2. THE STRATIGRAPHIC APPROACH

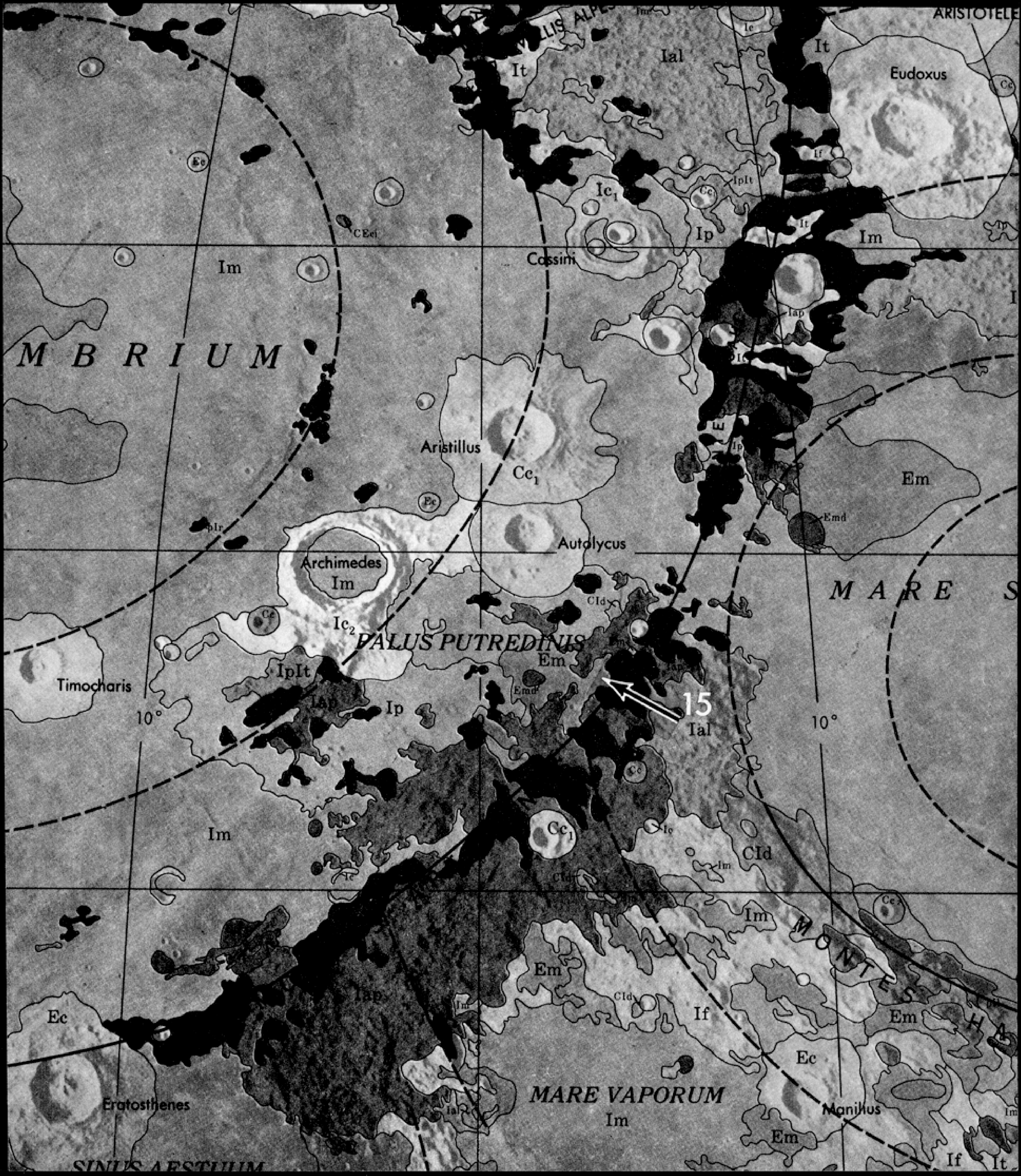


FIGURE 2.1 (OVERLEAF).—Geologic map of part of areas covered by figures 1.6 and 1.7. Important units include: Cc_1, Copernican crater materials; CId, *Copernican, Eratosthenian, or Imbrian* dark-mantling materials; Ec, Eratosthenian crater materials; Em, Eratosthenian mare materials; Ic_1 and Ic_2, Imbrian crater materials; Im, Imbrian mare materials; Ip, Imbrian plains materials (Apennine Bench Formation); Ial, Alpes Formation; Iap, materials of Montes Apenninus; If, Fra Mauro Formation; IpIt, Imbrian or pre-Imbrian materials, undivided; pIr, pre-Imbrian rugged materials. Arrow, Apollo 15 landing site. From Wilhelms and McCauley (1971).

2. THE STRATIGRAPHIC APPROACH

CONTENTS

GENERAL PRINCIPLES

Some earlier observers, influenced by experience with terrestrial geology, interpreted the Moon's surface in structural terms. Real or imaginary alignments of landforms were construed as faults or folds, and the present topography was explained as the product of progressive endogenic deformation of an originally simple surface (for example, Fielder, 1965). Crater and basin rims were thought to have been emplaced gradually along arcuate fissures. Chronologic sequences can be partly inferred in these structural models. A small crater inside a larger, or one crater rim that cuts across another, are signs of relative age in all but the most contrived scenarios. A sharp scarp that cuts a mare surface must be younger than the surface.

Our present understanding of lunar geology, however, has resulted from interpreting surface relations in terms of stratigraphic units (figs. 2.1, 2.2). Building upon centuries of thought that apparently began in 1669 with Nicolaus Steno (Woodford, 1965, p. 2–6), stratigraphers studying either the Earth or the Moon treat observations in terms of three-dimensional units of material. They do not consider a crater or basin as an isolated landform but as the source of a deposit. Similarly, a mare is not merely a surface with a certain color or smoothness but the upper bound of a stack of three-dimensional material layers. Each crater or mare deposit (1) is stratiform or tabular, (2) has a finite, normally varying thickness, (3) is laterally continuous over a finite area, (4) rests on other units, and (5) is bounded above either by additional units or by a free surface (fig. 2.2*B*; Shoemaker and Hackman, 1962; Mutch, 1970; Wilhelms, 1970b). Even topographically undistinctive terrains are composed of discrete rock units (fig. 2.3).

These geometric properties of discrete rock bodies imply that each body was formed at some instant or over some finite interval during the course of geologic time. Upon deposition, each crater and mare unit extended until it pinched out naturally or abutted against an obstacle. Interruptions of such depositional patterns as radiality of crater ejecta indicate blockage by an obstacle, superposition of a younger unit, or transection by a later structure (fig. 2.2*B*). Simply put, younger units overlie and thus modify older units. Age relations can be detected as far as the units extend. For the Moon, superpositional and transectional relations can generally be seen and interpreted in temporal terms much more quickly and efficiently from a photograph than on the surface. These simple observations form the basis for any understanding of lunar geologic history.

The detection and mapping of stratigraphic units and sequences do not necessarily imply that the genesis of the units is known but only that each unit or sequence was formed by a single process or related processes. A crater deposit could equally well be composed of impact ejecta or extruded volcanic material; nonstratigraphic criteria may be needed to distinguish between these origins. Matters of recognition and interpretation of units are kept separate as far as possible in photogeologic work (Mutch, 1970; Wilhelms, 1970b, 1972b). A major purpose of stratigraphic studies, however, is to help determine the origins of the units and of their constituent rocks. The debate about internal or endogenic origin versus impact or exogenic origins of lunar features is a thread running through lunar studies since their beginning.

CASE HISTORIES

Three examples illustrate the application of stratigraphic principles to problems of origin. Before direct exploration began, stratigraphic and theoretical studies had formulated pertinent questions and obtained many answers to genetic problems. Then, the major remaining problems were solved in general terms by data obtained directly from the Moon's surface by nine missions in the seven years between the flight of Apollo 11 in 1969 and the Soviet unmanned sampling mission Luna 24 in 1976 (table 1.2). The search for more specific answers, especially to the third question, the origin of terra materials, remains a field of active investigation. Later chapters of this volume further consider these "case histories" in a stratigraphic context.

Craters

The exogenic-endogenic controversy about the origin of craters probably occupied more early literature than did any other lunar topic (reviewed by Baldwin, 1949, 1963; Firsoff, 1961; Shoemaker, 1962b). The only major competitor for journal space was the Moon's surficial layer, and even that subject was commonly discussed with regard to impact-versus-volcanic arguments about crater origin (for example, Kopal and Mikhailov, 1962, p. 371–565; Salisbury and Glaser, 1964). The debate continued through the era of Ranger, early Luna, Surveyor, and Lunar Orbiter exploration (1964–68). Caldera origin was favored or entertained for several types of craters and is still favored by a few observers (Green, 1971, 1976; McCall, 1965, 1980). However, the impact origin of large fresh craters typified by Copernicus (fig. 1.6), and of most craters that share its principal features, had been settled in most minds at the beginning of the space age (Baldwin, 1965, p. 137).

Part of the solution was stratigraphic. An origin had to be consistent both with the morphology of typical crater deposits and with the spatial distribution of craters superposed on other stratigraphic units. The exterior deposits are massive, extensive, and similar in lateral morphologic gradation around craters ranging over more than five orders of magnitude in diameter. Therefore, the crater-formation process (1) released enormous energies and (2) operated similarly at all scales. These properties characterize *impacts* of cosmic projectiles, whose approach velocities range from the escape velocity of the Moon (2.4 km/s) to about 70 km/s, most typically from 16 to 20 km/s (Gault, 1974; Wetherill, 1977b). Relative to a planetary target, these velocities are *hypervelocity*, that is, greater than the speed of sound in the impacted medium (Baldwin, 1949, 1963; Shoemaker, 1962b). The hypervelocity projectiles range in size from dust particles to small asteroids. Thus, large *primary impacts* from space generate almost unlimited kinetic energies. Projectiles launched from the primary crater at lesser velocities (max 2.4 km/s) create morphologically varied *secondary craters* over great distances. The repetitive map patterns of crater deposits and the detailed morphologies of both primary and secondary craters (see chap. 3) match those of experimental impact and explosion craters much more closely than those of volcanic craters.

Stratigraphic relations, in combination with the properties expected of cosmic projectiles, also explain the spatial distribution of craters. The number of craters superposed on a given terrane is generally proportional to the age of the terrane (Gilbert, 1893; Baldwin, 1949, 1963; Öpik, 1960; Shoemaker, 1962a, b; Shoemaker and others, 1962a). For example, craters are more abundant on the older terrae than on the younger maria (figs. 1.6, 1.7). Different ages of the terranes and not different origins of the craters account for this relation. Within a given terrane, small craters are always more abundant than large craters, the sizes and frequencies are systematically related, and the most conspicuous craters are randomly scattered. This distribution is consistent with the inverse mass-frequency distribution of observable cosmic objects (Baldwin, 1949, 1963; Öpik, 1960; Shoemaker and others, 1962b; Hartmann, 1965a, b). Nonrandom distributions, which are also observed, are equally diagnostic of impact origins: Secondary craters are grouped around larger primaries. Apparently nonrandom distributions of large craters, such as the

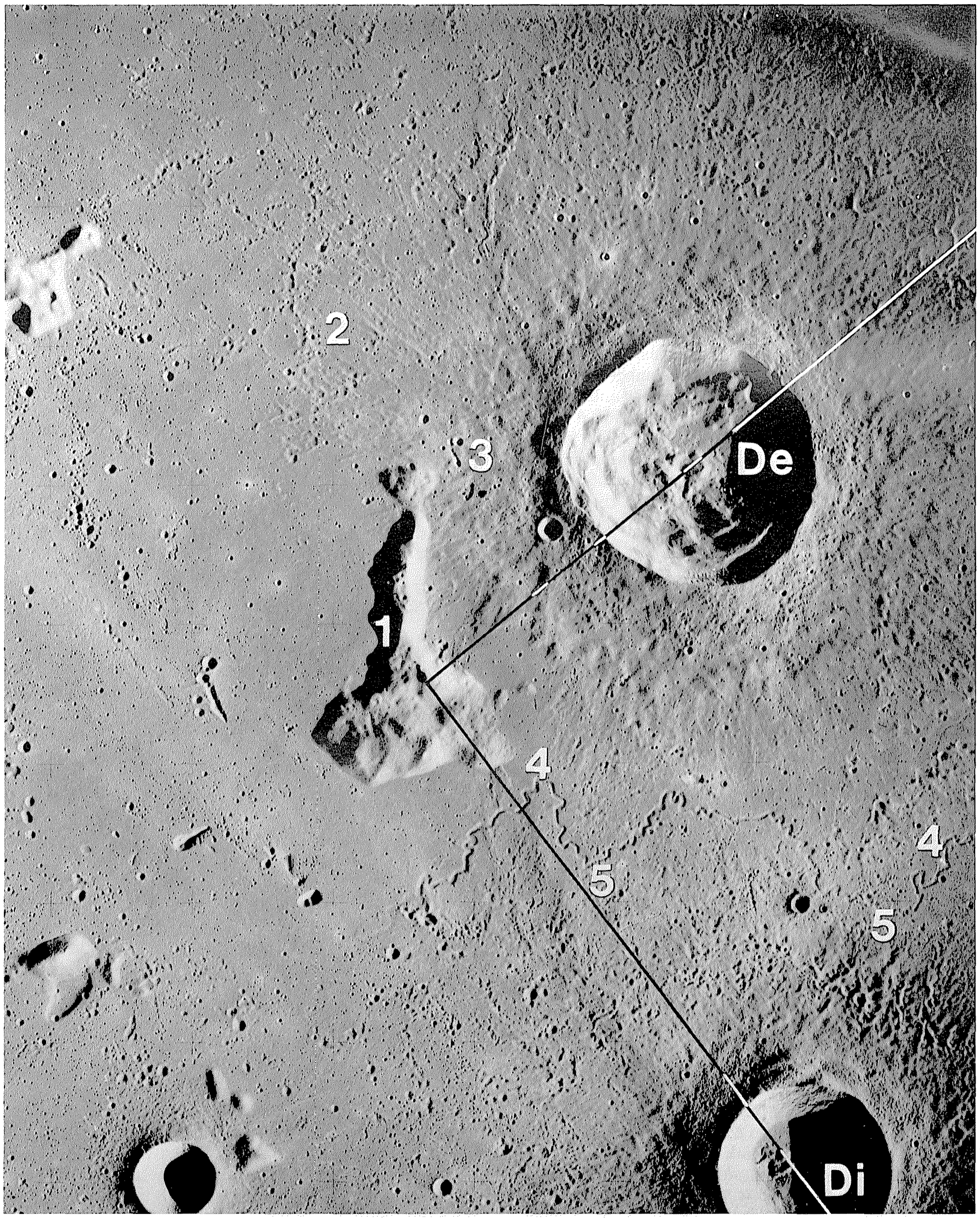


FIGURE 2.2.—Stratigraphic relations of craters Delisle (De; 25 km) and Diophantus (Di; 18 km), mare materials, and Imbrium basin. Massifs of Imbrium protrude through mare surface as islands (1). Mare unit (2) is overlain by ejecta of Delisle (3). Another mare unit containing sinuous rille (4) embays Delisle ejecta. Secondary craters of Diophantus (5) are superposed on rilled mare unit and Delisle.
A. Apollo 15 frame M–2076.

north-south-trending "chain" in the south-central nearside terra (fig. 1.8), which were ascribed to major subsurface structures in the early literature (for example, Fielder, 1965, p. 56), actually are coincidental alignments of primary craters of different ages (Baldwin, 1949, p. 158–160). When large craters of the same age are plotted together, almost all lineaments disappear (pls. 6–11). A falloff in crater density in the terra near the mare borders results from the inverse size-frequency distribution: The missing craters are mantled by ejecta of the largest members of the impact series, the ringed basins (figs. 1.6, 1.7). Thus, in any one epoch, the distributions of most large lunar craters are truly random and would require an internal generating process as random as primary impact—a prerequisite in conflict with the spatial regularities commonly cited by proponents of a volcanic or tectonic origin.

The origin of craters having apparently atypical morphologies or size-frequency distributions remained to be learned by a combination of remotely based analysis and sampling during the 1970's. Although no large craters were sampled individually, the overwhelming evidence from returned rock samples is that almost all lunar craters are of impact origin. The large degraded craters of the terrae, which apparently possess only a truncated rim flank, originally resembled fresh craters but have been eroded by impacts and deposition of later ejecta (fig. 2.3; chaps. 8, 9). Continued study has uncovered impact or modification processes that account for most of the odd landforms once ascribed to volcanism. Most elongate and irregular craters and clustered craters were formed by oblique or simultaneous primary or secondary impacts (chap. 3). Anomalous uplift of floors of impact craters in basins accounts for most remaining departures from the typical morphologies of large craters (chap. 6). Circular craters with dark halos were formed by impact excavation of dark materials from beneath lighter strata (chap. 13). A few small craters, all associated with mare or other dark deposits, may be endogenic (chap. 5). Impacts, therefore, created most lunar craters and thus are emphasized in this volume.

Mare versus basin

One of the most important products of the historical approach was the discovery that a mare and the basin that contains it are distinct features. Before the 1960's, these two features were almost universally thought to have been formed by the same process, either exogenic or endogenic; the terms "mare" and "basin" were equated. Even later, one might read that "Mare Imbrium" was created by a giant impact or that the "Imbrium basin" yielded samples of basaltic lava. There is conclusive stratigraphic evidence, however, that the mare materials are younger than the basin materials. Such craters as Archimedes that lie inside the Imbrium basin (figs. 1.6, 2.1) must be younger than that basin (Baldwin, 1949), except in the unlikely case that the basin rim grew up along internal ring fractures. The mare materials that fill Archimedes are younger still (Shoemaker and Hackman, 1962; Baldwin, 1963; Mutch, 1970; Wilhelms, 1970b). In stratigraphic terms (Shoemaker and Hackman, 1962), the sequence, from oldest to youngest, is: (1) basin material, (2) plains material of the Apennine Bench, (3) deposits of Archimedes, and (4) mare material (figs. 2.1, 2.4).

Early work also established the genetic relation of the circum-Imbrium terrane to the Imbrium basin. Gilbert (1893) and Baldwin (1949, 1978) perceived the radiality of the "Imbrium sculpture" system of grooves, and Shoemaker and Hackman (1962) added the recognition of craterlike Imbrium ejecta deposits (figs. 1.6–1.8). Mare Serenitatis fills another circular basin, which is overlain by the Imbrium sculpture or deposits (fig. 1.7). Yet Mare Serenitatis is unaffected by the Imbrium deposits, and so considerable time must have intervened after the Serenitatis basin formed and before Mare Serenitatis filled it (Baldwin, 1949, p. 210–213).

Maria and basins were, therefore, formed by different processes. Even before the Apollo missions, most workers had accepted these simple stratigraphic observations and knew that the maria are of volcanic and the basins of impact origin. Furthermore, the maria were identified as basaltic by their dark color and characteristic landforms. The basins were known to be exogenic by their similarity to craters and by the fact that only the kinetic energies of asteroidal masses impacting at cosmic velocities could supply the requisite energies of formation.

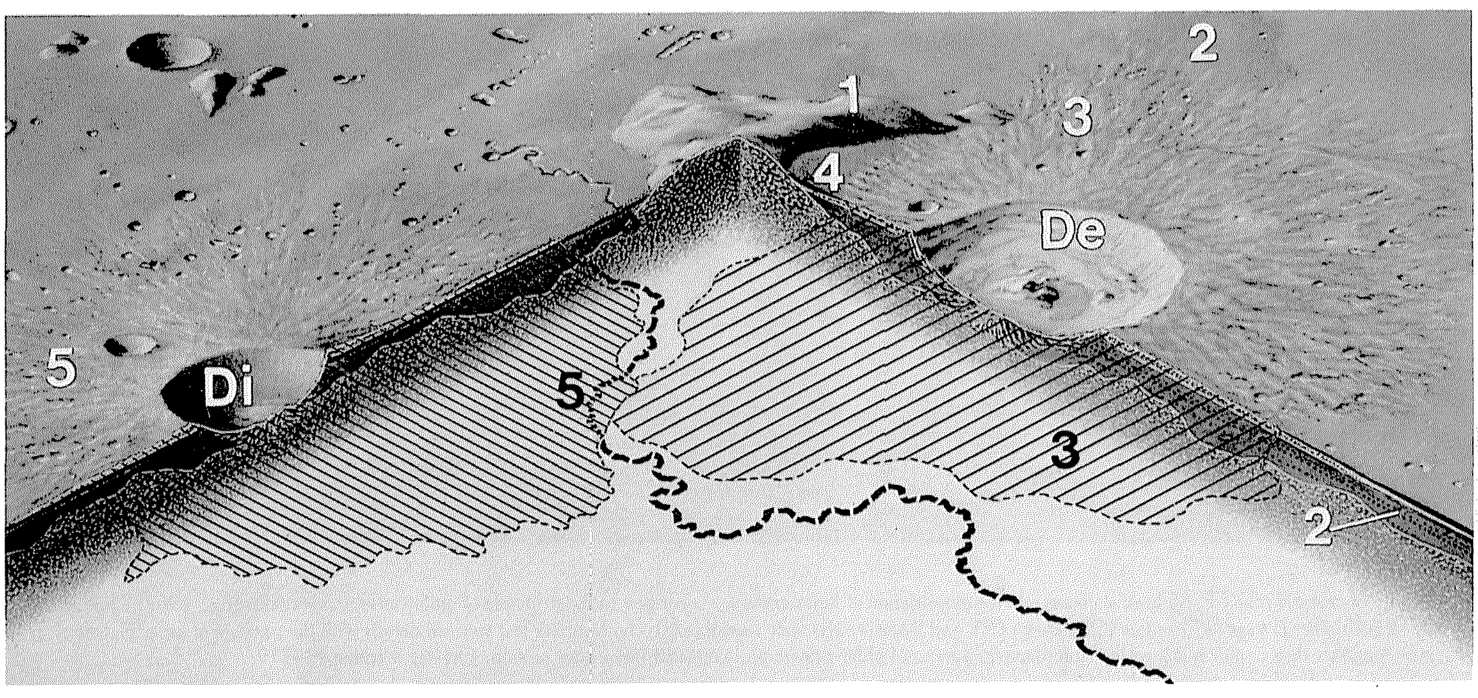
These conclusions were then confirmed by the first four Apollo landings between July 1969 and July 1971 (table 1.2). Apollo 11 returned rocks with basaltic composition and unmistakable igneous textures. Apollo 12 sampled other basalt flows half an aeon younger that could not have been generated by the same event as the Apollo 11 basalt samples.[2.1] The first nonmare mission, Apollo 14, returned entirely different rock—complex impact breccia—from deposits of the Imbrium basin (fig. 2.5*A*). Landing in the area covered by figure 2.1, Apollo 15 returned samples whose radiometric ages demonstrate a half-aeon age gap between the Imbrium basin and some of the mare basalt it contains (fig. 2.5*B*).

Terra materials

"Origin" of terra materials may mean either the chemical differentiation and igneous evolution that shortly followed the Moon's formation (see chap. 8), or the process that emplaced the visible landforms and photogeologically observed stratigraphic units. Stratigraphers, and this volume, concentrate on the timing and processes of the second, emplacement phase of the rocks' history.

Interpretations of emplacement processes and of relative ages are complementary. Recognition that the circum-Imbrium material is of impact origin enabled it to be used as a stratigraphic horizon;

[2.1] One aeon = 10^9 years, or 1 billion years in American usage. Ages in this volume have been recalculated using the radioactive-decay constants recommended in 1977 by the International Union of Geological Sciences (Steiger and Jäger, 1977). Most of them differ numerically from the ages given in the references cited in this volume.



B. Cutaway view including geologic cross section drawn along bent line in *A*. Interpretations of age relations depend on interpretations of landforms as expressions of three-dimensional, laterally continuous units whose depositional pattern is interrupted only by blockage by older units or superposition of younger units.

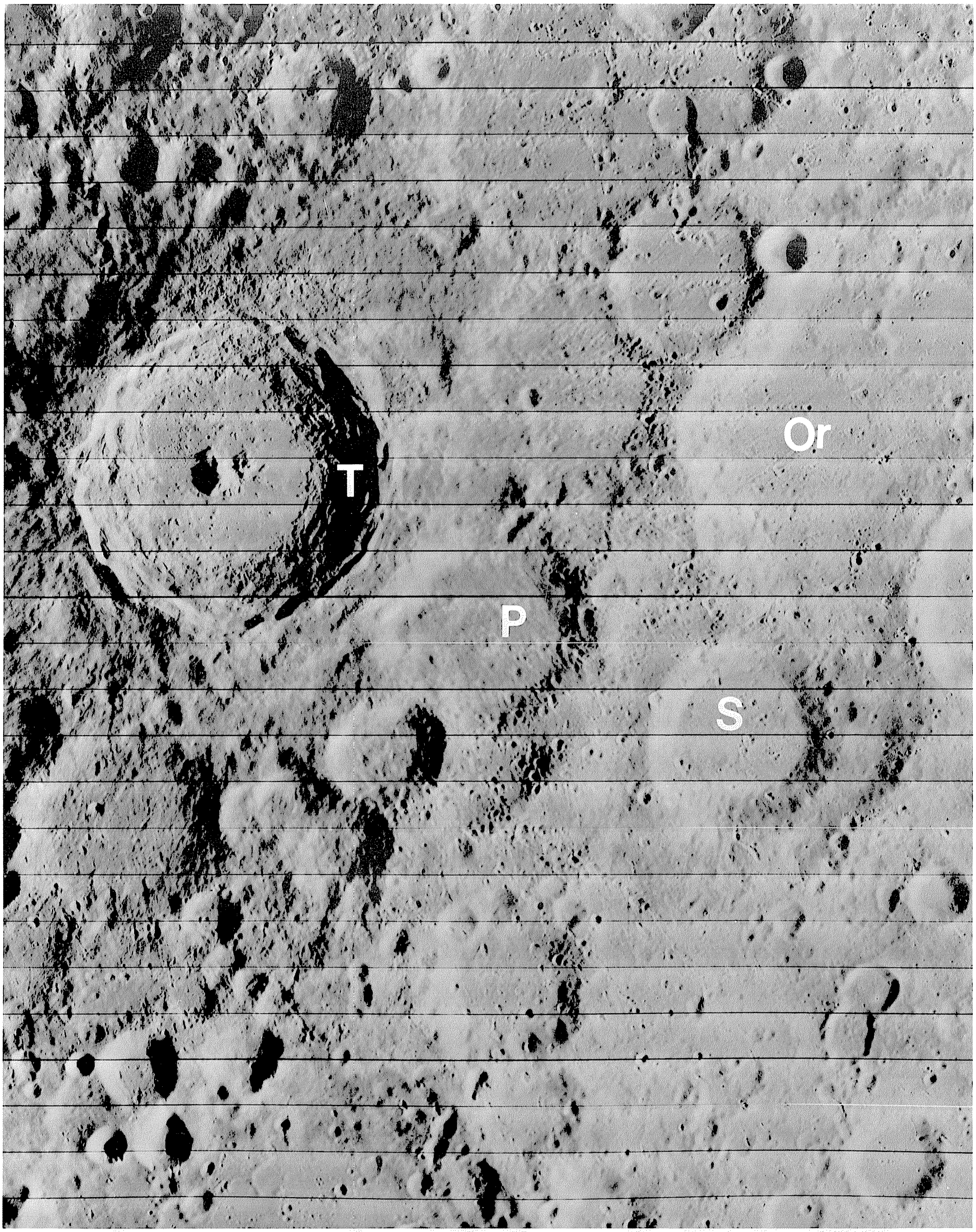


FIGURE 2.3.—Vicinity of crater Tycho (T; 85 km), showing relative degradation of lunar craters. According to the principle of uniformitarianism (Albritton, 1967; Mutch, 1970; Wilhelms and McCauley, 1971), such other craters as Orontius (Or), Pictet (P), and Saussure (S) once resembled Tycho but have lost textural details with the passage of time. Extent of Tycho deposits and secondary craters suggests that similar but now-invisible deposits surround older craters and compose intercrater terrain. Orbiter 4 frame H–119.

materials older and younger than the basin could be distinguished over much of the nearside outside the limits of the topographic basin. Moreover, the absolute ages of the spot samples collected by Apollo 14 could be extrapolated over the entire mapped extent of the unit (fig. 2.1). The samples from the Apollo 15 and 17 landing sites (figs. 2.5*B*, *D*) were also correlated with basins soon after the laboratory analyses (see chaps. 9, 10).

Some materials outside basin rims, however, were less readily interpretable. Two morphologic units sampled by Apollo 16 at the fourth major terra sampling site, the Cayley Plains and Descartes Mountains (fig. 2.5*C*), have proved crucial in assessing the general origin of the terrae. The history of their interpretation illustrates the interaction between photogeologic stratigraphy and its verification from actual samples of the mapped units.

The Cayley and other light-colored terra plains cover about 5 percent of the lunar terra surface and are the most distinctive terra landforms after the more craterlike ejecta of fresh basins (Wilhelms and McCauley, 1971; Howard and others, 1974). Superpositional relations and crater densities indicate that the plains-forming materials are older than the mare materials. Some of the photogeologic properties of the plains are marelike: They are smooth and level and are concentrated in depressions. In other ways, the plains-forming materials are like basin materials: They are brighter than the maria and may grade from thick in depressions to thin on adjacent more rugged terra. Accordingly, the plains-forming materials have been interpreted as both volcanic and impact deposits.

The concentration of the plains near Imbrium and their gradations with the coarse-textured basin ejecta implied lateral continuity of the two types of deposits and, thus, an impact-ejecta origin of the plains-forming material (Eggleton and Marshall, 1962; Eggleton, 1964, 1965). Similar superpositional relations of apparently isolated patches implied that all these patches belong to the same unit. The Descartes Mountains resemble coarser parts of the Imbrium ejecta blanket (Eggleton and Marshall, 1962).

Later, the same stratigraphic evidence was interpreted differently and helped support a revival of volcanic hypotheses (summarized by Wilhelms, 1970b, Wilhelms and McCauley, 1971, and Ulrich and others, 1981). The concentration of plains near basins was thought to result from marelike flooding of basin-related depressions, and the plains deposits were interpreted as younger material superposed on the blanket. Just as lateral continuity implies restricted time and mode of formation, its apparent absence may legitimately be interpreted as indicating an origin by various processes over extended times. Volcanic interpretations included (1) marelike materials brightened by longer exposure to impact cratering, or (2) materials more silicic than the basaltic maria. The plains-forming and gradational mantling materials were commonly thought to be facies of regional pyroclastic blankets, probably silicic ash-flow tuff, a highly fluid material that spreads widely and that partly conforms to the substrate (for example, Howard and Masursky, 1968; Cummings, 1972). The hummocky Descartes materials were interpreted as volcanic on the basis of their close morphologic similarities to certain terrestrial landforms (Milton, 1968a; El-Baz and Roosa, 1972; Head and Goetz, 1972; Trask and McCauley, 1972). Volcanic interpretations prevailed when Apollo landing sites were chosen (Hinners, 1972). However, a choice between mechanisms required analysis of actual samples.

One of the most significant turning points in the course of lunar geologic thinking came in April 1972, when Apollo 16 returned samples of complex terra breccia from typical patches of plains and Descartes materials (fig. 2.5*C*; Howard and others, 1974; Ulrich and others, 1981). As a result, volcanic interpretations were replaced by impact interpretations. Regional stratigraphic relations turned out to be better indicators of origin than did volcanic analogs. The significance of this terra sampling transcends the revised interpretations of the sampled units, because the hypothesis of impact origin could also be extended to undistinctive, previously uninterpreted terra materials peripheral to craters and basins (fig. 2.3). Like the circum-Imbrium terrane, such undistinctive terranes are coeval with the crater or basin they surround and constitute discrete stratigraphic horizons; they did not form piecemeal and do not present a hopelessly complex problem for relative dating. More and more basins have been identified since 1972, and their deposits have been increasingly recognized as similar both to those of craters and to one another (pl. 3). This series of analogous basin deposits constitutes the main stratigraphic framework of the lunar terrae.

CORRELATION OF SAMPLES AND STRATIGRAPHIC UNITS

Return of materials from the Moon has established the general origins of most lunar stratigraphic units. The maria consist of basaltic flows and pyroclastic blankets derived by internal melting (fig. 2.6). The terrae consist of complex, partly shock-melted breccia deposits that were assembled and emplaced by impacts (figs. 2.7, 2.8).

However, not all questions of origin and age have been solved by sampling. Especially serious is the fact that many returned samples have not been definitely identified with particular photogeologic units.

One problem is that all samples, except some of mare basalt from the Apollo 15 landing site (fig. 1.10*B*), were collected not from bedrock outcrops but from the overlying regoliths. Regoliths are composed of highly mixed materials and conceal the underlying bedrock stratigraphy and structure. Sample provenance commonly must be determined from the relative abundances of rock types at various points on the surface. This problem of correlating samples with source beds is more severe than is usually encountered on the Earth.

Second, not only the regolith but also the bedrock breccia itself is recycled from earlier deposits. A given sample thus may have acquired its chemical and textural properties during or before the impact. For example, the fact that the morphology of the photogeologically visible Cayley and Descartes units is gradational with that of the Imbrium-basin deposits does not necessarily indicate that the materials of those units are of Imbrium origin, because the morphology may have been imposed when the Imbrium impact reworked earlier materials. This situation is partly analogous to that encountered in terrestrial sedimentary conglomerate and partly unique to lunar terra breccia. The bedding and matrix fabric of a conglomerate are normally formed during sedimentation, whereas the component clasts are relicts of an earlier rock. The matrix textures of a lunar terra breccia also are generally acquired during ejection, emplacement, and subsequent cooling. The clasts, however, may have been

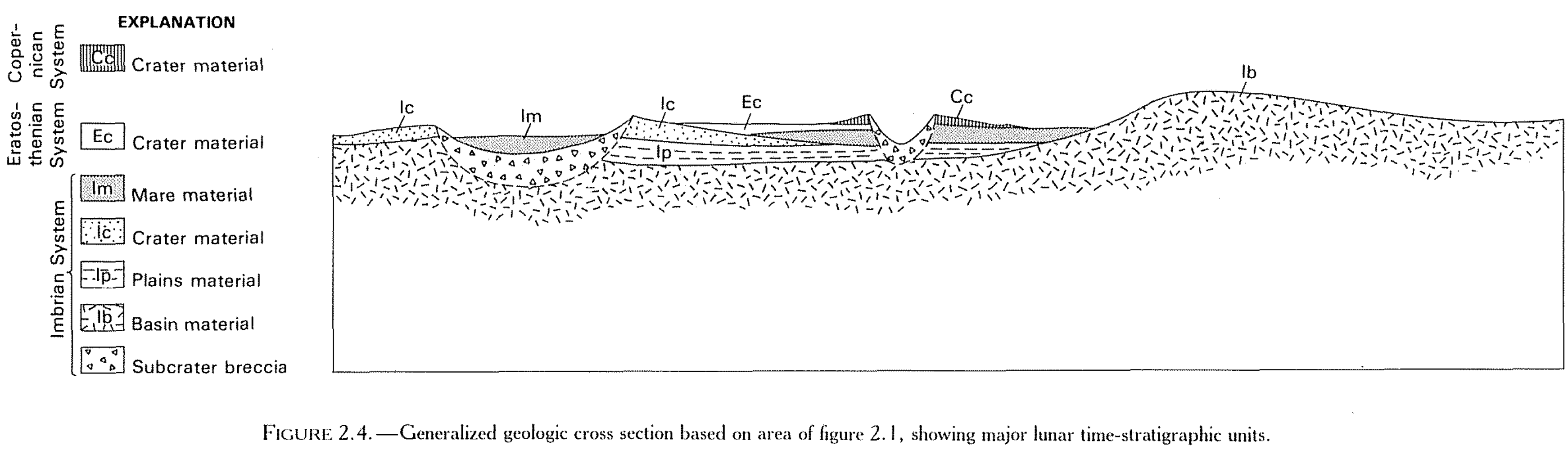
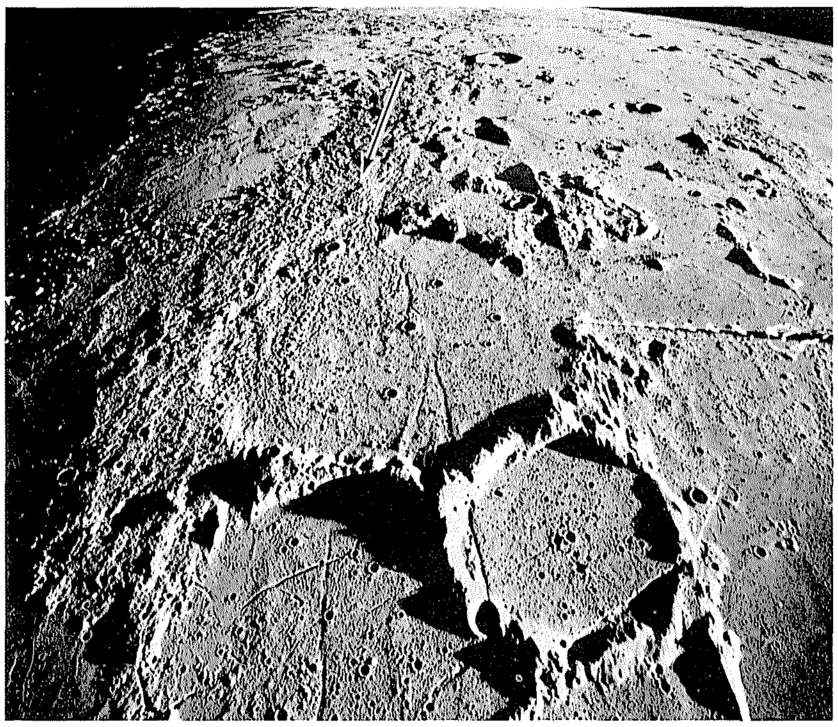


FIGURE 2.4.—Generalized geologic cross section based on area of figure 2.1, showing major lunar time-stratigraphic units.

formed either by an earlier event or in an earlier stage of the same event (see chap. 3); early-formed matrices may be broken up to become clasts in the final deposit. Intense mixing and recycling characterize the impact process.

Even a relatively uniform crystalline matrix of a terra breccia may be hard to date. It is not always clear whether impact-melted rocks (fig. 2.8) were heated sufficiently to reequilibrate the isotopes used in geochronology. Thus, the laboratory ages of the melt rocks may date an impact or an endogenic melting that preceded emplacement of the stratigraphic unit that contains them. Substantial petrologic, geochemical, geochronologic, and photogeologic work is required to distinguish the times of origin of the constituents of a terra breccia.

Lunar breccia poses the additional complexity that recycled pre-impact units may have been situated either in the primary target area of the new impact or outside that target area. Secondary impacts rework exterior target materials and incorporate them into new deposits, and the exterior and interior materials may have been lithologically similar before the impacts. Some investigators doubt whether the large volumes of melt rock found at two landing sites (Apollos 14, 16) are relatable to basins centered at great distances from these sites. Local origins in craters nearer the landing sites, followed by reworking during the basin impacts, are favored by many



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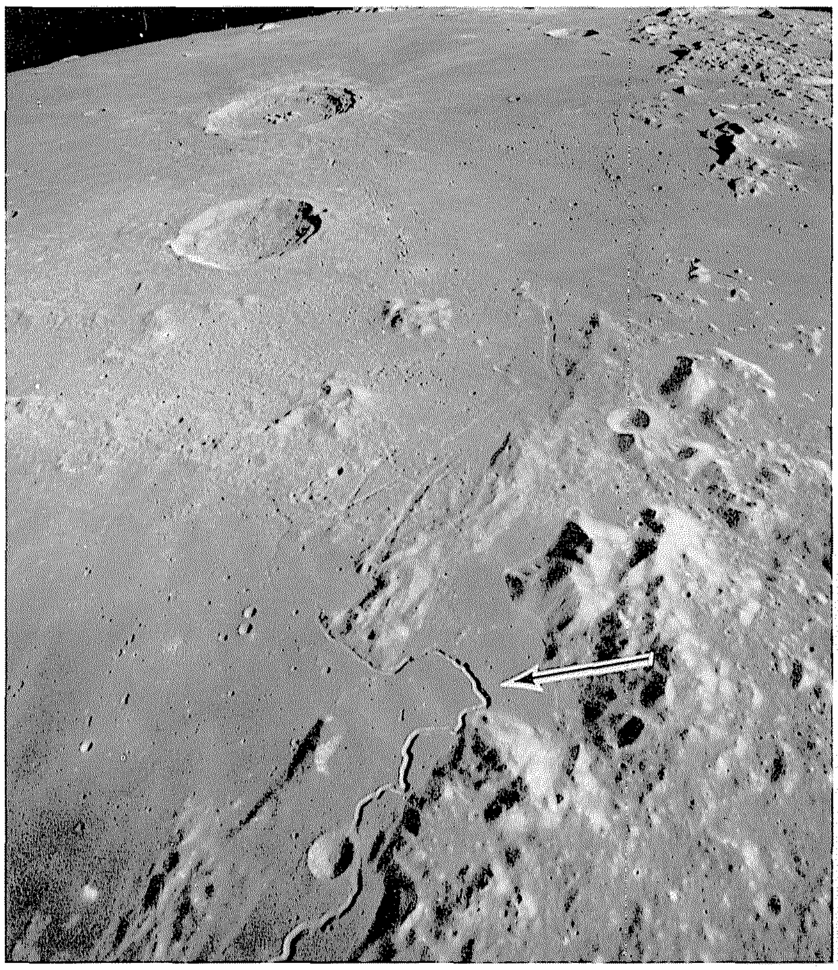

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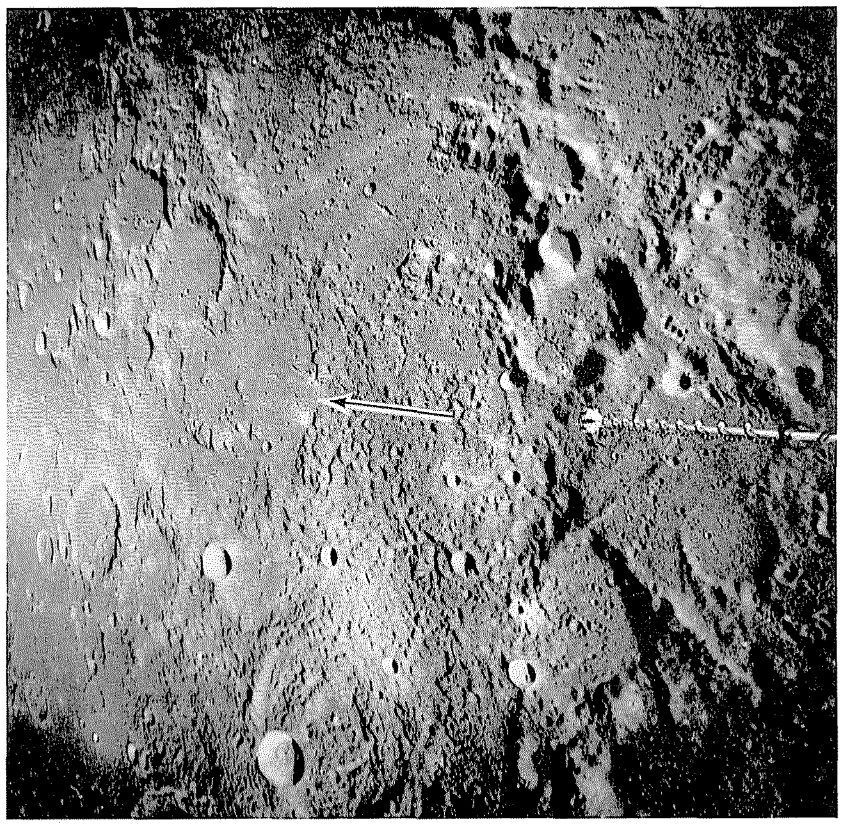

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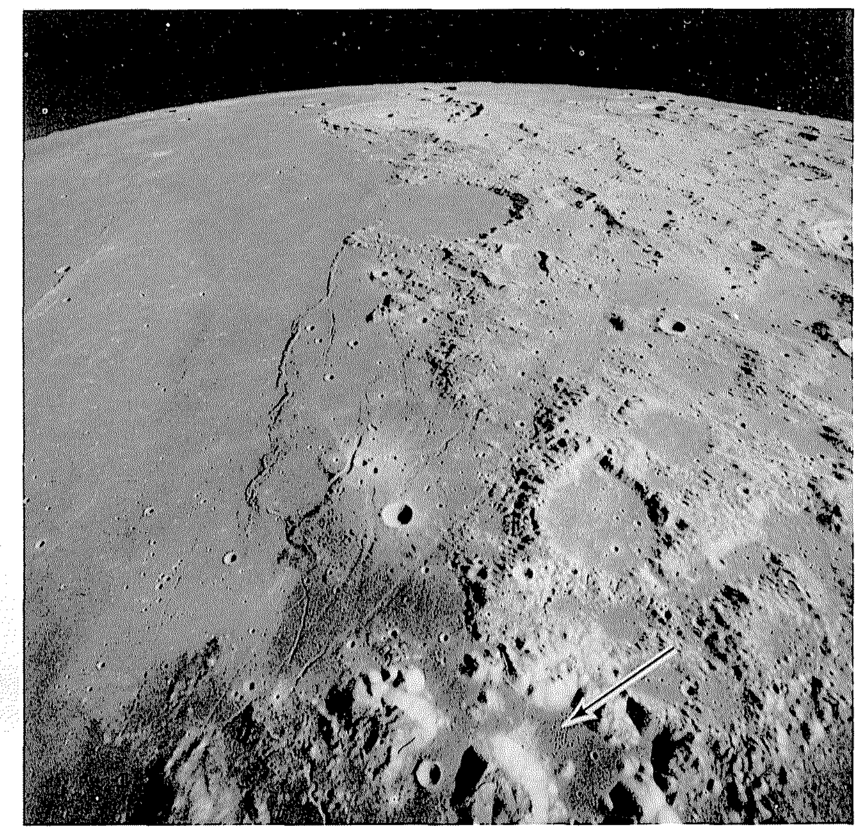

D

FIGURE 2.5.—Settings of four latest and most elaborate Apollo sampling missions (arrows). Each frame is an oblique view taken by an Apollo orbital mapping camera; boom of gamma-ray spectrometer protrudes into two views.

A. Region of Apollo 14 landing site on Fra Mauro peninsula. Large crater in center, to left of boom, is Fra Mauro (95 km, 6° S., 17° W.; compare fig. 1.8); Bonpland (60 km, left) and Parry (48 km, right) in foreground. View northward. Apollo 16 frame M–1419.

B. Region of Apollo 15 landing site in Palus Putredinis near Montes Apenninus. Large craters at upper left are Aristillus (55 km, 34 N., 1° E.) and Autolycus (39 km, 31° N., 1.5° E.) (compare figs. 1.6, 1.7). View northward. Apollo 15 frame M–1537.

C. Region of Apollo 16 landing site west of west rim of Nectaris basin (under boom; compare fig. 1.1). Fresh crater at bottom is Descartes A (16 km, 12° S., 15° E.), superposed on rim of crater Descartes. View westward. Apollo 16 frame M–566.

D. Region of Apollo 17 landing site in Taurus-Littrow Valley east of Mare Serenitatis. Large crater at top is Posidonius (95 km, 32° N., 30° E.; compare fig. 1.7). View northward. Apollo 17 frame M–939.

investigators, though not by me. Much of the uncertainty about the preimpact position of the constituent materials results from ignorance of the mechanics of very large impacts. Neither the size of the excavated part of basins nor the amount of melt they generate is agreed upon. These questions occupy considerable space in this volume.

In summary, the dominance of impact craters and basins on the Moon appears to be well established by analyses of the returned samples, although only a few individual units have been sampled directly. In the evolution of thought toward impact mechanisms, more and more layered rock bodies have emerged from anonymity among the Moon's seemingly chaotic features to take their place in the lunar stratigraphic column. The lithologic characterization and absolute ages of many of these units present more difficult problems.

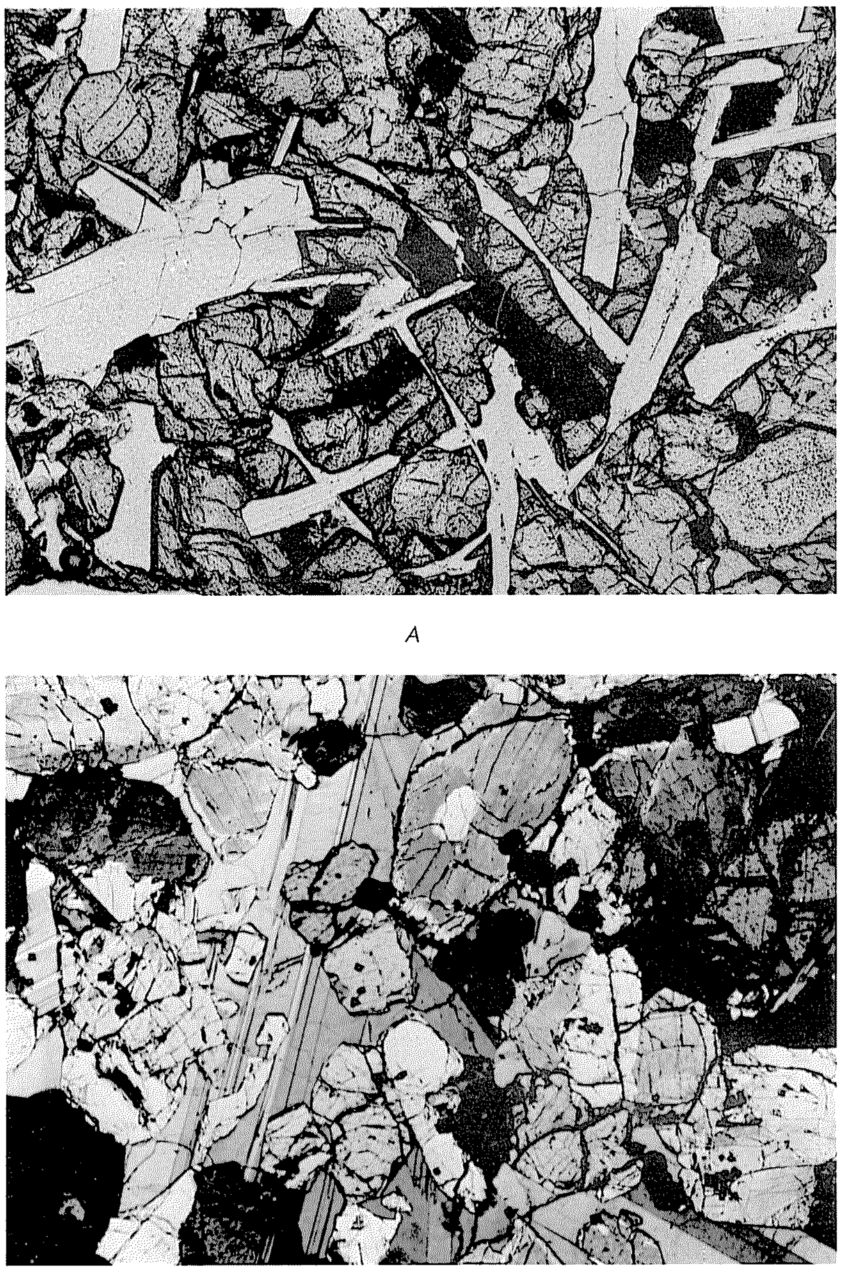

FIGURE 2.6.—Thin sections of typical mare basalt.
A. Sample 12051. Laths of plagioclase (light gray), surrounded and partly enclosed by grains of pyroxene (medium gray) (subophitic texture). Plane-polarized light; field of view, 2.2 mm.
B. Sample 15538. Laths of plagioclase (long parallel structure) partly enclose pyroxene grains poikilitically. Crossed polarizers; field of view, 2.2 mm.

Note: The Lunar Receiving Laboratory (LRL) at the U.S. National Aeronautics and Space Administration's (NASA) Manned Spacecraft Center (MSC), Houston, Tex., assigned numbers to lunar samples upon their arrival from the Moon according to the following scheme. The numbers contain five digits, followed by a comma and additional digits if the sample has been split. The first digits represent the mission number: 10, Apollo 11; 12, Apollo 12; 14, Apollo 14; 15, Apollo 15; 6, Apollo 16; 7, Apollo 17. In some Apollo 15 and most Apollo 16 and 17 samples, the subsequent digit represents the station from which the sample was collected. For Apollo 16: 0, station 10, the region near the landed lunar module (LM) and the geophysical instruments (Apollo Lunar Surface Experiments Package [ALSEP]); 3, station 13; 7, station 11 (stations 3 and 7 had been designated in premission planning but were dropped; Muehlberger and others, 1980). Some station numbers include intrastation samples as well. The last digit of Apollo 15, 16, and 17 numbers refers to the size of the sample: 0, unsieved material; 1, 2, 3, and 4, increasingly large pieces of sieved material; 5, 6, 7, and 9, "rocks," that is, samples larger than 1 cm across. The third and fourth digits are complexly derived designations for specific samples defined in the lunar-sample catalogs prepared by the LRL; for example, the fourth digit of Apollo 16 and 17 numbers, if odd, refers to parts of large rocks and, if even, to fragments from the soil.

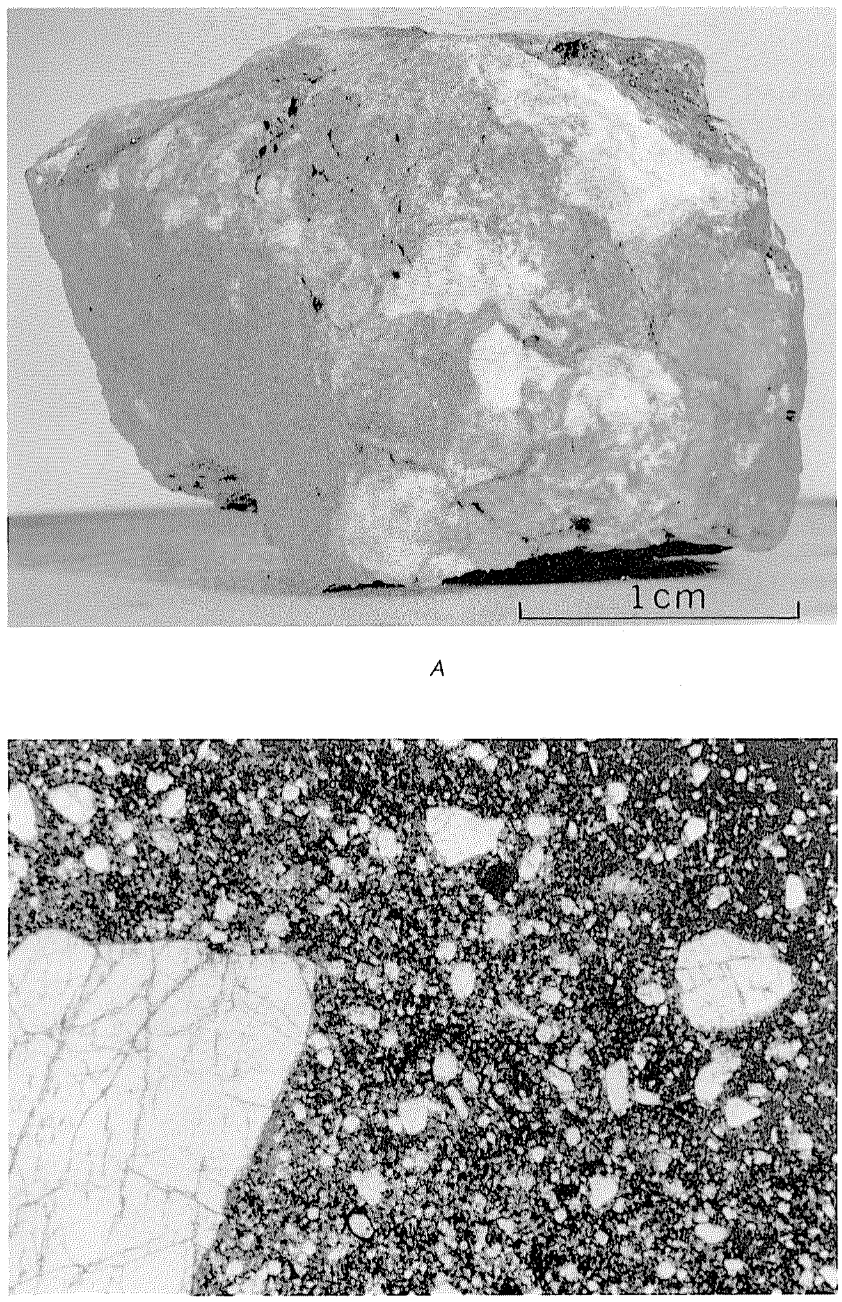

FIGURE 2.7.—Clast-rich "black and white" breccia (sample 15445) from station 7, Apollo 15 landing site, on flank of Montes Apenninus.
A. "Mug shot" made when sample first arrived at LRL from the Moon.
B. Thin section of part of sample (15445,66), showing ragged, chaotically arranged plagioclase crystals and other fragments in aphanitic matrix. Plane-polarized light; field of view, about 2 mm.

FIGURE 2.8.—Crystalline, igneous-appearing texture of impact-melt rock (James, 1973), sample 14310,170 from Apollo 14 landing site. Texture is partly subophitic, like that of basalt sample in figure 2.6*A*, and partly intersertal (fine-grained minerals in interstices of larger plagioclase crystals).