DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

GEOLOGIC ATLAS OF THE MOON
ALPHONSUS GA REGION
I-586 (RLC 15)

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. This 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.

A black dot is included, where necessary, to identify the exact feature named.

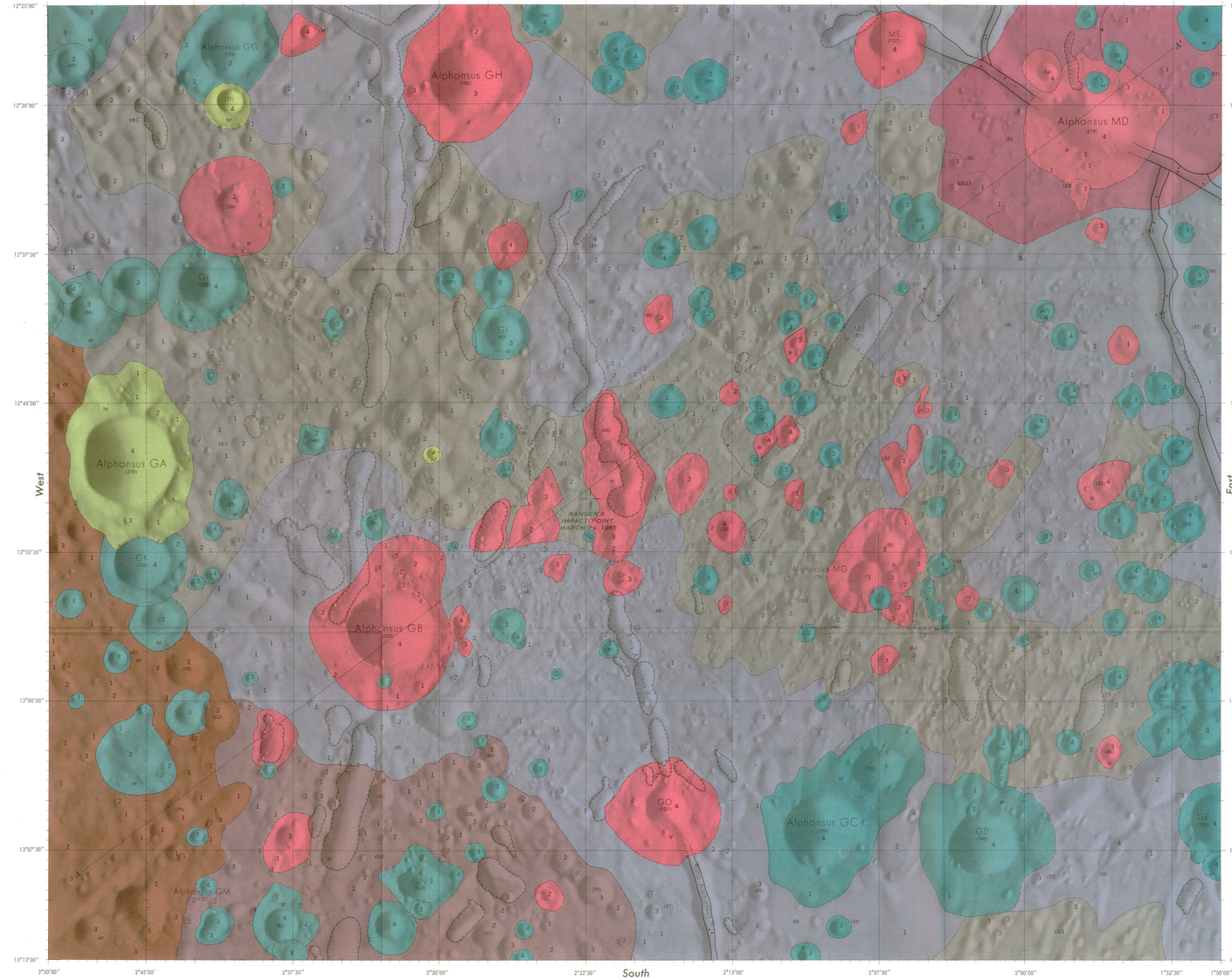
ELEVATIONS

All elevations are shown in meters. The relative heights of crater rims, and other prominences above the floor of Alphonsus and depths of craters were determined by the shadow measuring technique, utilizing Ranger IX 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

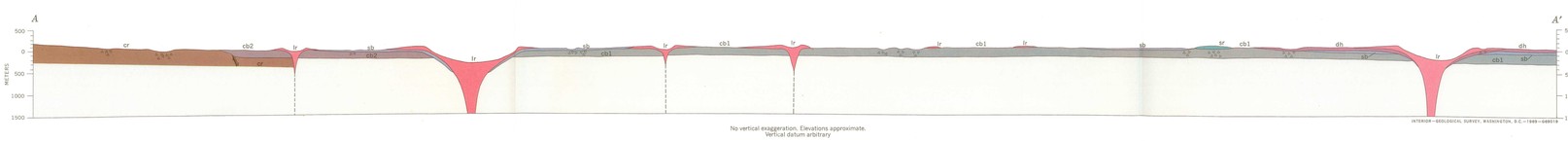
The configuration of the relief features shown on this chart is interpreted from Ranger IX television records. The pictorial portrayal of relief forms is developed using an assumed light source from the west, with the angle of illumination maintained equal to the angle of slope of the features portrayed.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



Lunar base chart RLC 15 by Aeronautical Chart and Information Center, U.S. Air Force, St. Louis, Missouri 63118

SCALE 1:50 000
MERCATOR PROJECTION
1 ½ 0 STATUTE MILES 1 2 3
1 .5 0 KILOMETERS 1 2 3

Principal sources of geologic information: Ranger IX photographs (Jet Propulsion Lab., 1965, 1966); Albedo data from Pohn and Wilday (1966) and from full Moon plates 5818 and 5819 taken at U.S. Naval Observatory, Flagstaff, Arizona. Work performed under contract WO-5171, Jet Propulsion Laboratory.



No vertical exaggeration. Elevations approximate.
Vertical datum arbitrary

GEOLOGIC MAP OF THE ALPHONSUS GA REGION OF THE MOON

By
John F. McCauley

1969

EXPLANATION

CRATER UNITS

hr

Materials of high-rimmed craters

Characterization
Occur in and around craters with steep interior slopes (A). Rim crest of associated crater is sharp and high; the profile from the limit of observable rim deposit to the rim crest is concave upward. Surface texture at this scale is smooth. Albedo intermediate to high. Only three occurrences mapped; Alphonsus GA is the largest
Interpretation
Impact crater ejecta, fallback, and talus. Consists of poorly sorted brecciated bedrock, shock-lithified regolith, shock-metamorphosed bedrock, and scattered small projectile fragments. The largest fragments are below the resolution of Ranger IX photography. Surface blocky and moderately rough at the 10-centimeter scale

lr

Materials of low-rimmed craters

Characterization
Rim of associated crater smooth; generally wider and lower than other crater units (hr and sr); profile is gently convex upward. Albedo intermediate to low. Alphonsus GH, GO, and MD, the best examples, are on structural troughs and rilles
Interpretation
Mostly ash-fall deposits surrounding volcanic vents. Irregular lobate occurrences such as those around the small crater 2 km north-northeast of Alphonsus MG may consist mostly of lava flows

sr

Materials of subdued-rimmed craters

Characterization
Occur in and around craters most of which have moderate to steep interior slopes (2 and 3). Rim crest of crater is rounded and relative relief is moderate; rim profile is either gently convex or concave upward. Surface texture is smooth. Albedo is indistinguishable from surroundings. Most common type of crater material within map area. Mapped only where clearly discernible in two or more successive pictures
Interpretation
Mostly impact crater ejecta similar to that described for unit hr. Mass wasting caused by seismic activity and meteorite bombardment has reduced original relief and rounded the original topography. Some occurrences may be of volcanic origin (such as material around Alphonsus GC) and may consist of fine to coarse tephra beneath a thin regolith produced by impact

INDEX MAP OF THE EARTHSIDE HEMISPHERE OF THE MOON
SHOWING REGIONS MAPPED GEOLOGICALLY FROM RANGER PHOTOGRAPHS
Large arrow indicates area of this report First number refers to base chart (RLC 15). Second number refers to published geologic map (I-586)

Contact
Dashed where approximately located; dotted where buried; queried where doubtful

Fault
Dotted where buried. Bar and ball on apparent downthrown side

Linear or irregular depression
Edges rounded; some surrounded by raised rims. Probably represent both degraded rilles and collapse depressions

Prominent scarp
Barb points downslope

Brecciated bedrock
Shown on cross section only

Crater types
Based on percentage of interior shadow at sun elevation of about 10 degrees:
4, >50 percent shadow
3, 25 to 50 percent shadow
2, <25 percent shadow
1, no shadow

BASIN FILL UNITS

dh

Dark halo material

Characteristics
Albedo low. Topography relatively smooth, crater density low. Surrounds rim material of Alphonsus MD and partly fills structural trough upon which crater is located
Interpretation
Volcanic ash derived from structurally controlled vent. Material is superposed on other floor units and is younger than basin fill unit. Unit has not been extensively reworked by impact at this scale and the original low albedo is preserved

sb

Smooth basin fill

Characteristics
Topography smooth to gently rolling. Less cratered than units cr, cb1, and cb2; more cratered than dh. Shallow rimless craters (1 and 2) predominate. Unit localized in topographic depressions except near rim of Alphonsus GH, where the albedo is slightly lower than elsewhere. In most places the contacts with other units are gradational but locally are marked by gentle scarps. Albedo intermediate
Interpretation
Mostly volcanic ash-fall and possibly ash-flow deposits from vents such as Alphonsus GB and GO. Older than dark halo material (dh) on basis of superposition and higher crater density. The original albedo of this unit was probably similar to that of dark halo material. Surface brightening is due to increased roughness at large scale caused by prolonged meteorite bombardment

cb1 **cb2**

Cratered basin fill

Characteristics
Topography moderately rough; numerous superposed craters and, while northeast- and northwest-trending ridges and troughs are present, Unit is generally higher than adjacent unit sb; contacts commonly marked by subtle rounded scarps. High density of craters (types 2 and 3 predominate). Unit cb1 *shows a pronounced northeast lineation trend; in addition to this trend,* cb2 *shows a northwest lineation*
Interpretation
Older volcanic material extensively reworked by impact. Originally may have consisted mostly of lava flows as suggested by the scarps that commonly mark contacts with other units

cr

Central ridge material

Characteristics
Topography rolling to gently hummocky; individual highs and lows have a general north-south orientation. A vague northeast- and northwest-trending lineament pattern, similar to that of the cratered basin fill units, is also present. Topographically higher than all basin fill units, but the contact is not marked by a sharp break in slope. Crater density is high but subdued types (2 and 1) predominate. Albedo intermediate
Interpretation
Structurally deformed crater floor material preferentially uplifted along north-south fractures by the Arzachel impact. Some Arzachel ejecta may be present

GEOLOGIC SUMMARY

INTRODUCTION

This map is one of a series prepared from photographs transmitted by Ranger IX (Jet Propulsion Lab., 1966, pls. A56-A58, B70-B82). It depicts the geology of some 724 sq km in the northeast part of the floor of Alphonsus (diameter about 115 km), a typical flat-floored old terra crater or basin with a subdued rim. Similar basins abound in the unconcentered terrae of the visible hemisphere and on the far side of the Moon. Alphonsus is of particular interest, however, because of a well-developed interior rille system and associated dark-halo craters.

Results were compiled first on a rectified photomosaic and later on a shaded-relief chart, both prepared by the U.S. Air Force Aeronautical Chart and Information Center. Limited narrow baseline stereoscopic coverage was available and employed qualitatively as an aid in classifying subtle relief features. Attempts to prepare a topographic map as a quantitative base using analytical photogrammetric techniques were not successful (Alderman and Wu, 1966).

The primary purpose of the effort was to apply extant telescopic geologic mapping techniques at larger scale in preparation for extensive analysis of Lunar Orbiter photography in support of the Apollo Program. An additional objective was to refine earlier preliminary studies of this area by G. P. Kuiper, H. C. Urey, M. H. Carr, and J. F. McCauley (in Hancock and others, 1966). Smaller scale geologic maps of the area have been prepared by Mazursky (1965), Carr (1966), McCauley (in Hancock and others, 1966), and Howard and Masursky (1968).

The central part of the map area (approximately the area covered by RLC 16) near the impact point was photographed at much higher resolution than the remainder. In addition, system limitations such as rapidly changing photo scale in successive pictures, vidicon shading within individual frames, and resolution falloff toward the edges of the map area complicate the problem of uniform classification of textural information. An impact-produced layer of fine surficial debris (Shoemaker, 1965) smooths and subdues stratigraphic and structural detail at this map scale, further hindering effective geological analysis. These problems necessitated a cutoff size of 200 meters for individual features within the map area for statistical and cartographic uniformity. In order to obtain maximum uniformity in the geological classification, a single set of uniformly developed continuous tone prints was used.

OBSERVATIONS

MAP UNITS

Five basin fill units can be recognized within this part of Alphonsus and are distinguished by differences in surface texture, relative relief, crater frequency, and, in one case, albedo. The units are:

1. The material of the central ridge of Alphonsus (cr). The surface of this unit exhibits considerable local relief but appears relatively smooth. A distinctive herringbone pattern resulting from the intersection of low northeast- and northwest-trending ridges is present. The extent of this unit with adjacent basin fill is gradational and locally obscured by later crater units. It is mapped at a gentle change of slope between flat-lying basin fill and the eastern flank of the central ridge, which rises gradually to the west.
2. The most widespread stratigraphic unit is heavily cratered material of intermediate albedo designated as cb1. This unit contains numerous superposed craters and is generally somewhat higher in elevation than adjacent units and separated in part from smooth basin fill (sb) by low, rounded scarps. It shows a pronounced northeast-trending pattern of coalescing craters and subdued elongate troughs and ridges.
3. Unit cb2 is similar texturally but less extensive areally. In addition, it has a pronounced northwest structural trend also consisting of troughs, ridges, and coalescing craters.
4. Smooth basin fill (sb) of intermediate albedo occurs around low-rimmed craters such as Alphonsus GB and GO, in the many linear depressions in the central and western parts of the map, and in the fault troughs in the northeast. This unit exhibits a low density of superposed craters and generally occupies topographic lows except around Alphonsus GB, where it overlies a more highly cratered surface (cb1 or cb2).
5. The smoothest unit (dh), of distinctively lower albedo than the other floor units, surrounds the crater Alphonsus MD at the northeast corner of the map. Like the smooth basin fill, it is relatively uncratered at the scale of this map. Southwest of Alphonsus MD it apparently overlies both smooth and cratered basin fill (sb and cb1) and partly fills the structural trough on which Alphonsus MD is located.

Three types of crater material are mapped:

1. The most common (sr) occurs in and around subdued craters with rounded rim crests and moderate interior slopes (3 and 4). Rim deposits surrounding these craters are narrow, smooth, and either gently concave or convex upward.
2. The second type (lr) includes a low apron of relatively smooth material that can be traced farther from the rim crest of the crater than the deposits of the other types of crater material. In profile, these rim units are topographically lower than either of the other types. (This effect is not measurable, however, because of the poor metric qualities of the Ranger IX pictures.) This unit occurs in and around craters located on or near rilles, or in and around closely spaced or overlapping craters whose trend is parallel to regional structure.
3. The least common types of crater material (hr), at the scale of this map, is associated with sharp-appearing craters with steep interior walls. The rims of these craters are high and concave upward in profile from the rim crest to the outer limit of the recognizable rim deposit. The largest example is Alphonsus GA at the west edge of the map. Craters of this type become more abundant at larger scale in the higher resolution pictures of the area surrounding the impact point (Trask, 1967) but on this map constitute only a miniscule fraction of the total number of craters present.

No distinction has been made between the materials that lie within craters and the materials on the exterior slopes. Impact cratering experiments (Moore, 1966) suggest that the rims and interiors both consist of fragmental debris. Numbers, however, have been used to indicate differences in crater geometry. At Ranger IX illumination (approximately 10°), 50 percent or more of the interior diameter of type-4 craters (in the east-west direction) is in shadow. In type-3 craters, 25 to 50 percent of the interior is in shadow. Some shadow is detectable in type-2 craters, but less than 25 percent of the interior diameter is covered; and the least distinct crater type-1 has no interior shadow—only a slight darkening on the wall sloping away from the sun. Shadow-length measurements indicate that the interior slopes of type-4 craters are close to the angle of repose, whereas type-3 and -2 craters have progressively lower slopes that are, however, greater than the sun angle. Interior slopes of type-1 craters are clearly less than 10°.

Linear depressions, some of which show interior shadows (slopes greater than 10°), are common throughout the map area. Their crests are rounded; some are surrounded by subdued (sr) or low (lr) rims. Many grade into sharp, steep-walled rilles at one end and at the other into a series of coalescing craters (for example, north and south of Alphonsus GO).

ALBEDO PROPERTIES

The albedo properties of the units mapped cannot be directly determined from Ranger IX pictures; Earth-based full-Moon data were utilized to estimate albedo variation (U.S. Naval Observatory, Flagstaff, Ariz., pls. 5818, 5819; and Pohn and Wilday, 1966). The albedo of the basin fill units is typical of the lunar maria and ranges from about 0.128 to 0.134. The central ridge and the surrounding basin units are similar in albedo, but the central peak (outside the map area) is very much brighter (up to 0.17). The albedo of low-rimmed crater materials ranges from intermediate at Alphonsus GO to low around Alphonsus MD, where it is the same as the surrounding dark halo material. The albedo of the rim surrounding Alphonsus GB is slightly lower than that of the surrounding basin fill. The albedo of the dark halo crater material around Alphonsus MD is about 0.115, according to Pohn and Wilday. This figure, however, is probably too high because of the small size of these features at telescopic resolution and the resulting sampling problem. An unusual characteristic of the dark halo craters in Alphonsus is that no bright material is observed on their interior walls under high illumination. For example, Alphonsus MD and KC (outside map area) show the same low albedo on their interior slopes as on their rims. Prominent dark halo craters elsewhere on the Moon, such as those near Copernicus and Theophilus, show bright interior slopes under high illumination. However, Alphonsus GB, a low-rimmed crater located on a rille, does show greater reflectivity on the interior slopes, although the rim material is of intermediate albedo.

CRATER STATISTICS

Craters of two and, probably, three genetic types—impact, volcanic, and collapse or drainage craters—are present within Alphonsus. They cannot be distinguished solely on the basis of morphology. In fact, only about 10 percent of all the craters present can be confidently identified according to origin. The remainder represent a mix of genetic types in unknown proportions. Nevertheless, crater-frequency statistics were obtained, if only for detailed comparison of cumulative crater frequencies with other parts of the Moon, particularly the mare areas photographed by Rangers VII and VIII and by Lunar Orbiter. The curve showing the total number of craters of all morphologic types (1-4; see accompanying graph) in the size range 0.2 to 2 km for all the major floor units has an average slope of about −2.7. The crater frequency, however, varies considerably for each stratigraphic unit. The central ridge (cr) actually exhibits the highest crater frequency except in the smallest size range measured. Most of the craters are of the subdued type (1 and 2), so that the unit initially appears less cratered than the others. The basin fill units (cb1 and cb2) have the next highest crater frequency. Within these units, sharper craters (e.g., type-4) tend to dominate the population, particularly within unit cb2. Smooth basin fill (sb) is less cratered than cr, cb1, and cb2, and the most common crater present on its surface are the subdued type (1 and 2). The least cratered unit is the dark halo material (dh), which shows many sharp craters in the large size ranges; however, these are located on rilles and surrounded by low rims and are considered secondary craters.

STRUCTURE

The most obvious structures in this part of the floor of Alphonsus are north- and northwest-trending rilles and linear depressions. Those in the northeast (Rima Alphonsus I) have steep walls, flat floors, and sharp edges. The linear troughs and rilles in the central (Rima Alphonsus II) and western parts of the map are shallower and have "U"-shaped floors and rounded edges. Both types have low-rimmed craters positioned along them that locally fill the adjacent depression. Rima Alphonsus II north of Alphonsus GO grades into a coalescing series of craters surrounded by low rims. The central ridge and all the basin fill units except the dark halo material (dh) show an intersecting northwest, northeast lineament pattern made up mostly of gentle ridges and troughs. The pattern is best developed in units cb1 and cb2 and the central ridge but also can be recognized within the smooth basin fill (sb). These structural trends coincide with the prevailing regional lunar grid directions.

INTERPRETATION

CRATER GENESIS

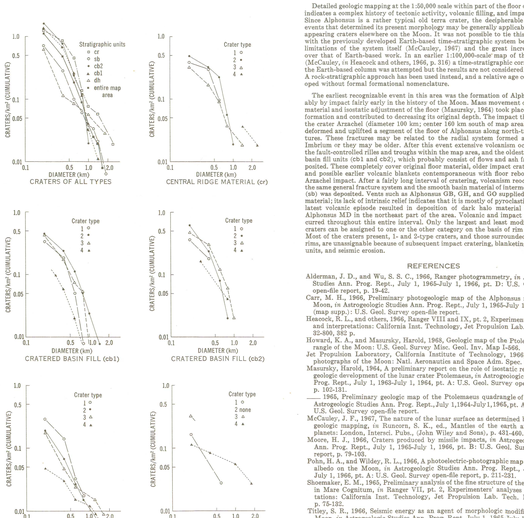
The craters surrounded by high concave-upward rim deposits (hr) are interpreted as relatively young impact craters. Those present, however, lack rays or bright halos and, therefore, probably have been modified since formation. The subdued-rim craters (sr) are probably older craters mostly of impact origin that have been substantially modified by later micrometeoroite bombardment and seismic erosion (Titley, 1966). Some aligned craters in this category could, however, be volcanic, such as the twin craters at Alphonsus GC. Both genetic types, if present, would have undergone sufficient modification to be morphologically indistinguishable. The low-rimmed craters (lr) are morphologically distinct, and the majority of those mapped show evidence of structural control. These are interpreted as volcanic craters of the mare type which played an important role in filling the Alphonsus basin. The linear depressions may be eroded and partly filled remnants of originally sharper fault troughs such as Rima Alphonsus I. Some, however, particularly those that grade into rimless chain craters, are probably collapse structures.

A relative age classification is not intended in the delineation of craters according to steepness of interior slopes (1-4). Some relative age relations can be inferred from the topographic base map at rim crest intersections and where one crater lies inside another. The range in form from sharp to very subdued can be explained by the impact model. This model implies that for craters of a given size and of the same original form, the most subdued will be the oldest. Proximity to larger younger craters, however, strongly influences the crater destruction rate. In addition, it is known that the smaller craters are destroyed first, and a very subdued crater in the small size range may indeed be younger than a sharp-appearing larger crater elsewhere on the map. In addition to ballistic erosion and deposition, other crater modification processes have surely operated within Alphonsus to further complicate crater age relations. The most obvious additional agent is crater burial by successively younger blankets of pyroclastic materials that were emitted from the many low-rimmed craters (lr).

CONCLUSIONS AND GEOLOGIC HISTORY

Detailed geologic mapping at the 1:50,000 scale within part of the floor of Alphonsus indicates a complex history of tectonic activity, volcanic filling, and impact cratering. Since Alphonsus is a rather typical terra crater, the decipherable sequence of events that determined its present morphology may be generally applicable to similar-appearing craters elsewhere on the Moon. It was not possible to tie this sequence in with the previously developed Earth-based time-stratigraphic system because of the limitations of the system itself (McCauley, 1967) and the great increase in scale over that of Earth-based work. In an earlier 1:100,000-scale map of the same area (McCauley, in Hancock and others, 1966, p. 316) a time-stratigraphic correlation with the Earth-based column was attempted but the results are not considered satisfactory. A rock-stratigraphic approach has been used instead, and a relative age column developed without formal nomenclature.

The earliest recognizable event in this area was the formation of Alphonsus, probably by impact fairly early in the history of the Moon. Mass movement of crater wall material and isostatic adjustment of the floor (Mazursky, 1964) took place after crater formation and contributed to decreasing its original depth. The impact that produced the crater Arzachel (diameter 100 km; center 160 km south of map area) extensively deformed and uplifted a segment of the floor of Alphonsus along north-trending fractures. These fractures may be related to the radial system formed around Mare Imbrium or they may be older. After this event extensive volcanism occurred along the fault-controlled rilles and troughs within the map area, and the oldest recognizable basin fill units (cb1 and cb2), which probably consist of flows and ash falls, were deposited. These completely cover original floor material, older impact crater materials, and possible earlier volcanic blankets contemporaneous with floor rebound and the Arzachel impact. After a fairly long interval of cratering, volcanism reoccurred along the same general fracture system and the smooth basin material of intermediate albedo (sb) was deposited. Vents such as Alphonsus GB, GH, and GO supplied most of this material; its lack of intrinsic relief indicates that it is mostly of pyroclastic origin. The latest volcanic episode resulted in deposition of dark halo material (dh) around Alphonsus MD in the northeast part of the area. Volcanic and impact cratering occurred throughout this entire interval. Only the largest and least modified of these craters can be assigned to one or the other category on the basis of rim morphology. Most of the craters present, 1- and 2-type craters, and those surrounded by subdued rims, are unassignable because of subsequent impact cratering, blanketing by volcanic units, and seismic erosion.



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For sale by U.S. Geological Survey, price $1.00