

LUNAR ORBITER PROJECT

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MISSION A

DESCRIPTION

Prepared by the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
 Langley Research Center
 Lunar Orbiter Project Office

LUNAR ORBITER MISSION A DESCRIPTION

As Approved by the
Ad Hoc Surveyor/~~Orbiter~~ Utilization Committee
September 29, 1965

Amended
June 1, 1966

Prepared by the
Lunar Orbiter Project Office
Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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I. INTRODUCTION

The Lunar Orbiter Project and the Surveyor Project have a joint goal of obtaining sufficient topographic and geologic data of the lunar surface to confirm Apollo LEM landing gear design and to locate LEM landing sites having slopes less than 6° and protuberances less than 1/2-meter high or depressions less than 1/2-meter deep on the front face of the moon.

The Lunar Orbiter contribution is topographic information of up to 10,000 km² of the lunar surface at resolutions approaching one meter and 30,000 km² at nearly eight meters resolution per flight. The Surveyor will contribute soil mechanics data and small scale relief of relatively small areas surrounding the Surveyor site. Obviously the strategy for site selection must balance the Orbiter and Surveyor capabilities against the Apollo requirements.

The purpose of this document is to present the Lunar Orbiter Mission A as approved by the Ad Hoc Surveyor/Orbiter Utilization Committee on September 29, 1965 and amended June 1, 1966. The approved mission reflects the inputs from many discussions among personnel in the Lunar Orbiter Project Office, Bellcomm, the U. S. Geological Survey, the Surveyor Project Office, NASA Headquarters, and the Manned Spacecraft Center. Bellcomm published a Lunar Orbiter Mission Planning Report which

suggested that the early Orbiter missions sample the various lunar terrain types which look promising from the earth. The USGS defined and mapped these promising terrain types and materially assisted in the selection of the sites for Mission A. The Surveyor I has been included as a Mission A site, and wherever feasible, proposed future Surveyor sites have been included.

II. MISSION A OBJECTIVES

- A. Photographic - To obtain detailed lunar topographic and geologic information of various lunar terrain types to assess their suitability for use as landing sites by Apollo and Surveyor.
- B. Selenodetic - To provide precision trajectory information which will improve the definition of the lunar gravitational field.
- C. Environmental - To provide measurements of micrometeoroid and radiation flux in the lunar environment for spacecraft performance analysis.

MISSION GROUND RULES
TERRAIN SAMPLING PHILOSOPHY

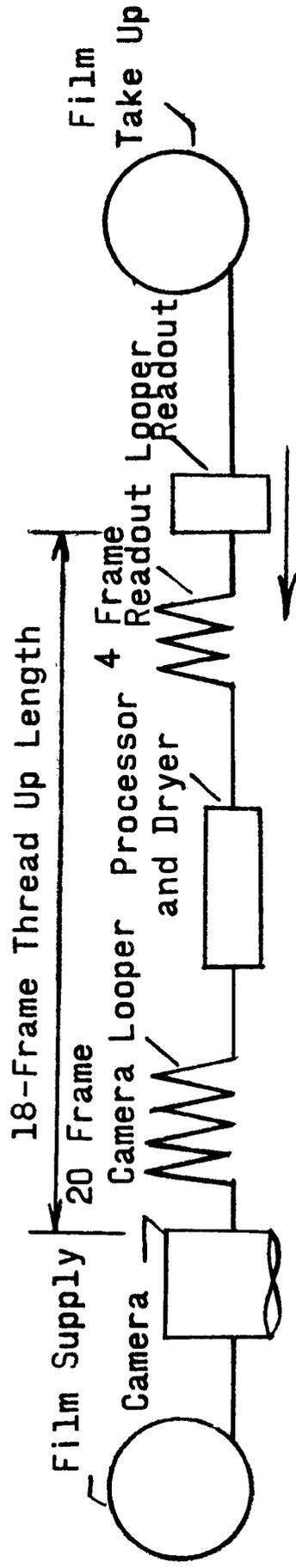
1. Obtain several samples of each of the significant terrain types.
2. Samples of like terrain types shall be reasonably distributed for Apollo launch window considerations.
3. Concentrate on the most promising areas within the Apollo Zone of ± 50 latitude, $\pm 45^\circ$ longitude.
4. Examine the Surveyor 1 site.
5. Examine promising future Surveyor sites.
6. Possibly perturb site selection if additional information (e.g. additional landed Surveyors) becomes available before accomplishing Mission A.

MISSION GROUND RULES (Concluded)

OTHER MISSION CONSTRAINTS

1. Minimum number of photo maneuvers for simplest mission
∴ One photo pass/site (except at Surveyor 1 site where two passes shall be used)
2. Photo readout between sites for early availability of data and mission control ∴ Four frames and four readout orbits between sites
3. Maximum of 9 equatorial sites within Apollo zone
4. Maximum photo coverage per site using one pass except for the Surveyor 1 site, where two 16-frame passes will be used, for a total of 160 frames ∴ 16 frames per pass
5. Coverage of any point within the area of interest ∴ Inclination limited to 11 to 12°
6. Lighting conditions and altitude must be adequate for
 - a. detection of 2m diameter base cones 1/2m high
 - b. detection of 7° slope of 7m X 7m area

Photographic Subsystem



Film Direction for Exposure, Processing, Drying, and Take Up

Film Direction for Readout

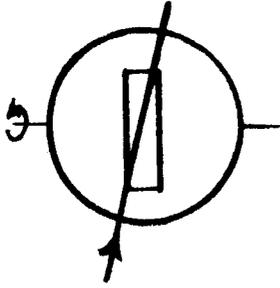
1. Photo system thread up length \approx 18 frames
∴ must take 19 frames to be able to read back first frame
2. Photo system film must be advanced at least one frame each eight hours to avoid film set, two frames each 15 hours to avoid bimat stick and two frames each 4 hours to avoid bimat dryout after start of photography.
3. 219 frames total capacity

III. ORBIT DESIGN

The transit time (earth to moon) for the Lunar Orbiter spacecraft is approximately 90 hours. Upon reaching the moon the spacecraft will deboost into an elliptical orbit that has a perilune altitude of about 200 km. Following a waiting period of several days during which time the orbit will be defined and the lunar physical properties will be calibrated, the spacecraft will transfer to an orbit with a minimum perilune altitude of 46 km. It is from this orbit that the primary photographic survey will be performed. Some of the significant orbital parameters and the reason for their selection are itemized in Figure 1.

It is noted in the figure that the perilune altitude varies between 46 and 60 km. This variation linearly affects the photographic resolution obtainable and is therefore of considerable interest. The variation is caused by earth effects and lunar gravitational anomalies (J_3). Figure 2 shows the perilune altitude variation due to the earth effects and the earth plus moon effects. In addition to the earth and moon effects on the perilune altitude, the photographic resolution is also degraded when photographing sites which are located off perilune. This is the direct result of an increase in the photographic altitude. The altitude change as a function of true anomaly (angle off perilune) is shown in Figure 2.

ORBIT DESIGN



ORBITAL PARAMETERS

REASON

POSIGRADE

VISIBILITY OF DEBOOST FROM EARTH

DESCENDING NODE PHOTOGRAPHY

PREFERRED TILT OF LIGHTING BAND

INCLINATION $\sim 12^\circ$

PHOTO ACCESS TO ALL POINTS IN APOLLO ZONE

INITIAL ORBIT PERIOD ~ 3.7 HOURS

POWER AND ΔV CONSTRAINTS

PHOTO ORBIT PERIOD ~ 3.5 HOURS

POWER AND ΔV CONSTRAINTS

INITIAL ORBIT PERILUNE ~ 200 KM.

IMPACT HAZARD AND WITHIN IMC OPERATING RANGE

PHOTO ORBIT PERILUNE $\sim 46 - 60$ KM.

IMPACT HAZARD AND PHOTO RESOLUTION

Figure 1

PHOTO ALTITUDE CONSTRAINTS

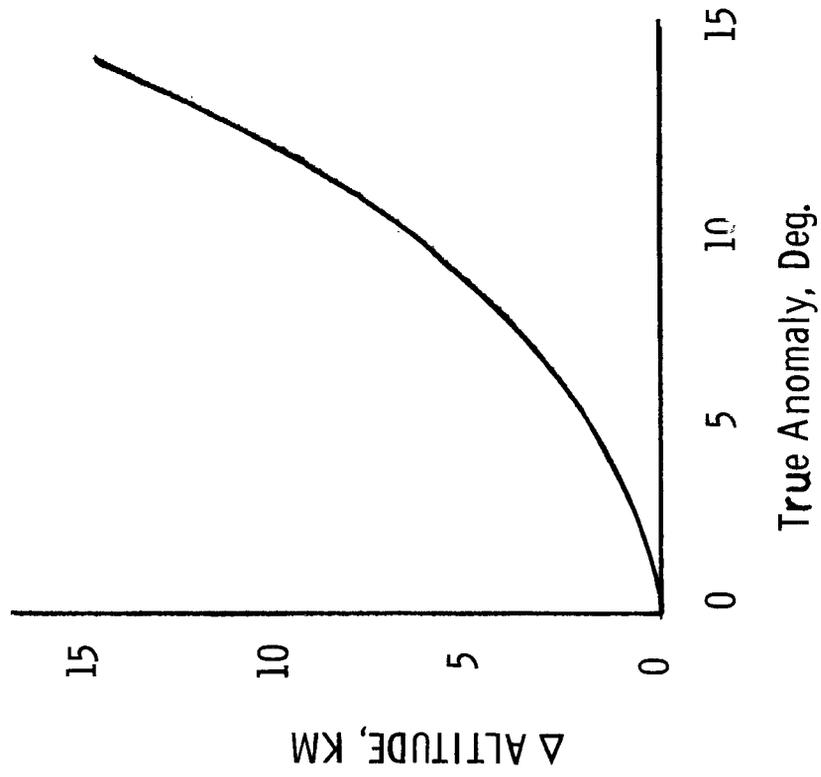
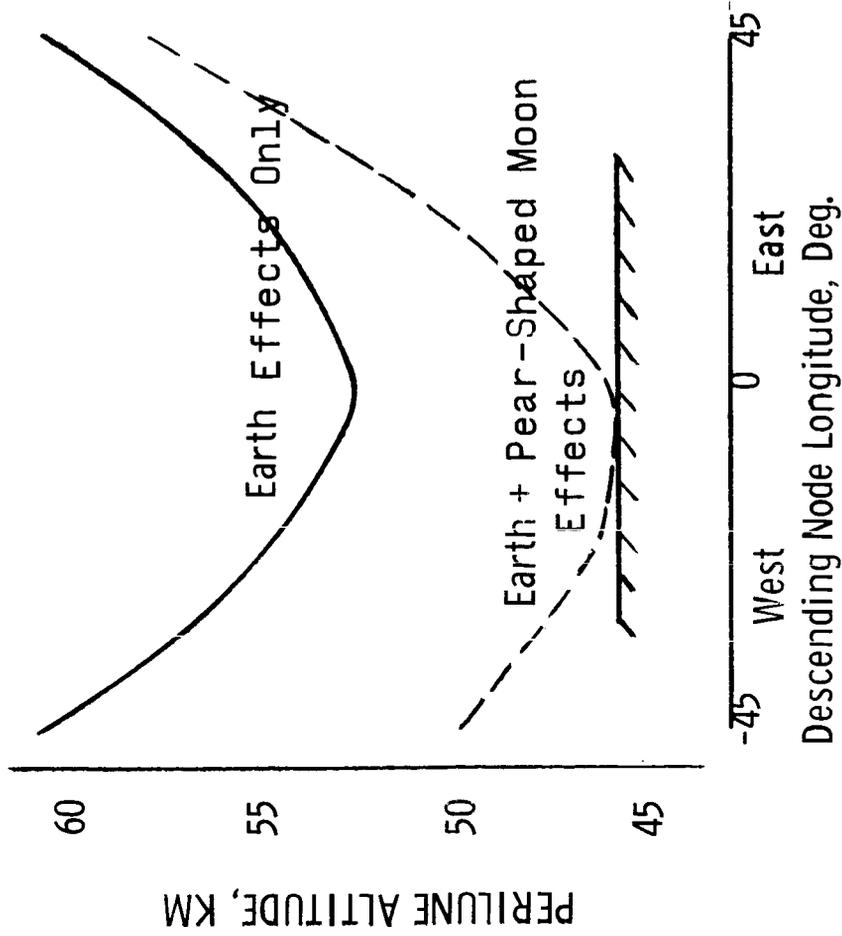


Figure 2

IV. SITE SELECTION

The ground rules for Mission A define that it shall be a terrain sampling mission which examines the Surveyor I site, examines promising future Surveyor sites, and concentrates on the Apollo zone. Figure 3 represents a tool for first-order site selection. This figure shows the approximate distribution of promising Surveyor sites, the significant mare and highland areas within the Apollo zone, and the Surveyor I site. Craters are randomly distributed throughout the area. From this figure the approximate areas to place Lunar Orbiter Mission A sites can be seen.

The exact locations of the sites for Mission A were selected by iterating between the geological considerations and the ground rules and constraints staying within the bounds defined by the orbital design. Ten sites were initially chosen within the Apollo zone. As a result of the action of the Ad Hoc Surveyor/Orbiter Utilization Committee, one of these sites (the crater Lansberg) was dropped and replaced by Surveyor site 5-50. Since the mission was proposed and approved, the successful Surveyor I mission has been performed. It has been proposed and approved that photography of the Surveyor I site be added to Mission A by deleting sites A-8, A-9, and A-10 and adding sites A-8.1 and A-9.1. Site A-9.1 is the Surveyor I site and

site A-8.1 is a relocation of site A-8 to prevent interference with photography of the Surveyor I site. The approved site locations for Mission A are shown on Figure 4 and are tabulated in the USGS site evaluations section of this document.

It has not been discussed, but it is considered that a 16-frame sequence of photography will be taken in the initial orbit and at least two frames read out such that the system performance can be evaluated before transfer to the photo orbit. The location of the site is in Mare Smythii and the site is designated A-0.

APPROXIMATE DISTRIBUTION OF SURVEYOR SITES AND SIGNIFICANT
MARE AND HIGHLAND AREAS IN APOLLO ZONE

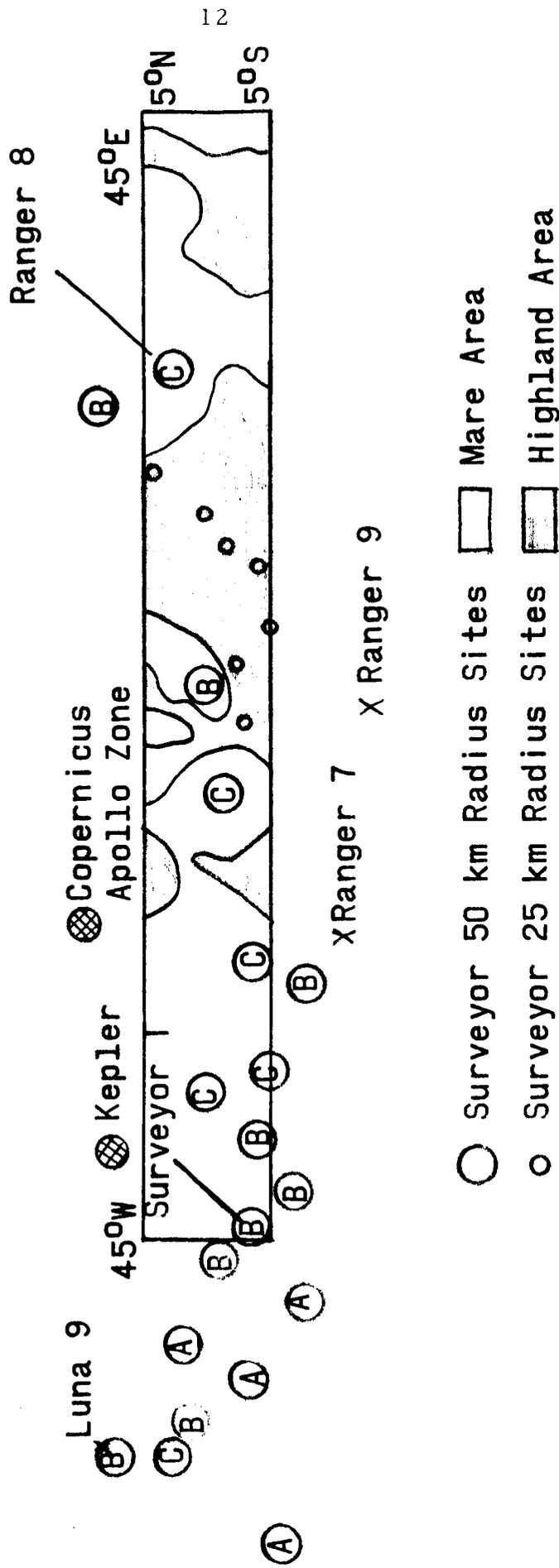
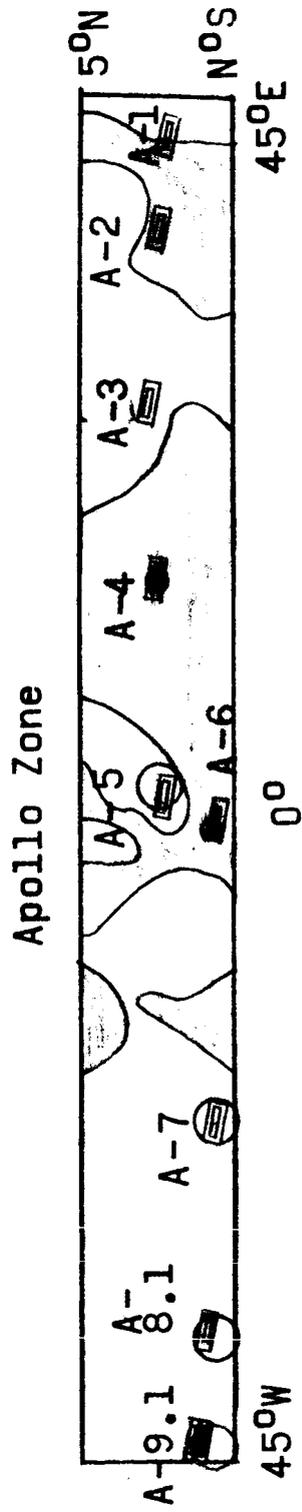


FIGURE 3

SITES SELECTED FOR ORBITER MISSION A



Note: Circles denote Surveyor sites.

Site No.	Lat.	Long.	Site No.	Lat.	Long.
A-1	0°50'S	42°20'E	A-6	4°00'S	2°50'W
A-2	0°10'S	36°00'E	A-7	3°45'S	22°45'W
A-3	0°20'N	24°50'E	A-8.1	3°00'S	36°30'W
A-4	0°00'	12°50'E	A-9.1	2°21'S	43°22'W
A-5	0°25'S	1°20'W			(Surveyor I)

Figure 4

V. LUNAR TERRAIN ASSESSMENT*

A. General Statement

The selection of Lunar Orbiter photographic sample areas has been based primarily on the 1:1,000,000-scale U. S. Geological Survey Lunar Terrain Map of the equatorial zone (lat. 10°N - 10°S ; long. 60°E - 60°W). Some 46 terrain units are delineated in this area at an average resolution of one kilometer. The data and analytical techniques employed in the discrimination of these units are of fundamental importance to the Unmanned Lunar Orbiter Missions and are briefly described in the following pages.

B. Data Sources

The data sources which provide the bases of morphological mapping and quantitative definition are categorized into two fundamental types:

1. Qualitative:
 - a. A.C.I.C. charts
 - b. Earth-based photography; Lunar Atlas, Pease, Herbig
 - c. U.S.G.S. 1:1,000,000-scale geologic maps
 - d. Ranger VII, VIII, and IX photography
2. Quantitative:
 - a. Slope component measurements

*By Dr. Lawrence Rowan, U.S. Geological Survey

This section is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

- b. Relative relief data
- c. Crater density studies

The USGS Terrain Map, therefore, is the product of careful analysis and correlation of these qualitative and quantitative data. The basic terrain units - mare, uplands, and craters - are described in numerical terms which have important applications to both engineering and scientific problems. The present paucity of high and moderate resolution data in most terrain types is emphasized here, because resolution is a highly influential factor in relative roughness, and consequently, in site selection and certification.

Qualitative Data

Geologic mapping on the 1:1,000,000-scale A. C. I. C. charts has been in progress since 1961, and has resulted in at least preliminary maps of the entire area covered by the Lunar Terrain Map. It is important to emphasize that geologists have studied the morphological details of this area carefully, using the best available photography and seeing conditions. The resulting geologic maps (Figure 5), therefore, provide very significant terrain data. The geologic boundaries are frequently transferred directly to terrain boundaries. Exceptions to this statement do occur, however, when chronologically similar geologic units have different morphological and relative roughness characteristics. Additional value is contained in these geologic

maps and interpretations, since they provide the necessary knowledge concerning genetic processes which will guide extrapolations of terrain roughness and bearing strength data. Current geological investigations using Ranger photography will have considerable influence on interpretations concerning these fundamental genetic processes and the formulation of discriminating criteria.

Quantitative Data

Photometrically derived slope component measurements are the primary quantitative source of information concerning lunar morphology. Approximately 150,000 measurements distributed among 48 individual sample areas constitute the raw data which have been treated statistically, in order that units of differential relative roughness might be numerically defined.

Briefly stated, the statistical analysis consists of visual appraisals of histograms and examination of the functional relations between relative roughness and various statistical parameters. Both approaches provide bases upon which judgments of relative roughness can be made and a roughness scale established.

Typical slope frequency distributions are shown in Figure 6. Opposing end points of the relative roughness spectrum are represented by slope component samples from Mare Nubium (Mare I-A) and Herschel (Sculptured

Highlands II-D). Clearly, the smoother mare is characterized by a "peaked" curve, while the rougher uplands yield a very low curve. One of a large number of the intermediate types is represented by the "Bode B" sample (II-B). It is apparent that slope frequency distribution curves provide a rapid means of evaluating relative roughness both in specific sample areas and for extrapolation purposes.

The differential degrees of peakedness of histograms can be efficiently expressed by the standard deviation, σ . This particular parameter expresses the dispersion of slope component values, while the mean, \bar{X}_{Ab} , defines the central tendency of the slope component population. These values, \bar{X}_{Ab} versus σ_{Ab} have proven to be efficient discriminators of terrain types (Figure 7). The transition in terms of relative roughness from smooth mare to rough uplands is clear in this diagram. Additionally, upland basins (II-A) group closely and suggest a fundamental morphologic difference when compared to the marial samples.

The above discussion only briefly outlines the general value of slope statistics as quantitative descriptors of lunar topography at the one-kilometer scale of resolution. Further analysis has suggested that definition of sub-units is also quite feasible at this and higher resolutions. Additional quantitative sources have been examined, especially in the highland units. The

photometric slope measurements are most efficient in areas of gentle topography. Relative relief measurements, therefore, provide an important supplementary parameter in the highland terrain units (Figure 8). The \overline{X}_R and $\overline{\sigma}_R$ values accompanying these diagrams clearly define the relief characteristics of II-B, II-C, and II-D. Unit II-A is excluded, since it is characterized by very low relief in these highland basins.

Increasing albedo in the maria has been frequently equated with increasing crater density, and therefore with increasing relative roughness. Figure 9 demonstrates a higher crater density in the ray-covered areas, as opposed to rayless maria. The albedo in the rayed area increases proportionally. These points suggest that the ray-covered areas in the maria are rougher than those which have no ray deposits. This generalization has been supported by slope frequency studies and analysis of Rangers VII, VIII, and IX photography. Similar relations have been demonstrated in the light and dark maria of Mare Serenitatis.

C. Resolution

Resolution, or slope length, is considered separately here from the above discussed parameters because of its profound effects on relative roughness. Generally, the unresolved relief at any point on the lunar surface

can be added to that which can be resolved and has been measured. It is implied, therefore, that statistical parameters used to express roughness will increase with decreasing slope length. Slope frequency analysis of the Ranger VII one-meter resolution frame, P₃:979, confirms this hypothesis (Figure 10). Lightly ray-covered maria yields an arithmetic mean, \bar{X}_{Ab} , of about 1.0° , and is characterized by a peaked frequency curve at one-kilometer resolution. At one-meter resolution, however, the curve is low and the $\bar{X}_{Ab} = 4.56^{\circ}$ (Figure 10). Significantly, the frequency curve is very similar to that shown for the uplands unit II-D in Figure 6. The functional relationship between slope length and the median for the average maria is shown in Figure 11. It is important, however, to note that detailed relationships for these parameters are unknown and must be defined for each major terrain type.

D. Terrain Calibration

Emphasis has been placed on terrain analysis techniques, results, and interpretations. Lunar morphology is, however, controlled in a complex way by volcanic processes, impact processes, and erosion. High resolution photography of areas which provide maximum information concerning these processes is necessary to a more complete understanding of lunar morphology. The rating scheme (A, B, C) used in Section VI for Mission A reflects the importance of these areas to terrain calibration. Since Rangers VII, VIII,

and IX did not provide high resolution coverage of dark maria, upland terrain units and crater units, particular attention has been given to these areas. Further development of extrapolation techniques for major terrain units is largely dependent upon adequate high resolution coverage of these areas. Terrain units considered to be especially critical for terrain calibration purposes are listed below in terms of increasing relative roughness at the one-kilometer resolution scale:

I-B	- Dark Mare
I-A	- Average Mare
I-C	- Ridged Mare
I-IV	- Ray-Covered Mare
II-A	- Highland Basins
III-B-2	- Floors of Deformed Craters
II-B	- Subdued Uplands
III-A-3	- Crater Rims
II-D	- Sculptured Highlands

Although the upland and crater units are rougher than the general mare types at one-kilometer resolution, they are important in terrain calibration studies. These areas may also prove to be of significantly higher bearing strength than the mare materials. Brief descriptions concerning terrain calibration and relative roughness are given in Section VI.

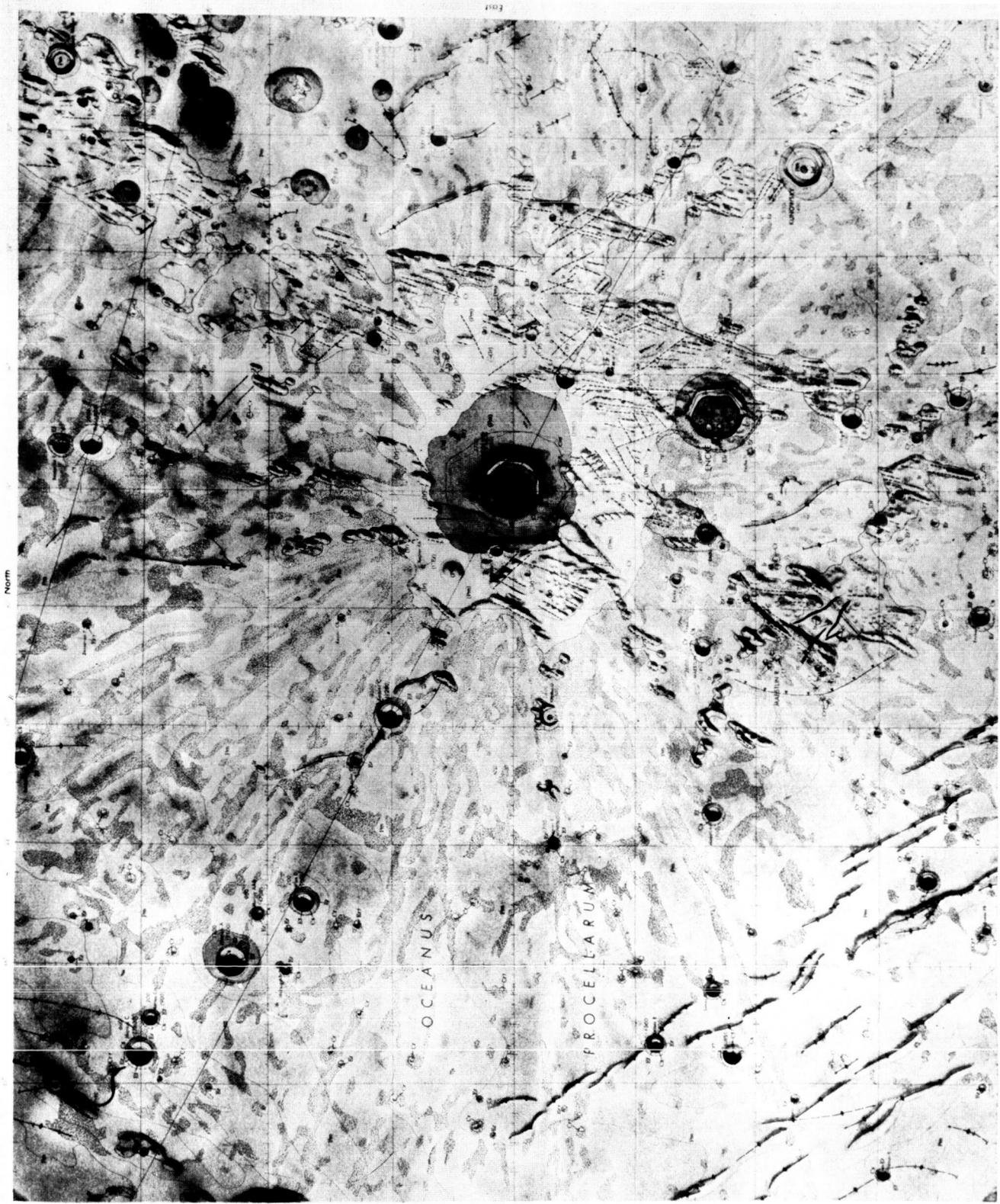


Figure 5 - U. S. Geological Survey I:1,000,000 geologic map of the Kepler Quadrangle.

TYPICAL SLOPE FREQUENCY DIAGRAMS

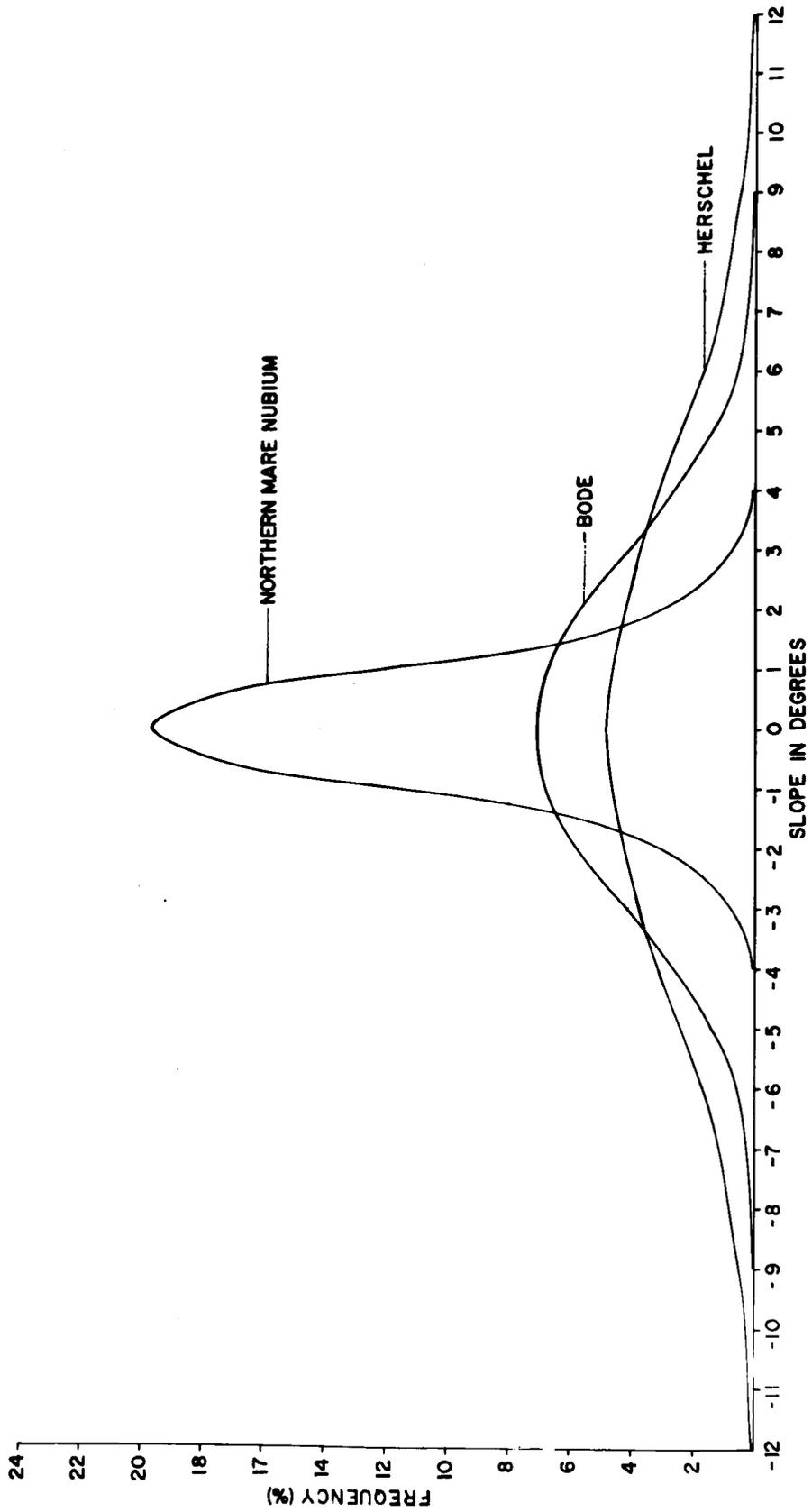


Figure 6. - Typical slope frequency diagrams at one kilometer resolution.

- I. SMOOTHER MARE
- II. ROUGHER MARE
- III. OLDER CRATER FLOORS
- IV. SUBDUED HIGHLANDS & OUTER CRATER RIMS
- V. ROUGHER HIGHLANDS & INNER CRATER RIMS

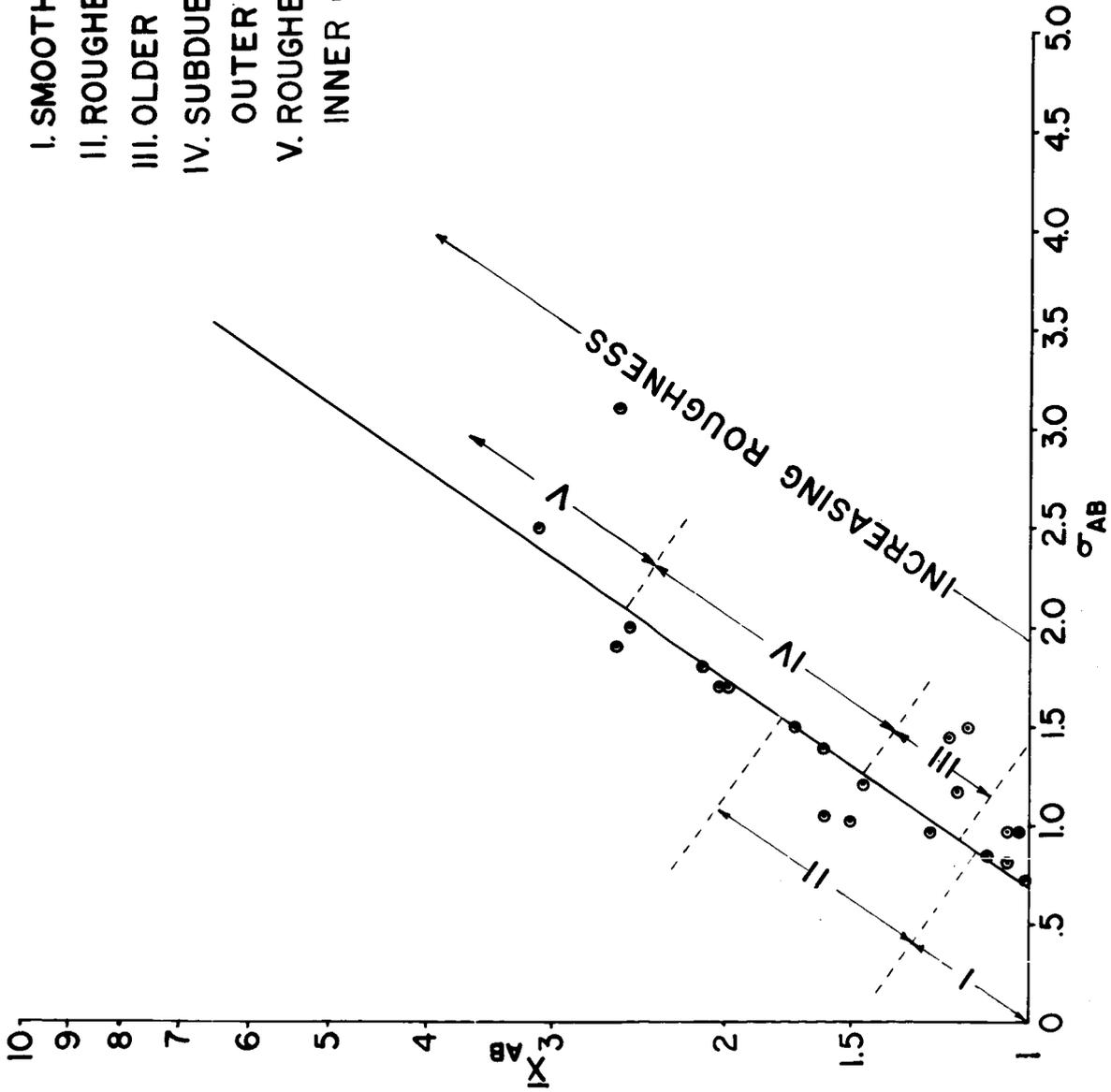


Figure 7. - Differential relative roughness defined by plotting the standard deviation, σ_{AB} , versus the automatic mean \bar{X}_{AB} .

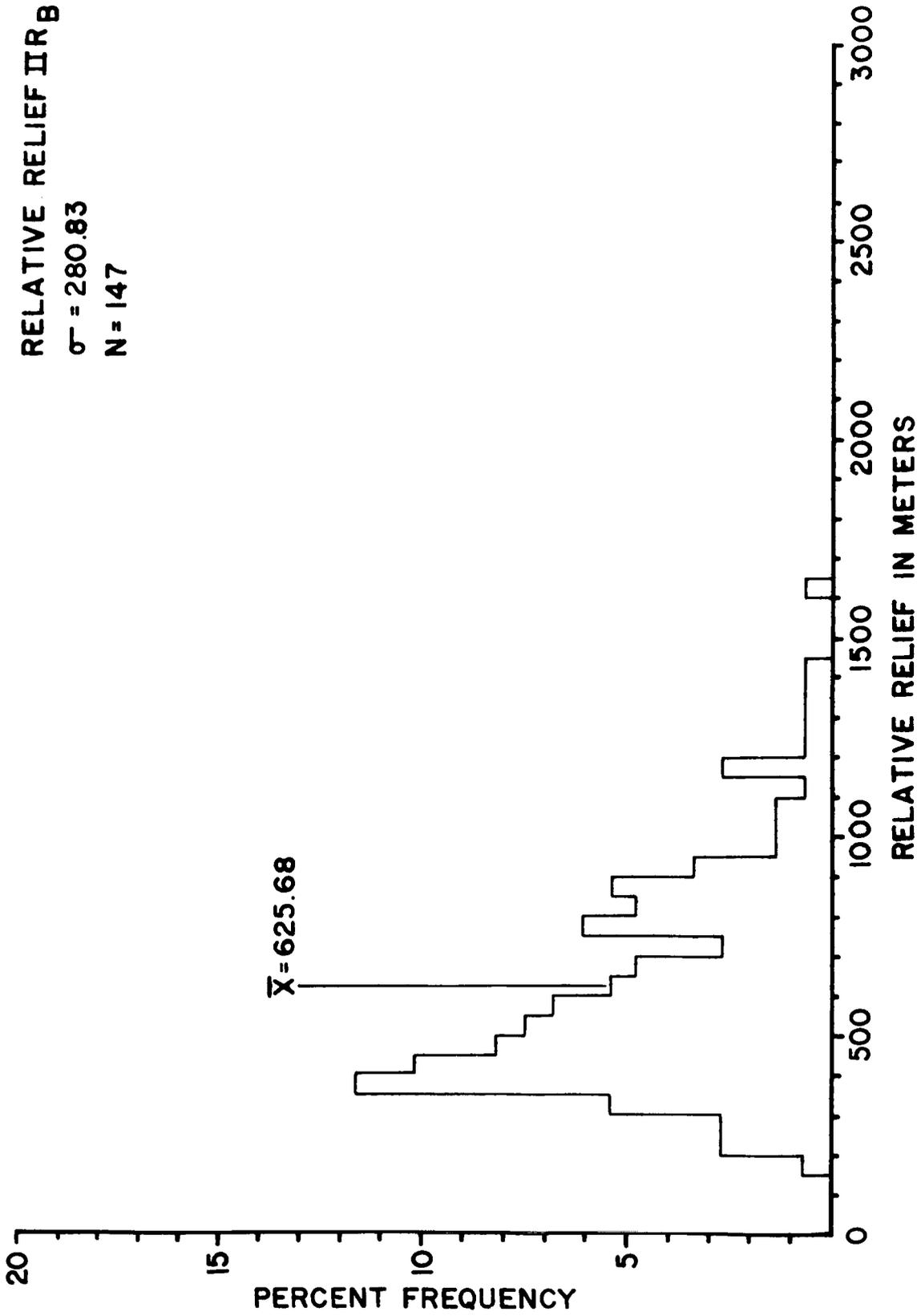


Figure 8a. - Histogram of relative relief data for Terrain Unit II-B.

RELATIVE RELIEF II-C
 $\sigma = 402.13$
N = 374

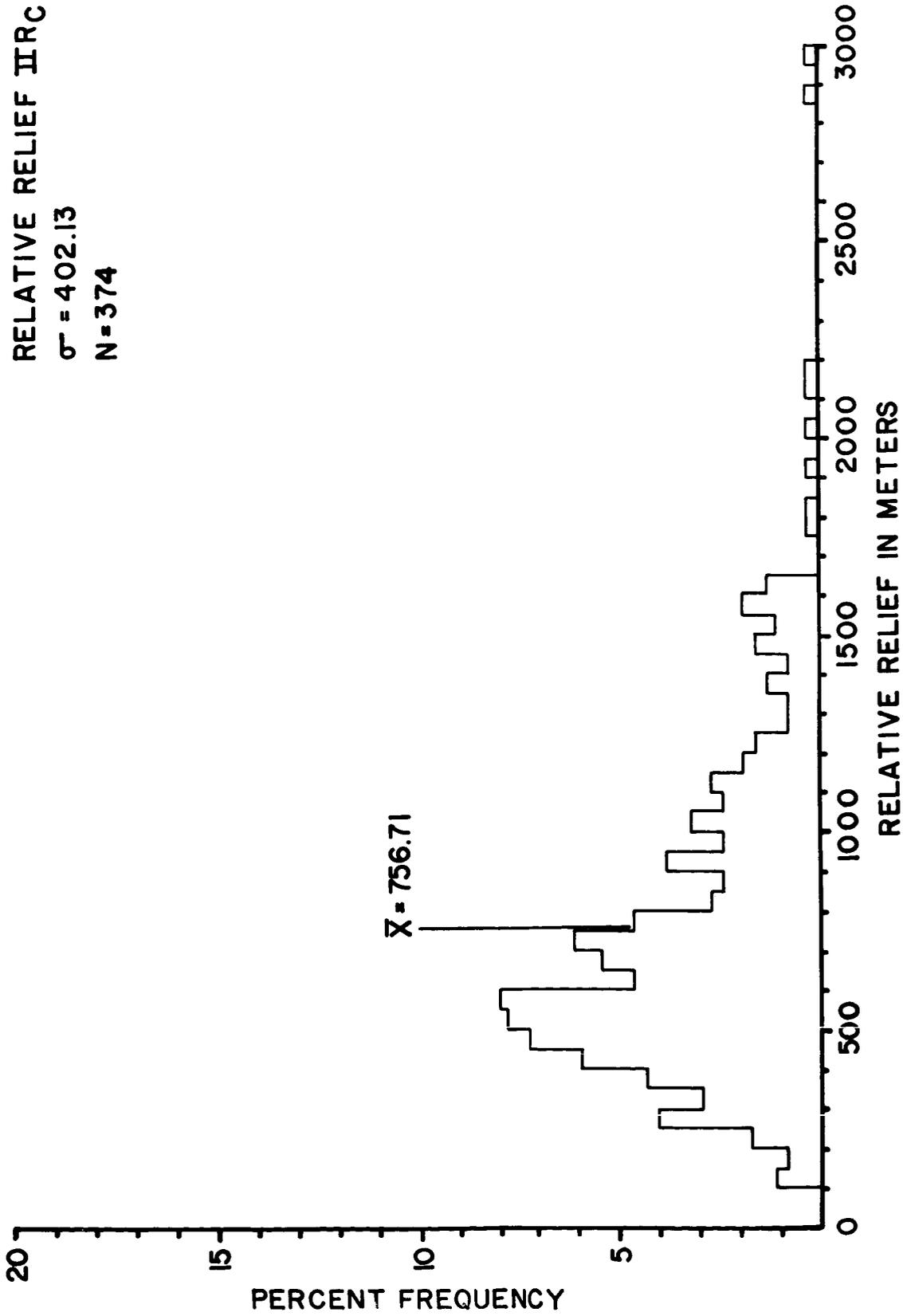


Figure 8b. - Histogram of relative relief data for Terrain Unit II-C.

RELATIVE RELIEF II R D

$\sigma = 454.70$

N = 28

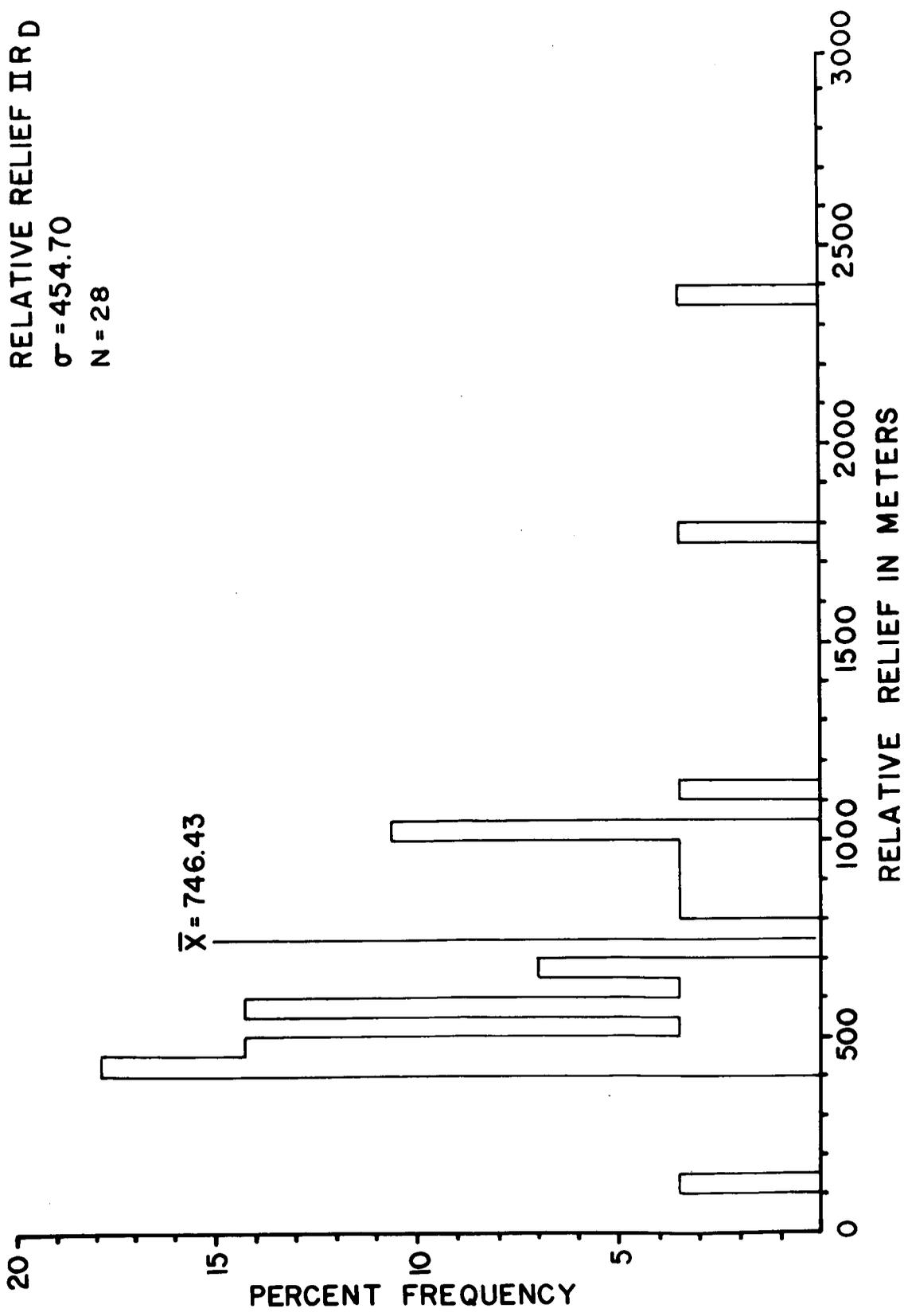


Figure 8c. - Histogram of relative relief data for Terrain Unit II-D.

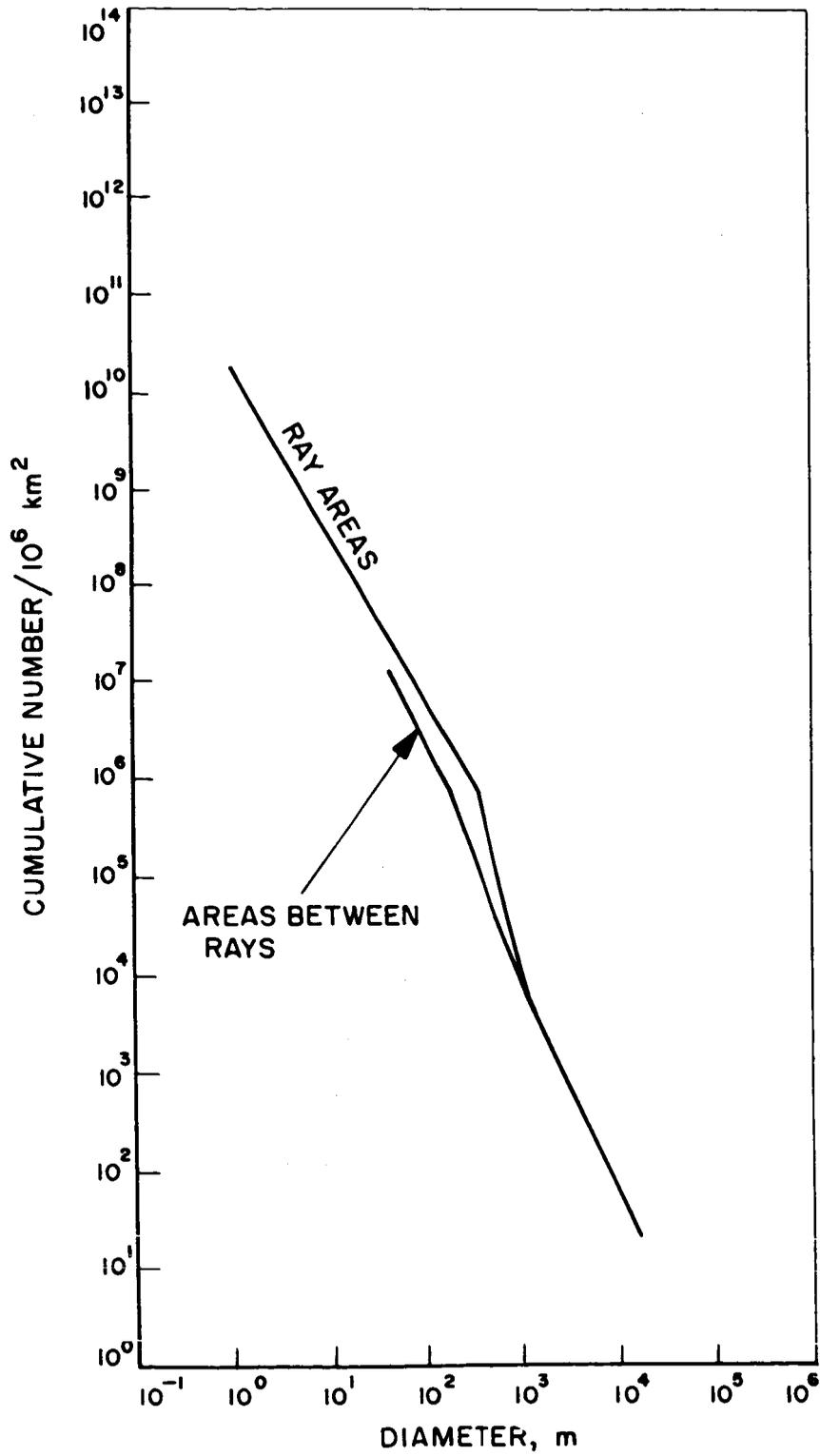


Figure 9 - Crater density in ray-covered mare and area between rays.

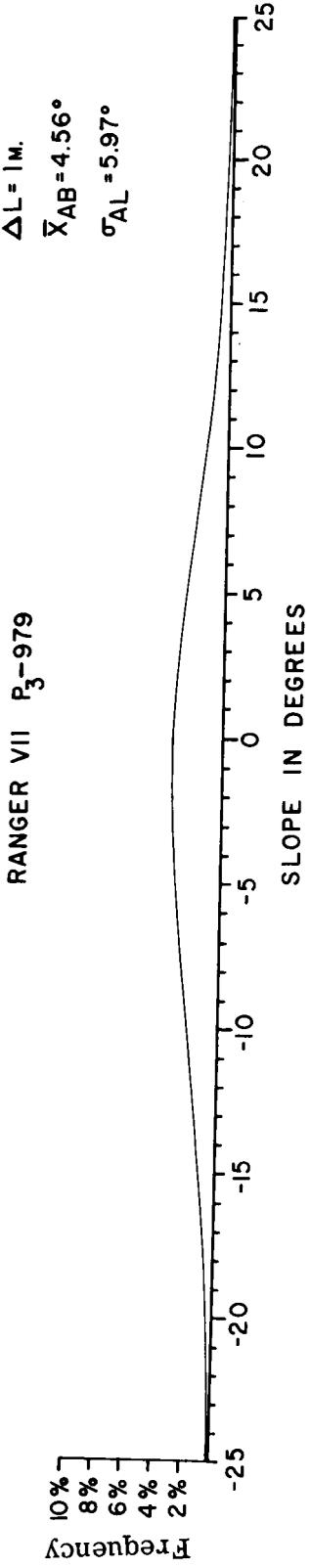


Figure 10 - Slope frequency distribution for Ranger VII, P3-979, at one meter resolution.

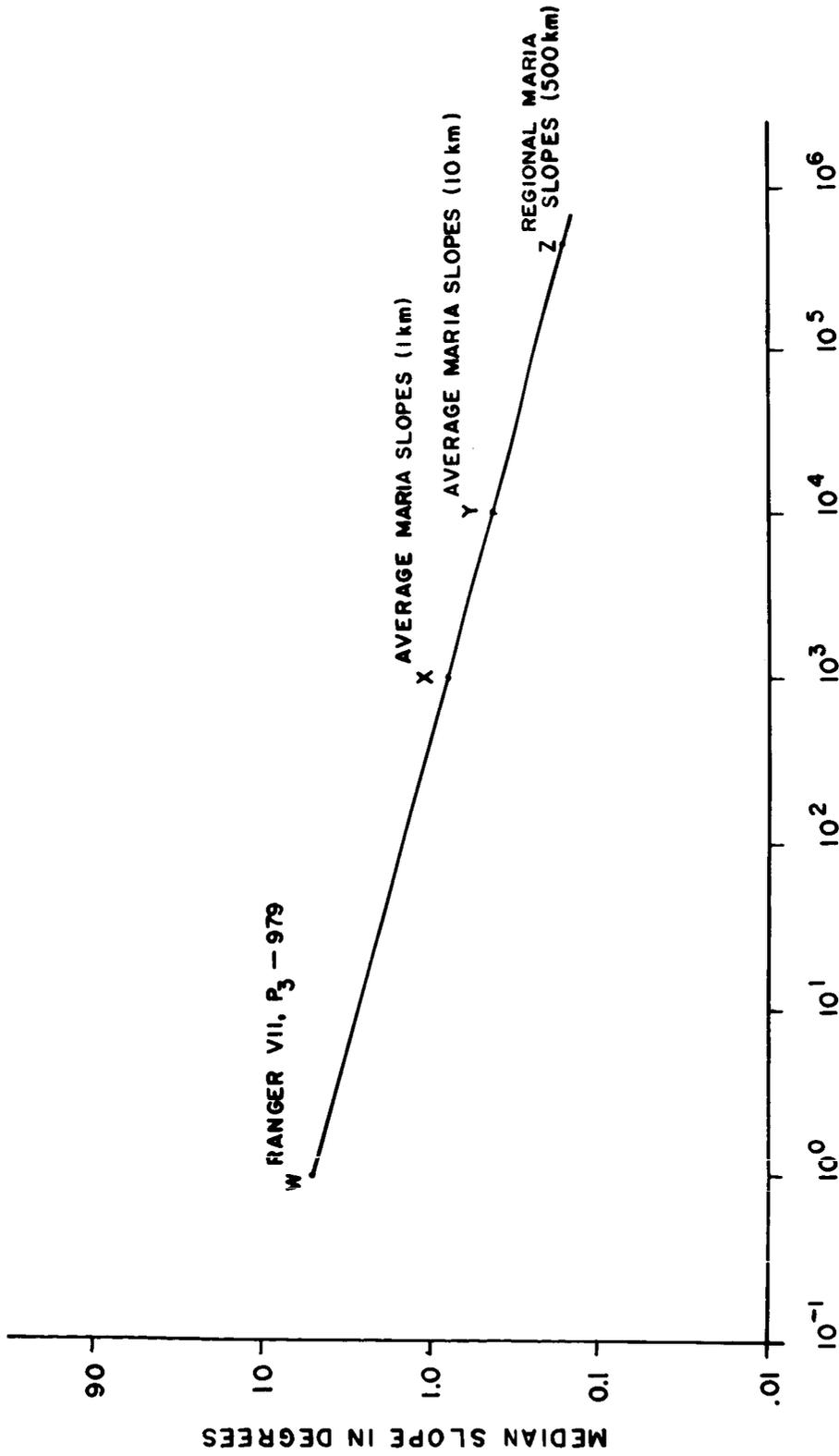


Figure 11, MEDIAN SLOPES AS A FUNCTION OF SLOPE LENGTH FOR THE LUNAR MARIA

VI. LUNAR ORBITER SITE EVALUATIONS *

MISSION A

* By Dr. Lawrence Rowan, U.S. Geological Survey

Site No.	Location		Terrain Calibration Evaluation
	Latitude	Longitude	
1	0°50' S	42°20' E	<p>RATING A: Inclusion of dark mare, moderately light mare, and uplands in this site make it a valuable terrain calibration area. The one-meter relative roughness of the two mare types is of special interest. The possible detection of genetic relationships at the contact of the upland and dark mare is of particular importance scientifically. The maria units are potential Apollo landing sites.</p>
2	0°10' S	36°0' E	<p>RATING B: Significant terrain calibration data is anticipated at this site for the upland units II-A and II-B, and the mare. Potential Apollo landing sites may be revealed here.</p>
3	0°20' N	24°50' E	<p>RATING B: Useful data concerning the small scale roughness and morphology of this area should be obtained. It is a potential Surveyor and Apollo landing site.</p>

Site No.	Location		Terrain Calibration Evaluation
	Latitude	Longitude	
4	0°00' S	12°50' E	<p>RATING A: It is anticipated that high resolution photography of terrain units II-A, II-B, II-C, and II-D will provide the data necessary to define the one-meter resolution roughness of the upland areas. This site is a potential Surveyor and Apollo landing area.</p>
5	0°25' S	1°20' W	<p>RATING B: This is an especially good example of smooth mare with low subdued ridge structures, which are important in the evaluation of mare origin and development. It has high potentiality as an Apollo and Surveyor landing site.</p>
6	4°00' S	2°50' W	<p>RATING A: This area is particularly important to terrain calibration, because it provides high resolution photography of upland unit II-D, as well as the deformed crater floor III-B-2. The crater floor is a previously selected Surveyor landing site. It is anticipated that this coverage will be of high value when bearing strength data becomes available for the major terrain types.</p>

Site No.	Location		Terrain Calibration Evaluation
	Latitude	Longitude	
7	3°45' S	22°45' W	<p>RATING B-: This is a moderately good example of mare which has low sinuous ridges, small craters, and a light ray covering. It should provide important information regarding the development of older mare surfaces and their characteristic morphology. It is a previously selected Surveyor landing site (16-50).</p>
8.1	3°00' S	36°30' W	<p>RATING A: This is a superior example of a relatively linear mare ridge system, which is especially important in the definition of 1-meter scale roughness. It provides an excellent opportunity to investigate the genetic processes concerned in the development of this type of mare morphology. It is a highly rated Surveyor landing site (11-50).</p>
9.1	2°21'S	43°22'W	<p>Surveyor I landing site.</p>

VII. COMPARISON OF MISSION WITH CRITERIA

The approved Lunar Orbiter Mission A has been presented and it is of importance to compare the results with the objectives, ground rules, and constraints. Figure 12 gives a summary of the terrain samples and it is seen that a reasonable balance is obtained, that is, six mare samples which are the highest priority type, four highland samples, and one crater sample. It is of interest to note that after the second site one mare and one highland sample have been obtained. This is important to the terrain calibration objective in case of early spacecraft failure.

Figure 13 shows the site distribution for each terrain type. The mare sites are reasonably distributed between about 42°E and 43°W . The most promising highland areas exist only in the eastern portion of the Apollo zone and three sites are distributed in this area. The one crater site is selected near the central part of the Apollo zone and all selected sites are located within the Apollo zone.

Six of the nine sites are proposed Surveyor sites and site 9.1 is the Surveyor I site. Of the three non-Surveyor sites, one (site 3) could become a Surveyor site and the other two (sites 1 and 2) are in the extreme eastern part of the Apollo zone which is not accessible to Surveyor.

Because of the film handling constraints, it is important to review the film utilization for Mission A. Figure 14 shows a film budget superimposed on a mission profile. The conclusion is that the film requirements to perform Mission A are within the total film capacity of the system. In fact, there are 10 frames in excess of the requirement. For general information, the nine sites and the nominal lighting conditions are shown on Figure 15.

The conclusion of the comparison of the mission with the criteria is that the Lunar Orbiter Mission A satisfies the objectives, ground rules, and constraints and is within the capabilities of the Lunar Orbiter system.

TERRAIN SAMPLING SUMMARY

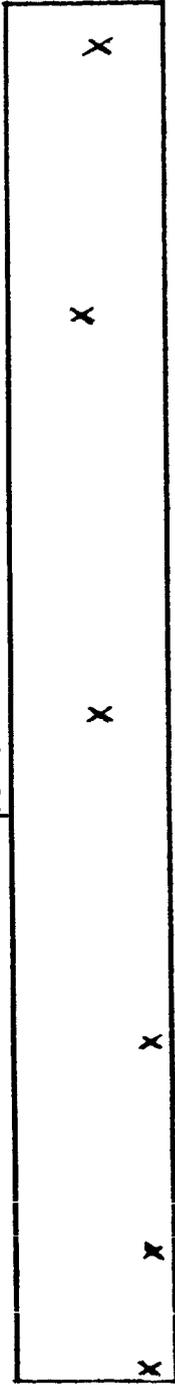
High Resolution Coverage

Site Terrain No. / Type	1	2	3	4	5	6	7	8.1	9.1	Σ
Mare	80%		100%		95%		100%	100%	95%	6
Highland		60%		100%	2%	60%				4
Crater						25%				1
Other	20%	40%			3%	15%			5%	

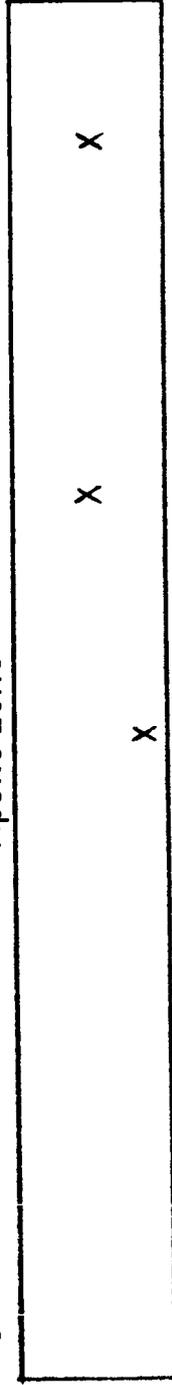
Figure 12

TERRAIN TYPE DISTRIBUTION

A. Mare



B. Highland



C. Crater

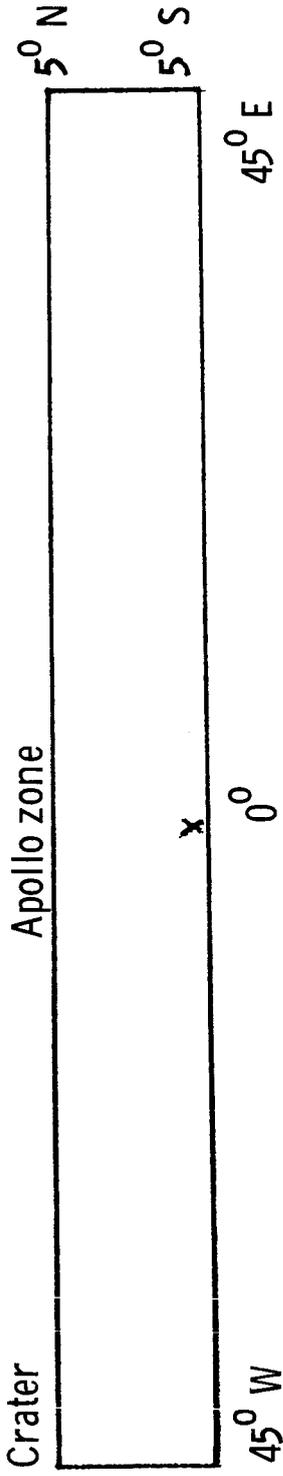
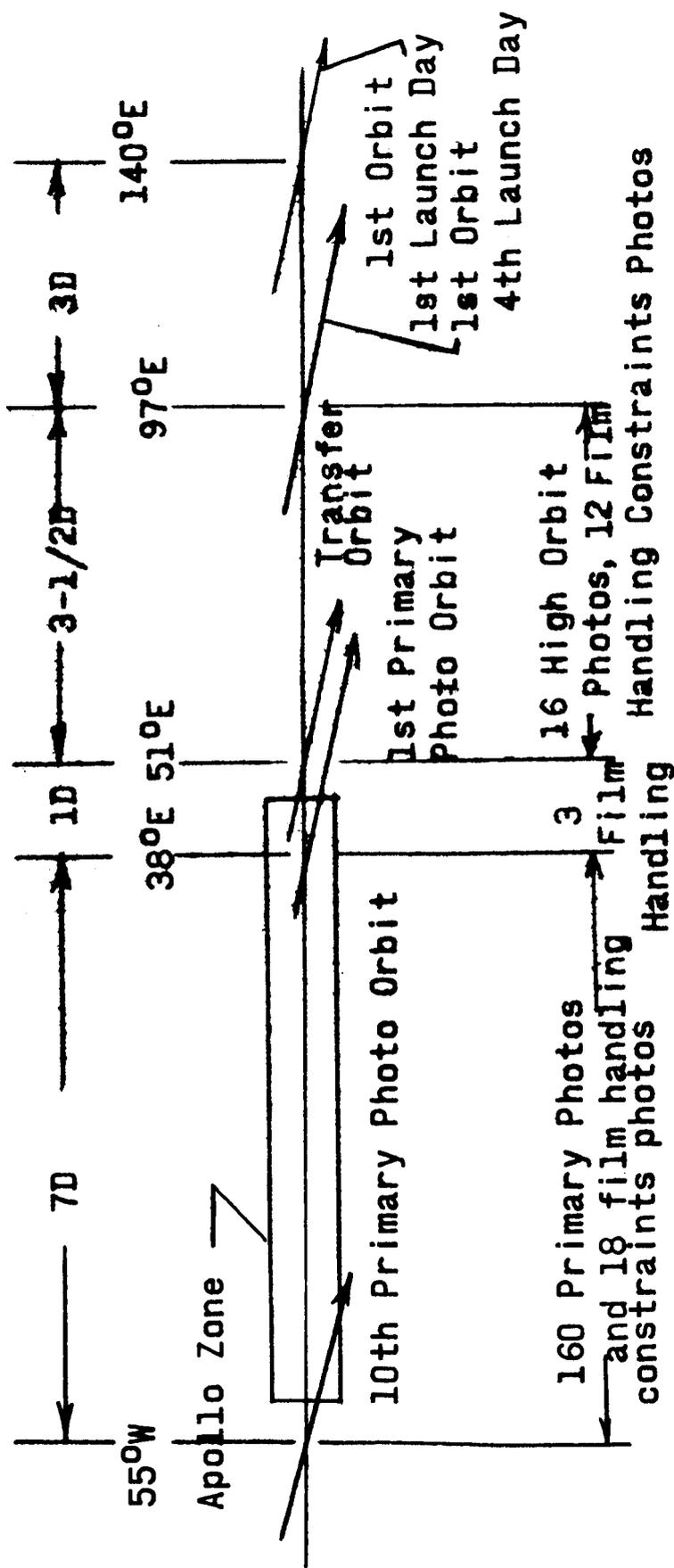


Figure 13

LUNAR PHASE MISSION PROFILE AND PHOTO FRAME BUDGET



219 Frames available
 209 Frames required
10 Contingency Frames

160
 18
3
12
 209 Frames Required

Constraints Photos
 Handling Constraints Photos

Figure 14

LIGHTING FOR MISSION A SITES

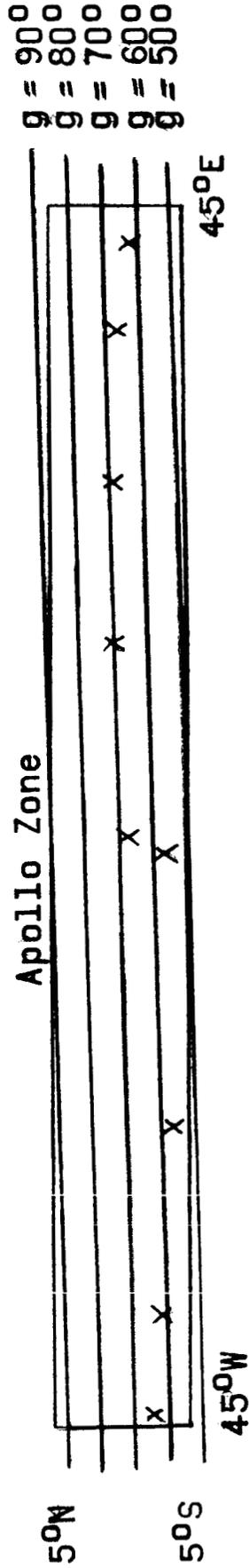


Figure 15