MINUTES OF THE APOLLO SITE SELECTION BOARD MEETING

held at

Apollo Action Center
955 L'Enfant Plaza North, S.W.
Washington, D.C. 20024

July 10, 1969

On July 10, 1969, the Apollo Site Selection Board met at NASA Headquarters. The meeting agenda is attached as Attachment A and attendees are listed in Attachment B.

Introduction

Capt. Scherer reported on the status of the H-1 prime landing site decision, first noting that at the last ASSB meeting MSC was given an action item to investigate the possibility of using Fra Mauro and/or Hipparchus as additions to the candidate set of Sites 2, 3, and 5. MSC replied by TWX on June 12, recommending against inclusion of Fra Mauro and Hipparchus on account of low N-numbers and lack of photographic coverage. They recommended including Site S-III instead and requested a response by June 16. A June 16 response noted that the GLEP Site Selection Subgroup Meeting of June 17 would consider site S-III after which a definite answer would be sent. The Subgroup recommended against using S-III primarily because it is not representative of the "younger" mare. The subsequent Headquarters response to MSC concurred with the recommendation to drop Fra Mauro and Hipparchus and to include S-III.

Capt. Scherer noted a request by Adm. Middleton-KSC that Mr. R. E. Mose be recognized as his representative at those ASSB meetings which Adm. Middleton could not attend.

Development of Reference Site List

Dr. D. U. Wise - NASA HQ/MAL introduced the discussion of lunar science rationale and how it leads to site selection and sequencing. He re-emphasized the need to develop a reference site list for purposes of mission planning and noted that the ensuing discussion would indicate how the GLEP Site Selection Subgroup arrived at the recommended site list and alternates.

A detailed write-up of the science objectives presentations is not included here since it is the intent of the speakers to do so in the near future. Rather, their summary chart of the 24 Set B sites vs. objectives is included as Attachment C, which should be referred to in conjunction with the brief summaries below. Additional copies of the presentation material are available upon request.

Age Dating

Dr. D. U. Wise - NASA HQ/MAL discussed the importance of absolute age dating techniques in establishing a time-framework in which lunar samples and events can be linked. Such techniques, highly developed in terrestrial and meteoritic studies, depend upon the radioactive decay of an element whose initial abundance is well known. The method "dates" the time at which a given sample became a closed system for a particular element, e.g., the time at which a rock containing radioactive K^{40} cooled sufficiently to retain the gaseous A^{40} decay product. Such an age might reflect a time of volcanism, impact melting or even accretion to form the moon.

Terrestrial experience tells us that a variety of age-dating techniques must be used on a multitude of samples in order to circumvent the usual difficulties of anomalous dates and varying geology. The samples must be collected in their geologic context.

Dr. Wise described the significant ages one wants to obtain on the moon. Prime is the age of the moon's formation or oldest crust, an age which might enable one to distinguish among various origin theories. A key site for locating such material are Fra Mauro (old Imbrian debris blanket). Another site would be in the bland SE highlands - an area <u>not</u> represented in Set B. Next in sequence (as determined by photogeologic mapping which establishes <u>relative</u> ages) is the time of the giant impact events now recorded as mare basins. Fra Mauro is one of the few lunar sites where such an age can be established. Following at some unknown time interval is the age of mare fill - examples of which will be abundant in the lunar exploration on account of the bias towards mare landings. Filling out the sequence are significant post-mare events such as the Copernicus and Tycho impacts and associated volcanism. Equally of interest is the apparent concentration of sinuous rille formation during this last period of lunar history.

Lunar Composition

The significance of determining various aspects of lunar composition was discussed by Dr. N. W. Hinners-Bellcomm/MAS. He first indicated the great desire of geochemists to find "primitive" solar system material in order to deduce conditions of formation of planets and satellites from the condensing solar nebula. Current information on those conditions is based upon analysis of terrestrial and meteorite samples, solar and stellar spectroscopy, and theoretical nuclear physics. The earth and meteorites both exhibit evidence of complex physical and chemical change which obscures the original state. The source of energy for the changes is thermal and the earth has also been surficially modified by atmospheric weathering. The moon's small size might result in a lower heat flow and has resulted in a very small atmosphere thus leading us to speculate that it may still have original material on the surface. One could search for such material in the highlands since they appear to represent the oldest, thus most primitive, lunar material.

Next in importance to finding primitive material is establishing the bulk composition of the moon both in terms of its major element chemistry and its radioactivity. The former is expected to relate especially to theories of origin, e.g., if the moon is totally unlike the earth it can hardly have fissioned from it. The latter is important in that radioactivity is expected to be a main source of energy for any lunar changes which have occurred since its formation. In order to establish lunar bulk composition, one must sample the spectrum of surface sites which are located in a variety of geologic units. Of greatest import are those sites showing evidence of differentiation and/or deep-seated materials (impact excavations, ejecta blankets, explosive craters). Orbital surveys of radioactivity and major element content should help delineate the lunar compositional variations.

Lastly, Dr. Hinners discussed how molecular and isotopic analysis of any current or past lunar atmosphere would give clues to lunar origin and evolution. Areas of transient event sightings and sinuous rilles are favored for such investigations.

Deployment of mass spectrometers is necessary for study of the current atmosphere while sample analysis will give clues to the past atmosphere.

Major Geomorphic Processes

Dr. Wise referred to the study of major processes of construction and destruction of lunar land forms as being useful in answering 2nd and 3rd order questions about the moon but as being absolutely essential in that it is the "glue" that holds the first order questions together. Knowledge of dominant processes provides the basis for the selection of samples and for determining their place of origin. It also provides a major clue to past energy expenditure on the moon, be it internal or external in ultimate source.

Of particular interest in process studies are the sinuous rilles and their implications for lunar degassing and the possible occurrence of resources useful in future exploration.

Another area in need of attention is the significance of volcanic cratering, once thought by many to represent only a very minor aspect of lunar geology but now recognized as being of major import.

Dr. Wise summarized by noting that our photography covers the entire lunar surface and that it is the correlation of a landform with a process that will enable us to extrapolate from a few landing sites to most of the moon.

Lunar Geophysics

There is no doubt that investigation of surface sites will never let us see >99% of the moon. Dr. M. T. Yates - Bellcomm/MAS described how the seismic signal is the only direct probe available to see that 99%. He stated that at first cut, the location of lunar seismometers is site independent but geometry dependent in that station spacings of $\sim$1000 km are desirable with good angular separation. Thus high latitude sites such as Tycho assume great importance.

Once the basic network requirements have been fulfilled ($\geq$ 4 active stations/network) geographic locations are of considerable interest, e.g., highland-mare contact zones and suspected tectonic regions.

The seismic data is expected to yield information on layering in the moon, rate of release of thermally induced strain and on the number and energy of meteorite impacts. In the absence of internal moonquakes, the meteorite impacts are expected to provide a prime source of seismic energy. Dr. Yates also pointed out the value of an S-IVB impact - the three spatial and one time coordinates are known, thus tremendously reducing the uncertainty in data interpretation.

Relative to heat flow, it was pointed out how that quantity bears on theories of hot vs. cold moons and lunar differentiation, and how it ties in with estimates of lunar radioactivity. Difficulties in interpretation are abundant - especially since a heat flow value does not uniquely determine T(r) - it does limit the models, however. It is important to obtain the early measurements from homogeneous regions and to correlate results with the geology.

An orbital vantage point appears well suited to study of lunar gravity and geodesy, especially in determining the extent of mascons and hydrostatic equilibrium. Such data will be supplemented by laser ranging to lunar surface reflectors. The preferred location of the reflectors, which actually enable one to measure physical librations, are at widely separated latitudes and longitudes.

Tidal gravimetry on the surface is expected to be a more sensitive method than on earth in providing an independent control on models derived from seismic information.

Recommended List of Reference Sites with Discussion

The Group for Lunar Exploration Planning (GLEP) recommended a prime set of sites to be used for the Lunar Exploration Program (see GLEP report below). Dr. F. El-Baz - Bellcomm/MAS, presented a summary of the salient characteristics of the recommended set and alternates preceded by the general requirement that a set of siees for the first phase (assuming 10 missions) should include:

1. The two types of mare material, "older" or "eastern" and "younger" or "western"
2. Regional stratigraphic units such as blanket (ejecta) deposits around mare basins
3. Various types and sizes of impact craters in maria and in highlands
4. Morphological manifestations of volcanism in maria and in highlands
5. Areas which may give clues to the nature and extent of processes, other than impact and volcanism, which may have acted upon the lunar surface.

A brief geological description of the 10 prime sites follows. The site locations are shown on a geologic map (Attachment D).

1. Landing Site 2 ("Older" or Eastern Mare)
   This site is located entirely within relatively old (Imbrian) mare material. There are many large subdued craters 200-600 m in diameter; the number of

intermediate size craters 50-200 m in diameter is fewer than on younger mare material in other sites. This crater distribution is common on many apparently old surfaces including the Imbrian blanket (Fra Mauro Formation). It may reflect a thicker layer of surficial debris in these areas of relatively old terrain so that intermediate size craters have an initially soft appearance and are rapidly destroyed. An alternative explanation is that a mantle of pyroclastics is present; some craters near the site may be volcanic and could be the source of the pyroclastics. Determination of the age and nature of mare material (Imbrian) is the prime object of a landing in this site; determination of whether or not pyroclastics are present will have application to many other areas with similar crater populations.

2. <u>Landing Site 5</u> (Younger or Western Mare)
This site is located within relatively young (Eratosthenian) mare material. In contrast to Landing Site 2, the area around this site displays a large number of intermediate size craters 50-200m in diameter and a small number of larger subdued craters 200-600m in diameter. The site is surrounded by well-developed Keplerian ray clusters.

Small, weakly-developed crater clusters and lineaments radial to Kepler occur within the site. Thus some material derived from depth at Kepler may be present in the surficial material and fine-scale textural details related to the Kepler rays may also be present. There are more resolvable blocks (> 2m) around craters than in the three sites to the east (Landing Sites 1, 2 and 3) suggesting that the surficial material is generally coarser grained and that the debris blanket is thinner. The chief goal of a landing in the site is determination of the age and composition of the Eratosthenian mare material.

3. Fra Mauro Formation

The site of the Fra Mauro Formation is in an extensive geologic unit covering great portions of the lunar surface around Mare Imbrium. Therefore a mission to this site would result in an understanding of the nature, composition, and origin of this widespread formation. The latter is interpreted as ejecta from Imbrium. An alternative to the Fra Mauro Formation, although in somewhat different terrain (the Cayley Formation), would be Hipparchus.

4. Rima Bode II

Rima Bode II is a single linear rille which runs close to a fresh, elongate crater and a crater chain. Both the rille and the crater are possible sources of a number of dark geologic units most probably of volcanic origin. Therefore, the site was selected as an example of a volcanic region where deep seated material is expected. The alternative to this site in Hyginus which displays very similar characteristics, but is less fresh-appearing. The aforementioned site of Littrow would meet part (sampling of the Sulpicius Gallus Formation) of the objectives of a mission to Rima Bode II.

5. Censorinus

Censorinus is a 3.8 km probable impact crater located within, but near the edge, of a highland block south-southeast of Mare Tranquillitatis. The proposed landing site is to the north of the crater within the ejecta blanket and about 1 km from the rim. The site offers a unique opportunity to sample, early in the lunar exploration plan, both highland material and features associated with a fresh impact crater. Censorinus is large enough to exhibit clear signs of impact, but small enough to be investigated on a foot traverse. If operational constraints indicate the impossibility of landing on the Censorinus ejecta blanket, the site of Littrow (where a fresh wrinkle ridge meets the Serenitatis

Bench and both are covered by dark mantling material) may be considered for the fourth landing.

6. Copernicus (peak)

The crater Copernicus is a bright rayed crater, up to 95 km in diameter, whose visible radial rays spread out distances of several hundred kilometers. The walls of the crater Copernicus expose a vertical section of about 4 km of the lunar crust. The floor, 60 km in diameter, is nearly circular, and contains a small, almost central, multiple peak, with large masses to the east and the west, where the highest peak rises 800 meters. These peaks may have brought to the surface material that once lay at considerable depth. A mission to the central peaks would be mainly a sampling mission, with some emphasis on structural relationships. Samples of large blocks on the peaks, of the floor material, and of the mounds on the floor would be of significance to the geochemistry of the moon.

7. Marius Hills

The Marius Hills are domes and cones near the center of Oceanus Procellarum, and west-northwest of the crater Marius, where isolated hills and clusters of hills rise above the mare surface and form part of a major north-south median ridge system that stretches irregularly for some 1900 km through Oceanus Procellarum. Many of the hills exhibit the convex upward shapes suggestive of terrestrial laccolithic instrusions; and some resemble terrestrial shield volcanos. The variety of these features and their similarity to terrestrial volcanic structures strongly suggests that the area has been subjected to intensive and prolonged volcanic activities.

8. <u>Tycho (rim)</u>

Tycho is also a fresh impact crater, in the southern highlands. However, it is much larger than Censorinus (about 85 km in diameter) and thus offers an opportunity of studying the many features common to large, fresh impact events, including associated volcanism. The vicinity of the landing site of Surveyor VII is the proposed landing site. In that area one encounters several generations of flows, a pond or pool, ejected blocks (probably from Tycho), other ejecta features and structures, and last but not least the Surveyor VII spacecraft.

9. Rima Prinz I

The Harbinger Mountains region of the moon includes numerous sinuous rilles and associated materials. The longest and, most probably, the youngest of the sinuous rilles in this area is Rima Prinz I. The latter is a double sinuous rille, i.e., a small meandering rille is enclosed within a larger sinuous rille. Sinuous rilles have aroused considerable interest because of the implications of the mode of their formation to the origin of the moon and its history. To study a sinuous rille, one must get down to the valley floor to sample the material and examine the displayed structures. Rima Prinz I was selected because of the freshness of its details. A landing near the mouth or terminus of the rille would allow an examination of the lower part of the eroded valley. The alternative to Rima Prinz I is Schröter's Valley which displays very similar characteristics, but appears older than Rima Prinz I.

10. Descartes

The area of the southern highlands north of the crater Descartes is characterized by hilly, groovy, and furrowed deposits. It is bound on the west by a hilly and pitted stratigraphic unit and on the east by rugged hills which bound Mare Nectaris. The Descartes region, which is very similar to an area to the west and northwest of Mare Humorum, is thought to include a distinctive pattern of morphological manifestations of volcanism in the lunar terrae. Many of the elongate grooves and furrows are reminiscent of terrestrial volcanos. It is believed that a mission to a region of intensive and prolonged volcanism within the lunar terrae is most important, from both the geological and geochemical viewpoints. An alternative to this site would be Abulfeda.

Background on Derivation of Reference Site List - GLEP Report

Dr. N. W. Hinners - Bellcomm/MAS presented the recommendations of the Group for Lunar Exploration Planning (GLEP). These recommendations arose from the June 17 meeting of the GLEP Site Selection Subgroup at MSC.

The first recommendation was that Descartes, an upland volcanic site representative of large areas of the highlands, be added to Set B. Hinners pointed out that this proposed addition is a direct result of study of the Orbiter photography. He also noted that the low resolution ($\sim$40 meters) requires that additional photography be obtained before landing at the site. The ASSB approved inclusion of Descartes in Set B.

It was next pointed out that Set B lacks a caldera-type site and that the GLEP is considering such for possible future inclusion in Set B. Their preliminary caldera sites include, in priority order,

a. Gaudibert

b. Lassell

c. Gambart

Ritter/Sabine

The priority arises from the seismic net considerations which put greater emphasis on higher latitude sites.

A second recommendation was that a formal mechanism be established to ensure adequate consideration of candidate site photography. The GLEP feels that simply including such as targets-of-opportunity does not lead to getting the job done. This is particularly true for those missions prior to Apollo 16 and institution of the CSM science. Capt. Scherer noted that General Phillips has given him an action item to resolve the problem.

A list of the current candidates for further photography is shown in Attachment E.

The GLEP recommendations for a mission assignments follows:

G-1	Site 2
H-1	Site 5 (or 4) (1)
H-2	Fra Mauro Fm.
H-3	Rima Bode II (2)
H-4	N to W of Censorinus
J-1	Copernicus Peaks
J-2	Marius Hills (3)
J-3	Tycho Rim (3)
J-4	Rima Prinz I
J-5	Descartes

Site Assignment Alternates:

Science Alternates:

a. Hyginus - meets some objectives of Rima Bode II and Fra Mauro Fm.

b. Littrow - meets some objectives of Rima Bode II. Should not be considered after H-3.

c. Hipparchus - meets some objectives of Fra Mauro Fm. Should not be considered after H-2.

d. Abulfeda - meets some of Descartes objectives. Consider for J-2 → J-5 missions.

e. Schröter's Valley - meets many of Rima Prinz I objectives. Consider for J-2 → J-5 missions.

Recycle Alternates:

G-1 Sites 3, 5.

H-1 Site 3, Assuming G-1 lands at site 2; Site 2 if G-1 lands at Site 3.

H-2 Sites 4R and 6R

Hinners noted that the list was derived considering the expected evolution in capability and also considering constraints imposed by operations. For example, the J-missions are better for the J-sites in terms of number of EVA's and mobility. Tycho is accessible only in the early part of the year so it had to be switched from J-2 to J-3 even though it is a better non-mobility mission than Marius Hills. Descartes has been placed last in order to obtain the needed photography on either the J-2 or J-3 mission.

Considerable discussion followed at this point and throughout the remainder of the meeting. It can best be summarized by Gen. Phillips' comments that he feels the list is well thought out, scientifically, and that it is time that the list settles down. It was generally agreed that on the second mission we would not be ready to give up recycle and that either Site 3 or Site S-III would be included as a prime target (see Introduction by Scherer). Gen. Phillips stressed that in the next month he would like STAC, the LPMB, and Management Council to have an opportunity to hear the presentation and discuss the merits of the Reference Sites.

The GLEP list was approved as a list to be used for planning purposes. MSC (O. E. Maynard) was given an action item to report back next month on the mission planning aspects of the list. Consideration should be given to the possibilities of using the prime science sites in a recycle mode. Considering the possibility that we may fly to certain sites with a high chance of abort before landing, MSC should look at what kind of orbital mission might be accomplished if such an event were to occur.

Differences Among Apollo Sites as Evidenced by Recent Remote Sensing Data

Dr. A. F. H. Goetz Bellcomm/MAS reported results of a recent remote sensing study of the Apollo Prime Sites conducted by himself and co-investigators at Caltech. Using the 24" and 60" Mt. Wilson telescopes they found that:

1. The Apollo sites differ significantly from each other in spectral reflectivity (0.4 → 1.1μ) but these differences do not include the variety evidenced over the moon as a whole, nor even just over the mare regions. Compositional differences can be inferred independent of age and/or texture effects. Differences in composition observed probably reflect differences in minor constituents or valence state (e.g., Fe^{++} vs. Fe^{+++}).
2. The Apollo sites do not differ significantly from each other in spectral emissivity (8.2 → 13.4μ) and are indistinguishable from the great preponderance of the lunar surface in that regard. However, Plato (and a previously studied locality in Mare Humorum) does differ significantly from the rest of the lunar surface.

The small lunar reflectivity differences found in this study can be explained as the result of differences only in minor constituents, or even only in relative valence state of iron, whereas emissivity differences imply differences in Si/O coordination number and, therefore, in major constituent abundances. Thus, the surface materials of the Apollo sites can be regarded as probably representative of the general lunar surface in average Si:O ratio, and representative as well of much of the Mare areas in minor element abundance or iron oxidation level. Apollo Site

4 (III P-II) and 5 (II P-13) appear to be the most similar to one another, Apollo Sites 1 (II P-2) and 3 (II P-8) clearly differ from those two but show similarity to each other in the visible; Apollo Site 2 (II P-6) is most distinctive. Sampling one site from each of these three groups would be sufficient to ascertain the maximum compositional variations represented by the five sites. If only two sites were to be visited, then Apollo 2 and one western site may represent the best strategy, based on these inferred compositional differences.

Preliminary Photographic Guidelines for Lunar Exploration Sites and Requirements for Additional Lunar Exploration Photography

Mr. J. H. Sasser - MSC presented preliminary photographic requirements for the exploration sites. These are:

HR (<4 m) Stereo of 3Σ ellipse (1 m Apollo)

MR (<30 m) Stereo of 3Σ ellipse (8 m Apollo)

MR (<30 m) Stereo of 70 nm approach (8 m Apollo)

If the above were to be accepted as the requirements, all prime sites and science alternates require further HR stereo photography and all except Censorinus require MR stereo (Sasser noted that on account of albedo and slope variations, photometric reduction techniques are not expected to be useful).

With regard to obtaining boot-strapping photography, an MSC analysis of Site 2 Orbiter and Apollo 10 Command Module photography showed that from 60 nm the 250 mm lens provides photo coverage equivalent to Orbiter MR photography and that

80 mm appears suitable for stereo analysis. MSC also concluded that Site S-III on H-1 provides better opportunities for boot-strap photography than Sites 3 or 5. Along these lines Mr. O. E. Maynard - MSC presented preliminary data on photographic coverage of exploration sites assuming various H-1 landing sites, various times for photography and in some cases a 500 fps plane change after LM rendezvous. A more complete report will be made at a subsequent ASSB meeting.

Considerations for Lunar Afternoon Landings

At the last ASSB meeting MSC was given an action item to investigate the potential for using afternoon landings as a means of having a recycle opportunity to a single site. Mr. J. P. Loftus - MSC reported that MSC considered the problem from many aspects:

1. Lunar surface visibility

   The PM sun elevation range would be greater than for AM landings. The non-uniformity of windows and multiple cabin reflections are expected to degrade visibility although external sunshades might alleviate the problem.

2. Ascent stage thermal control

   Asymmetrical thermal properties of the AS lead to potentially unacceptable cabin temperatures for a landing into the sun.

3. The proposed solar array for the extended LM will be mounted on the -Z side of the LM and must of

course be oriented into the sun (it is currently assumed that the array will be deployed automatically).

4. Descent/Ascent Guidance/LOI-TEI Performance

   Both 2 and 3 might be alleviated by a 180° yaw maneuver just before touchdown. The ΔV penalty is ∿100 fps (18 seconds hover). The ascent yaw penalty is ∿40 fps or 8 sec. More critical, perhaps, is a ΔV penalty of up to 1000 fps for high latitude sites occasioned by non-optimum PM launch geometry at a given site.

5. S-band communications

   It appears that there is increased S-band communications blockage for the maneuvers considered for the PM landings.

The MSC conclusion and recommendation was that the consideration of the afternoon landings be dropped. General Phillips concurred.

Summary of Action Items

The MSC (O. E. Maynard) will conduct mission planning and other analysis to determine the actions necessary to conduct the Apollo Lunar Exploration missions to the set of sites approved for planning purposes.

ATTACHMENT A

APOLLO SITE SELECTION BOARD
AGENDA
July 10, 1969

I. DEVELOPMENT OF REFERENCE SITE LIST

A. Purpose and General Introduction

D. U. Wise - HQ/MAL — 10 mins.

B. Broad Scientific Problems and Specific Sites

1. Age Dating

D. U. Wise - HQ/MAL — 20 mins.

2. Composition

N. W. Hinners - Bellcomm/MAS — 30 mins.

3. Major Geomorphic Processes

D. U. Wise - HQ/MAL — 15 mins.

4. Bulk Geophysics

M. T. Yates - Bellcomm/MAS — 30 mins.

C. Recommended List of Reference Sites with Discussion

F. El-Baz - Bellcomm/MAS — 60 mins.

D. Background on Derivation of Reference Site List - GLEP

N. W. Hinners - Bellcomm/MAS — 15 mins.

II. DIFFERENCE AMONG APOLLO SITES AS EVIDENCED BY RECENT REMOTE SENSING DATA

A. F. H. Goetz - Bellcomm/MAS — 15 mins.

III. PRELIMINARY PHOTO GUIDELINES FOR LUNAR EXPLORATION SITES

J. H. Sasser - MSC — 15 mins.

IV. REQUIREMENTS FOR ADDITIONAL LUNAR EXPLORATION PHOTOGRAPHY

J. H. Sasser - MSC — 15 mins.

V. CONSIDERATIONS FOR LUNAR AFTERNOON LANDINGS

J. P. Loftus - MSC — 15 mins.

Added Item: "Bootstrap" Orbital Photography of Exploration Sites

O. E. Maynard - MSC

Board Members Present

Lt. General S. C. Phillips, MA, Chairman
Capt. L. R. Scherer, MAL, Secretary
Mr. Owen E. Maynard, MSC
Dr. Wilmot N. Hess, MSC
Maj. General John D. Stevenson, MO
Dr. Donald U. Wise, MAL
Dr. Ernst Stuhlinger, MSFC

Board Members Absent

Mr. John Disher, ML
Adm. Roderick O. Middleton, KSC
Mr. Oran W. Nicks, SD
Mr. John D. Hodge, MSC

Other Attendees

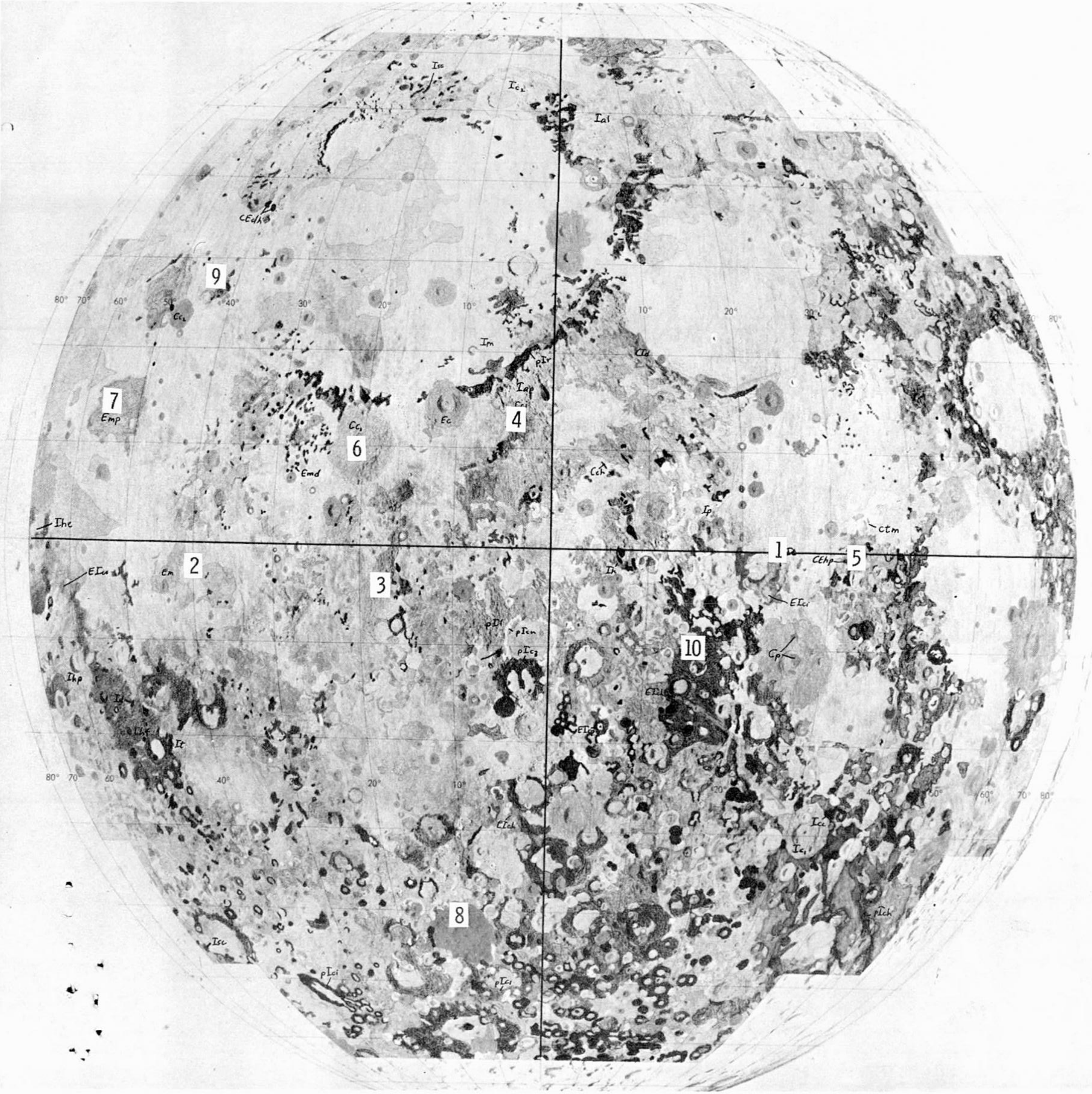
E. M. Davin, NASA HQ/MAL
R. J. Green, NASA HQ/MAL
U. Liddel, NASA HQ/MAL
W. T. O'Bryant, NASA HQ/MAL
J. K. Holcomb, NASA HQ/MAO
E. W. Land, Jr., NASA HQ/MAO
D. R. Anselmo, Bellcomm/MAS
R. A. Bass, Bellcomm/MAS
C. Bidgood, Bellcomm/MAS
A. P. Boysen, Jr., Bellcomm/MAS
F. El-Baz, Bellcomm/MAS
A. F. H. Goetz, Bellcomm/MAS
J. W. Head, Bellcomm/MAS
N. W. Hinners, Bellcomm/MAS
V. S. Mummert, Bellcomm/MAS
P. F. Sennewald, Bellcomm/MAS
A. W. Starkey, Bellcomm/MAS
R. Troester, Bellcomm/MAS
M. T. Yates, Bellcomm/MAS
J. I. Kistle, NASA HQ/MAT
D. L. Winterhalter, NASA HQ/MAT
R. L. Wetherington, NASA HQ/MAT
R. E. Moser, KSC/LO-PLN
D. Spencer, KSC/AP
J. H. Suddath, MSC/EG
C. R. Huss, MSC/FM
J. P. Loftus, MSC/HA
J. A. McDivitt, MSC/PA
C. H. Glancy, MSC/PD
C. H. Perrine, MSC/PD
L. C. Wade, MSC/TJ
J. H. Sasser, MSC/TJ
J. E. Blahnik, TRW/Houston
H. Masursky, USGS

SET B SITES

SITE	SITE DESCRIPTION	GEOLOGY AND GEOCHEMISTRY								
		AGE DATING				COMPOSITION				
		"ORIGINAL CRUST"	TIME OF GIANT IMPACTS	MARE FLOODING	POST-MARE TIME SCALE	PRIMITIVE ROCKS	DEEP-SEATED ROCKS	DIFFERENT-IATED ROCKS	TRANSIENT EVENTS	ATMOSPHERE
CENSORINUS	SMALL, FRESH IMPACT CRATER IN HIGHLANDS.	?	?		*	*			?	
FRA MAURO FORMATION	BLANKET EJECTA MATERIALS SURROUNDING MARE IMBRIUM	?	*			*	*			
MOSTING C	SMALL FRESH IMPACT CRATER IN MARE			*	*					
LITTROW	MARE RIDGE AND VERY DARK (VOLCANIC?) MATERIAL AT EDGE OF MAJOR MARE BASIN.			*				?	?	?
ABULFEDA	VOLCANIC(?) CRATER CHAIN AND ASSOCIATE MATERIALS IN THE SOUTHERN HIGHLANDS.	?				?	*	?		
HYGINUS	LINEAR RILLE AND ASSOCIATED CRATER CHAIN SOUTH OF MARE VAPORUM.		?	*	*		*	?	?	?
RIMA BODE II	LINEAR RILLE, ELONGATE CRATER, AND ASSOCIATED MATERIAL.			*	*		*	?		?
TYCHO	RIM OF VERY YOUNG LARGE RAYED IMPACT CRATER IN SOUTHERN HIGHLANDS.	?			*	?	*	?	?	
SCHROTER'S VALLEY	LARGE SINUOUS RILLE WITH SMALLER MEDIAN RILLE, ORIGINATING IN "COBRA HEAD".				*		*	?	*	*
ARISTARCHUS PLATEAU	COMPLEX OF VOLCANIC(?) CONES, DOMES, CRATER CHAINS, AND RILLES			?	*			?	*	*
GASSENDI	CRATER WITH A COMPLEX OF LINEAR AND SINUOUS RILLES AND MARE FLOODING			*	*				*	*
ARISTARCHUS	A YOUNG LARGE IMPACT CRATER				*			?	*	*
DIONYSIUS	A BRIGHT RIMMED CRATER WITH ALTERNATING LIGHT AND DARK RAYS.				*				?	
S. ALEXANDER	A COMPLEX OF DOMES, SCARPS, AND RILLES IN THE HIGHLANDS NEAR A MAJOR MARE BASIN	?	*	*		?				
TOBIAS MAYER DOME	A DOME, SINUOUS RILLE AND HIGHLAND RIDGES	?		*	?					?
COPERNICUS C D	DARK MANTLING MATERIAL AND DOMES ON COPERNICUS EJECTA AND SECONDARIES.				*		?	?		
MARIUS HILLS	COMPLEX OF VOLCANIC(?) DOMES, CONES, MARE RIDGES AND SINUOUS RILLES.			?	*		*	*	?	*
HADLEY-APENNINES	YOUNG SINUOUS RILLE AND APENNINE MOUNTAIN FRONT AT EDGE OF MARE IMBRIUM	?	*	*	*	*	*			*
ALPHONSUS	DARK HALO CRATER, RILLES, AND FAULTS AT THE EDGE OF A LARGE CRATER FLOOR.	?					?	?	*	*
COPERNICUS PEAK	CENTRAL PEAKS OF A LARGE IMPACT CRATER	?			*	?	*	?		
COPERNICUS WALL	WALL OF A LARGE IMPACT CRATER.	?			*		*			
RIMA PRINZ I	A YOUNG DOUBLE SINUOUS RILLE WITH ACCESS TO THE RILLE MOUTH			*	?		?			*
HIPPARCHUS	OLD CRATER WITH BASIN FILL									
DESCARTES	AN AREA OF PROBABLE VOLCANISM IN A HIGHLAND TERRAIN.				?	?	?	*		

SITE	MAJOR PROCESS INDICATORS									
	CRATERING			TRANSPORT			VOLCANIC/TECTONIC			
	IMPACT	VOLCANIC	CHAIN	RILLE	EJECTA	GRAVITY FLOW AND SLUMP	FAULT	DOME	FLOWS	RIDGES
CENSORINUS	*				*					
FRA MAURO FORMATION	*				*					
MOSTING C	*				*	?				
LITTROW	*			*					*	*
ABULFEDA		*	*	?	*		?		*	
HYGINUS		*	*	*			?	*	*	
RIMA BODE II		*	*	*	*		*		*	
TYCHO	*				*				*	
SCHROTER'S VALLEY		?		*	*	*				
ARISTARCHUS PLATEAU		*		*				*	*	
GASSENDI	*	*		*	*	?	*		*	*
ARISTARCHUS	*	?			*	*	*			
DIONYSIUS	*				*	*				
S. ALEXANDER	*	?			?		*	*	*	
TOBIAS MAYER DOME		?	*	*	*			*		
COPERNICUS C D	*	*	?					*	*	
MARIUS HILLS		*		*				*	*	*
HADLEY-APENNINES	*			*		*	*			
ALPHONSUS	*	*		*		*	*		*	
COPERNICUS PEAK	*	?				?		*	?	
COPERNICUS WALL	*	?				*	*		?	
RIMA PRINZ I				*		*				
HIPPARCHUS	?	?				*				
DESCARTES		*					?	*	*	*

SITE	GEOPHYSICS					
	SEISMOLOGY					
	AZIMUTHAL DEPENDENCE	SEISMICITY -TECTONIC	ACTIVE SEISMIC	GRAVITY	GEODESY	HEAT FLOW
CENSORINUS	*			*	*	
FRA MAURO FORMATION						*
MOSTING C	*			*		
LITTROW	*	*	*			
ABULFEDA		*				
HYGINUS		*	*			
RIMA BODE II		*	*			
TYCHO			*	*	*	
SCHROTER'S VALLEY		*	*			*
ARISTARCHUS PLATEAU		*				
GASSENDI	*	*				
ARISTARCHUS		*				*
DIONYSIUS	*					
S. ALEXANDER	*					
TOBIAS MAYER DOME			*			
COPERNICUS C D						
MARIUS HILLS		*	*	*	*	*
HADLEY-APENNINES	*	*	*			
ALPHONSUS	*	*				
COPERNICUS PEAK			*			
COPERNICUS WALL						
RIMA PRINZ I			*			
HIPPARCHUS						*
DESCARTES						



MISSION ASSIGNMENTS

1. LANDING SITE 2
2. WESTERN MARE
3. FRA MAURO FORMATION
4. RIMA BODE II
5. CENSORINUS (NORTHWEST)
6. COPERNICUS (CENTRAL PEAKS)
7. MARIUS HILLS
8. TYCHO (NORTH RIM)
9. RIMA PRINZ I
10. DESCARTES

GEOLOGIC UNITS

	MARE	TERRA
COPERNICAN		
ERATOSTHENIAN		
IMBRIAN		
PRE-IMBRIAN		

ATTACHMENT E

CANDIDATES FOR FURTHER PHOTOGRAPHY

SET B SITES	ORBITER REFERENCE	
MOSTING C	III	S-18
ABULFEDA	V	V-19
RIMA HADLEY	V	V-26
COPERNICUS CD	V	V-33
CENSORINUS	V	V-12
OTHERS		
GAMBART	I	S-13
GAMBART C	II	S-10.2
MOSTING	III	S-16
HEVELIUS	III	S-31
GAUDIBERT	IV	FRAME 72
RITTER/SABINE	IV	FRAME 85
POSIDONIUS	IV	FRAME 86
DESCARTES	IV	FRAME 89
BOSCOVICH	IV	FRAME 97
DAVY	IV	FRAME 108
LASSELL	IV	FRAME 113
DAWES	V	V-15.1
VITELLO	V	V-41

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MSC-TJ/L. C. Wade
KSC-LO-PLN/R. E. Moser
KSC-LO-PLN-3/C. B. Netherton
USGS/H.Masursky
USGS/E. M. Shoemaker

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C. R. Huss

CPMS 7-336

Done - 8/15/69

PACE
GURLEY
BENNETT
MURRAH
ELK
JENNESS
BERRY
BABB
R. ROSE
(J. DREYFUS TRW)
MAYER
TINDALL
BROWN
PARTEN
OWEN

RECOMMENDED LUNAR EXPLORATION SITES

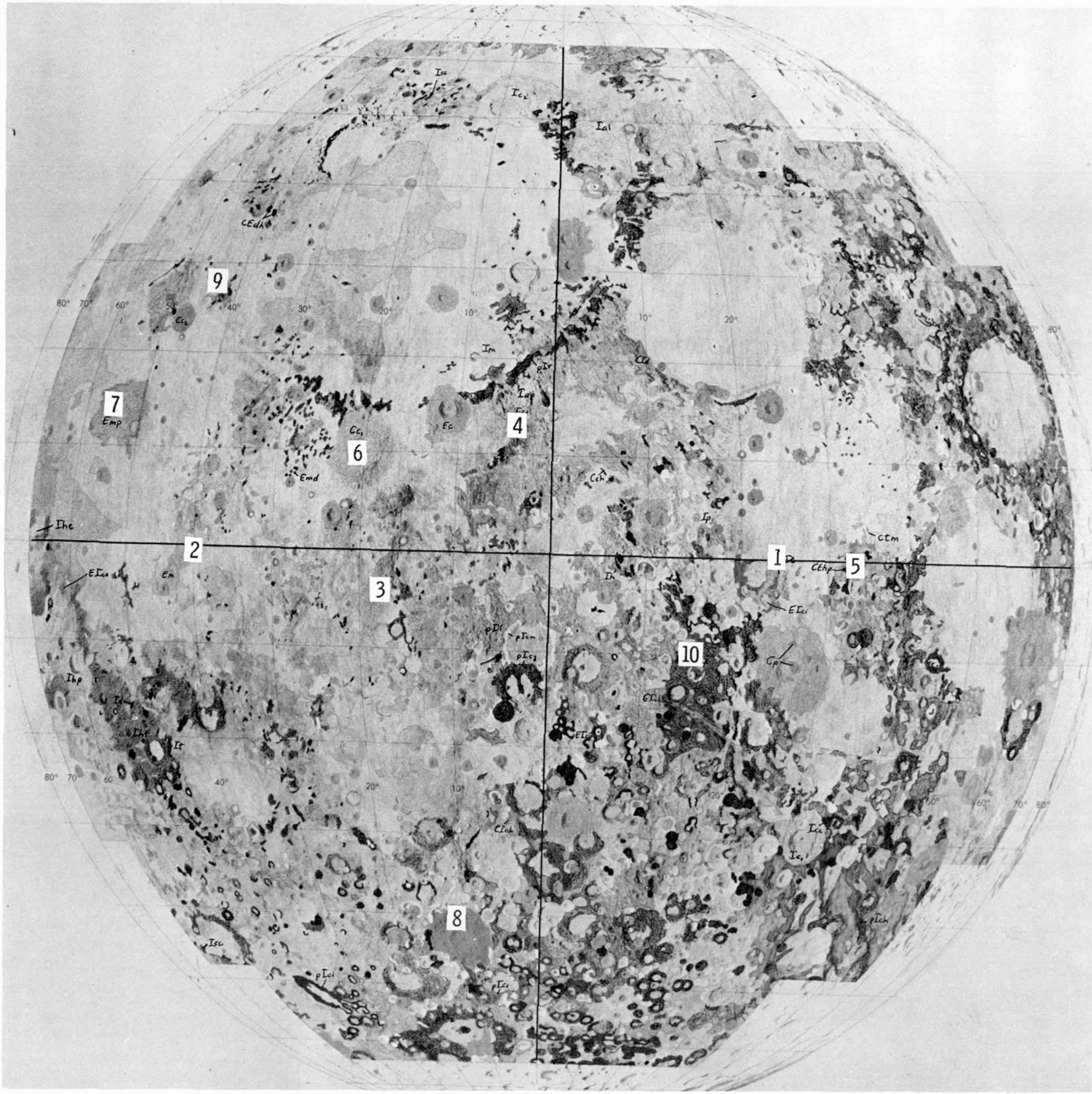
(Apollo II through Apollo 20)

Presented to the

Apollo Site Selection Board

July 10, 1969

FAROUK EL-BAZ/MAS



MISSION ASSIGNMENTS
(BASED ON ACCESSIBILITY)

1. LANDING SITE 2
2. WESTERN MARE
3. FRA MAURO FORMATION
4. RIMA BODE II
5. CENSORINUS (NORTHWEST)
6. COPERNICUS (CENTRAL PEAKS)
7. MARIUS HILLS
8. TYCHO (NORTH RIM)
9. RIMA PRINZ I
10. DESCARTES

GEOLOGIC UNITS

	MARE	TERRA
C		
E		
I		
P		

GEOLOGICAL PROBLEMS OF THE MOON

A. MAJOR SURFACE UNITS

I. MARE MATERIALS

EASTERN (IMBRIAN) MARE
WESTERN (ERATOSTHENIAN) MARE
SULPICIUS GALLUS FORMATION

II. HIGHLAND MATERIALS

RUGGED TERRA MATERIAL
BLANKET (EJECTA) DEPOSITS
OLD BASIN FILL
OLD (PITTED) PLAINS

B. MAJOR PROCESSES

I. CRATERING

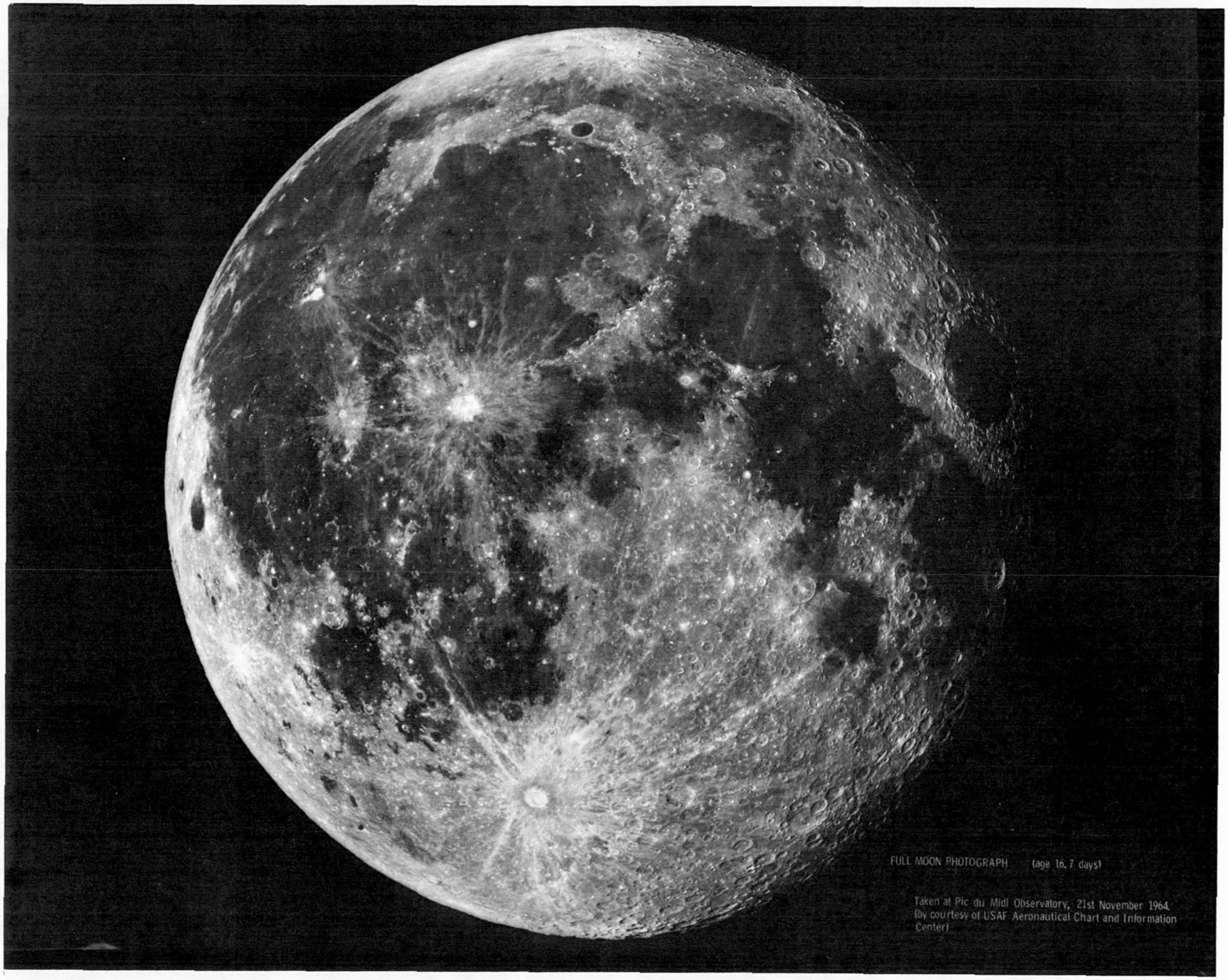
SMALL MARE CRATERS
SMALL IMPACT CRATERS
LARGE IMPACT CRATERS
OLD (REBOUND) CRATERS
COLLAPSE CRATERS
CRATER CHAINS (MAARS)
VOLCANIC CALDERAS

II. VOLCANISM

INTRUSIVE
EXTRUSIVE
- DOMES AND CONES
- FLOWS AND RIDGES

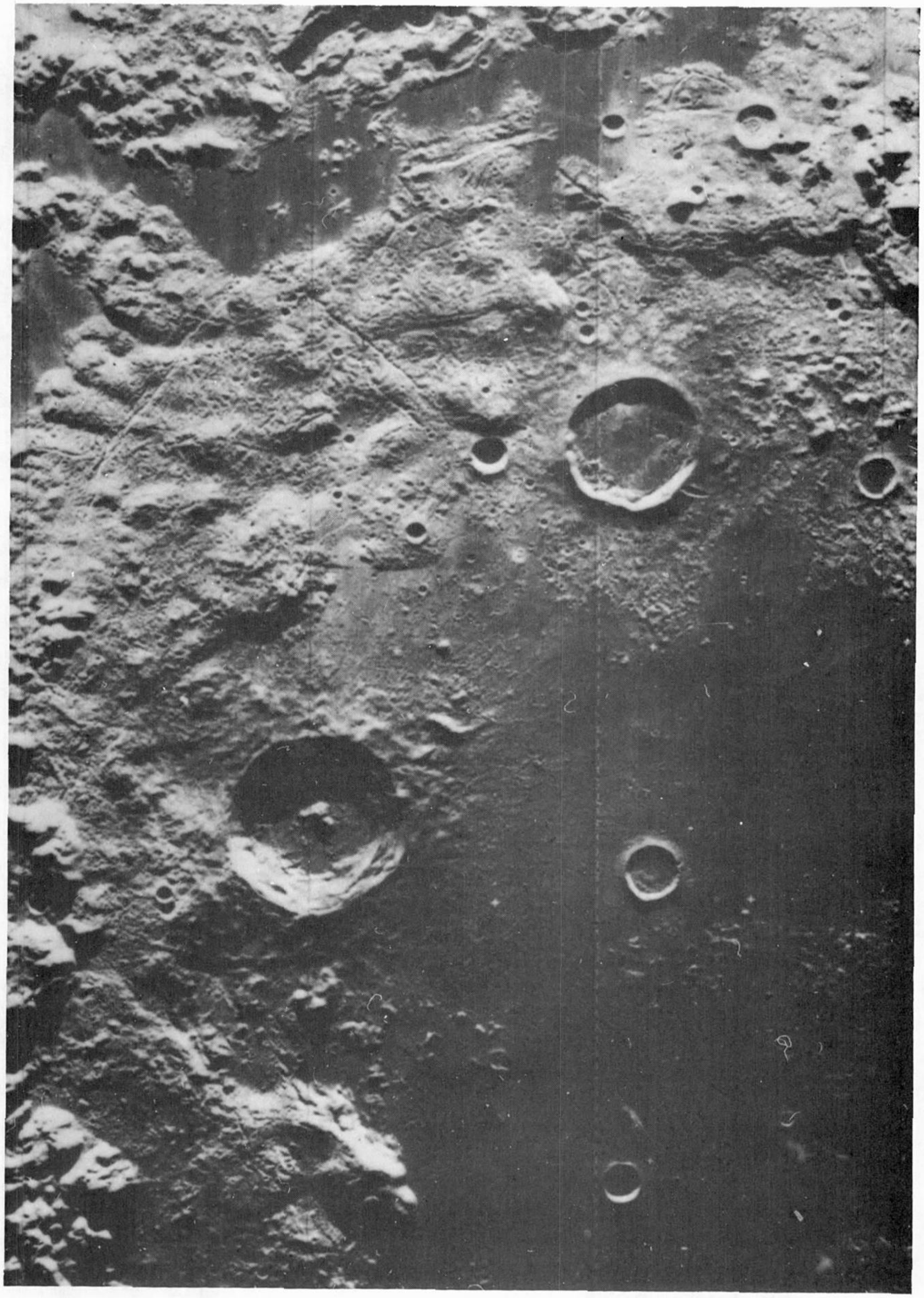
III. OTHER PROCESSES

EROSION AND DEPOSITION
FAULTING AND COLLAPSE
SLUMPING AND MASS WASTING



FULL MOON PHOTOGRAPH (age 16.7 days)

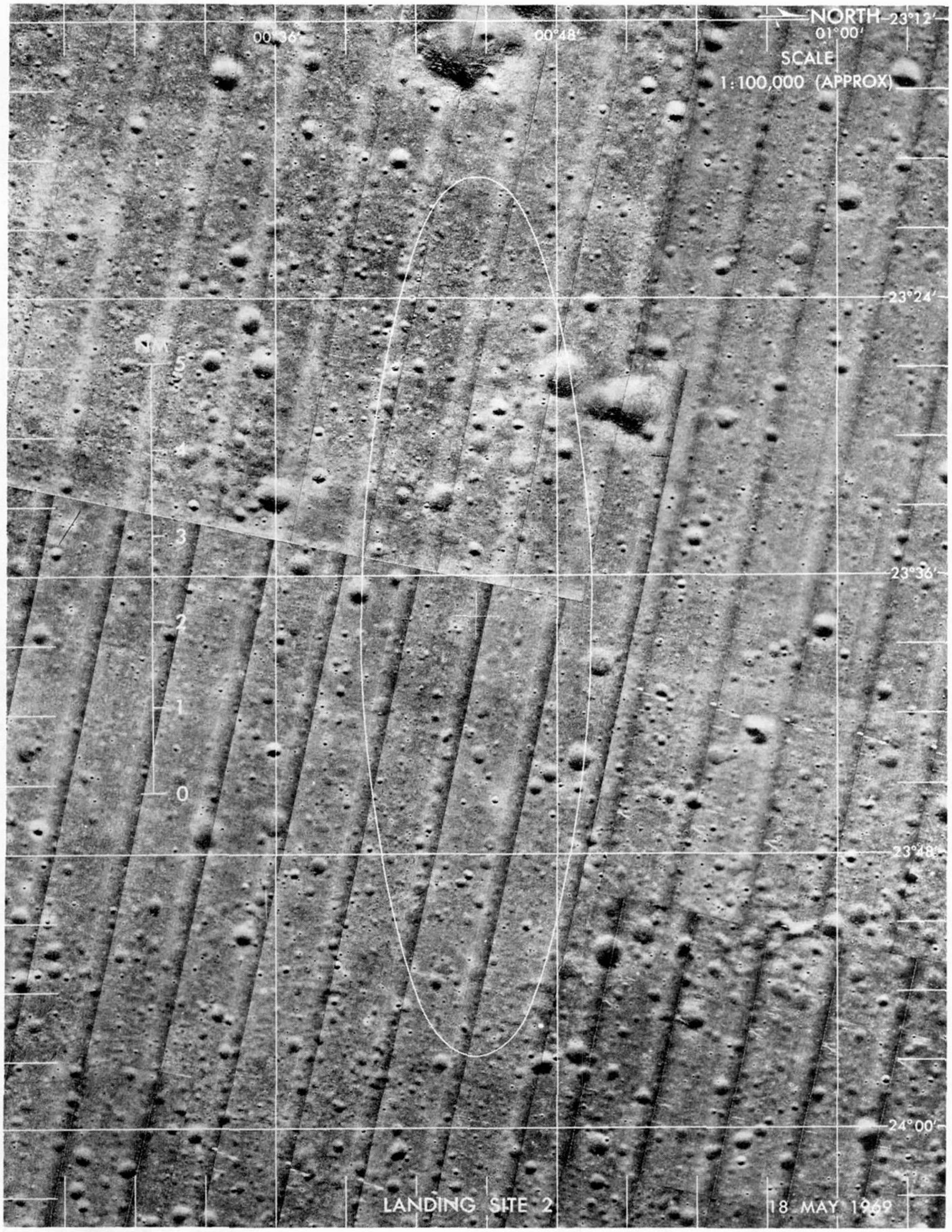
Taken at Pic du Midi Observatory, 21st November 1964.
(by courtesy of USAF Aeronautical Chart and Information Center)



MISSION ASSIGNMENTS
(BASED ON ACCESSIBILITY)

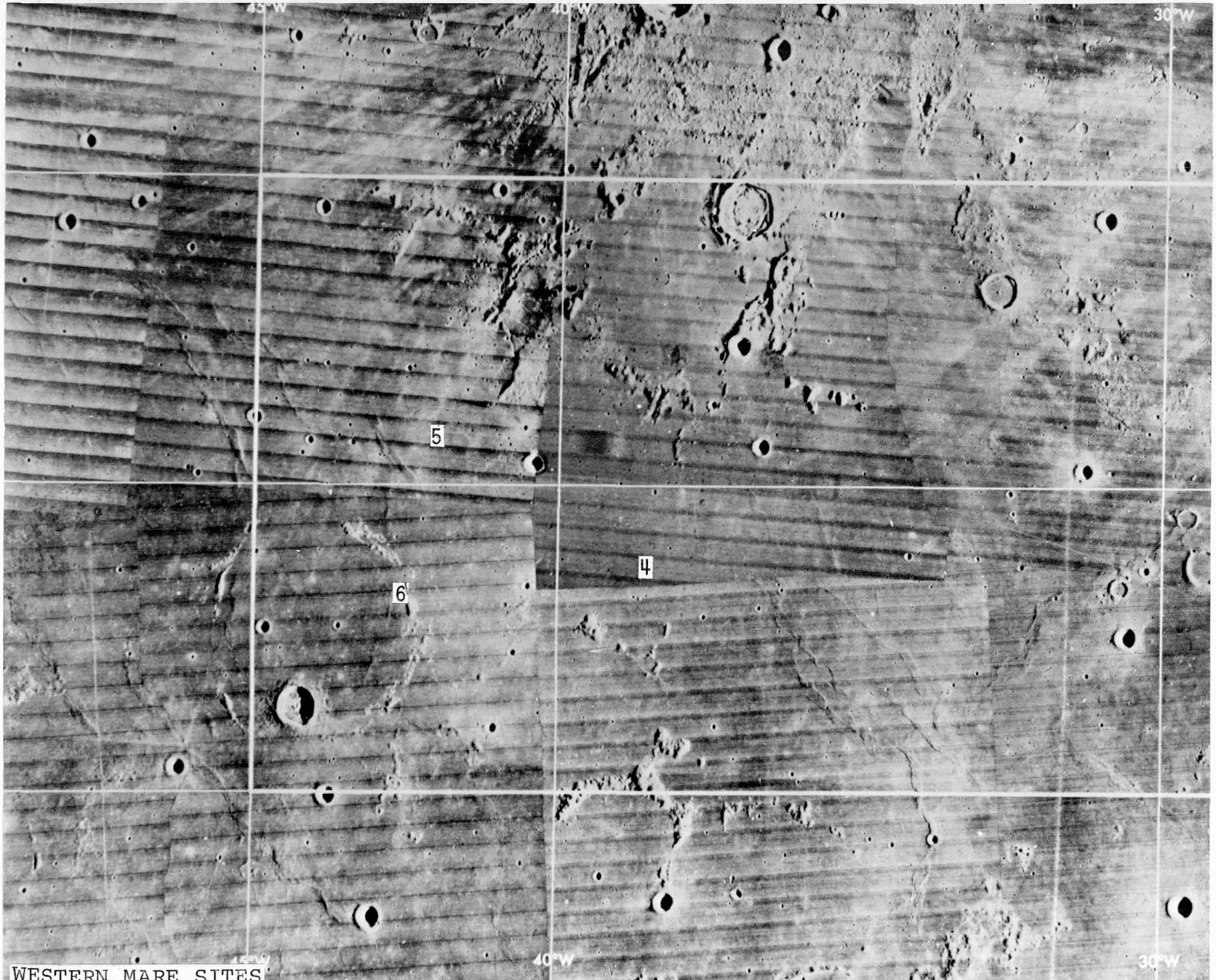
NO	APOLLO	MISSION	SITE
1	11	G-1	LANDING SITE 2
2	12	H-1	WESTERN MARE
3	13	H-2	FRA MAURO FM.
4	14	H-3	RIMA BODE II
5	15	H-4	CENSORINUS (NW)
6	16	J-1	COPERNICUS (PEAKS)
7	17	J-2	MARIUS HILLS
8	18	J-3	TYCHO (NORTH RIM)
9	19	J-4	RIMA PRINZ I
10	20	J-5	DESCARTES

6

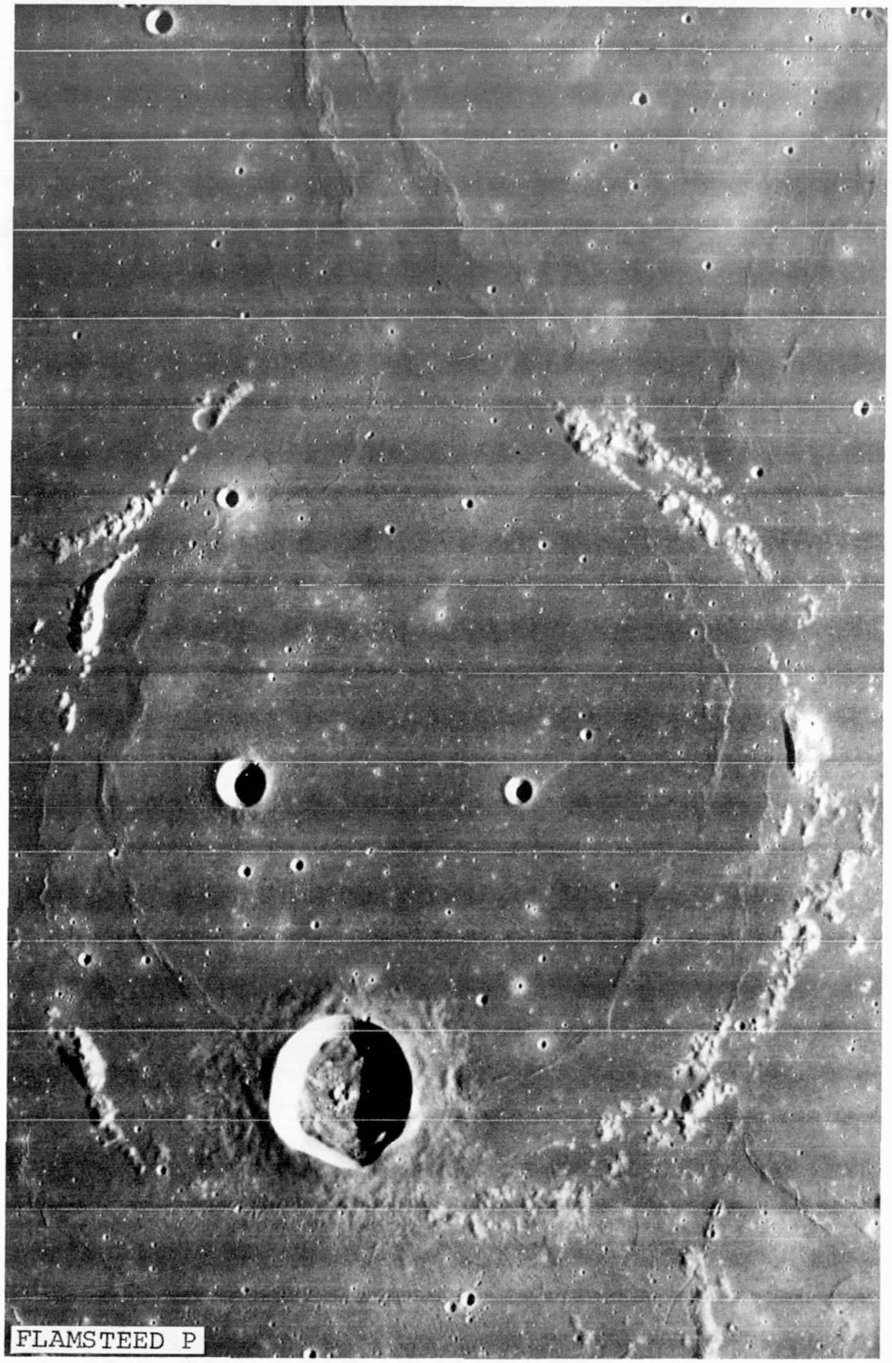

NORTH
23°12'
00°36'
00°48'
01°00'
SCALE
1:100,000 (APPROX)
23°24'
NM
5
4
3
2
1
0
23°36'
23°48'
24°00'
LANDING SITE 2
18 MAY 1969

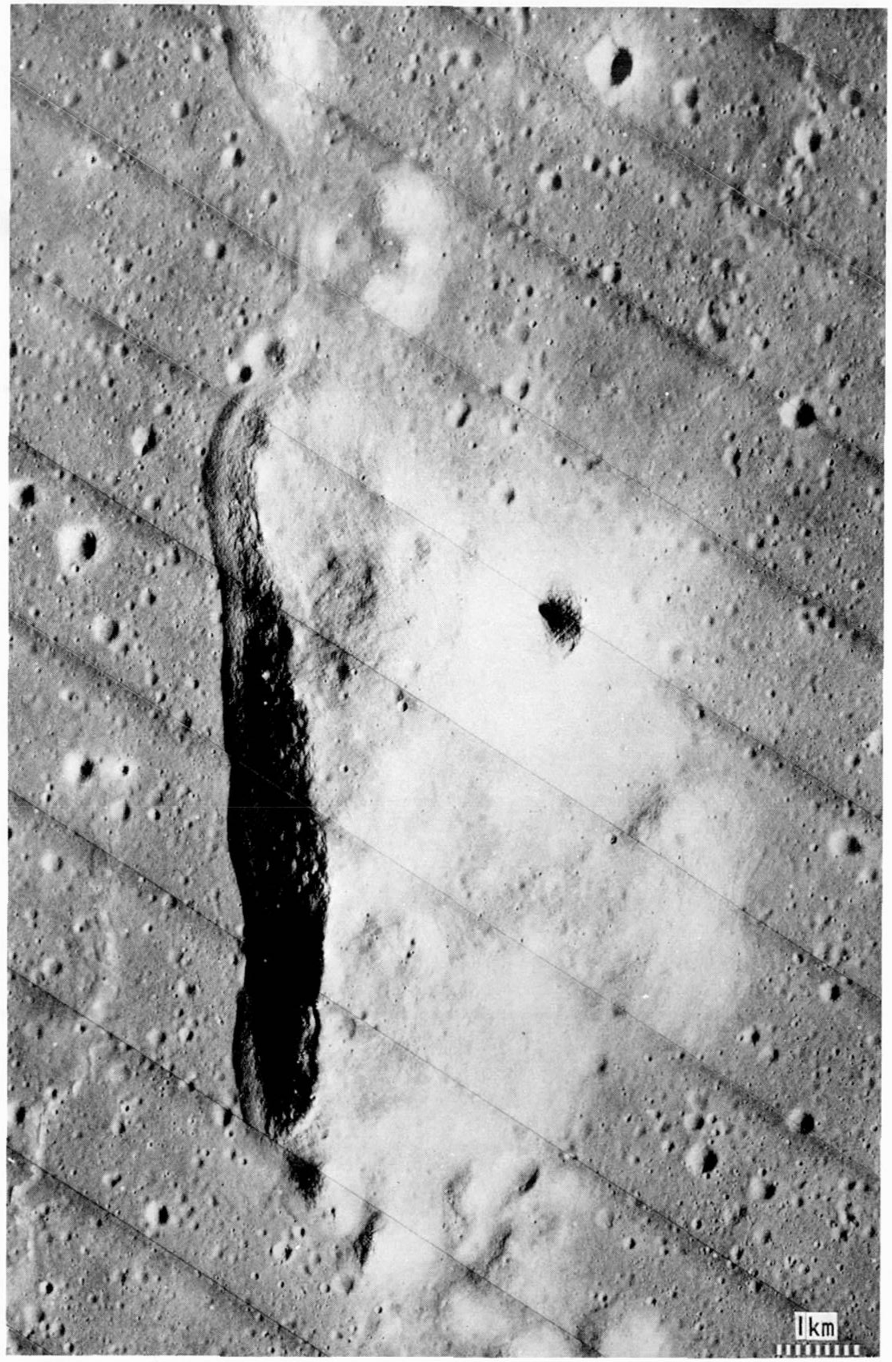
EASTERN VERSUS WESTERN MARE

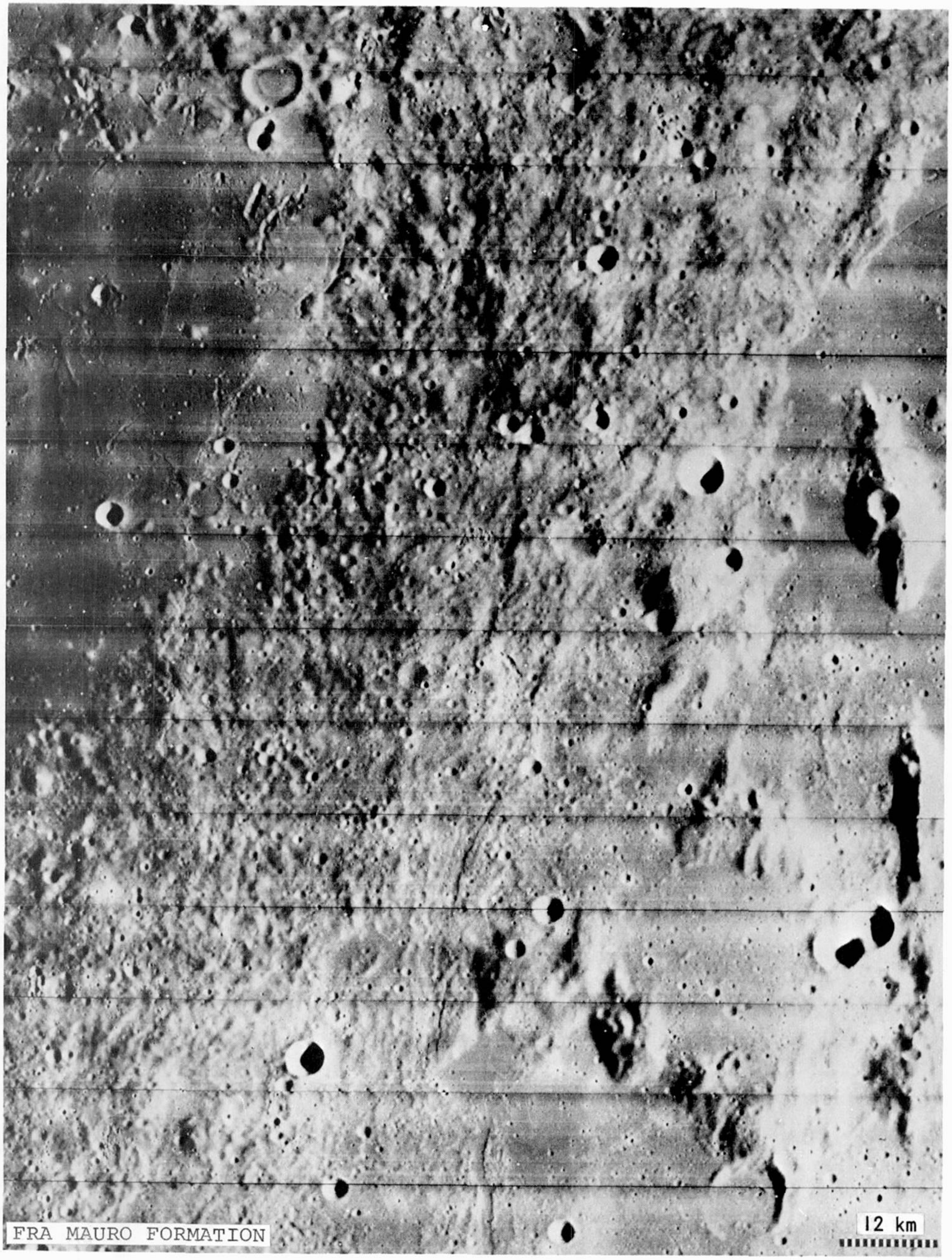
SITE	LANDING SITE 2	SITES 4, 5 OR 6
COLOR	BLUER	BLUE
CRATERS	SUBDUED	SHARP
REGOLITH	THICK	THIN
AGE	IMBRIAN	ERATOSTHENIAN

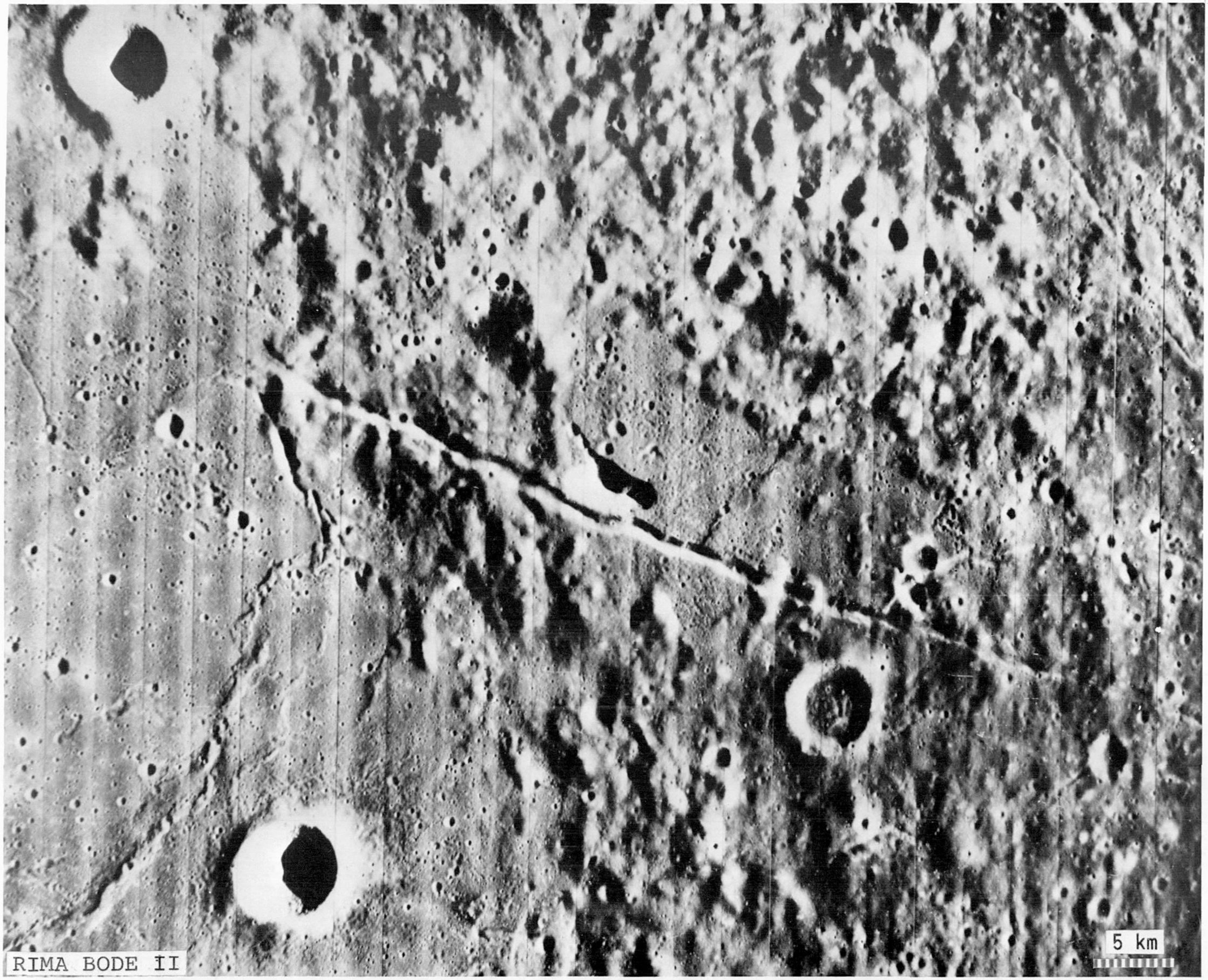


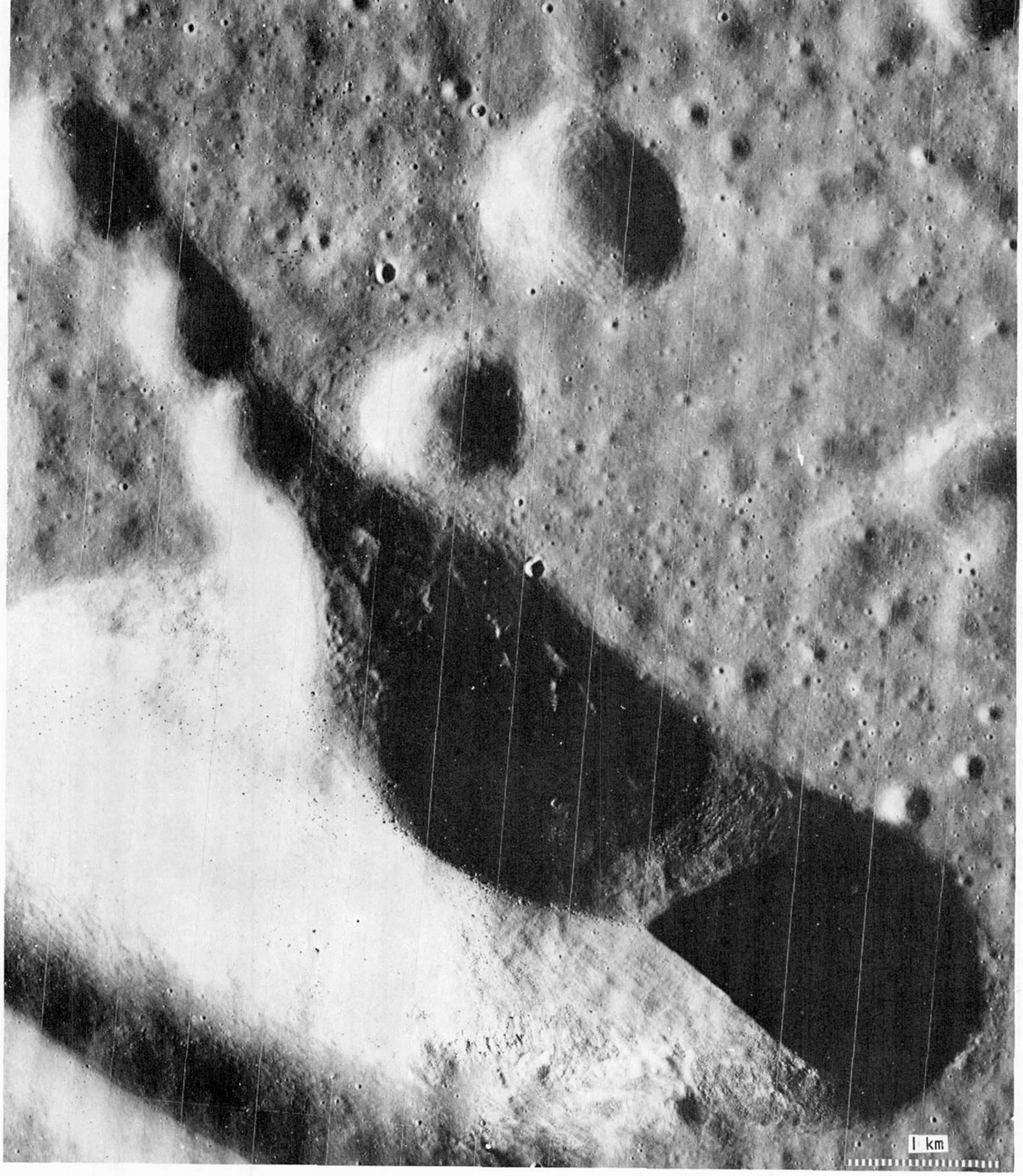
WESTERN MARE SITES

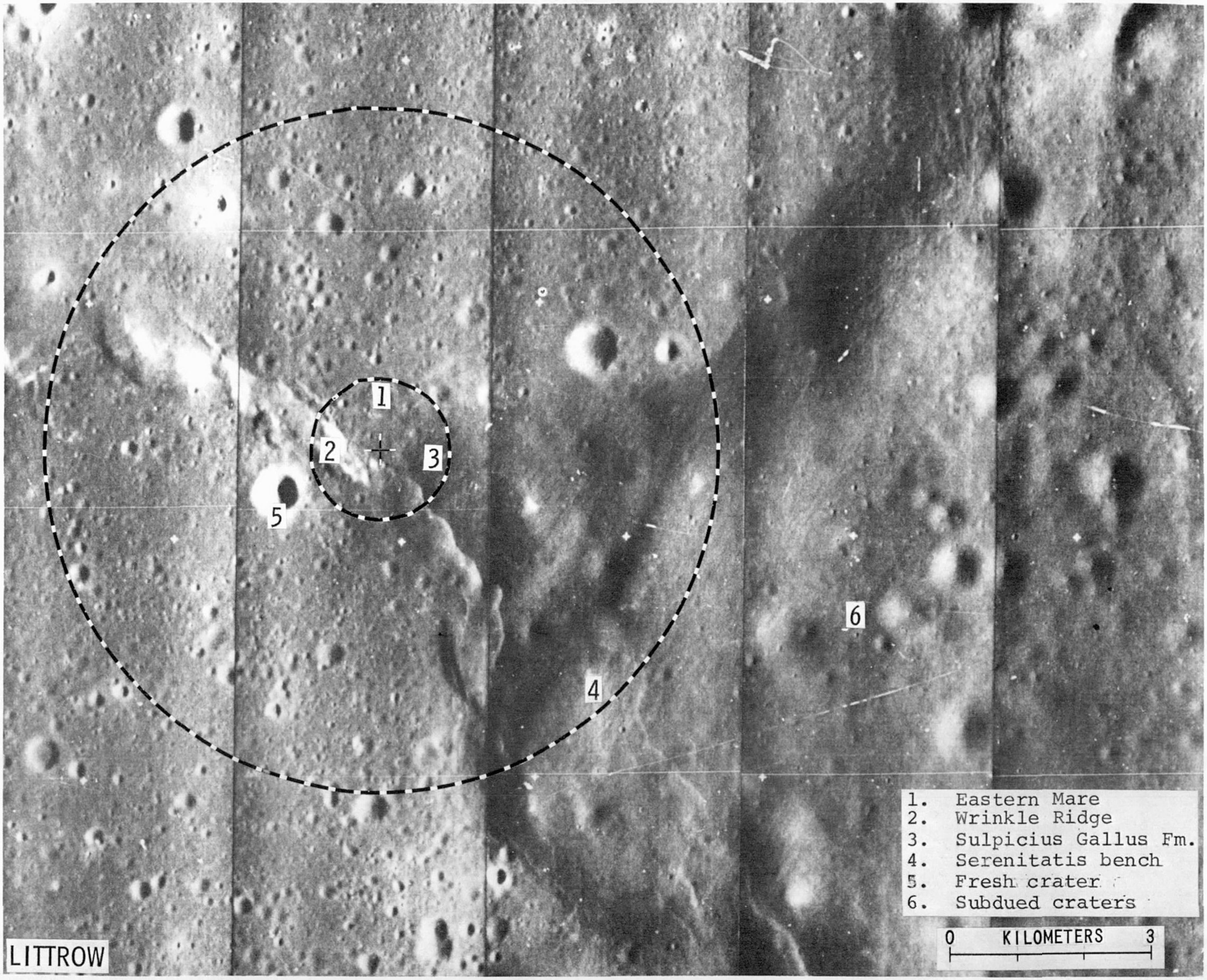

FLAMSTEED P


1km

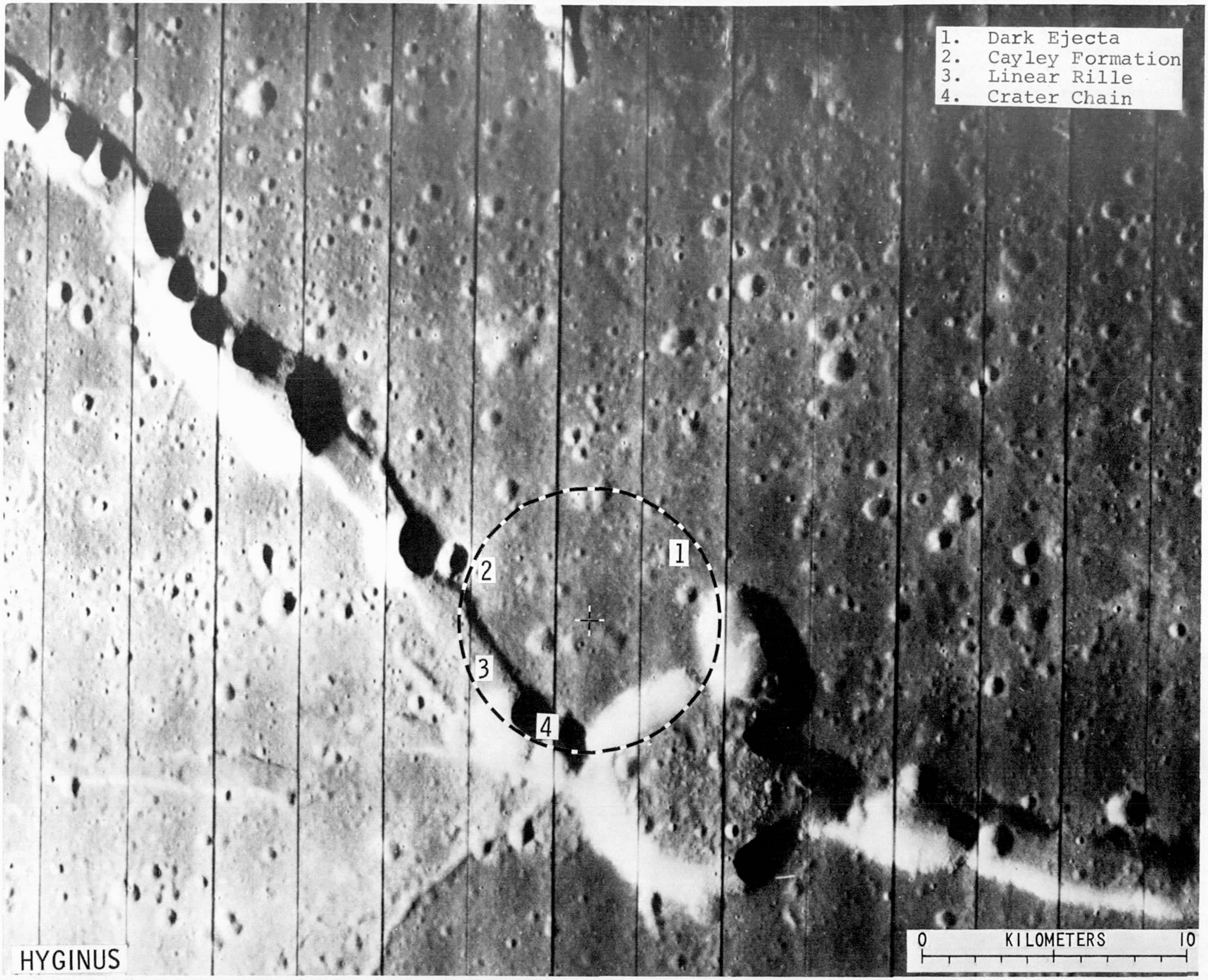

FRA MAURO FORMATION
12 km

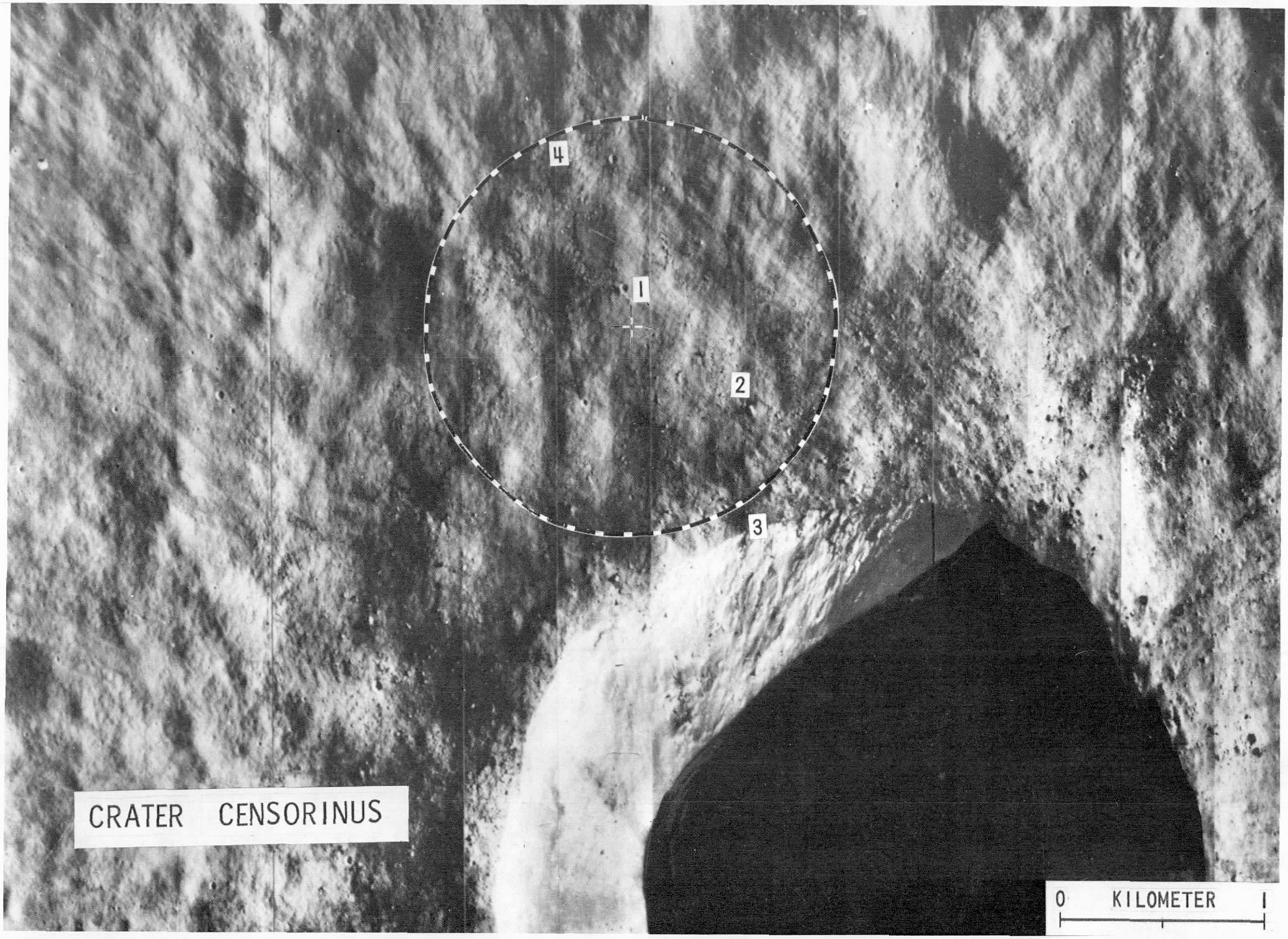

RIMA BODE II
5 km


1 km

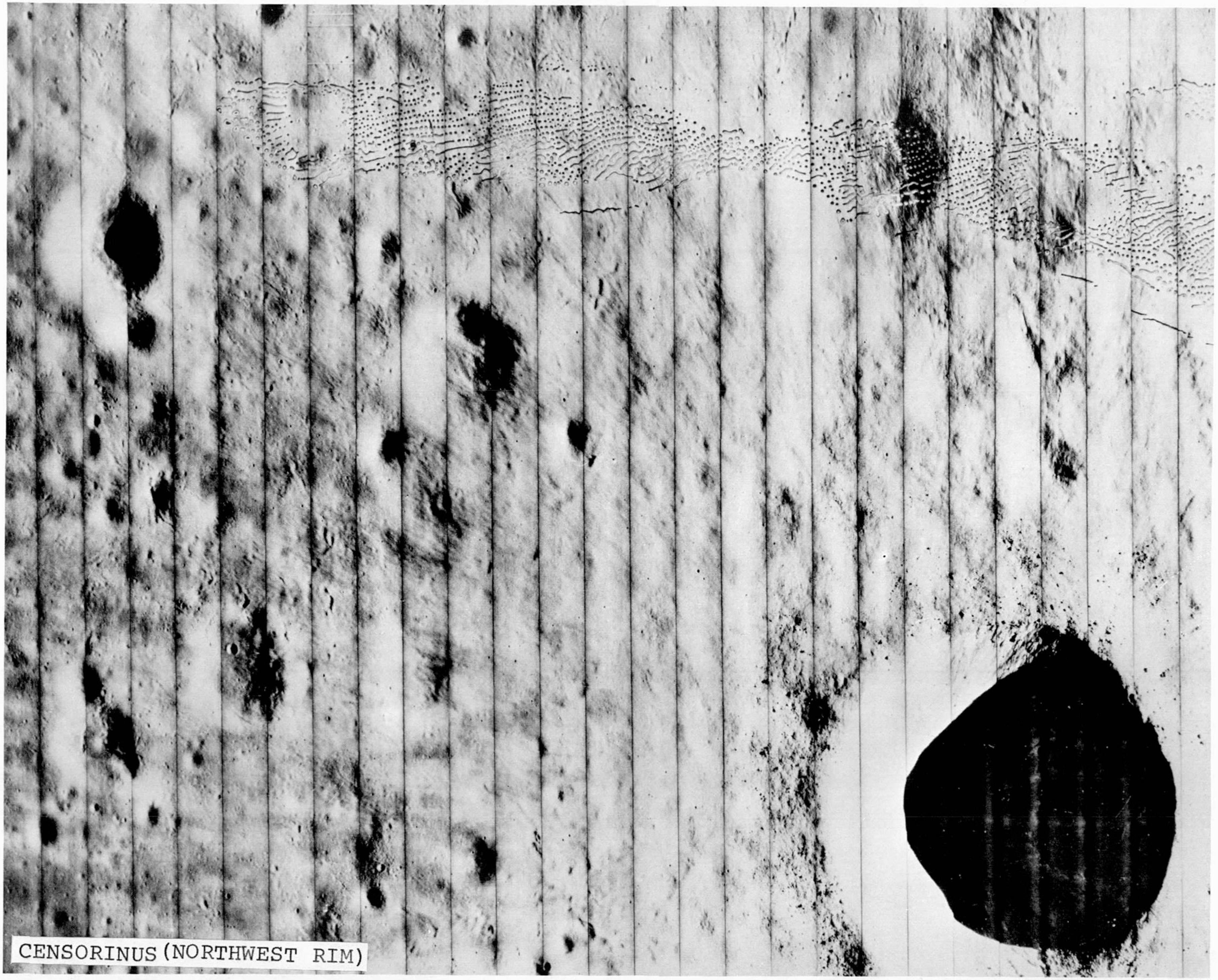


1
2
3
5
4
6
1. Eastern Mare
2. Wrinkle Ridge
3. Sulpicius Gallus Fm.
4. Serenitatis bench
5. Fresh crater
6. Subdued craters
0 KILOMETERS 3
LITTROW

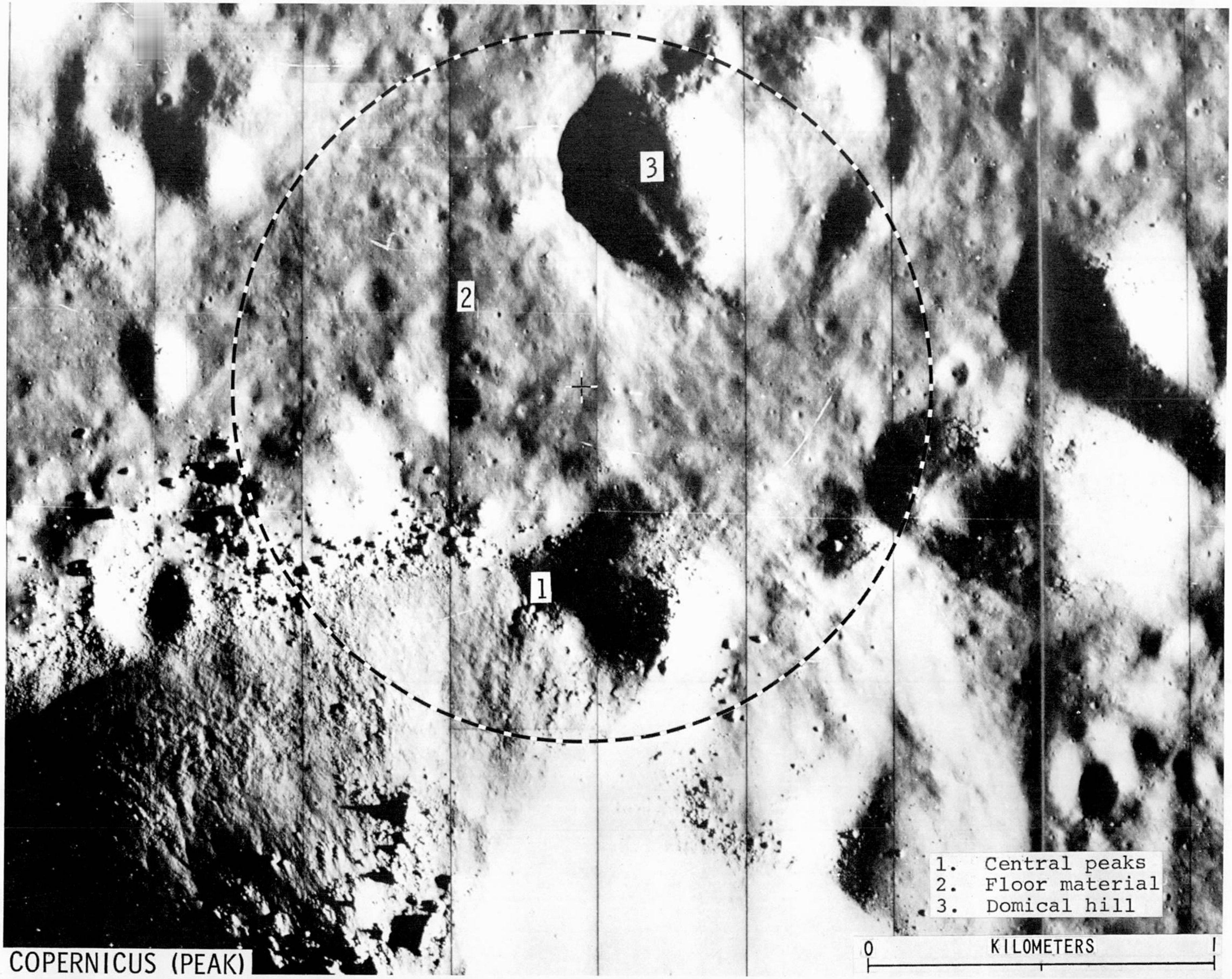

1. Dark Ejecta
2. Cayley Formation
3. Linear Rille
4. Crater Chain
1
2
3
4
0
KILOMETERS
10
HYGINUS

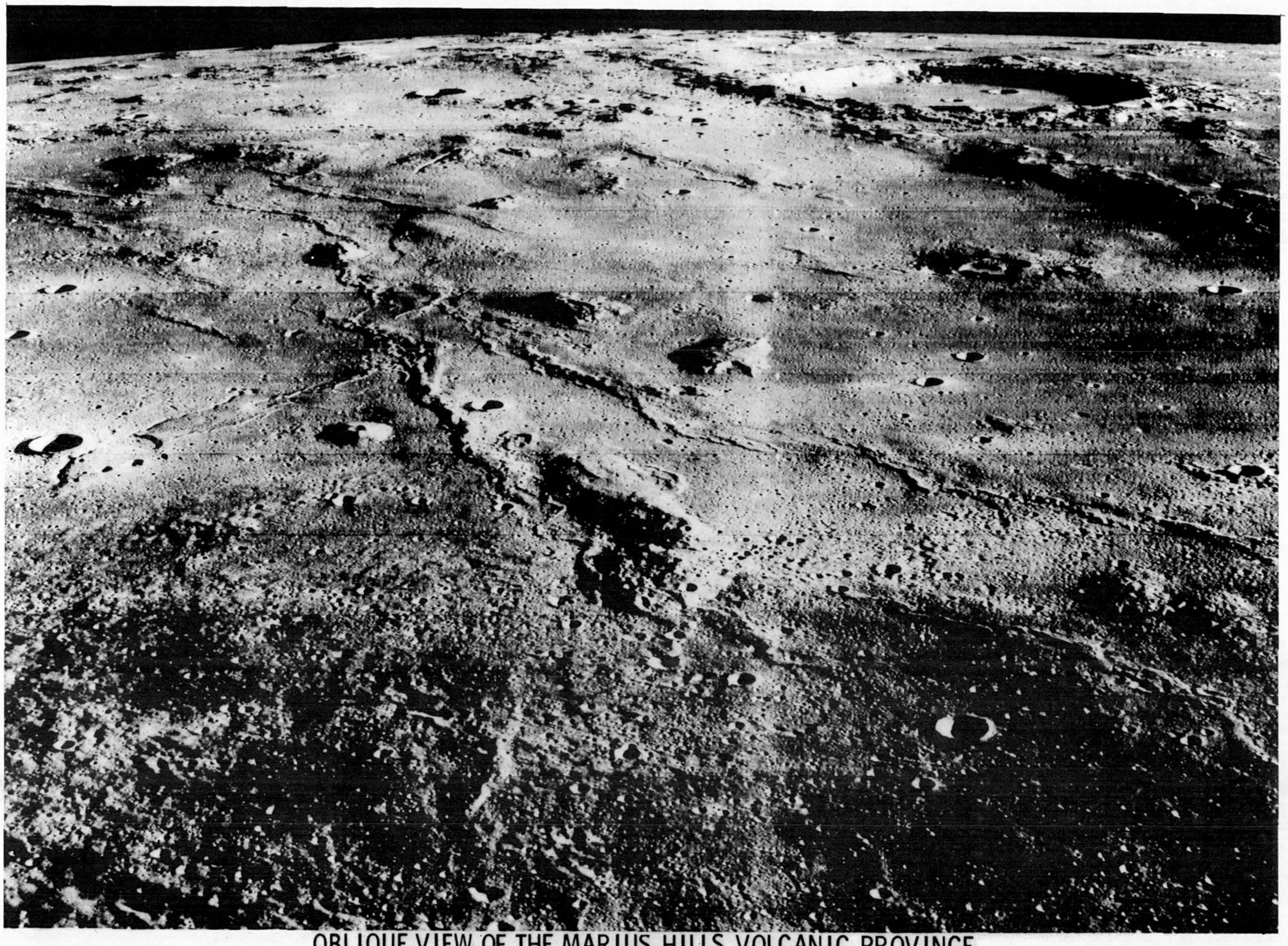


4
1
2
3
CRATER CENSORINUS
0 KILOMETER 1

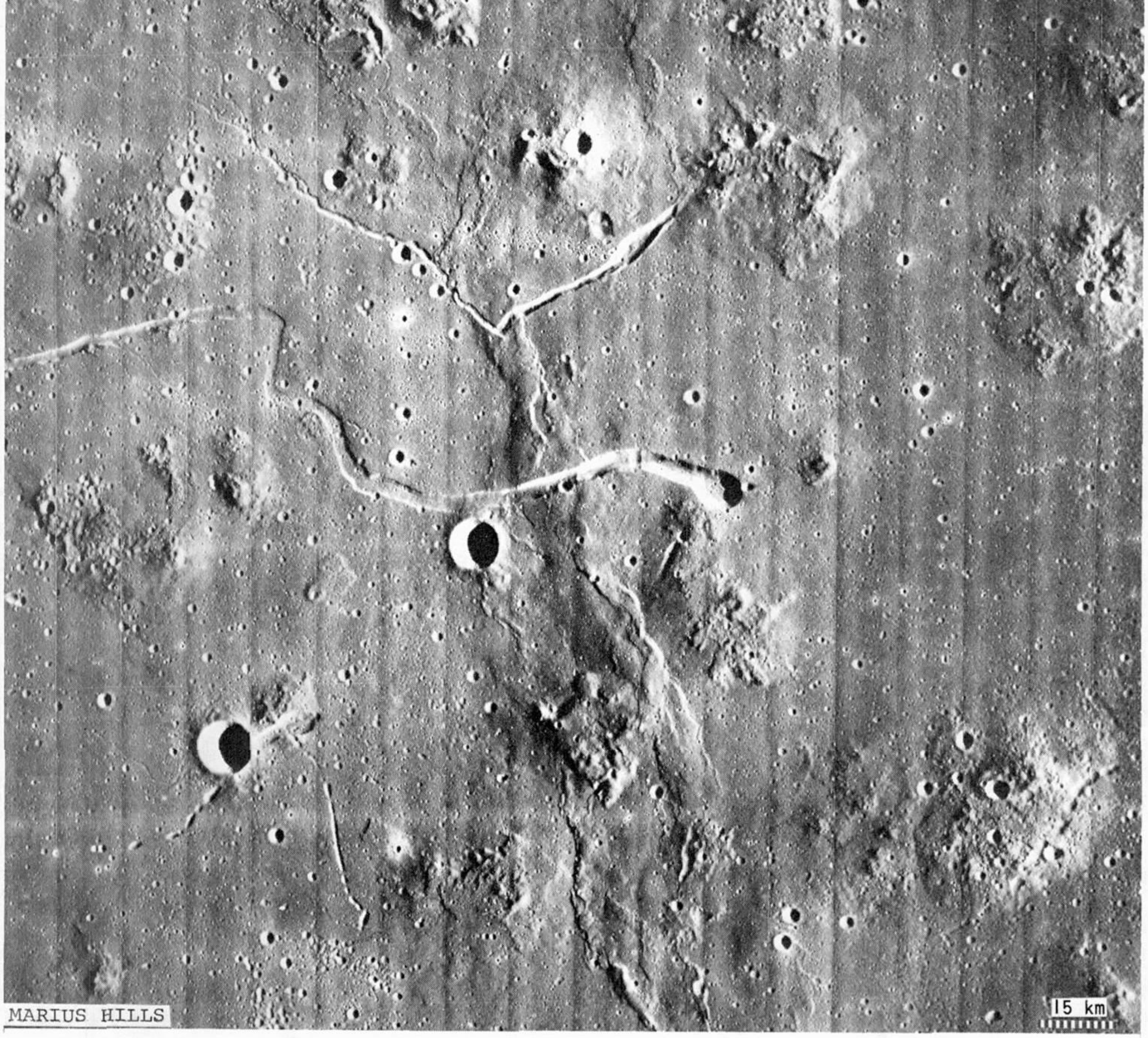

CENSORINUS (NORTHWEST RIM)

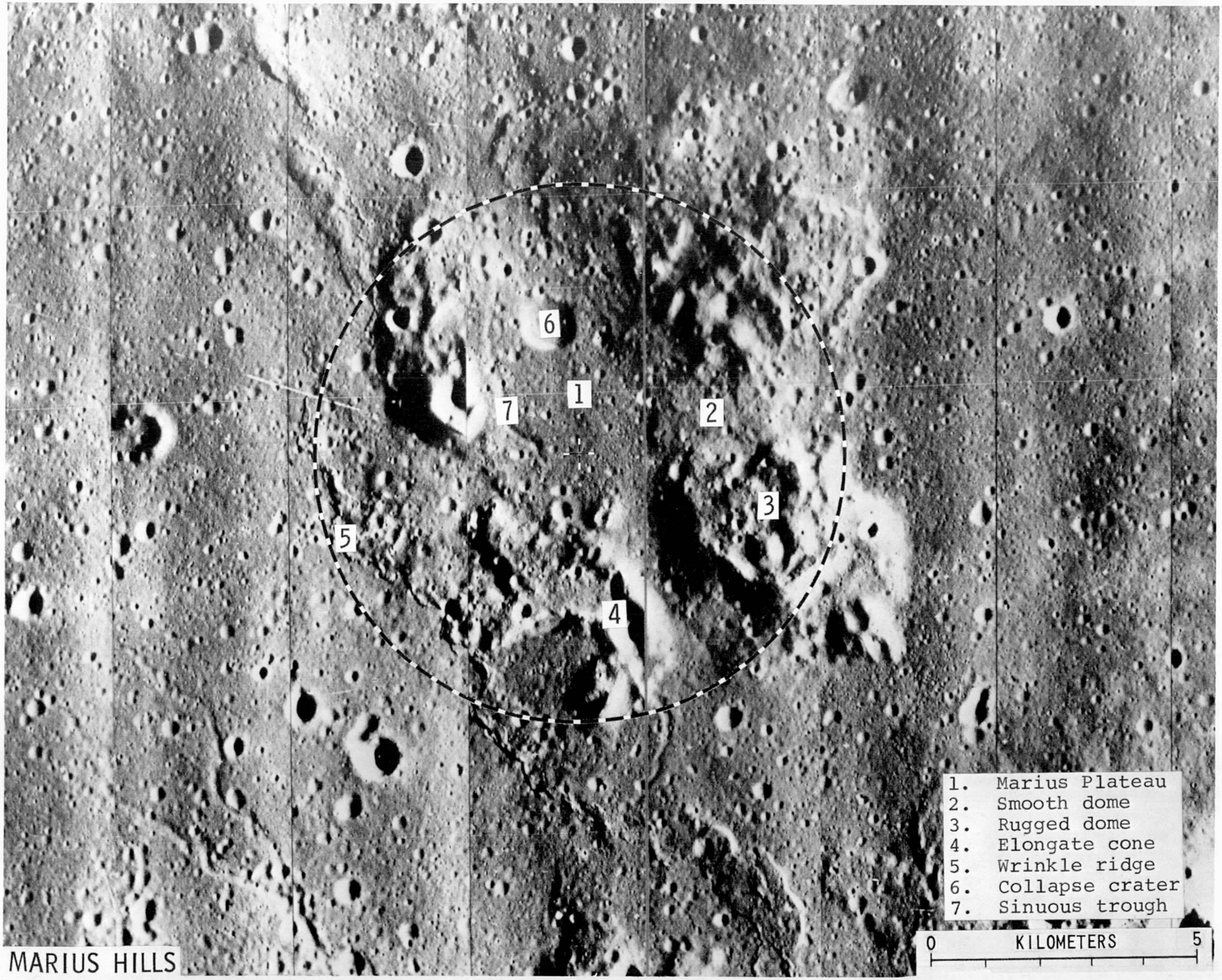

COPERNICUS


3
2
1
1. Central peaks
2. Floor material
3. Domical hill
0
KILOMETERS
1
COPERNICUS (PEAK)

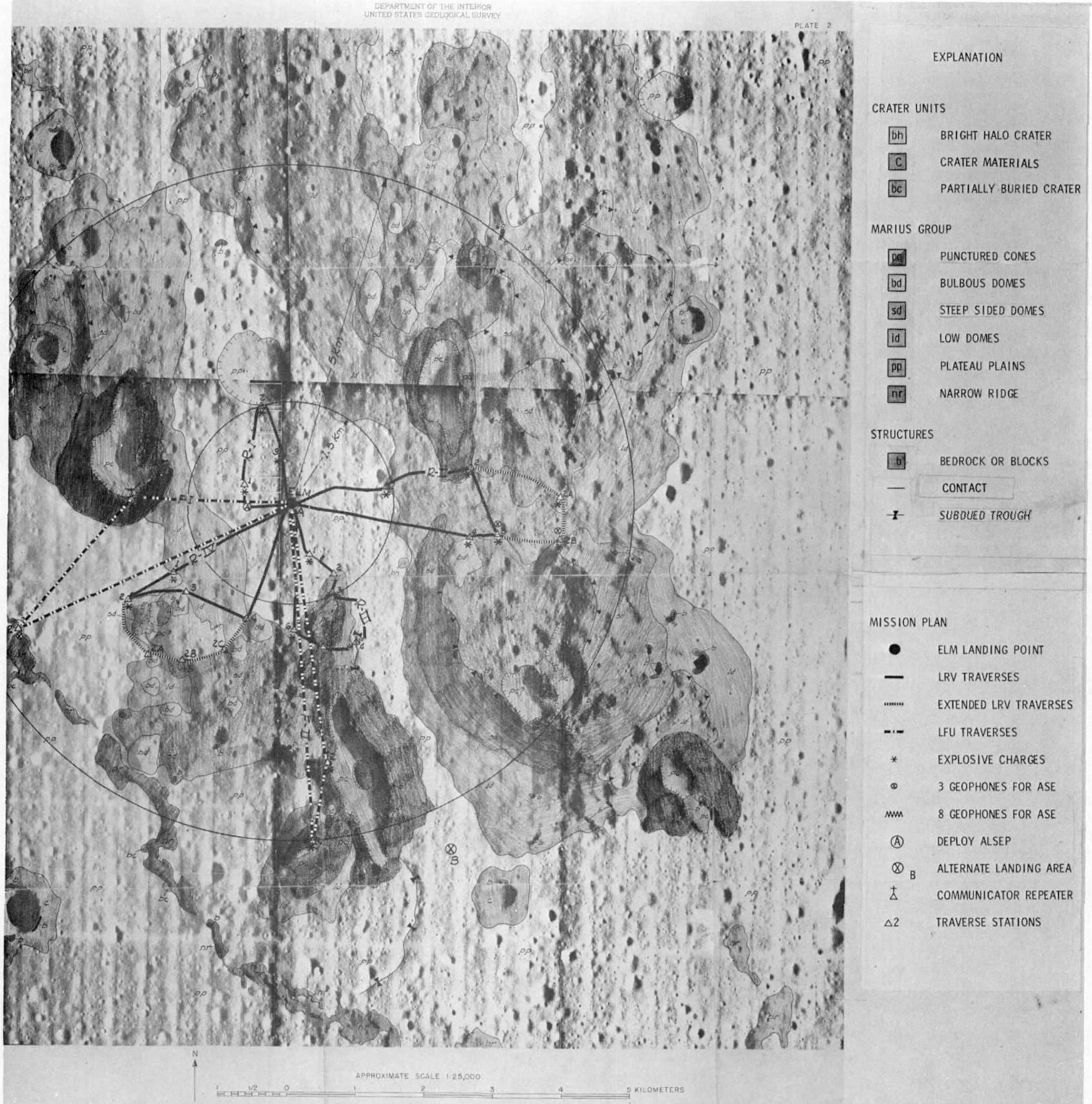


OBLIQUE VIEW OF THE MARIUS HILLS VOLCANIC PROVINCE


MARIUS HILLS
15 km


6
1
7
2
3
5
4
1. Marius Plateau
2. Smooth dome
3. Rugged dome
4. Elongate cone
5. Wrinkle ridge
6. Collapse crater
7. Sinuous trough
0 KILOMETERS 5
MARIUS HILLS

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

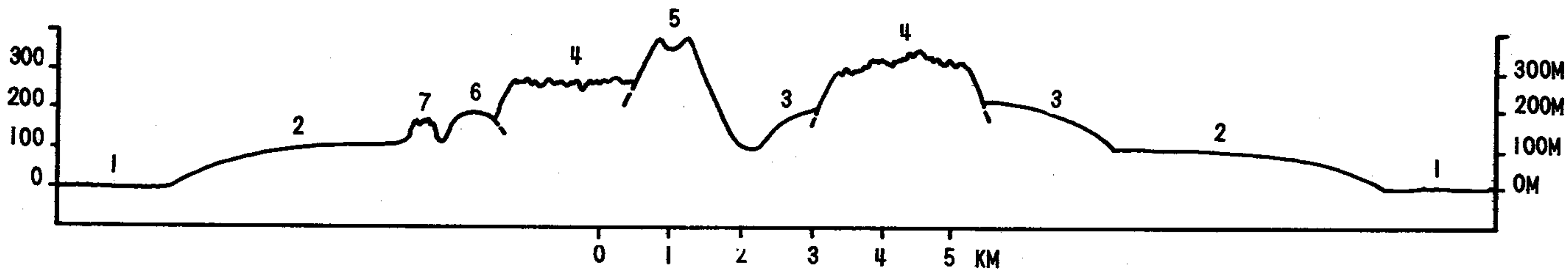


PRELIMINARY LARGE SCALE GEOLOGIC MAP OF MARIUS HILLS – LUNAR ORBITER V

BY

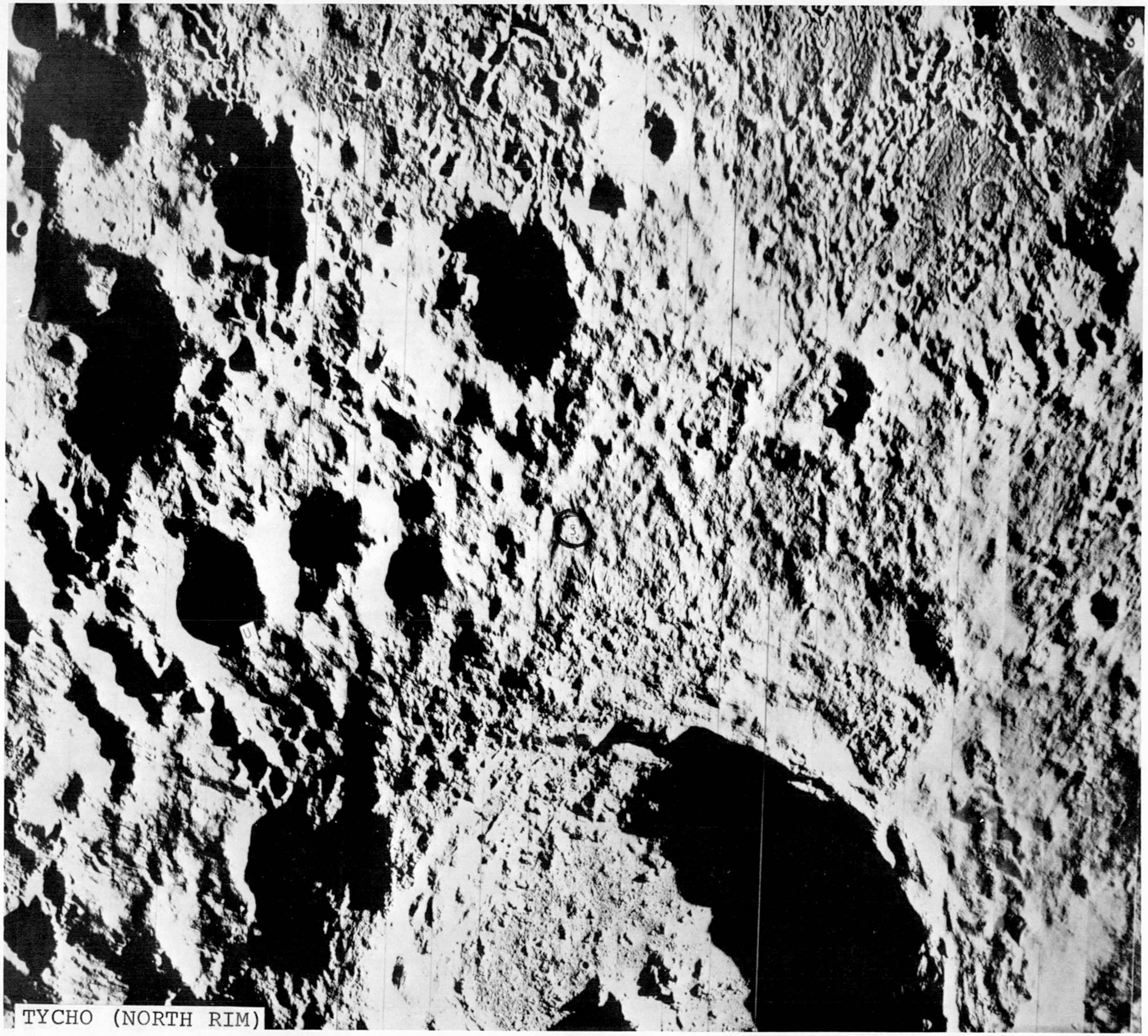
JOHN F. McCAULEY

1968

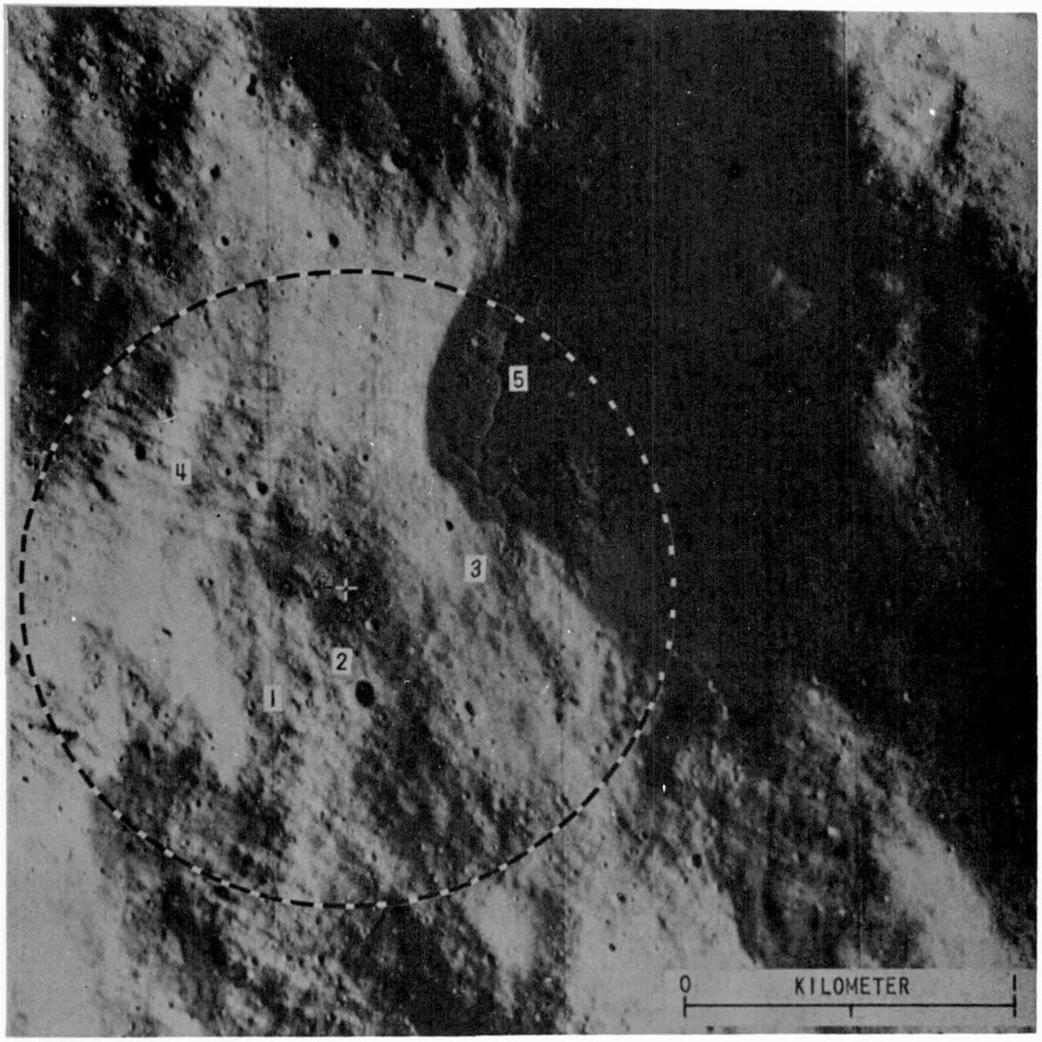


SCHEMATIC CROSS SECTION OF THE MARIUS HILLS REGION

1. MARE MATERIAL
2. "MARIUS PLATEAU" MATERIAL
3. SMOOTH LOW DOMES UP TO 100 M
4. RUGGED STEEP DOMES (200-300 M)
5. PUNCTURED CONES (UP TO 300 M)
6. BULBOUS DOMES
7. MARE RIDGE MATERIAL



TYCHO (NORTH RIM)

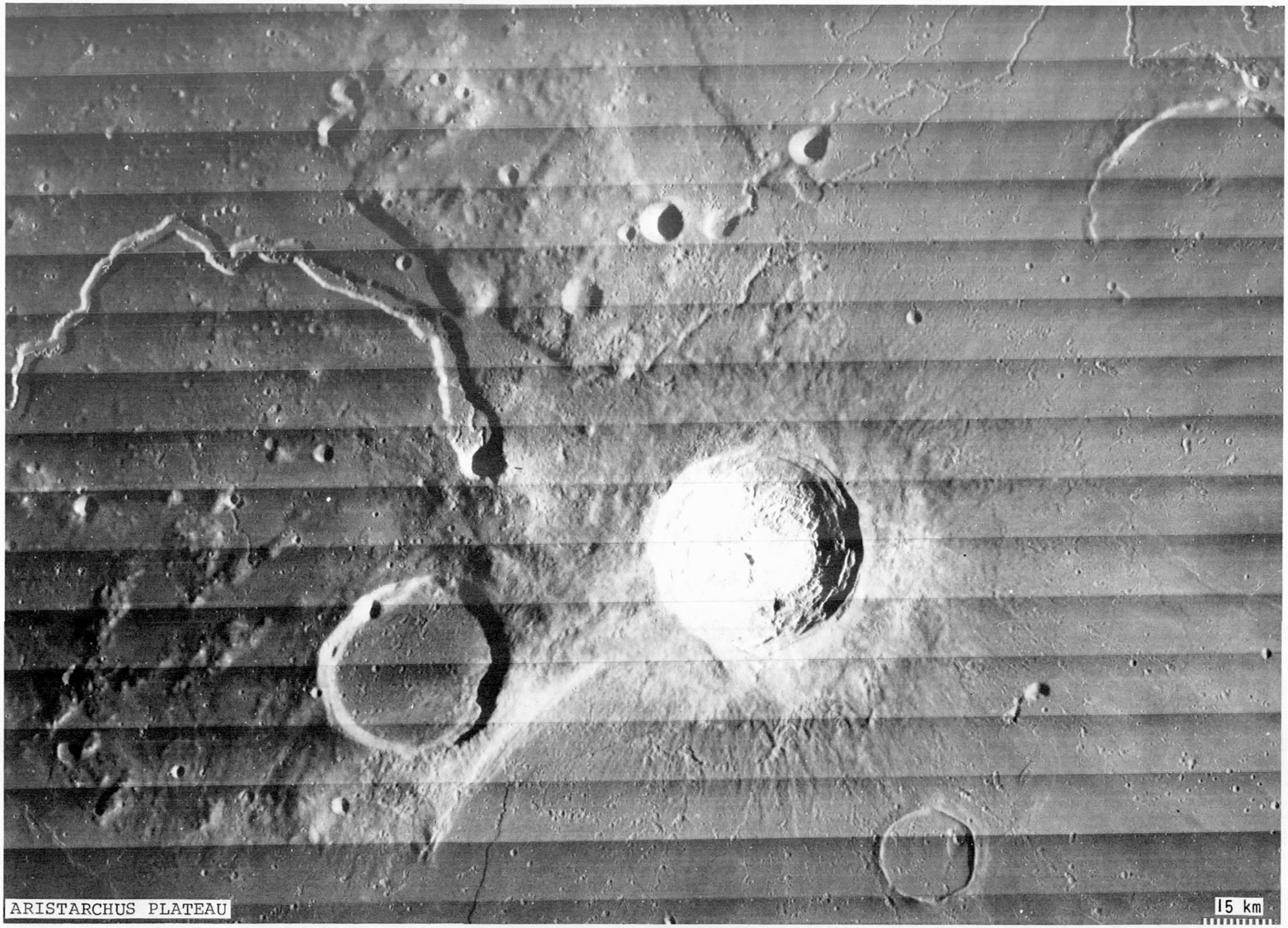


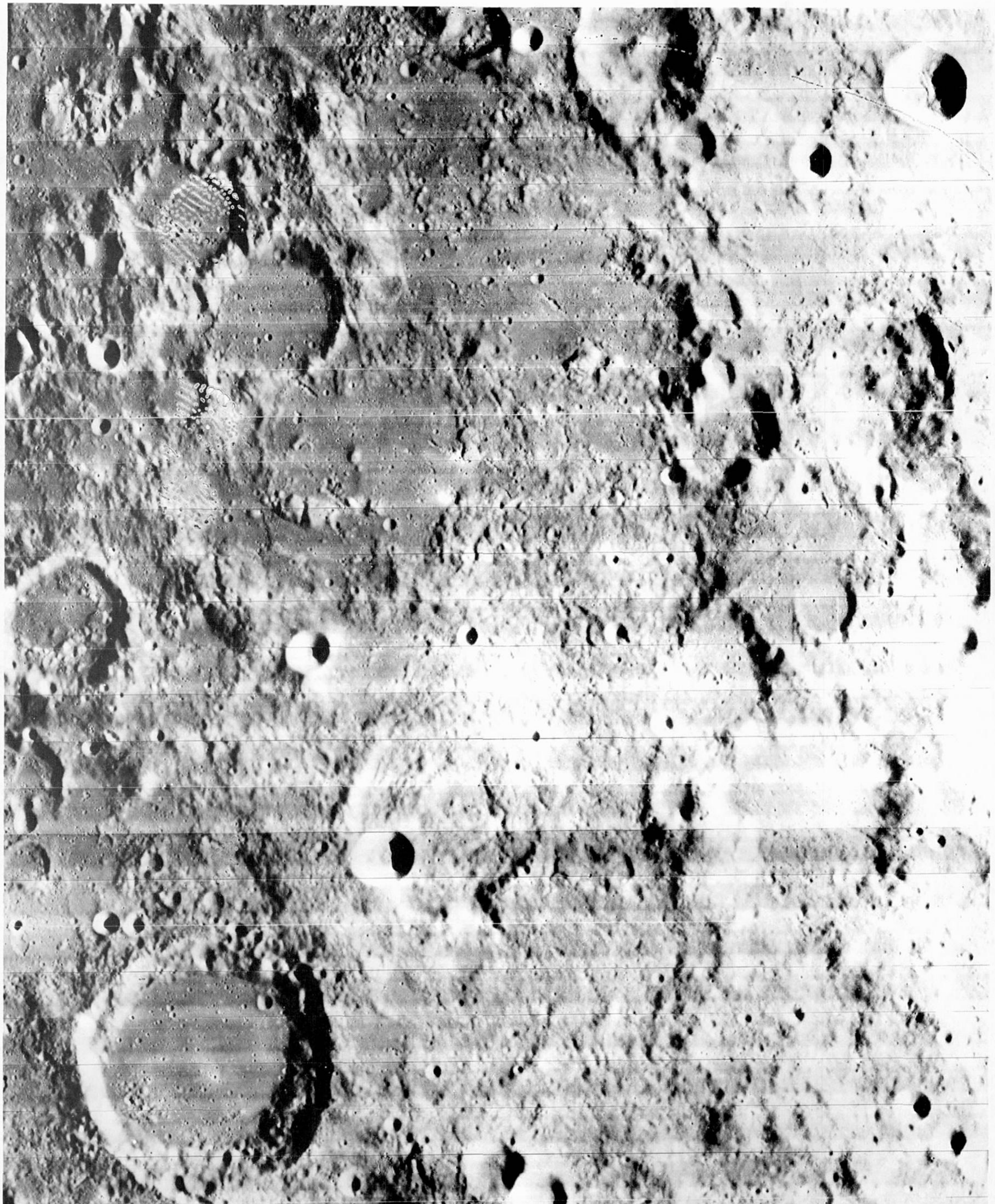
PROPOSED LANDING SITE ON EJECTA RIM OF CRATER TYCHO

1. SURVEYOR VII LANDING SITE : TO EXAMINE THE SPACECRAFT
2. SMALL FRESH CRATER : TO EXAMINE AND SAMPLE BLOCKS
3. SUCCESSIVE FLOWS : TO EXAMINE AND SAMPLE FLOW FRONTS
4. BRAIDED TEXTURE : TO EXAMINE IMPACT-PRODUCED TEXTURES
5. "LAVA" POOL : TO SAMPLE THE FILL AND STUDY THE FRACTURES


HARBINGER MOUNTAINS


RIMA PRINZ I
1 km


ARISTARCHUS PLATEAU
15 km


DESCARTES
15 km

LUNAR EXPLORATION SITES AND THE GEOLOGICAL PROBLEMS OF THE MOON

A. MAJOR SURFACE UNITS	SITES
I. MARE MATERIALS	
EASTERN (IMBRIAN) MARE	LANDING SITE 2
WESTERN (ERATOSTHENIAN) MARE	SITES 4, 5 OR 6
SULPICIUS GALLUS FORMATION	RIMA BODE II (OR LITTROW)*
II. HIGHLAND MATERIALS	
RUGGED TERRA MATERIAL	CENSORINUS AND DESCARTES (OR ABULFEDA)
BLANKET (EJECTA) DEPOSITS	FRA MAURO FORMATION
OLD FILLED BASINS	(HIPPARCHUS)
OLD PITTED PLAINS	——— [SOUTHERN HIGHLANDS AND NORTH POLAR REGION] **
B. MAJOR PROCESSES	
I. CRATERING	
SMALL MARE CRATERS	SITE 2 AND 4, 5 OR 6
SMALL IMPACT CRATERS	CENSORINUS
LARGE IMPACT CRATERS	COPERNICUS AND TYCHO
OLD (REBOUND) CRATERS	——— [POSIDONIUS AND GASSENDI]
COLLAPSE CRATERS	MARIUS HILLS
CRATER CHAINS (MAARS)	(HYGINUS)
VOLCANIC CALDERAS	——— [CRATER Y IN MARE ORIENTALE]
II. VOLCANISM	
INTRUSIVE	——— ["MARE DOMES"]
EXTRASIVE	
DOMES AND CONES	MARIUS HILLS AND DESCARTES
FLOWS AND RIDGES	(LITTROW)
III. OTHER PROCESSES	
EROSION AND DEPOSITION	RIMA PRINZ I (OR SCHRÖTER'S VALLEY)
FAULTING AND COLLAPSE	(HYGINUS)
SLUMPING AND MASS WASTING	——— [COPERNICUS WALL AND APENNINE MTS.]

*SITES IN PARENTHESIS ARE CONSIDERED AS ALTERNATES TO FIVE OF THE TEN SITES

**SITES IN BRACKETS ARE NOT IN THE LIST OF TEN SITES AND USED ONLY AS EXAMPLES

THE TEN LUNAR EXPLORATION SITES

A. MAJOR SURFACE UNITS

I. MARE MATERIALS

- LANDING SITE 2
- SITES 4, 5 OR 6
- RIMA BODE II

II. HIGHLAND MATERIALS

- FRA MAURO FM.
- CENSORINUS
- DESCARTES

B. MAJOR PROCESSES

I. CRATERING

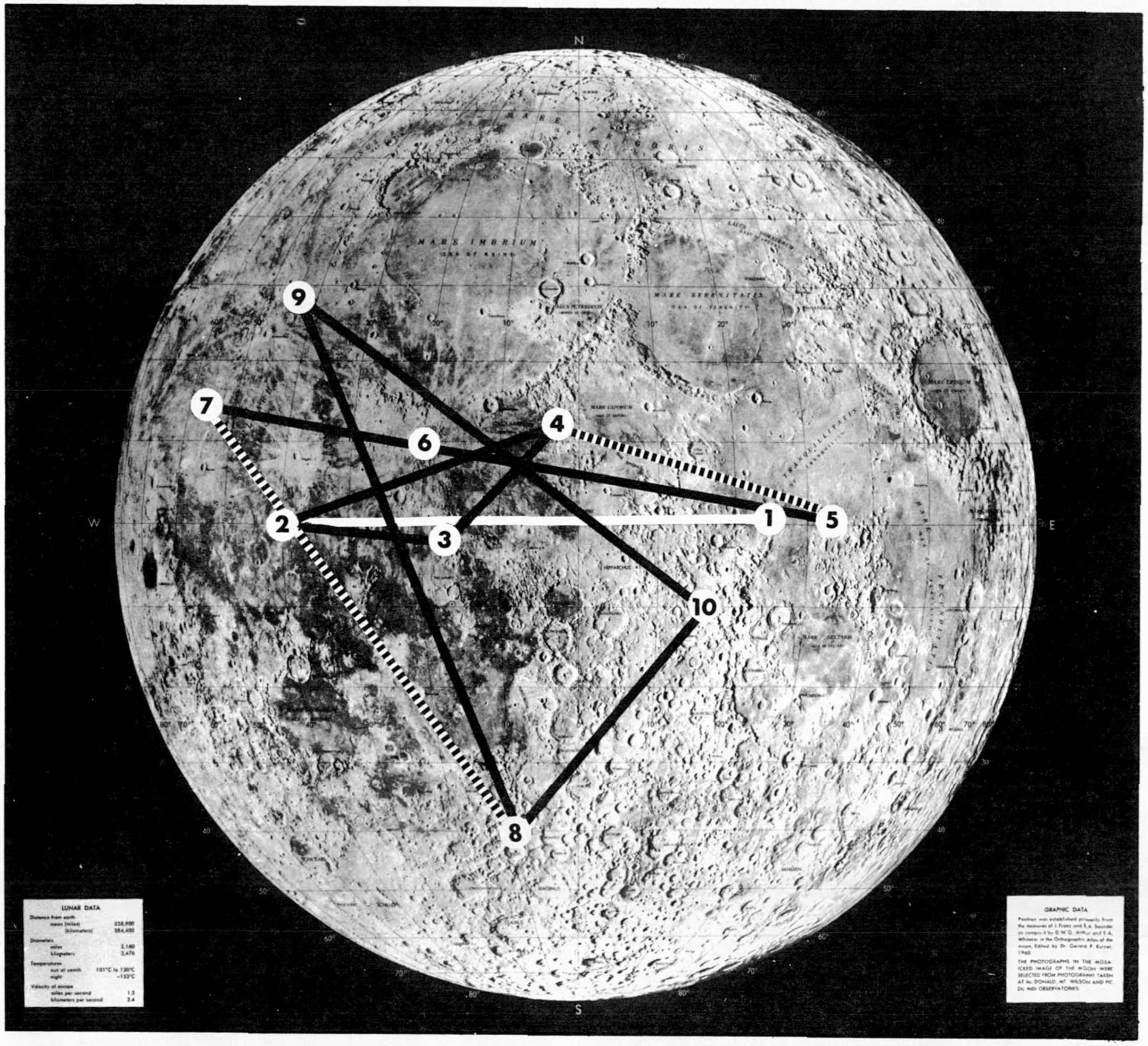
- CENSORINUS-EJECTA
- COPERNICUS-FLOOR
- TYCHO-NORTH RIM

II. VOLCANISM

- RIMA BODE II
- MARIUS HILLS
- DESCARTES

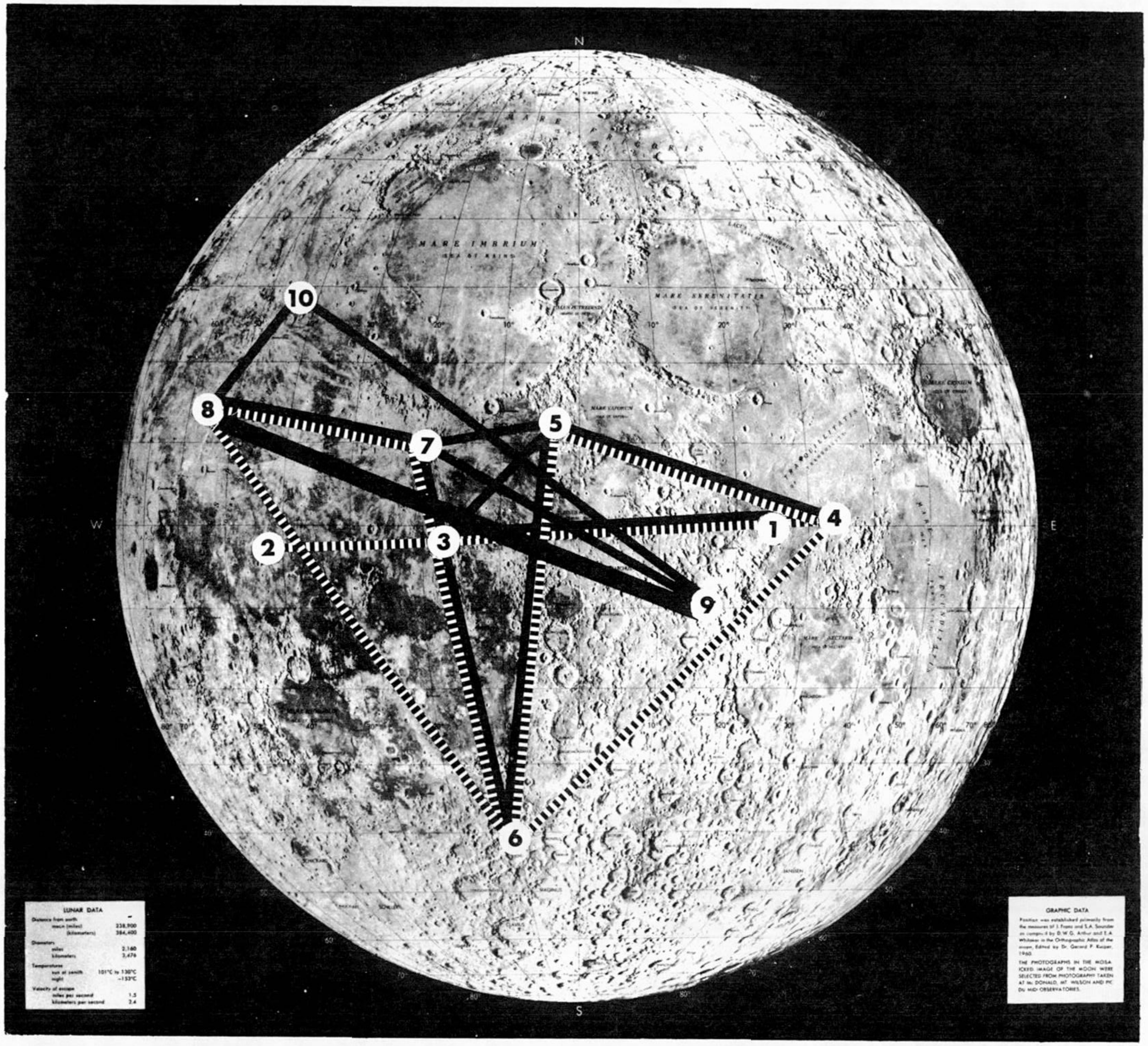
III. SINUOUS RILLE FORMATION

- RIMA PRINZ I



ALSEP DEPLOYMENT
(BASED ON ACCESSIBILITY)

1. LANDING SITE 2
2. WESTERN MARE
3. FRA MAURO FORMATION
4. RIMA BODE II
5. CENSOINUS (NORTHWEST)
6. COPERNICUS (CENTRAL PEAKS)
7. MARIUS HILLS
8. TYCHO (NORTH RIM)
9. RIMA PRINZ I
10. DESCARTES



MISSION ASSIGNMENTS
(BEST SEISMIC NETWORKS)

1. LANDING SITE 2
2. WESTERN MARE
3. FRA MAURO FM.
4. CENSORINUS (NW)
5. RIMA BODE II
6. TYCHO (NORTH RIM)
7. COPERNICUS (PEAKS)
8. MARIUS HILLS
9. DESCARTES
10. RIMA PRINZ I

C. R. Huss

APPENDIX

CHARACTERISTICS OF THE TEN LUNAR EXPLORATION SITES

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FAROUK EL-BAZ/MAS

10 July 1969