow depressions and low ridges trending northeast and northwest give the unit a herringbone appearance. The west edge of the ridge is marked by a series of depressions. Less densely cratered than the cratered Cayley (unit* Icac*) but more densely cratered than Alphonsus rim material (unit* pIar*)*
Interpretation
pIar, *consists of impact ejecta and uplifted bedrock covered by a thick fragmental debris layer. Downslope movement of the fragmental layers has destroyed most of the craters in the rim*
pIacp, *shock metamorphosed bedrock, may have formed by rebound at the time of the Alphonsus impact*
pIacr, *shock metamorphosed bedrock and ejecta, an uplifted part of the original Alphonsus floor. Uplift caused by isostatic readjustment and possibly triggered by the formation of the Imbrium basin*

pIrr

Pre-Alphonsus crater rim material

Characteristics
Forms irregular rim of craters partly buried by Alphonsus rim material (unit pIar*). Cut by north-northwest-trending fractures (Imbrian sculpture) and by northeast- and northwest-trending fractures. Has very low relief and barely stands above the surrounding terrain*
Interpretation
Remnants of impact craters older than Alphonsus. Original texture of rim destroyed by fracturing, meteorite bombardment, and downslope movement of surficial materials. Thick surficial fragmental layer

pIt

Regional terra material

Characteristics
Materials having moderate relief and intermediate albedo. Topography dominated by ridges trending north-northwest radial to Mare Imbrium. Northwest and northeast-trending ridges also occur. Few craters less than 5 km in diameter present. Large craters are polygonal with walls parallel to the principal structures. Patterned ground over most of the surface
Interpretation
Very old cratered and fractured terrain of indeterminate origin covered by a thick surficial layer

COPERNICAN SYSTEM
COPERNICAN AND ERATOSTHENIAN SYSTEMS
IMBRIAN AND ERATOSTHENIAN SYSTEMS
IMBRIAN SYSTEM
PRE-IMBRIAN

Contact
Queried where doubtful

(Izsc)
Concealed contact
Buried unit indicated by symbol in parentheses

Fault
Dotted where buried. Bar and ball on downthrown side

Rille
Dotted where buried. Bar and ball or ball only on downthrown central part; where rille is very narrow shown as single line with ball

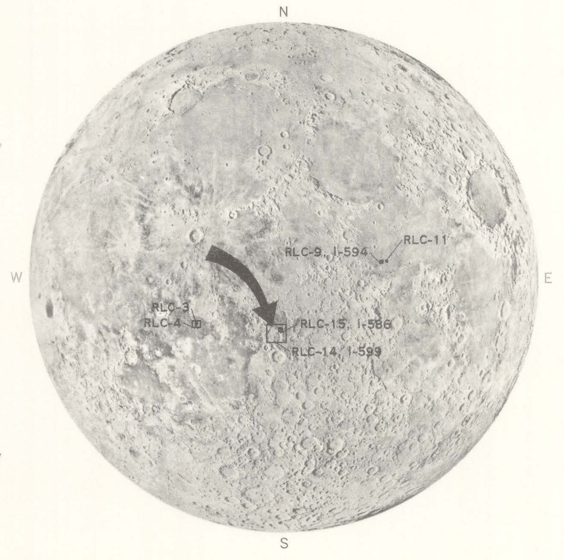
Linear depression
Interpretation: Probable fault or fracture

Linear ridge
Interpretation: Probable upthrown fault block or horst

Rim crest of buried crater

Brecciated bedrock
Shown on cross section only

Ranger IX impact point



INDEX MAP OF THE EARTHSIDE HEMISPHERE OF THE MOON SHOWING REGIONS MAPPED GEOLOGICALLY FROM RANGER PHOTOGRAPHS

Large lines indicate area of this report. First number refers to base chart (RLC-14). Second number refers to published geologic map (I-599)

INTRODUCTION

This 1:250,000-scale geologic map is one of a series prepared largely from photographs transmitted by Ranger IX (reproduced in a report by Jet Propulsion Lab., 1966). It depicts the geology of the crater Alphonsus (in which Ranger IX impacted) and environs. The primary objective of the mapping was to apply extant lunar mapping techniques used on relatively small scale telescopic photographs to the larger scale Ranger photographs, in preparation for extensive analysis of Lunar Orbiter photography in support of the Apollo program. An additional objective was to shed more light on the formation of Alphonsus and its associated features. The map outlines rock units that are inferred from surface features and characteristics, such as topography and albedo. Each rock unit is assigned an age and arranged in the explanation so that the youngest units are at the top and the oldest at the bottom. The age classification is based on the early work of Shoemaker and Hackman (1962), and subsequent revisions reported by McCauley (1967) and Wilhelms (1966). The geology of the region had been mapped at a scale of 1:1,000,000 on the basis of Earth-based photographs and observations (Howard and Masursky, 1968). A more detailed, 1:50,000-scale map of part of the Alphonsus floor was prepared by McCauley (1969), who used Ranger IX photographs as his source of geologic information.

OBSERVATIONS

The crater Alphonsus (diam 115 km) lies in the western part of the central highlands, close to the edge of Mare Nubium. Immediately to the north is the crater Ptolemaeus (diam 150 km), and immediately to the south is the crater Arzachel (diam 100 km). Alphonsus is typical of many highland craters in that it has a flat heavily cratered floor, a central peak, and a broad sparsely cratered rim. Less typical features are the network of intersecting rilles on the floor, the dark-halo craters, and the central ridge.

East of Alphonsus, the rims of several craters are partly covered by Alphonsus rim material (pIar). Alphonsus K is a typical example. These craters, the oldest in the area, are similar to Ptolemaeus (outside map area) but smaller. Their low, extensively fractured rims (pIrr) barely stand above the surrounding terrain. The next youngest crater is Alphonsus. Its rim is about 30 km wide. Steep inward-facing slopes abut abruptly against its floor, and the shallower sloping outer part of the rim grades imperceptibly into the surrounding terrain. The rim is lowest to the north and south, where north-northwest-trending fractures cut across it. The steep inward-facing scarps on the east and west walls are approximately parallel to the north-northwest trend of widespread lineaments that Gilbert (1893) called Imbrian sculpture. Patterned ground occurs over most of the rim, and the crater density is low, in contrast with that of the crater floor. The rim overlies part of the rim of Ptolemaeus to the north and is itself overlain by Arzachel rim material (Izr) to the south. The youngest pre-Imbrian craters (pIor, pIof) lie in the rim of Alphonsus and have been almost completely destroyed by faults. Alphonsus B is the best example.

The central ridge of Alphonsus resembles the rim in that it is less cratered than the floor and is intensely fractured. The principal structures trend northwest and northeast and give the ridge a herringbone appearance. Faint lineaments can be traced from the central ridge across the level floor of the crater. The west edge of the ridge is marked by a chain of craters (EIch) that coincides with one of the lineaments radial to Mare Imbrium.

The unit that forms the densely cratered level floor of Alphonsus and other smaller basins is designated the Cayley Formation (Morris and Wilhelms, 1967). Two facies are distinguished—one cratered (Icac), the other smooth (Icas)—except in small isolated patches where the unit is undifferentiated (Icau). The cratered unit is almost completely saturated with craters, especially those that range from 300 meters to 3 km in diameter, whereas the crater density of the smooth unit is comparable to that of typical mare material. Most of the craters are shallow with rounded subdued rims and, in contrast to many craters in mare areas (outside map area), blocks are almost completely absent. Several low positive relief features, principally northwest- and northeast-trending ridges, occur on the floor, especially in the west half.

Three main types of craters younger than the Imbrian sculpture are distinguished: (1) Arzachel secondary craters (Izsc), (2) relatively fresh-appearing high-rimmed craters (CEh), and (3) craters associated with rilles (CErc, Ccd) or forming chains (EIch). Elongate clusters of shallow subdued craters (Izsc) alined approximately radial to Arzachel probably formed by the impact of Arzachel ejecta. The high-rimmed craters (CEh) are the youngest primary impact craters that are large enough to map at this scale; older, more subdued small primary craters are not mapped. The rille and chain craters are of special interest in that they are not impact features. The dark-halo craters (Ccd) are the most conspicuous of the rille craters. Their low, rounded convex-upward rims are less cratered than the surrounding terrain, and the craters are elongate and encircled by a broad area of material with very low albedo. Their location on rilles strongly suggests that they are volcanic. Similar rille craters that lack the dark halos are interpreted as old dark-halo craters (CErc). Other probable volcanic craters (EIch, CEch) occur in chains alined along structural lineaments. The most prominent example is the chain (EIch) along the western edge of the central ridge.

INTERPRETATION

Alphonsus is interpreted as a pre-Imbrian impact crater that formed after Ptolemaeus but before Arzachel. It formed in an already densely cratered terrain (represented by pIt). The Ptolemaeus-like craters (pIrr) are representatives of the pre-Alphonsus crater population. After the Alphonsus impact, the next major event was the formation of the north-northwest-trending troughs and fractures of the Imbrian sculpture, triggered by the great Imbrium impact. Between the Alphonsus and Imbrium events, craters similar to Alphonsus B (pIor) formed on the rim of Alphonsus.

Isostatic readjustment began after Alphonsus formed, and continued over a long period. It probably caused uplift and fracturing of the crater floor (Masursky, 1964). The central ridge, which parallels Imbrian sculpture, may have formed at the same time as the Imbrium basin, or soon after, as a result of isostatic uplift and failure along Imbrian fractures. In addition to uplifting the central ridge, isostatic readjustment produced tension in the crater floor, which resulted in formation of the rilles.

While readjustment was taking place, Alphonsus was being filled both with ejecta from nearby craters and with volcanic materials. Since the fractures of the Imbrian sculpture terminate abruptly against the materials that form the floor of Alphonsus, the floor materials formed mostly after the formation of the Imbrium basin. The dark-halo craters provide the clearest evidence of volcanism within Alphonsus. The fact that they are located on rilles is clearcut evidence of structural control. Furthermore, because their rim materials fill adjacent depressions, they are not subsidence features. The similar rille craters (CErc) are probably older dark-halo craters whose halos have been destroyed by overturn of the near-surface materials. Other probable volcanic craters are those which form chains (EIch) parallel to structural lineaments on the floor and rim of Alphonsus. The volcanism was possibly triggered by the Alphonsus impact (Carr, 1964), which may have created a local thermal anomaly and caused extensive brecciation beneath the crater, enabling magma to rise to the surface.

During the period of filling, which may still be going on, cratering by impact continued. Alpetragius and Arzachel formed to the south, and ejecta from Arzachel covered the southern rim and part of the floor of Alphonsus. Continued cratering rounded the rim of Alphonsus, and a surficial layer of fragmental debris formed over the entire region. As fresh craters formed, old ones were filled in and old rims worn down so that every gradation from fresh craters with well-defined rims to barely discernible rimless depressions is present. Slumping of the fragmental layer on all steep slopes has formed patterned ground and destroyed many of the smaller craters. Mixing and movement of the near-surface layer has partly masked all geologic contacts, so that all units appear to grade into one another.

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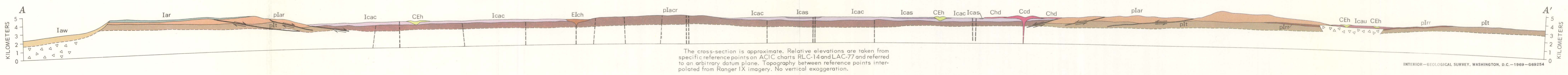

The cross-section is approximate. Relative elevations are taken from specific reference points on ACIC charts RLC-14 and LAC-77 and referred to an arbitrary datum plane. Topography between reference points interpolated from Ranger IX imagery. No vertical exaggeration.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1969

GEOLOGIC MAP OF THE ALPHONSUS REGION OF THE MOON

By
Michael H. Carr
1969