ADVANCED GEOLOGIC EXPLORATION SUPPORTED BY A LUNAR BASE: A TRAVERSE ACROSS THE IMBRIUM-PROCELLARUM REGION OF THE MOON

Mark J. Cintala

NASA/Johnson Space Center, Advanced Research Projects Office, Code SN12, Houston, TX 77058

Paul D. Spudis

U. S. Geological Survey, 2255 North Gemini Drive, Flagstaff, AZ 86001 and Department of Geology, Arizona State University, Tempe, AZ 85287

B. Ray Hawke

Planetary Geosciences Division, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, HI 96822

Inherent with the existence of a permanent manned presence on the Moon should be the ability to conduct extended geological explorations. Not only would a wide variety of features become accessible to scientists, but the sophisticated investigations performed in the field would make the spectacular Apollo efforts pale in comparison. An example of such a traverse is presented here, with the Imbrium Basin and its environs the region selected to be studied. A field crew of six to eight members would travel a total distance of almost 4000 km as they visited 29 separate localities in an attempt to characterize the processes involved in the formation and evolution of a variety of major lunar features. Among the sites chosen in this expedition would be the Apennine Mountains, the Apennine Bench, Mare Imbrium, the Aristarchus Plateau, Oceanus Procellarum, the extreme western highlands, and Eratosthenes, Copernicus, and Aristarchus Craters.

INTRODUCTION

The Apollo missions to the Moon were able to acquire data that without question revolutionized the planetary sciences. A multitude of other disciplines, however, also reaped major gains. Among these other branches of science are those dealing with particles and fields, solar-planetary relationships, astronomy, astrophysics, isotopic studies, biology, and the interplanetary medium. This list is certainly not exhaustive, nor does it include topics in engineering or other disciplines affected by “spinoff,” which would be much too extensive to address here. Although Apollo was inarguably undertaken as a politically motivated project, the sheer volume of the scientific return and analytical innovations was probably unsurpassed by that of any other single effort on record. Thus, if history can be taken as a suitable guide, it would require no gift of prophecy to foresee that the existence of a lunar base, however limited in initial extent, would provide the opportunity to expand our knowledge of the Moon—and of planets in general—by orders of magnitude.
The scientific importance of maintaining a permanent or semi-permanent manned presence on the Moon is perhaps best illustrated by considering the time spent on or in the vicinity of the Moon by Apollo astronauts. Apollo command/service modules spent a total of 716 hours and 2 minutes in closed lunar orbit, while the total stay-time on the surface was 299 hours and 44 minutes. Of the time on the surface, only 81 hours and 9 minutes saw the crews outside of their lunar modules (Baker, 1981). More correctly, at least one crew member was outside of the landing vehicle for that period of time. Generously assuming that both astronauts were performing science-related extravehicular activities (EVA) for the entire period of surface operations, a total of 162.3 man-hours are found to have been spent on surface science during the entire Apollo program. By way of comparison, this amounts to just under seven days for a two-person field team working 12 hours a day, which would comprise the beginnings of a reconnaissance effort in a terrestrial field-geology context. To contend that the Moon is a well-studied object from a geological standpoint would be severely optimistic.

Separate from these time limitations were others that were just as confining. The transportation capability on the surface during the final three missions, while outstanding in comparison with the walking EVAs of the first three flights, nevertheless left much to be desired. The lack of timely rescue capabilities levied the requirement that the astronauts could never be farther from the lunar module than their consumables (oxygen and cooling water) would permit them to walk, should the roving vehicle have failed; this cast an imposing shadow over the traverse planning teams (e.g., Muehlberger et al., 1980) and, of course, on the geological exploration itself. The quantity of scientific equipment that could be delivered to the surface of the Moon was relatively small, owing to the limited payload capacity of the lunar modules. (This is not to detract from the capabilities of the spacecraft or equipment itself, which were marvels of engineering. It is instead an indication that the variety of scientific experimentation was determined, for the most part, by engineering constraints that were in turn fixed by the available technology.) At the other end of the lunar visits, the quantity of lunar samples to be returned to Earth was likewise preordained by vehicle performance guidelines. All of these criteria were non-negotiable; the very success of the Apollo missions under these and other anticipated but unspecified contingencies serves as a testament to the ingenuity and dedication of all those involved in the construction of the flight plans and field activities.

The new generation of field geology made possible by the existence of a lunar base would suffer from few of the difficulties or limitations cited above. As an example, the quantity of samples available for study would be limited only by the ability of the scientists to find them, and the quality of those chosen would be enhanced by the time available to the field scientists in making their selections. The easy access to laboratory facilities would permit any number of investigations without, what would be in retrospect, the unreasonable restrictions caused by vehicle capabilities. The nature of the study—not time constraints, solar flares, or utter hopelessness of rescue—would dictate the duration of a stop at any particular locality. Should the time spent at a given locality be greater than that planned, the ability to rest, resupply, and repair malfunctioning equipment would minimize the impact on subsequent studies at different sites.
This contribution indulges in some speculation regarding a model traverse that might be undertaken by a field-geology team supported by a lunar base and its facilities. It is not intended to be a definitive study, but it might instead serve as an example of the sort of exploration made possible by the new capabilities, as well as to illustrate the requirements and rationale behind an extended scientific traverse across the lunar surface.

FIELD SUPPORT

It would be an exercise in futility to attempt to predict the equipment available to the next generation of lunar explorers, not only in terms of its sophistication, but also its quantity. Therefore, in the interest of a succinct contribution, a number of items and capabilities will be assumed. It is hoped that this list will not be unreasonable and that the reader will allow the unheralded appearance of these devices and instruments for the sake of the exercise. Without them or their counterparts, the traverse described herein would certainly be impossible; indeed, without the technology necessary to construct such hardware, the lunar base itself might be equally improbable.

Fundamental Requirements

In terms of both duration and distance, the expedition to be described here will be long by any standards. It could indeed be stressful to a single crew while presenting taxing demands on the technology used to develop vehicle-power and mobile life-support systems. A myriad of operational scenarios could be devised that would invoke unmanned, automated, and/or teleoperated segments of the traverse, such as those between scientific sites. Evaluation of the interaction between man and machine at that level, however, is well beyond the scope and intent of this contribution. A fully manned operation will be assumed for the duration of the exploration.

The team will consist of scientists and support technicians; should the geologic traverse vehicle (GTV) be manned during its movement between sites, the technicians would probably double as GTV operators and mechanics. The number of scientists is difficult to suggest, but some requirements help in refining the estimate. As discussed below, it would be extremely desirable to have relatively short-range excursion capability from the "base camp" (as defined by the location of the GTV). As envisioned here, these "rovers" would require a crew of two for reasons of efficiency and safety. Thus, should two rovers be allowable, and with two scientists left at the base camp, the number of scientists becomes six for the purposes of this exercise. Thus, including two technicians/transport crew members, the size of the field team is suggested to be six to eight, depending on the number of rovers.

Transportation and Logistical Support

The shape and details of the GTV are unknown and of little concern to this paper. Its mode of transportation is also problematic, although it will more likely be a wheeled or tracked vehicle than a rocket-powered one for reasons of economy. While the flying
version would be desirable in the sense that it would be faster and might double as a remote-sensing platform, lunar-orbiting spacecraft could provide such support. Therefore, the GTV assumed here will be a ground vehicle capable of negotiating steep (>30°) slopes of poorly consolidated material. It will be required to include or provide the following:

- Shelter and consumables
- First-order analytical equipment (described below)
- Navigational equipment and communications
- Sample-collecting equipment
- Reusable geophysical instrumentation (e.g., magnetometers, gravimeters, etc.)
- Multi-spectral cameras
- Pressure suits for all crewmembers, as well as spares

The two rover vehicles would be carried or towed by the GTV; each should have a nominal traverse distance of at least 50 km between recharging or refueling. As it would be extremely desirable for the scientists to study the surroundings as they moved between stops, the rovers should be ground vehicles in order to maximize the scientific return of the forays from the base camp. It would be very useful if they were also pressurized, offering sufficient room for sleeping and other activities while the independent excursions were taking place. Clearly, it would not be efficient to suffer untimely returns to the base camp when dictated by consumables or crew fatigue. Thus, each would be, in effect, a scaled-down, more agile version of the GTV in some respects, but without the extensive scientific support instrumentation. Multiple EVAs would be possible from each rover before they would return to the base camp for recharging.

Resupply of the consumables required by the team, as well as delivery of samples to the better equipped main complex would be accomplished by periodic ferry flights originating at the lunar base. The frequency of these flights would be set by a number of factors to be determined elsewhere.

**Analytical Instrumentation**

It should go without saying that the more instrumentation capable of being carried inside the GTV, the more "bits per buck" will be obtainable. On the other hand, it is unlikely that a complete geochemical/petrologic laboratory could be included in the vehicle. With this in mind, it would be highly desirable to have the following instrumentation:

- microscopes (binocular, petrographic) and thin-sectioning equipment
- equipment for first-order chemical analysis (primarily to obtain whole-rock compositional information)
- computer support

It would probably be more efficient for the rovers to have payload capacity relegated to samples than to analytical instrumentation. It would be useful, however, if they would include binocular microscopes and small X-ray fluorescence units with supporting hardware. This would provide the crews with enhanced sample characterization capabilities, thus permitting decisive sample selection in the field.
Field Equipment

Personal field equipment similar to that carried on Apollo would be used by all crewmembers, but a major advantage of this sort of exploration is the ability to perform investigations on a much larger scale than had been done previously. Thus, deep drill-coring operations (i.e., more than a few hundred meters) would be within the realm of possible field operations. Deep coring, however, is an extremely time-intensive proposition even on Earth with all of the requisite materials readily at hand. The Moon will present an environment that is much more inimical to such activities; lubricating fluids for the core tubes and bits, for instance, will present a severe challenge to geological engineers. A new drilling technology, the foundations of which might well have been laid already (Rowley and Neudecker, 1984), would be required in order to make such important studies possible. Given the deep-coring capability, a core-extrusion unit will be necessary for use in the field: 100 m of core-tubing, 10 cm in diameter and full of rock and regolith would possess a mass of roughly 2 metric tons. It is obvious that the field team would have to break down the core in the field, sampling it at strategic intervals. In this way, the bulk of the core could be left at the site for future retrieval, if desired, while representative samples could be returned to laboratories better equipped than that aboard the GTV.

The use of a backhoe or similar device would permit regolith studies on a scale that would minimize statistical extrapolations, setting stratigraphic studies on a firm basis. Comparatively deep trenches could be excavated with little effort, yielding a spatially extensive cross-section of regolith stratigraphy. Indeed, removal of regolith to the basal bedrock in some mare areas could become commonplace, a capability that cannot be overemphasized in terms of regolith science and studies of solar history.

These two devices will increase the scientific capabilities of the field team commensurate with the magnitude of the entire expedition. Indeed, they would provide a considerable incentive for the very concept of the extended traverse.

THE TRAVERSE

Before the traverse itself is described, a few points should be made. First and foremost, the route is presented only as an example and should be treated as such. The area covered, however, was chosen for a number of reasons.

The Imbrium Basin and its environs have been geological favorites for many years, not only for the basin's prominence on the lunar nearside, but also for the wide diversity of geologic formations and other features found in that lunar quadrant. A very important aspect of this region of the Moon, however, is the fact that it contains features that were crucial in the development of the lunar stratigraphic system (Shoemaker and Hackman, 1962). This classification scheme has been the vehicle for describing the geologic history of the Moon as it is presently understood (e.g., Mutch, 1970; Wilhelms and McCauley, 1971; Wilhelms, 1985); its only major drawback is the lack of established ages for a range of specific features, which would define an absolute chronology. One of the most important contributions of the proposed exploration thus would be the “calibration” of.
the lunar relative time-scale in terms of absolute ages, which would occur upon sampling the key formations to provide fodder for the various age-dating techniques. In addition to establishing an absolute time-scale for the lunar nearside, the traverse would provide the opportunities to examine a number of critical processes, which are described below.

**Multi-Ring Basin Formation**

Perhaps the most important process operating during the early histories of the terrestrial planets was the formation of the huge multi-ring basins characteristic of all large, solid bodies studied to date (Baldwin, 1949, 1963; Hartmann and Kuiper, 1962; Stuart–Alexander and Howard, 1970; Hartmann and Wood, 1971; Moore et al., 1974; Head et al., 1975; and many others). The impact events responsible for their formation on the Moon not only created major topographic features (i.e., gigantic crater-like structures that measure thousands of kilometers in diameter), but they also rearranged millions of cubic kilometers of lunar crust (see, for example, Moore et al., 1974; Head et al., 1975), created vast quantities of shock-melted material (Head, 1974a; Moore et al., 1974), generated sources of seismic energy that modified pre-existing terrain (Schultz and Gault, 1975a,b), and provided topographic “traps” for large volumes of subsequently erupted volcanic materials (see the review of Head, 1976). Thus it should come as no surprise that an understanding of these features and the mechanisms that were active during and after their formation is very high on the priority list for lunar geologists.

**Large Crater Formation**

Aside from some of the mare basalts, virtually every lunar sample that has been studied exhibits signs of shock damage (G. Ryder, personal communication, 1984), which is a consequence of crater formation by impact. Even a casual look at a telescopic photograph of the Moon is sufficient to demonstrate the importance of large craters in shaping the landscape and affecting the evolution of the lunar crust. By analogy, the same must be true of the other solar system bodies that possess high densities of craters. Thus, the mechanisms involved in the formation of large craters—indeed, craters of all sizes—are among the most important in the evolution of planetary surfaces. In this light, the study of craters, especially large ones (tens of kilometers across), will also receive considerable attention on the traverse.

**Volcanism**

Insofar as mare basalts cover more than one-sixth of the lunar surface (Head, 1975), volcanism played a highly visible role in the development of the surface and in the evolution of the interior of the Moon. These deposits are extremely diverse in composition, both on the basis of remote-sensing geochemistry (e.g., Pieters, 1978; Bell and Hawke, 1984) and analysis of returned samples (see the review of Papik et al., 1976), as well as in the ages of their emplacement (e.g., Boyce et al., 1974; Schultz and Spudis, 1983). These characteristics imply that the lunar interior (the source of the basalts) underwent a highly complex evolution during and after the period of early lunar bombardment. The origins of various lunar volcanic features are still problematical but have the potential of yielding
important information on the factors governing the different styles of lunar volcanism. Among such structures are mare rilles and ridges, domes, dark mantles and dark halo craters, cones, individual flows, and the intricate volcanic complexes exemplified by the Marius Hills and Aristarchus Plateau (e.g., Whitford-Stark and Head, 1977). Since the Imbrium Basin is flooded with mare basalts, substantial emphasis will be placed on the study of volcanic deposits and related features.

The suggested route, which is approximately 4000 km in length, is illustrated in Fig. 1. In reality, the starting and ending points would be governed strongly by the location of the lunar base itself, although it is easily conceivable that another leg could be added.

Figure 1. The proposed traverse is illustrated here, somewhat schematically, on a National Geographic (Lambert Equal Area) base map. While the individual segments of the trip are drawn here as straight lines, they would, in reality, be much more sinuous. Orbital remote-sensing data would undoubtedly perturb the path taken by the field team in their quest for the widest variety of data possible. With this in mind, it is also important to note that the indicated stations represent only the prime field sites—many shorter, less complex stops will occur between the numbered locations.
to the trip from the base to a suitable starting site. The following paragraphs give an
abbreviated description and rationale for the major stops, which are keyed to the numbers
in the figure. At the end of each paragraph are the distance between that site and the
previous site and letters indicating the principal purposes for studying that site. They
are as follows:

A—Aristarchus Plateau, an impact-volcanic complex
B—Basin structure and stratigraphy, usually applied to the Imbrium Basin
   on this traverse
C—Large crater deposits and/or structure
V—Volcanic features and/or deposits.

Murchison Crater Floor (Stop 1)
An old, degraded crater, Murchison possesses a floor with an unusual morphology,
being partially covered with either impact melt or volcanics. In addition, the walls and
surroundings of the crater are mapped as Fra Mauro Formation, while parts of the floor
are classified as Cayley Formation (Wilhelms, 1968). Both of these unit types were visited
by Apollo missions, and their origins are still intensely debated. Finally, a ray from the
young crater Tryenecker crosses the center of Murchison's floor, which provides an
opportunity to establish a date for that crater's formation. (B, V; 0 km)

Fra Mauro Formation/Bode Dark Mantle (Stop 2)
The Fra Mauro Formation on the backslope of the Imbrium Basin will be sampled
again on a line radial to the basin center (this technique will be employed throughout
the traverse; since deeper materials should have been ejected to shorter overall distances,
any radial variations in composition should, in theory, be related to vertical inhomogeneities
in the target before the impact). A "dark mantle" of probable pyroclastic origin, associated
with the sinuous rille Rima Bode and shown to be bluish in color by Earth-based spectral
observations (Pieters et al., 1973), occurs in the "backwaters" of Sinus Aestuum. Early
basalts to the east of these deposits are also bluish, indicating that they could be related
(Head, 1974b). (B, V; 110 km. This single leg of the trip is more than 15% longer than
all of the Apollo traverses combined.)

Mare Vaporum (Stop 3)
The Vaporum basalts were emplaced in a pre-Imbrian impact feature that was about
200 km in diameter. Work at this site will concentrate on the geophysical study of the
Vaporum Basin's structure as well as on the Vaporum basalts themselves. (B, V; 150
km)

Ina (Stop 4)
First noticed on Apollo 15 panoramic photography, this feature has been interpreted
to be a caldera (El-Baz, 1972; Strain and El-Baz, 1980). It is remarkable in that it has
virtually no superposed impact craters, an observation that indicates a very young age
for this feature and the probable volcanic process that created it. Nearby Imbrium Basin
deposits will also be visited. (B, V; 150 km)
Conon Crater (Stop 5)
A crater 21 km in diameter and, more importantly, 3 km deep represents a substantial excavation into its target terrain. Insofar as Conon is located in the backslopes of the Apennine Mountains, which form a portion of a ring surrounding the Imbrium Basin, it represents an important “window” into the stratigraphy of Imbrium ejecta, as well as possible pre-Imbrian materials. Its ejecta should contain exciting clues regarding the crustal structure of the Moon before Imbrium was formed. (B, C; 110 km)

Apennine Scarp/Possible Imbrium Impact-Melt Pool (Stop 6)
The basin-facing side of the Apennine Mountains probably represents a major fault zone; if so, the stratigraphy sought at Conon Crater might also be exposed here. A multispectral survey of the scarp from the GTV should provide information on any such layering. A number of small “pools” of possible melt generated by the Imbrium Event are also in this region; study of these rocks would yield very useful data in deciphering the nature of the Imbrium-forming impact. (B; 115 km)

Apennine Bench Formation (Stop 7)
This region, just inside the Apennine Front south of Archimedes Crater, has been something of an enigma to geologists. While it has superficial resemblances to impact melt deposits such as those found inside the Orientale Basin (Head, 1974a; Moore et al., 1974), most recent interpretations give it a relatively old volcanic origin (Hackman, 1966; Hawke and Head, 1978; Spudis, 1978). If such were the case, it would represent the largest recognized deposit of non-mare volcanics on the Moon. (B, V; 90 km)

Montes Archimedes (Stop 8)
Orbital gamma ray detectors found abnormally high thorium concentrations in the rugged area just south of Archimedes Crater (e.g., Metzger et al., 1979). This area is also very red in a spectral sense (Malin, 1974; see, for example, McCord et al., 1976 for a description of lunar spectral types). The origins of these “red spots,” which are scattered across the nearside, are uncertain (e.g., Malin, 1974). Sampling the rocks exposed at Archimedes would be a significant step in unraveling this mystery. [B, V(?); 80 km]

Wallace Crater (Stop 9)
Wallace is an old, flooded, unremarkable crater whose position in the Imbrium Basin brings it more attention than it deserves of its own accord. Rays and secondary-crater fields from Copernicus Crater occur in this area; thus, this site will mark the beginning of the radial sampling process for that classic crater. Relatively young basalts unsampled by Apollo are also abundant at this site, and a geophysical study will shed light on pre-mare basin stratigraphy. (B, C, V; 240 km)

Eratosthenes Crater Ejecta/Southwest Apennines (Stop 10)
Eratosthenes Crater is the type area for the definition of the Eratosthenian System of the relative lunar time-scale and, as such, will be studied in some detail. Examination of its ejecta will shed light not only on the emplacement dynamics of ejecta from large
craters, but also on the azimuthal variation of Imbrium Basin deposits—the projectile that formed Eratosthenes impacted the southwestern portion of the Apennine Mountains. Deposits from the pre-Imbrian Aestuum Basin appear to have been excavated by this impact, so there is a chance that these materials could also be collected at this stop. (B, C; 100 km)

**Eratosthenes Crater Interior (Stop 11)**

This site is important not only from a scientific standpoint, but it will also provide a good test for the terrain-handling capabilities of the GTV in that local slopes of up to 30° will be encountered. The interior of the crater will be sampled, with special emphasis on the impact melt on the floor; it will be used to establish the time of formation of the crater. A multi-spectral panorama of the crater interior will be very useful, as will a detailed study of the central peaks and the geophysical profiling of the crater subsurface. (C; 40 km)

**Copernicus Crater Rays and Secondaries (Stop 12)**

The radial sampling of Copernicus will continue with a stop closer to the crater but still in its discontinuous deposits. In addition to the crater's ejecta, the "background" basalts will be collected, since the two are undoubtedly well mixed at this distance from the crater. These samplings will aid in deciphering the dynamics of ejecta emplacement, which are only partially understood. (B, C, V; 80 km)

**Copernicus Crater Continuous Ejecta (Stop 13)**

This radial sampling stop is located in the "continuous ejecta deposit" of the crater, which is most likely a combination of crater ejecta and local material that intermixed as the ejecta impacted (Oberbeck, 1975). One of the major goals at this stop is to determine the relative proportions of actual crater ejecta and local material in the deposit. The mare basalts are very thin here, leading to the probability that much of the Copernicus ejecta will consist of Imbrium ejecta, which is much older; thus, azimuthal sampling of Imbrium material should also continue at this site.

**Copernicus Crater Rim Materials (Stop 14)**

The view into the 93-km crater at this site should help to mollify the rigors endured by the crew to this point in the trip. Ejecta from deep in the crust should be present at this location, as are large concentrations of impact melt (Howard and Wilshire, 1975; Hawke and Head, 1977). Samples of the ejecta will aid in the reconstruction of the effects of the Imbrium impact event, and the melt will be used in dating Copernicus, which will also define the beginning of Copernican time in the lunar stratigraphic system. This site is tailor-made for a panoramic multi-spectral survey. (B, C; 30 km)

**Copernicus Crater Central Peaks (Stop 15)**

Recent Earth-based observations suggest that the central peaks of Copernicus are composed largely of olivine (Pieters, 1982), suggesting the presence of uncommon lunar rock types. The material in the peaks probably came from a significant depth (on the
order of several kilometers), and a sampling effort here would be very informative. The thick impact-melt deposits on the floor will be sampled for compositional and textural variations to be compared with those examined at the rim. A geophysical survey of the crater is very high in priority. (C; 30 km, downhill)

**Montes Carpathus/Copernicus Crater Ejecta (Stop 16)**

The Apennines grade into the Carpathian Mountains on the extreme southern edge of Imbrium; a stop is planned here to continue the azimuthal study of Imbrium stratigraphy. The on-going examination of Copernicus ejecta will also profit from this locality, and possible pyroclastic deposits in the area will be sampled. (B, C; 140 km)

**Tobias Mayer Rilles/Copernicus Crater Ejecta (Stop 17)**

A muted volcanic complex exists to the northwest of Copernicus near the crater Tobias Mayer. Associated with this complex are a number of small rilles and potential calderas. This area will be studied in some detail, both geochemically and geophysically. The final opportunity to sample Copernicus ejecta in any significant concentration will probably occur at this stop. This will be the first of a series of mare sites located well into Mare Imbrium and Oceanus Procellarum. (B, C, V; 110 km)

**Euler Crater (Stop 18)**

This 28-km crater is surrounded by fairly young basalt flows (e.g., Schaber, 1973), which are the principal targets of this leg of the exploration. The continuous ejecta deposits of Euler, which probably contain pre-mare materials, will also be sampled. (B, C, V; 145 km)

**Mons La Hire (Stop 19)**

The Imbrium Basin is so thoroughly flooded that few remnants of its inner ring structure remain exposed. La Hire is one of those unburied massifs, and it, too, is spectrally red (Malin, 1974; Head and McCord, 1978). It will be studied both as a segment of an inner ring of Imbrium and as a spectrally distinct feature. (B; 180 km)

**Eratosthenian Flows West of Mons La Hire (Stop 20)**

In mid- to late-Eratosthenian time, a series of eruptive events covered a large portion of the Imbrium Basin from the southern border with Oceanus Procellarum to the northern reaches of Mare Imbrium (e.g., Schaber, 1973). Remote-sensing data suggest a composition for these lavas that is not represented in the samples returned by Apollo astronauts or Luna spacecraft (Whitaker, 1972; Etchegaray-Ramirez et al., 1983). These flows thus represent a significant, relatively late volcanic episode in the Moon's history. (B, V; 30 km)

**Gruithuisen Domes (Stop 21)**

Two separate groups of “red spots”—the Mairan and Gruithuisen Domes—are detectable with Earth-based instrumentation near the northwestern boundary of the Imbrium Basin. They are domical features, and have been interpreted to be the result
of a late stage of non-mare extrusive volcanism (Head and McCord, 1978). Whether they are indeed volcanic or simply represent more red ring massifs (such as Mons La Hire) is still debated. Sampling these distinctive features will help to settle the question and perhaps provide data on a potentially important process. A number of spectrally differentiable basalt types (Pieters, 1978) will also be sampled during the trip to the domes. (B, V; 410 km)

**Prinz Rilles/Aristarchus Crater Ray (Stop 22)**

The Aristarchus Plateau and its immediate surroundings represent an area of remarkable diversity, in terms of both geology and the processes that were involved in its evolution (e.g., Zisk et al., 1977). Five full sites will therefore be dedicated to the exploration of this region of the Moon. This stop will be utilized to investigate the Prinz Rilles, which comprise a series of valley-like depressions in obviously volcanic terrain. A ray from Aristarchus Crater extends across this location; collection of material in that area will begin the radial sampling of this 40-km crater. Highland samples in this area will also be collected as the opportunities arise. (A, B, C, V; 300 km)

**Aristarchus Crater Rim (Stop 23)**

If it could be possible, the view here should be even more impressive than its equivalent was at Copernicus, since Aristarchus is less than half the diameter of the former, but almost as deep. The crater's continuous ejecta blanket will be examined at this site, while the rim structure and stratigraphy will be probed. The abundant impact-melt flows and ponds in this area will also be sampled for comparison with that on the crater's floor. (A, C, V; 75 km)

**Aristarchus Crater Floor (Stop 24)**

The melt sheet and central peaks will be high-priority sampling objectives here. In addition, a multi-spectral panorama will be acquired, and a geophysical profile will also be made. Special emphasis will be placed on an attempt to establish the stratigraphy of the crater's northwestern wall, which cuts through the volcanic plateau. The GTV will receive another workout during these investigations. (A, C, V; 25 km)

**Vallis Schröteri/Aristarchus Plateau Dark Mantle and Basalts (Stop 25)**

An effort as intensive as any on the traverse will be made at this site. The dark mantle materials, which probably represent pyroclastic eruptives, will be on an equal sampling priority with the flow basalts in the area, and a number of geophysical profiles will be taken across the Plateau. It is anticipated that the GTV-defined base camp will be rather mobile during this leg of the exploration, because the largest sinuous rille on the Moon, Schröter's Valley, will also be an object of extensive scrutiny. It is likely that Aristarchus ejecta is fairly common across much of the Plateau, so the radial sampling effort might well continue. [A, C(?), V; 60 km]
**Schiaparelli Basalts (Stop 26)**

Remote-sensing data show the basalts to the northeast of Schiaparelli Crater to be titanium-rich, but they appear to be very young on the basis of superposed-crater abundances. Since the vast majority of high-titanium basalts returned by the Apollo missions are very old (e.g., Taylor, 1982), samples of these flows will be very interesting for modelers of the evolution of the lunar interior. (V; 180 km)

**Lichtenberg Crater and Basalts (Stop 27)**

Not only is Lichtenberg Crater interesting because it excavated pre-mare material in northern Oceanus Procellarum, but the basalt flows that embay its ejecta deposits appear to be the youngest recognized lava flows on the Moon (Schultz and Spudis, 1983). (C, V; 300 km)

**Struve L Crater (Stop 28)**

Struve L is about 14 km in diameter and is a very good candidate for an Orientale Basin secondary crater. It also possesses a floor that is unusual in the sense that it might be comprised predominantly of impact melt from the Orientale Basin (Schultz, 1976a). If not, it would still offer a very good chance at obtaining Orientale ejecta. This stop is in a region of the Moon (the western “shores” of Oceanus Procellarum) that is teeming with diverse features and formations, many of which will be sampled between sites. (B, C; 370 km)

**Balboa Crater (Stop 29)**

Large craters with fractured floors are not uncommon on the Moon. While their origins are not certain, the leading hypothesis to account for their morphology is the intrusion of magma below the crater into the material that was disaggregated by the impact (Schultz, 1976b). Balboa represents one such crater, and a geophysical survey of its interior should provide some answers to the questions regarding the responsible processes. (C; 190 km)

**CONCLUSIONS**

This traverse would be an ambitious undertaking, but the scientific dividends it would yield are equal in magnitude to the challenge. Many variations of the route can be proposed, especially in the Oceanus Procellarum region. In fact, much difficult debate was involved in planning the path that is presented above. Some might view this as a sign of uncertainty or the lack of a clear goal for the exploration. On the contrary, the prospects opened by such capabilities are overwhelming, particularly in light of the pressures and limitations under which all similar planning had occurred in the past. When suddenly confronted with the profoundly exciting ability to travel over such great distances with highly sophisticated support equipment, it is almost unfair to ask that one's composure be maintained. The prospects are magnificent, and much remains to be done...
Acknowledgments. The authors would like to thank Fred Hötz, Wendell Mendell, Jeff Taylor, and Dave Vaniman for very helpful—not to mention entertaining—reviews of this paper. Arthur C. Clarke and Stanley Kubrick, ahead of their time as usual, provided no small incentive for thinking big. (We might, however, respectfully suggest a site different from Clavius Base. . .)

REFERENCES


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