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SUBJECT: Scientific Rationale Summaries for Apollo Candidate Lunar Exploration Landing Sites - Case 340

DATE: March 11, 1970

FROM: J. W. Head

ABSTRACT

A summary of the scientific rationale for each Apollo landing site listed by the Group for Lunar Exploration Planning on February 7, 1970 is presented. These sites include the Fra Mauro Formation, Littrow, Censorinus, Davy crater chain, Marius Hills, Descartes, Tycho, Copernicus central peaks, and Hadley-Apennines. In addition, a summary of the scientific rationale for Flamsteed P, the Apollo 13 backup site, and Hyginus is presented.

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MEMORANDUM FOR FILE

INTRODUCTION

Apollo candidate lunar exploration sites are selected to achieve an understanding of regional lunar geology, geochemistry, and geophysics, and to establish an absolute time scale for the origin and evolution of major lunar historic events and processes. In order to achieve this understanding, the set of sites should include:(1)

1. The two types of mare material, "eastern" and "western".
2. Regional stratigraphic units such as blanket (ejecta) deposits around mare basins and highland plains units.
3. A variety of impact craters both in the maria and highlands.
4. Volcanic complexes and features in the maria and highlands.
5. Areas characteristic of processes such as tectonism or sinuous rille development which are not clearly related to volcanism or impact.
6. Areas providing access to deep-seated or generally inaccessible geochemical and petrologic samples.

Apollo missions 11 and 12 have visited and sampled an eastern and western mare region. The purpose of this memorandum is to summarize the scientific rationale for the Apollo candidate lunar exploration landing sites listed by the Group for Lunar Exploration Planning (GLEP) on February 7, 1970 (Table 1). Duplicate sites were listed by GLEP for Apollo missions 15 and 17, and both are discussed for each

mission. Also included is a discussion of the Apollo 13 back-up site, Flamsteed P. Figure 1 shows the location of the candidate sites described. Table 2 summarizes the salient geological, geophysical, and geochemical characteristics of these sites.

These rationale summaries were prepared for inclusion in revisions and appendices to the Apollo Flight Mission Assignments Document (M-D MA500-11; SE 010-000-1).[2] The Apollo 13 and Flamsteed P backup mission rationale were included in the January 23, 1970 revised appendix for the Apollo Flight Mission Assignment Document.

SCIENTIFIC RATIONALE SUMMARIES

Apollo 13 (H-1) Fra Mauro Formation

The Fra Mauro Formation, an extensive geologic unit covering large portions of the lunar surface around Mare Imbrium, has been interpreted as the ejecta blanket deposited during the formation of the Imbrium basin. Sampling of the Fra Mauro Formation may provide information on ejecta blanket formation and modification, and yield samples of deep-seated crustal material giving information on the composition of the lunar interior and the processes active in its formation. Age dating the returned samples should establish the age of pre-mare deep-seated material and the time of formation of the Imbrium basin, thus providing important points on the geologic time scale leading to an understanding of the early history of the moon.

Apollo 14 (H-2) Littrow

The Littrow area landing site lies on the eastern edge of Mare Serenitatis in the vicinity of a series of straight rilles and wrinkle ridges oriented parallel and sub-parallel to the edge of the basin. A mantling material of very low albedo as well as a topographic bench lie in the vicinity of the landing site. Analysis of material from Mare Serenitatis will provide geochemical and age data which can be related to results from Apollo 11 and 12 to show compositional and age differences for different maria. Investigation of the wrinkle ridges should provide an understanding of the composition, origin and significance of these widespread mare features. The dark mantling material appears to be younger than most other features in the site. It is probably among the youngest of lunar surface materials and may record the latest stages in the process of basin filling in Mare Serenitatis.

Apollo 15 (H-4) Censorinus

Censorinus is a small (3.5 km diameter) bright crater of probable impact origin located in a segment of the highlands just southeast of Mare Tranquillitatis. The composition and age of highland materials and mechanics of crater formation at a young crater are among the primary objectives of a mission to the edge of the continuous ejecta blanket of Censorinus. Study of the distribution, structure, and morphology of the ejecta material should provide information relating to the mechanics of crater formation. Sampling of the landing area will not only provide data on the composition of the highland surface material, but should also provide information about shallow highland material excavated by the event which produced Censorinus. Since the crater Censorinus is relatively very young, possible age dating of the event producing the crater will provide an important point on the lunar time scale. Age dating of the highland material sampled at this site will serve to clarify an understanding of the relationship of this area to the extensive mare regions.

Apollo 15 (H-4) Davy Crater Chain

Davy crater chain is a probable volcanic crater chain crossing the highland-mare boundary slightly northwest of the crater Alphonsus. The chain of craters, several of which are thermally anomalous, stretches some 60 km from Davy C, located in plains material, to Davy G on an upland plateau. Since the craters forming the Davy crater chain are analogous to terrestrial maar-type volcanic craters which often bring up deep mantle material, the primary objective of this landing site concerns the acquisition of material from deep within the lunar interior. A landing near the point where the crater chain crosses into the highlands should also provide samples of the plains material on the floor of Davy Y, a widespread unit in highland basins, and highland material. Acquisition of these materials will provide data on the physical properties of the lunar interior as well as on the characteristics and age of several widespread geologic units.

Apollo 16 (J-1) Marius Hills

The Marius Hills are a series of domes and cones located northwest of the crater Marius near the center of Oceanus Procellarium. The morphologic units which comprise these hills are analogous in form and sequence to terrestrial volcanic complexes which display a spectrum of rock compositions and ages. The various geologic units suggest that a prolonged period of volcanic activity has occurred in the Marius Hills area and that magmatic differentiation has produced a spectrum of rock types and a series of volcanic landforms

displaying characteristic structural relationships. Therefore, the primary objectives of a mission to the Marius Hills are to study the spectrum of geologic units in order to establish the extent and age of possible magmatic differentiation and to determine the structural relationships of volcanic landforms in the maria.

Apollo 17 (J-2) Descartes

The Descartes landing site lies in the central lunar highlands several hundred kilometers west of Mare Nectaris, and is the site of hilly, grooved and furrowed terrain which is morphologically similar to many terrestrial areas of volcanism. The Descartes area is also the site of extensive development of highland plains material, a geologic unit of widespread occurrence in the lunar highlands. The primary objectives of a mission to this site would be the examination and sampling of a highland volcanic complex and of the plains material. Knowledge of the composition, age, and extent of magmatic differentiation in a highland volcanic complex will be particularly important in understanding lunar volcanism and its contribution to the evolution of the lunar highlands. Comparison of this highland volcanic complex to mare volcanic complexes such as Marius Hills will provide a sample of a wide spectrum of lunar volcanic activity. An understanding of the composition and age of the highalnd plains material will add to our knowledge of the processes which modify large areas of the lunar highlands.

Apollo 17 (J-2) Tycho

The crater Tycho is an 85 km diameter very young crater of probable impact origin located in the southern lunar highlands. Bright rays from Tycho spread across the near side of the moon. A mission to the northern crater rim of Tycho would land in the vicinity of the Surveyor VII spacecraft. Among the principal objectives would be the investigation of the composition of the highlands and of features associated with a young large impact crater. The origin and nature of the ejecta, flows, and associated volcanism located on the crater rim are of interest in this regard. Since Tycho is approximately 4 km deep, the ejecta material should provide samples from deep within the highlands. The composition and age of this material will provide important information about the formation and evolution of the lunar highlands. Establishment of the age of the relatively young event which produced Tycho will add an important point to the lunar time scale.

Apollo 18 (J-3) Copernicus Peaks

Copernicus is a relatively young, very large bright-rayed probable impact crater approximately 95 km in diameter and located just south of Mare Imbrium. A mission to the floor of the crater Copernicus, 4 km below the crater rim, would have as its primary objectives the examination of the central peaks and the crater floor material. The central peaks, which rise up to 800 meters from the crater floor, probably represent deep-seated material, which is of importance in determining the internal characteristics of the moon. Examination of the domes and textured material of the crater floor will provide an understanding of the process of crater floor filling and help clarify the role of volcanism in post-event crater modification. Age determinations of the central peak material, the cratering event, and the subsequent crater fill material will provide a time scale of importance in understanding the origin and modification of large impact craters.

Apollo 19 (J-4) Hadley-Apennines

Rima Hadley is a V-shaped lunar sinuous rille which parallels the Apennine Mountain front along the eastern boundary of Mare Imbrium. The rille originates in an elongate depression in an area of associated volcanic domes and generally maintains a width of about 1 km and a depth of 200 meters until it merges with a second rille approximately 100 km to the north. The origin of sinuous rilles such as Rima Hadley is enigmatic but is probably due to some type of fluid flow. The Apennine Mountains rise up to 2 km from the area of Rima Hadley and contain ancient material exposed during the excavation of the Imbrium basin. The determination of the nature and origin of a sinuous rille and its associated elongate depression and deposits will provide information on an important lunar surface process and may yield data on the history of lunar volatiles. Sampling of Apenninian material should provide very ancient rocks whose origin predates the formation and filling of the major mare basins.

Hyginus

The crater Hyginus is located just south of Mare Vaporum at the juncture of the two branches of the Hyginus linear rille. The crater itself is approximately 10 km in diameter and is characterized by a very low crater rim and numerous domical hills on the crater floor. The two linear rille branches trend northwest and east-southeast, respectively,

and are characterized by associated chains of low-rimmed craters. One of the two smooth plains-forming units surrounding the crater may be of volcanic origin and closely related to the origin of Hyginus. The other is characteristic of widespread upland plains-forming units whose origin is not well understood. The craters associated with Hyginus rille are morphologically similar to terrestrial volcanic craters known as maars. On earth, deposits associated with this type of volcanic crater often contain samples brought up from deep within the mantle. The primary objectives at this landing site are the sampling of possible deep-seated material and the plains-forming material in the vicinity of Hyginus crater and rille.

Backup Mission (Flamsteed P)

The Flamsteed ring (Flamsteed P) is a circular structure approximately 100 km in diameter located in the Oceanus Procellarum region of the moon and is characteristic of a class of structures common on mare surfaces. The ring has been variously interpreted as the remnant of an old eroded and flooded crater, as a young volcanic caldera-like structure still in the process of development, and as a possible igneous ring dike. The Flamsteed ring is filled with relatively young (Eratosthenian) mare material. The regolith is relatively thin over most of the mare material and numerous blocks are seen around craters. A number of scarps suggestive of volcanic flow fronts are seen in the area and an anomalously smooth unit which may represent relatively very young volcanic material occurs in the vicinity. Determination of the age and composition of the Eratosthenian mare material and related features, and the age, composition, and origin of the Flamsteed ring are of primary interest at this site. (3)

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2015-JWH-kmj

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Attachments
Figure 1
Tables I & II

REFERENCES

1. F. El-Baz, "Characteristics of the Ten Lunar Exploration Sites," Bellcomm Memorandum for File, B69 08003, August 1, 1969, Category C.

2. "Apollo Flight Mission Assignments," NASA Document M-D MA 500-11, SE 010-000-1, October, 1969.

3. Based on material by N. J. Trask/USGS in F. El-Baz, "GLEP Site Selection Subgroup Third Meeting," Bellcomm Memorandum for File, B68 12106, December 19, 1968, Category C.

GROUP FOR LUNAR EXPLORATION PLANNING (GLEP)

LIST OF CANDIDATE LUNAR EXPLORATION

LANDING SITES

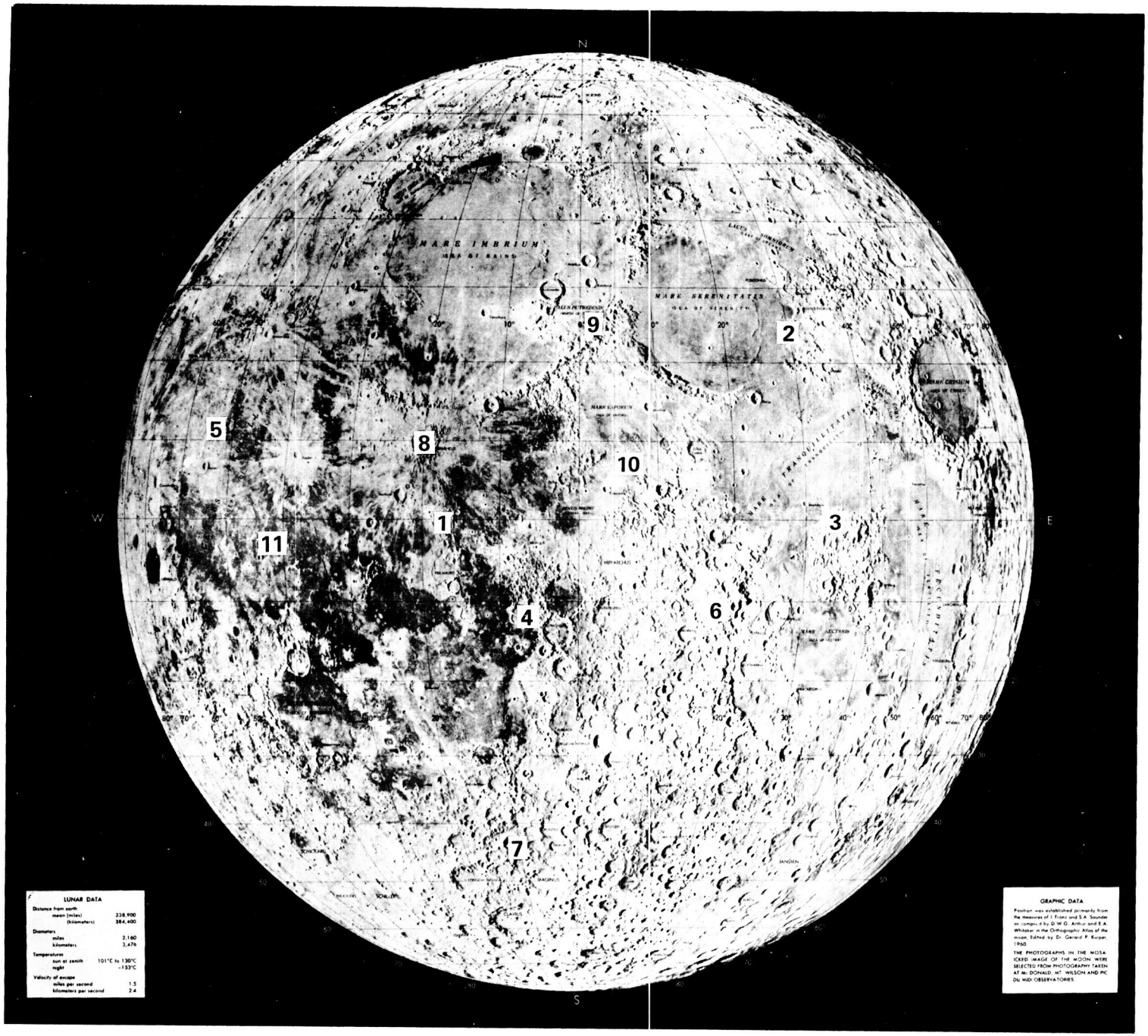
(FEBRUARY 7, 1970)

MISSION		SITE
APOLLO 13	H-2	FRA MAURO FORMATION
APOLLO 14	H-3	LITTROW
APOLLO 15	H-4	CENSORINUS/DAVY CRATER CHAIN
APOLLO 16	J-1	MARIUS HILLS
APOLLO 17	J-2	DESCARTES/TYCHO
APOLLO 18	J-3	COPERNICUS CENTRAL PEAKS
APOLLO 19	J-4	HADLEY-APENNINES

TABLE 1

TABLE 2. SUMMARY OF THE SALIENT CHARACTERISTICS OF SEVERAL CANDIDATE LUNAR EXPLORATION SITES

CANDIDATE SITES	GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS																				
	CHRONOLOGY				COMPOSTION					PROCESSES											
										CRATERING			TRANSPORT			VOLCANIC-TECTONIC				
	"ORIGINAL CRUST"	ORGIN OF MAJOR MARE BASINS	MARE FLOODING	POST-MARE TIME SCALE	PRIMITIVE ROCKS	DEEP-SEATED ROCKS	DIFFERENTIATED ROCKS	TRANSIENT EVENTS	ATMOSPHERE	IMPACT	VOLCANIC	CHAIN	RILLE	EJECTA	GRAVITY FLOW AND SLUMP	FAULT	DOME	FLOWS	RIDGES	SEISMICITY
FRA MAURO FORMATION	?	×			×	×				×				×						
LITTROW			×				?	?	?							×		×	×	×
CENSORINUS	?	?		×	×					×				×						
DAVY CRATER CHAIN	?			?	?	×	?		?		×	×		×	?			?		?
MARIUS HILLS			?	×		×	×	?	×		×		×				×	×	×	×
DESCARTES				?	?	?	×				×					?	×	×	×	×
TYCHO	?			×	?	×	?	?		×				×				×		?
COPERNICUS CENTRAL PEAKS	?			×	?	×	?			×	?				?		×	?		?
HADLEY-APENNINES	?	×	×	×	×	×	?	?	?	×	?		×		×		×	×	×	?
HYGINUS	?		?	?	?	×	?	?	?		×	×		?		×	?	?		?



1. FRA MAURO FORMATION
2. LITTROW
3. CENSORINUS
4. DAVY CRATER CHAIN
5. MARIUS HILLS
6. DESCARTES
7. TYCHO
8. COPERNICUS CENTRAL PEAKS
9. HADLEY-APENNINES
10. HYGINUS
11. FLAMSTEED P

FIGURE 1

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FROM: J. W. Head

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