BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: A Proposed Plan for Geologic Exploration on the Second Apollo Landing Mission - Case 710

DATE: January 31, 1968

FROM: A. F. H. Goetz

ABSTRACT

A discussion is given of a geological EVA connected with a hypothetical second Lunar Landing Mission. Based on specific exploration objectives derived from interpretation of Orbiter photography, two sample geological traverses are developed. The traverses are consonant with the operational constraints of EVA time, astronaut mobility, lighting conditions and landing location.

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MEMORANDUM FOR FILE

I. INTRODUCTION

The purpose of this paper is to discuss in detail the geologic EVA connected with a hypothetical second Lunar Landing Mission (LLM2). The major geologic exploration objectives are discussed as well as their possible attainment within the constraints of astronaut mobility, lighting conditions and landing location. The earth based system of geologic mapping is not directly applicable to the moon. Therefore, a series of priorities must be established for features of interest and examined in light of the information at hand, mainly in the form of Orbiter photographs.

II. ASSUMPTIONS

Several assumptions and constraints are used as guidelines:

1. A specific Apollo site, II P 6-1, was chosen.
2. Only emergency redesignation capability is present with the result that the landing is random in the ellipse.
3. The ALSEP will be deployed requiring 1 EVA period of the two available.
4. Astronaut mobility was tested on the first lunar landing mission and no major restrictions were placed on their capability to carry out the assigned tasks.
5. Two and a half hours of EVA time are available for non-operational activities and astronauts may traverse as far as 1 km from the LM.

III. GENERAL OBJECTIVES

The main scientific objectives of LLM2 are to deploy an ALSEP, to investigate as many different geologic features and to return as varied a sample as time and other constraints will permit. The details of the scientific value of ALSEP have been treated extensively elsewhere and will not be discussed here.

IV. REGIONAL GEOLOGY

Site II P 6-1 is centered at 0°45'N, 23°37'E in the southwest corner of Mare Tranquillitatis. This region is covered by the geologic map of the Julius Caesar quadrangle at a scale of 1:1,000,000. Fig. 1 shows the II P 6-1 site relative to Sabine D. Stratigraphically, from the oldest to youngest, the units defined are Imbrium mare material of the Procellarum Group, Eratosthenian craters without rays or light halos and Copernican satellite craters. The major structural features are a series of mare ridges which trend NW-SE and are found to the east of the landing site. These ridges are part of an extensive system crossing Mare Tranquillitatis. An elongate depression trending NW and bordered by faults is located 20 km NE of the landing site. The Langley report on Orbiter II compares the ridge and depression system to the Western United States Basin and Range province. This region is classified as a blue mare and does not exhibit anomalous cooling during an eclipse. Surveyor V and Ranger 8 also landed in this region.

V. SITE GEOLOGY

Fig. 2 shows the landing ellipse in detail. The area is characterized by little or no regional slope. Albedo variations are restricted mainly to the areas surrounding fresh craters. Blocks larger than 1 m are found only in and around fresh craters and at the borders of large partially filled craters. Flow structures, ridges, rilles and domes are virtually absent in site II P 6-1. Patterned ground can be found about a few large, shallow, partially filled craters. Several classes of craters are present:

1. Shallow "ghost craters" underlie most of the present surface. These structures include a crater chain near the southwestern border of the ellipse.

2. Partially filled craters with obliterated rims and small depth/diameter ratios are numerous. Two of the largest in the ellipse have diameters of 600 meters.

3. Fresh craters can be divided into several classes:

    A. Concentric craters with raised bright rims and containing blocky material. In the site area there are 10 such craters ranging in size from 55 to 150 meters.

B. Flat bottomed or arched floor craters having raised bright rims exhibiting some block material. The size ranges from 30 to 80 meters in diameter. Forty-one craters of this type, having a diameter greater than 30 meters, were counted in the site.

C. Conical ("dimple") craters having raised rims, sometimes exhibiting bright rays but having no blocks within the 1 meter resolution limit. Fifty-three craters of this type ranging in size from 30 to 55 meters were counted. Craters having diameters less than 30 meters were not counted.

D. Conical ("dimple") craters without detectable raised rims and rarely exhibiting bright rays make up the fourth class of features. This class contains the majority of craters less than 30 meters in diameter found in this site. A number of rimless crater chains are present. The preferred chain orientation is NW-SE, in alignment with the prevailing structural trend seen in surrounding areas. However, other chain orientations are also present but no preferred directions are apparent. The rimless crater chains oriented along the general NW-SE structural trend of the area appear similar to those found by Surveyor V and have been called subsidence features by Shoemaker.[1] The presence of these crater chains suggests subsurface void spaces possibly associated with volcanic flows.

Several conclusions about the surface and subsurface structure can be made from investigations of the crater morphology. The experimental results of Oberbeck and Quaide[2] were used in conjunction with crater diameter vs morphology counts to determine the thickness of the debris layer. It was found that in II P 6-1 the overlying debris layer has a thickness ranging between 5 and 10 meters.

As seen above, the major geologic features can be identified from orbital site photography. From this photography the features to be investigated and documented by the astronaut can be defined.

VI. SPECIFIC OBJECTIVES

1. Sample the debris layer and the "basement."

   A primary objective is to sample each unit sufficiently to identify variations and possible facies changes.

Of course this will probably not be possible in the case of the basement material. However, within the limits of the astronauts' capability a concentrated effort should be made to sample a fresh concentric type crater to obtain a basement sample.

2. Observe and photograph detailed structural relationships and surface textures not visible on one meter resolution vertical photography. Photography of crater rim structures will give information on their origin and subsequent erosion. Investigation will yield data on the immediate subsurface mare structure, its degree of consolidation and the type of material. Oblique photographs of patterned ground as well as other positive features should be made.

3. Investigate and photograph different crater types. As mentioned in Section V there are a number of different types of craters. The origin of crater chains, in particular, is a matter of dispute. Investigation of their floors and common rim relationships will establish whether they are of volcanic or impact origin or are subsidence features.

4. Sample large rocks and investigate and photograph their relationship to the surface. In site II P 6-1 large rocks are associated only with concentric craters and several large, shallow, partially filled craters. In the case of old craters the origin of the rocks is not clear. If they are remnants of the original throwout, then a study of their relationship to the present surface will make an important contribution to theories of deposition and erosion. Samples should be taken at the rock surface as well as below the surface in order that studies can be made of the effect of the lunar radiation environment.

5. Sample and probe in permanently shaded areas beneath rocks. The possible presence of frozen volatile materials in the permanently shaded areas of the moon has been suggested.[3] Surface exposures of large permanently shaded areas will be found primarily at high latitudes. However, under the northern or southern overhangs of large rocks permanently shaded areas might be found in the equatorial regions.

VII. VISIBILITY

In order to plan the surface EVA in detail, the visibility of features of interest must be established. In another paper,[4] the author has determined the visibility of rimless craters, raised rim craters and blocks using the lunar photometric function and contrast criteria. The visibilities were based on the simple model of a horizontal surface providing an unobstructed view of the features superimposed upon it. For example, for most azimuths, at low sun angles a one meter diameter crater is visible to about 55 meters by an astronaut on the ground. Looking away from the sun, because of the high backscattering properties of the lunar surface and therefore reduced contrast, a one meter crater is visible at about 40 meters. However, at this azimuth a washout occurs at less than about 20 meters. From the docking hatch of the LM, at 7 meters elevation, the astronaut could detect a 1 meter rimless crater at a distance of between 60 and 120 meters.

Positive features, such as crater rims and blocks, are visible at much greater distances because there is no foreshortening. For instance a one meter block, because of the inherent high contrast due to the albedo differences of rocks, is visible to 2 km, the astronaut's limit of resolution. Rims of craters having diameters greater than about 30 meters are visible to the horizon.

VIII. TRAVERSE PROFILE

Many geologic features of interest are visible to a distance comparable with the astronauts' 1 km radius of action, defined by the emergency oxygen supply. Therefore, a site independent profile within the landing ellipse can be developed which does not require accurate map location by the astronauts.

At the commencement of the geologic EVA a visual survey of the surrounding surface from the LM roof docking hatch is made.* Major features of interest are noted along with their approximate azimuths and distances. A traverse is laid out, approximately, to cover as many of the main objectives as possible within the 2 1/2 hour traverse time limit. A traverse speed of 3 km/hr is assumed. This approximate traverse can be altered under way, at the discretion of the astronauts, to include new features of interest which are sighted.

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*At present, the docking hatch is not scheduled to be used for this purpose. However, it is used here to demonstrate the best vantage point for *in situ* traverse planning. The LM egress platform also could be used for a visual survey. However, the field of view of an astronaut standing on the platform would be limited to approximately 200°. Traverse plans similar to those discussed later in this paper could be developed directly from the surface, since most of the features would be visible. However, more time and effort would be required.

Two specific traverses are outlined in the following, beginning at points chosen at random in site II P 6-1. The main features visited are all visible from the LM docking hatch.

Traverse A

Figure 3A shows a sample traverse laid out from a randomly chosen landing point. Five sites for investigation are chosen, the first four of which are visible from the LM docking hatch and the fifth of which would be "discovered" during the traverse from station 4 to the LM. In the following, the objectives are:

Station 1: Distance from the LM: 350 m. Concentric crater 60 m in diameter, slightly eroded, contains several small younger conical craters. Chance of finding basement type material scattered around rim. Photograph structure and describe type of erosion and filling. Sample. Stay time 20 minutes.

Station 2: Distance from station 1: 400 m. Concentric crater 70 m in diameter. Structure and apparent age very similar to station 1. Objectives same as station 1. Observe similarities and differences particularly with relationship to the depth to basement and type of material. Stay time 20 minutes.

Station 3: Distance 560 m. Three craters, two with diameters of about 20 m, with apparent common rims. Each contains a smaller younger crater in its wall. The third crater is a practically rimless, 30 m diameter, conical crater, possibly containing a small flat floor. Study structural relationships particularly between craters with a common rim. Photograph with intent to establish the origin of the different features. Sample. Stay time 20 minutes.

Station 4: Distance 450 m. A 25 m dim raised rim crater with a light ejecta blanket. This is the only bright crater within 1 km of the LM and should, therefore, be easy to detect. A second smaller crater is found on the north rim of this crater. Determine depth of bright material. Stay time 20 minutes.

Station 5: Distance 250 m. N-S trending crater chain. Craters about 10 m or less in diameter. Also an intersection of an E-W trending crater chain of slightly larger craters. Investigate to determine origin. Sample if necessary. Photograph. Stay time 20 minutes.

Return to LM. Distance 300 m. Total distance traveled: 2.31 km. Walking time: approximately 50 minutes. Total time at station 1, 1 hour 40 minutes. Total traverse time: 2 1/2 hours.

Traverse B

Figure 3B shows a similar traverse laid out from a hypothetical landing point approximately 1.9 km south of the landing point in traverse A. In many cases the traverse objectives and features visited are similar, which is due of course, to the homogeneous nature of the mare surface.

Station 1: Distance 300 m. Bright raised rim crater, diameter 15 m. This crater is at the head of an irregular chain extending NW-SE. Sample different albedo materials. Photograph relationships to other chain craters. Stay time 10 minutes.

Station 1 - Station 2: Distance 170 m. Traverse west of chain. Photograph and sample if worthwhile. Investigate elongate crater near station 2. If low velocity impact structure, attempt to sample projectile. Stay time 10 minutes.

Station 3: Distance 600 m. Bright concentric type crater structure. Diameter 35 m. Appears somewhat eroded. Bright appearance may be an artifact of the Orbiter II photograph. Crater is positioned in the wall of a very shallow ghost crater. Photograph structural relationships of the two. Sample, attempt to retrieve basement rocks. Staytime 20 minutes.

Station 4: Distance 770 m. Partially filled conical crater, 60 m in diameter. This crater appears to have a smaller diameter-depth ratio than most eroded structures. Investigate for subsidence or drainage.

Station 5: Distance 120 m. A smaller version of station 4. Crater diameter 20 m. However, raised western rim suggests an eroded impact structure. Also elongated. Photograph and sample as necessary. Staytime 10 minutes.

Station 6: Distance 350 m. Large shallow ghost crater, approximate diameter 180 m. At least two boulders are visible on the Orbiter II photograph. It is not clear whether the boulders are remnants of the original impact structure which has been eroded and filled or whether the boulders originated outside the immediate area. The former case is more probable. Sample the boulders and sample the surface under any overhangs that might provide permanently shaded areas. If possible, move the boulder and photograph depositional features in cross-section. Sample beneath boulder. Photograph any structures of interest in crater. Staytime 20 minutes.

Station 7: Distance 130 m. Small crater chain trending NE-SW. Photograph relationships. Determine if craters are subsidence features.

Return to LM. Distance 350 m. Staytime 10 minutes. Total distance traveled: 2.44 km. Walking time approximately 55 minutes. Total time at stations 1 hour 35 minutes. Total traverse time 2 1/2 hours.

IX. TRAVERSE DISCUSSION

Each traverse accomplished most of the objectives put forth in Section VI. Of course not all landing points will be within 1 km of a fresh crater or a crater chain or, because of terrain considerations will be in view of such a feature. However, the main features of interest outlined previously are sufficiently numerous over the entire site so that approximately 80% of them should be encountered on any traverse.

Some consideration must be given to the constraints placed on the astronaut mobility by the near field visibility. Because of the zero phase washout phenomenon he probably will not wish to walk directly away from the sun and, conversely, because of the potential visor glare problem the visibility may be quite poor while facing the sun directly. This constraint would, for instance, affect traverse B. The paths between station 2-3 and 3-4 would not be negotiable. A shortening of the traverse by moving directly from station 2 to 4 would decrease the total distance by about 1 km and the traverse time by about 20 minutes. However, no fresh crater, which is a high priority objective, would be visited. Therefore, a priority decision must be made in the original rough mission plan which would either alter the traverse path to include a high priority feature at the exclusion of others or bypass it completely.

A. F. H. Goetz

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A. F. H. Goetz

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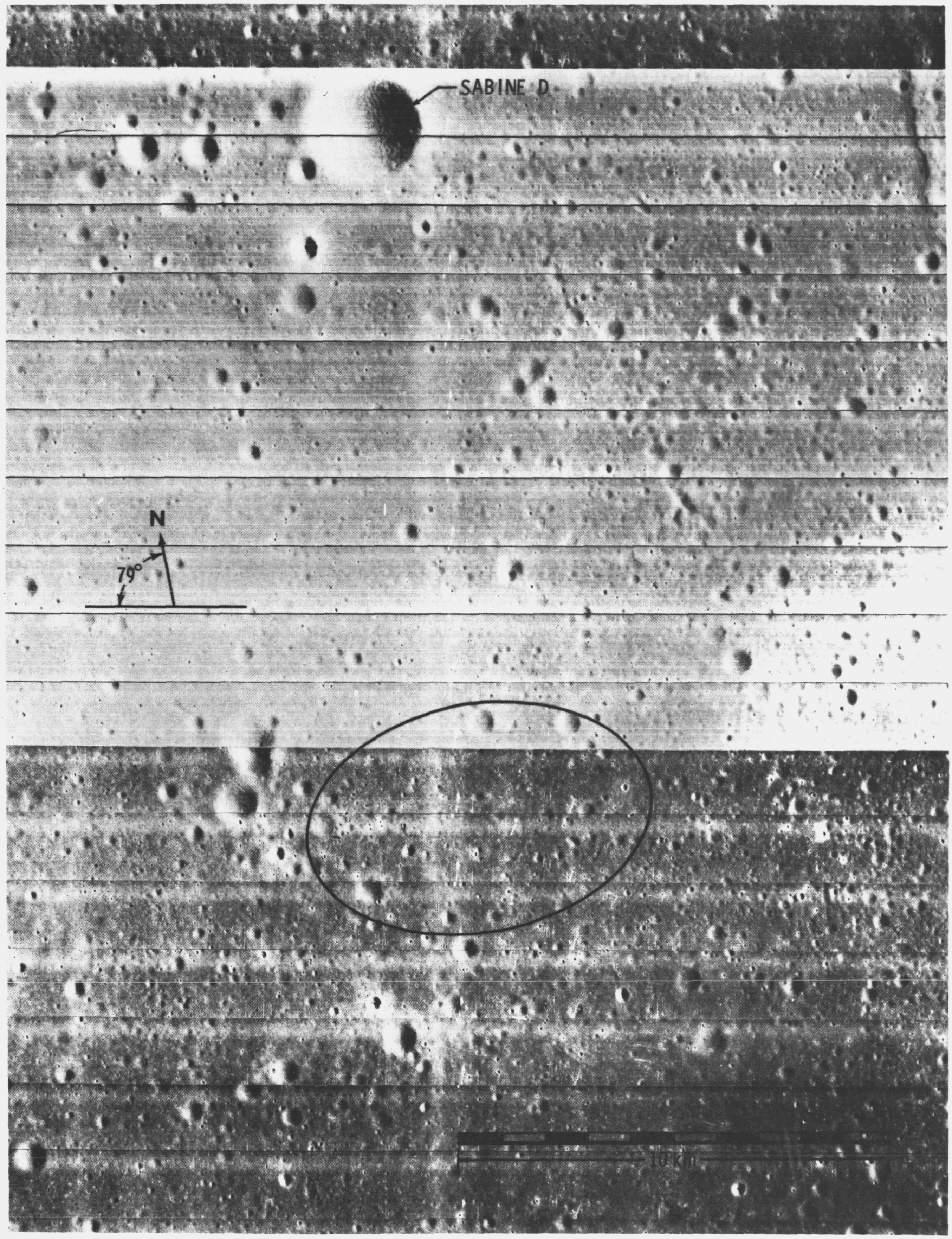


FIGURE I. LANDING SITE II P6-I IN SOTUHWESTERN MARE TRANQUILLITATIS

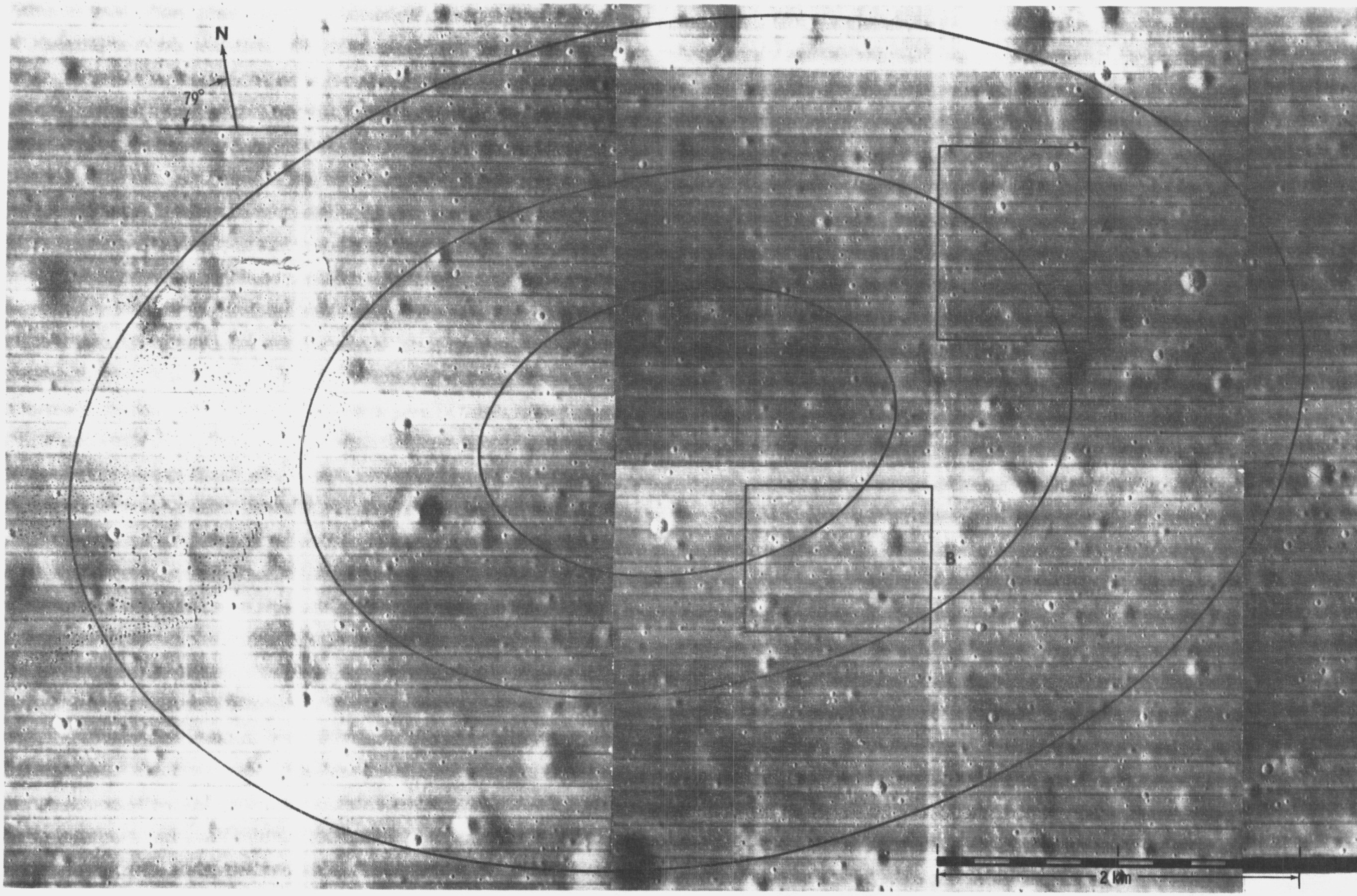


FIGURE 2. SITE II P6-I SHOWING OUTLINE OF MISSION A AND B AREAS SHOWN IN DETAIL IN FIGURE 3

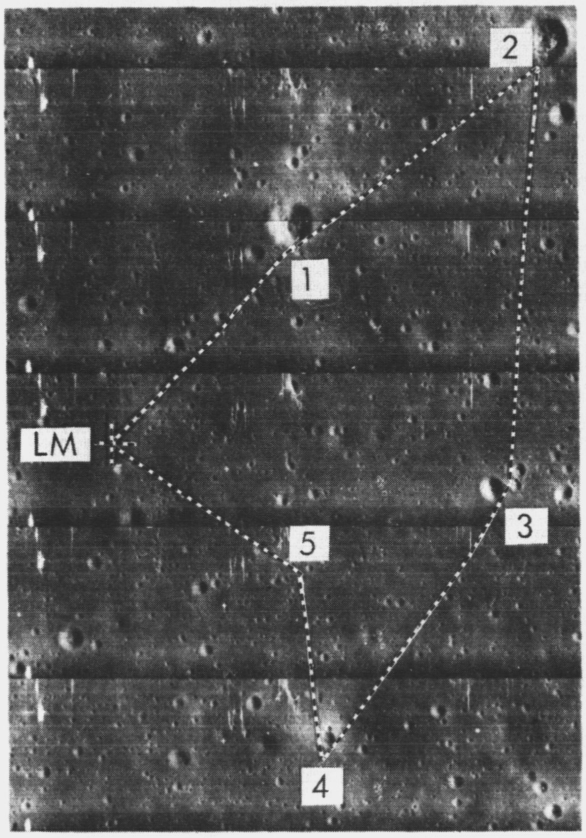
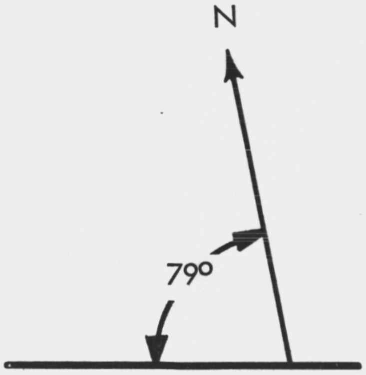


FIGURE 3A. TRAVERSE A



1 KM

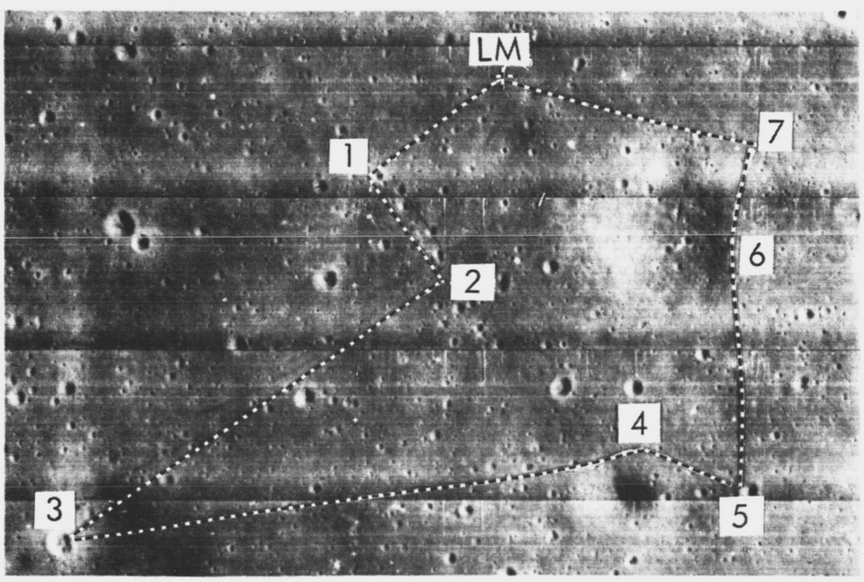


FIGURE 3B. TRAVERSE B

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