TECHNICAL LETTER: ASTROGEOLOGY-9

EARLY APOLLO INVESTIGATIONS FIELD TEST 5
October 4-7, 1965
Hopi Buttes, Arizona

By
John W. M'Gonigle, Paula G. Ables,
and Robert D. Regan

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

Prepared by the Geological Survey for the National Aeronautics and Space Administration
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This report is one of a series "Early Apollo Investigations Field Tests" that presents the results of tests carried out by Manned Lunar Exploration Studies Section of the Branch of Astrogeology, U.S. Geological Survey, for the Early Apollo Program. The tests are conducted to evaluate scientific instrumentation, geological and geophysical techniques, and integrated operational procedures that are potentially suitable for use in lunar exploration during Early Apollo.

Two other series, "Apollo Applications Program Investigations Field Tests" and "Advanced Systems Investigations Field Tests," report on tests conducted to evaluate instrumentation, techniques, and integrated procedures, suitable for the later stages of lunar exploration.
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Abstract

A field test in which the test subjects wore pressurized space suits was held during October 1965 in the Hopi Buttes area, Arizona. The purpose of the test was to evaluate the capability of test subjects to perform simple geological and geophysical operations on foot traverses, and to try out techniques of handling data during the test.

Geologic maps prepared by a data analysis team from information transmitted by the test subjects were compared with maps of the Hopi Buttes area prepared by geologists and geophysicists prior to the test as the basis for evaluating the test subjects' geological and geophysical operations. A task analysis team timed the suited subjects' activities, and compared their performance to timed activities of a subject in shirt sleeves.

It is concluded that although it takes about twice as long to perform geologic operations in a space suit as it does in shirt sleeves, and Apollo foot-traverse techniques are restricted to small areas of moderate relief, the quality of a space-suited geologist's observations is not impaired.

Introduction

A suited test of a simulated Early Apollo lunar surface mission was conducted October 4-7, 1965, in the Hopi Buttes volcanic field in northern Arizona by personnel of the U.S. Geological Survey, Branch of Astrogeology, Flagstaff, Arizona, and of the Crew Systems Division, Manned Spacecraft Center, Houston, Texas.

The test site was selected for its accessible exposures of rocks representative of the general geology of mapped portions of the Hopi Buttes volcanic field.

The purpose of this report is to evaluate the efficiency of the geological and geophysical tasks and sequences of tasks performed by suited test subjects, and also of the techniques of recording and analyzing data during the field operations. The report includes analyses of the geologic operations undertaken by the test subjects, of the methods used to handle geologic information during the test, and of time and motion data.

Suits for the test were supplied by the Crew Systems Division, Manned Spacecraft Center (MSC), Houston, Texas. Two suit technicians,
two portable life support systems (PLSS) technicians, a communications technician, and a medical monitor participated throughout the test. The success of the test was due in large part to the generous support of this MSC group, headed by Mr. Earl La Fevers.

Gordon A. Swann was test director and coordinated the efforts of U.S. Geological Survey personnel, who served as test subjects and provided test support in electronics, visual documentation, surveying, task analysis, and data reception and analysis.

Six geologists from the Astrogeology Branch mapped the geology of a portion of the Hopi Buttes using aerial photographs as a base. R. L. Sutton compiled the geology from the photos onto a topographic base at a scale of 1:8500 (pl. I). W. A. Mason, J. R. McCord, and T. J. W. Lee contributed information used in this report. P. G. Ables wrote the section on task analysis and the appendix. R. D. Regan wrote the section on geophysics.

Objectives

Objectives of the test were to record the performance of suited test subjects doing specific simple geological and geophysical operations, and during the test to try out techniques of handling data reported by the test subjects.

Geologic methods used by the test subjects included examination and oral descriptions of lithologic and topographic features, sampling of soils, of rock outcrops of basalt and sandstone, and of loose surficial fragments of basalts and tuffs, and the use of a soil penetrometer. In addition, the subjects photographed objects, using a sun compass and a clinometer mounted on the staff to determine the orientation of the staff-mounted camera, and briefly used a staff-mounted television camera to augment their oral descriptions.

Geophysical methods included the laying out of a seismic line 120 meters long and the simulated firing of squib charges by the test subjects, who also took magnetic readings with a hand-held magnetometer along the trend of the seismic line.

Several geologists manned the communications data reception and
analysis facility (CDRA), where communications to and from the test subjects were recorded on tape, and where the traverses and geologic information were plotted on maps.

Test Constraints

The dominant constraint of the test was that the subjects wore a 3.7 space suit, pressurized at about 347 psi with an oxygen supply which lasted about 45 minutes. The subjects were limited to foot traverses and to tools and instruments they could carry by hand. The CDRA was restricted to radio voice communication with the test subjects and to indirect observation of their activities via a television camera mounted on the top of a mock-up of a lunar excursion module (LEM).

Geology of the Test Site

The Hopi Buttes test site, about 75 miles east of Flagstaff, Arizona, and about 30 miles northeast of Winslow, Arizona, is in a region of sedimentary and volcanic rocks (fig. 1). The test site is within a portion of the Hopi Buttes mapped during the summer of 1965 by R. L. Sutton, David Cummings, G. G. Schaber, D. L. Schleicher, P. S. Osborn, T. N. V. Karlstrom, and J. W. M'Gonigle.

The mapped portion of the Hopi Buttes is used as the control against which geologic maps prepared from data gathered by test subjects can be compared to determine the effectiveness of geologic methods used in a test. The control geology is established through field geologic mapping upon aerial photographs and transfer of the photogeology onto topographic base maps. Petrographic studies are made of rock specimens if necessary. Geophysical investigations, which include seismic, gravity, and magnetic studies, are made of the geologically mapped areas.

Most of the sedimentary rocks in the area around the test site (pl. I) are nearly flat-lying, and are best exposed in the sides of mesas that are capped by volcanic flows. Volcanic dikes, plugs, flows, and necks are common in the area. Quaternary erosion has created good exposures of the volcanic features, and has resulted in widespread deposition of several alluvial units of varying thickness and extent.
In the Apollo 5 test site (pls. I and II) the LEM mock-up was situated on sandy alluvium containing pebbles of basalt and tuff. A small intermittent stream 100 feet north of the LEM location issues from a high mesa to the east. The predominantly sandy stream bed locally contains a great number of pebbles, cobbles, and boulders of basalt and tuff fragments. East of the LEM location, the stream crosses a breached dike of basalt averaging about 3 feet thick and up to 15 feet high, intruded into the Triassic Wingate Sandstone. About 320 feet of the Rockpoint Member of the Triassic Wingate Sandstone make up the oldest sedimentary unit visible in the test site, and this unit is overlain by about 30 feet of the Lukachukai Member of the Wingate Sandstone, visible in the sides of the high mesas east of the LEM location. Three hundred and forty feet of the lower portion of the Pliocene Bidahochi Formation, consisting of claystone, minor sandstone and tuff, unconformably overlies the Lukachukai Sandstone. Capping the mesa, and unconformably overlying the Bidahochi Formation, is about 220 feet of basalt, apparently made up of at least two flows. Locally a 2- to 4-foot zone of cross-bedded sandy to pebbly tuff is visible beneath the basalt cap rock.

In many places the Triassic and Pliocene sediments are locally obscured by slump blocks, by talus, and by thin veneers of pebbles and cobbles, mainly of basalt fragments from the mesa cap.

Test Facilities

Facilities at the test site directly involved in the conduct of the test included a LEM mock-up, a CDRA trailer, and an electronics van (fig. 2, top). The LEM mock-up was the principal point at which foot traverses by the test subjects began and ended. Mounted on top of the LEM was a Kintel 20/20 television camera, which was used to monitor the test subjects' activities.

The CDRA trailer housed a team of geologists who maintained radio communication with the test subjects, observed their activities on a television screen (fig. 3), and prepared geologic maps as the test proceeded. Radio communications were recorded by Sony tape recorders. Control of the television camera was handled in the CDRA trailer.
Figure 1: Site of Apollo field test 5 in the Hopi Buttes area.
Figure 2.--Apollo test 5 setup: top view looking north and bottom view, southeast. 1, LEM-Shelter; 2, generator truck; 3, CDRA trailer, 4, electronics van; 5, LOX tanks; 6, house trailer; 7, dressing van.
Figure 3.--Interior of CDRA center. Monitor is speaking with test subject, who is shown on television screen.
Figure 4.—Test subject wearing thermal garment and thermal overshoes.
Figure 5.--Suited test subject using staff and carrier on geologic traverse.
Figure 6.--Test subject making measurement with penetrometer.
Figure 7.--Test subject using television camera mounted on staff.
Figure 8.--Test subject unreeing seismic line, carrying staff equipped with thumper.
The electronics van personnel maintained the portable radios used by the test subjects and relayed television signals from the LEM camera to the CDRA. Audio signals were placed on the diplexer of the TVM-IC microwave relay and transmitted with the video signals to Flagstaff. Video and audio recording was done in Flagstaff on a Sony Videorecorder and a Kinescope film recorder.

Additional facilities at the test site (fig. 2, bottom) included an electric generator truck, a trailer in which space suits were maintained for use by the test subjects, and a trailer carrying two 50-gallon tanks of liquid oxygen (LOX) for refilling the portable life support systems (PLSS) tanks for the space suits.

Equipment Tested

Pieces of equipment tested included:

1. Three space suits of the Apollo A4-H type, weighing 28 to 29 pounds. Two of the suits had bubble-type helmets in which the subject's head was free to rotate and the visor was fixed in the closed position. The helmet of the third suit swiveled at the neck ring when the head was moved; its visor was movable and could be lifted or brought down for pressurization. Suit pressure was maintained at a 3.7 ± 0.2 psi differential across the suit.

2. A thermal garment (fig. 4), worn during most of the traverses, is designed to provide micrometeorite, thermal, and abrasion protection. It is a two-piece suit weighing 8 or 9 pounds.

3. Portable life support systems (PLSS) were training mock-ups resembling the lunar PLSS in size and shape. The liquid oxygen supply lasts approximately 45 minutes. The training PLSS weighs between 37 and 38 pounds when fully loaded with LOX, whereas the lunar PLSS will weigh between 52 and 60 pounds.

4. Staff, equipped with a sun compass, clinometer, and a film camera (fig. 5).

5. A tool and sample carrier, which contained cloth sample bags, a geologic hammer, a trowel, a scintillometer, and a small penetrometer for measuring bearing strength (figs. 5 and 6).
6. A hard-line Kintel 2000 (525 line resolution) camera, adapted for mounting on the staff (fig. 7).

7. A seismic line, 120 meters long, payed out from a hand-held reel attached to the staff (fig. 8). Three geophones were attached to the line at 50-meter intervals.

8. A small hand-held Oy vertical component magnetometer of Finnish manufacture, with a sensitivity of about 25 gammas.

Test Site Procedures

Operations performed during the test were centered around geological and geophysical traverses made by the test subjects. Support groups performed most of their functions during these traverses.

Traverses

Each test subject made six traverses on foot within sight of the LEM. The first subject each day established stations along his traverse for sampling, observation, and instrument reading. The other two subjects that day occupied the same stations, essentially duplicating the first man's traverses. This procedure was followed throughout the test to provide better control for time and motion studies of the subjects' activities.

The first traverse went eastward along the small intermittent stream north of the LEM, across a low divide to a southern fork of the stream, and along it to the LEM. On this traverse the subjects sampled alluvium and rock fragments along the stream, took photographs and penetrometer readings, and described the geology along the route of traverse (pl. II, stations 1-7).

The second and third traverses were made along intermittent exposures of a dike to the north, east, and southeast of the LEM (pl. II, stations 8-10 and 11-13). During these traverses the subjects took samples of various zones in the dike and of the adjacent country rock, photographed and described the rock types from these zones, photographed and described textural and geomorphic features of the dike, and
photographed and made a brief description of the mesa to the east.

The fourth traverse ran eastward along the base of a slope north-east of the LEM in which the Wingate Sandstone is exposed (stations 14-19). The subjects sampled material in the slope and alluvium and rock fragments distributed in and near a small stream which follows the base of the slope. They photographed and described geologic features along the line of traverse, and also features of the mesa side toward which they were headed. This traverse did not begin at the LEM, but adjacent to station 14.

On the fifth traverse (stations 20-28) a staff-mounted television camera was used in conjunction with the subjects' descriptions of geologic features along, and at a distance from, the traverse.

The sixth traverse (stations 29-31) was devoted to geophysical operations normal to the trend of the dike outcrop north of the LEM. The subjects plugged a seismic line into a data recorder and walked 20 meters, carrying a reel which payed out the seismic line and a staff with a squib-activated thumper attached to it. At this point they attached a geophone to the line. The subjects payed out 100 more meters of line, attaching geophones at 70 and 120 meters. They then returned along the line, stopping at 5-meter intervals to simulate the firing of the squib charges in the staff. The subjects did not attempt to retrieve the seismic line or the geophones.

The other geophysical operation of the sixth traverse consisted of taking magnetic readings along the trend of the seismic line with a small magnetometer.

A surveying team, using plan table and telescopic alidade, plotted stations occupied by the test subjects during the first run over each traverse. The location data, referred to a previously surveyed coordinate system, was radioed to the CDRA for immediate use.

On Monday, October 11, following the suit test, one of the test subjects returned to the test site and re-enacted the first four traverses in shirt sleeves, to permit comparison of a suited and unsuited mission over the same area. A member of Task Analysis accompanied the test subject.
Task analysis

On each traverse a member of Task Analysis, carrying a tape recorder, accompanied the test subject, recording descriptions of the subject's activities and the time required to perform them. The observer kept close enough to the subject to record his conversation with the CDRA.

Photography

The Documentation unit made a photographic record of the test, with motion picture and still cameras. A sound motion picture camera was used for general coverage of the test, and a portable hand-held motion picture camera was used to record detailed close-ups of suit articulation and geologic operations.

CDRA

In the field CDRA trailer, an attempt was made to record the geologic information transmitted by the test subjects in the form of maps prepared during each traverse. One member of the CDRA team talked with the subjects by radio, and made a tape recording of the conversation, as well as brief notes of their sample and photograph numbers and descriptions and a second member remotely controlled the direction and focus of the LEM television camera, so as to monitor the subjects' activities for the benefit of the CDRA team and the video-recorders. From data radioed into the CDRA by the surveying team, the third member plotted the location of the test subjects on a map sheet divided into a coordinate system. On this map sheet, the plotter drew sketches of the terrain from the television images and from the subject's terrain descriptions. He also made brief notes of the subject's geologic descriptions of features near the station. The plotter was handicapped during the first run on a given traverse by not having the location of a station before description at that station by the test subject.

Procedures after Tests

The performance of the test subjects and the CDRA team were
evaluated after each test.

Task analysis

Representative transcripts of test subjects' taped records of the suited traverses and the shirt-sleeve simulation are presented in Appendix B. The transcripts are accompanied by brief descriptions and a time line.

The intervals required by the test subjects to perform tasks were obtained from magnetic tapes recorded both by the Task Analysis team and in the CDRA. Times required for the following activities were analyzed.

1. Walking over various types of terrain
2. Near-field and far-field description
3. Sampling
   a. grab
   b. surface or near-surface
   c. outcrop
   d. oriented
4. Photography
5. Use of penetrometer to determine bearing strength
6. Simulated active seismic experiment

Movements required to perform various tasks are best presented in a film report prepared by the film documentation unit.

CDRA

Replotting of suited traverses on one map and plotting of geologic information from the transcripts in Appendix B permitted evaluation of the CDRA team's ability to handle geologic information during the test, by comparing this map with the individual traverse maps. By comparing the mission and post-mission traverse maps with the control map the geologic effectiveness of the suited test could be evaluated.

Negatives from the staff film camera were too poor for study of the photographs taken by the test subjects.
Test Evaluation

Geology covered by test subjects

The test subjects covered only a small part of the mapped area of the Hopi Buttes (pl. I). The geologic features they examined directly included alluvial deposits, an igneous dike, sedimentary sandstones, and coarse debris in stream beds. The coarse debris contained fragments of various sedimentary and volcanic units from beyond the test area, in the adjacent mesa to the east. Under favorable circumstances, the information provided by the fragments in the coarse debris could be extrapolated to particular distant rock units.

The subjects examined features fairly typical of the general geology of the mapped portion of the Hopi Buttes, and their detailed descriptions, photographs, and samples would be sufficient to establish the general nature and composition of most features in the area surrounding the test site that can be identified in aerial photographs. Such a procedure will be useful in extrapolating information obtained at lunar landing sites into remote areas mapped on Orbiter and telescopic photographs.

The geologic performance of the three test subjects was very similar. In part, of course, this was inherent in the test, since the subjects occupied the same sampling stations and traversed the same routes. Nevertheless, their activities and observations were surprisingly uniform, even though no particular descriptive format was agreed on beforehand. Far-field descriptions were similar from subject to subject, but varied in timing within traverses and between subjects. They were often given while a subject was resting, with the result that traverses contained a low percentage of dead time (without radio transmissions or geologic activities).

The television camera mounted on the staff provided fairly good image coverage of the test site, but movement of the camera when the subjects walked made the Kinescope footage useless as a running record of their activities.

On the first four traverses, each subject collected about 28 samples with a total weight of about 19 pounds and took an average of 18 photographs.
The test subjects did not function mentally exactly as they would under conditions of standard geologic field work. Often they were aware of the minor importance of certain geologic features in the context of terrestrial geology, but pretended that they did not and frequently spent more time in describing or sampling than they would have normally. They were trying to be fairly objective in their investigations, as they imagined a lunar astronaut would have to be.

In addition, the methods of recording information differed from those generally used in standard geologic field work. Ordinarily a geologist makes notations on maps, aerial photographs, and in notebooks and can use these records while in the field. The geologist's notations summarize his observations, whereas the running commentaries of the test subjects were generally first impressions.

Lack of the usual notes and maps resulted in the following:
1. A tendency to repeat information.
2. Some areas between the traverses were skipped or overlooked in the general descriptions.
3. Variation in completeness of descriptions throughout a traverse.
4. A tendency to re-define or correct earlier statements.
5. Far-field descriptions lacked detail.

Comparison with control geology

A comparison of the field test results with those obtained by standard field techniques shows that:
1. Examination and sampling of the dike was of comparable quality in both investigations.
2. Sampling of the lower portion of the sedimentary sequence (the Wingate Sandstone) was less thorough than during the standard field work, because the space suits hampered climbing steep slopes. Although neither the Bidahochi Formation nor the volcanic flows capping the mesa were reached during the test, correct conclusions as to their general composition were made on the basis of rock fragments distributed in stream channels. Thicknesses of these units could be measured from good photographs taken by suited subjects.
3. Few features were actually mapped during the suited test. Portions of the dike and of various stream channels were walked out and plotted in the CDRA from tracking the subjects. However, maps could be made from aerial photographs (incorporating the subjects' descriptions) and from staff film and television images.

Geophysics

Geophysical measurements were magnetic readings along the trend of the seismic line near the surface expression of the dike (pl. II, station 8) north of the LEM. The instrument used in a pre-test survey was not available, and a hand-held magnetometer was used.

There is excellent agreement between pre-test and suited-test measurements, with any difference due mainly to errors in locating the test subjects' stations. Nothing significant about the subsurface structure can be obtained from the data shown in figure 9. Results from an areal survey indicate that anomalies in this area are caused by intrusive rocks, represented in part by the dike. In addition, there are sharp variations in the magnetic field over the dike, which are characteristic effects of lightning strikes.

The test subjects had little difficulty using the magnetometer, and it operated very well, considering the proximity of the metallic components of the suit.

CDRA

One man monitored and taped communications with the test subjects. The brief written notes made by the monitor aided both the other CDRA personnel and the test subjects when clarification on certain points such as station location or sample numbers was requested. At times, questions by the monitor helped direct the course of the geologic descriptions.

The television monitoring system enabled the CDRA personnel to follow the test subjects' activities and to examine close or distant features referred to by them. Foreshortening of the television images caused some difficulty in preparing the terrain sketches.
Figure 9.--Magnetic readings across the trend of a basaltic dike.
Copies of the plots made in the CDRA, which were used along with post-mission tape transcriptions in the compilation of plate II, are given in figures 9-14.

Some of the CDRA plots show more detail than others; in general, this was due less to differences between subjects or plotters than to differences in clarity of the radio transmissions. On a few traverses, the personnel in the CDRA could understand very little of what the subject said, and on several others, interruptions of radio communications lasted for several minutes. However, most communications were recorded on separate tapes by the Task Analysis personnel who attended the subjects on the traverses, so that post-mission analysis of the complete transmissions was usually possible.

Radio reception during the traverses represented by figures 12 and 14 was poor, but post-mission analysis of the tapes made it possible to use these traverses in compiling plate II, stations 11-13 and 20-28 respectively.

Task Analysis

The tests demonstrated that is is feasible to work out tasks and sequences of tasks in shirt sleeves that will be practical for suited operation and to evaluate these under suited conditions at 1 g. The ratio of the average time spent on a suited traverse to the time spent on the same traverse in shirt sleeves is 2.2:1 (table 1). This ratio may be considerably improved by better equipment (sample bags, etc.), more mobile suits, more experienced subjects, and conditions of 1/6 g.

Walking speed was determined for three types of terrain. In order of increasing difficulty these are: (1) firm level ground (fig. 15); (2) gently sloping uneven surfaces strewn with pebbles, cobbles and boulders; (3) slopes of 15°-20° covered by loose material strewn with pebbles, cobbles, and boulders, which make footing uncertain.

Table 2 shows the times required to perform other operations, which bring the percent of the total time to 77. The remaining time was taken up in maintenance and repair of equipment, loss of communications, resting, correcting faceplate fogging, and in receiving instructions. Table 3 shows the times required to perform operations during the seismic experiment.
Table 1.--Walking speed of suited and shirt-sleeved test subjects under various conditions

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<th>Conditions</th>
<th>Subject A</th>
<th>Subject B</th>
<th>Subject C</th>
<th>Average</th>
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<td>Carrying staff and equipment carrier (fig. 15) over:</td>
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<tr>
<td>Firm level ground</td>
<td>92.4 ft/min</td>
<td>76.0 ft/min</td>
<td>77.6 ft/min</td>
<td>82 ft/min</td>
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<td>Gently sloping uneven surfaces strewn with pebbles, cobbles and boulders</td>
<td>77.2 ft/min</td>
<td>56.8 ft/min</td>
<td>53.5 ft/min</td>
<td>63 ft/min</td>
</tr>
<tr>
<td>Slopes of 15°-20° covered by loose sandy material strewn with pebbles, cobbles, and boulders</td>
<td>45.5 ft/min</td>
<td>32.5 ft/min</td>
<td>61.3 ft/min</td>
<td>46 ft/min</td>
</tr>
<tr>
<td>Carrying staff-mounted TV camera up 15°-20° slope</td>
<td>50.5 ft/min</td>
<td>48 ft/min</td>
<td>40 ft/min</td>
<td>46 ft/min</td>
</tr>
<tr>
<td>Paying out seismic line over firm level ground</td>
<td>99.6 ft/min</td>
<td>63.2 ft/min</td>
<td>57.5 ft/min</td>
<td>73 ft/min</td>
</tr>
</tbody>
</table>

Total time spent on traverses:

<table>
<thead>
<tr>
<th></th>
<th>min</th>
<th>sec</th>
<th>min</th>
<th>sec</th>
<th>min</th>
<th>sec</th>
<th>min</th>
<th>sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>134</td>
<td>09</td>
<td>144</td>
<td>27</td>
<td>101</td>
<td>31</td>
<td>126.7</td>
<td>56</td>
</tr>
<tr>
<td>Operating TV camera</td>
<td>32</td>
<td>27</td>
<td>35</td>
<td>00</td>
<td>35</td>
<td>00</td>
<td>34.2</td>
<td></td>
</tr>
<tr>
<td>Geophysics</td>
<td>30</td>
<td>21</td>
<td>35</td>
<td>28</td>
<td>34</td>
<td>16</td>
<td>33.4</td>
<td></td>
</tr>
</tbody>
</table>

Percentage of total traverse time spent walking:

|                | 22  | 27  | 21  | 23  | 31  |
Figure 10.—CDRA plot of traverse 1.
Figure 11. --CDRA plot of traverse 2.
Figure 12.--CDRA plot of traverse 3.
Figure 13.--CDRA plot of traverse 4.
Figure 14.--CDRA plot of traverse 5.
Figure 15.--Test subject walking with staff and carrier during geologic traverse.
Figure 16.--Test subject, behind staff and carrier, examining grab samples.
Figure 17.--Test subject, in suit with thermal garment, collecting sample from an outcrop of dike.
<table>
<thead>
<tr>
<th></th>
<th>Suited</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Shirt-sleeved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subject A</td>
<td>Subject B</td>
<td>Subject C</td>
<td>Average</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>A. Near-field description</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of times carried out</td>
<td>18</td>
<td>24</td>
<td>16</td>
<td>19</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Total time spent at activity</td>
<td>14 min 43 sec</td>
<td>23 min 39 sec</td>
<td>15 min 34 sec</td>
<td>17 min 57 sec</td>
<td>13 min 42 sec</td>
<td></td>
</tr>
<tr>
<td>Average time/activity</td>
<td>49 sec</td>
<td>59 sec</td>
<td>58 sec</td>
<td>56 sec</td>
<td>46 sec</td>
<td></td>
</tr>
<tr>
<td>Average percent of time spent at activity during traverse</td>
<td>11</td>
<td>16</td>
<td>15</td>
<td>14</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 sec</td>
<td>36 sec</td>
<td>53 sec</td>
<td></td>
<td>24 sec</td>
<td>40 sec</td>
</tr>
<tr>
<td>Mean Standard deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **B. Far-field description** |         |         |         |         |         |              |
| No. of times carried out | 9       | 8       | 3       | 7       | 2       |              |
| Total time spent at activity | 14 min 02 sec | 5 min 13 sec | 2 min 07 sec | 7 min 07 sec | 3 min 05 sec |              |
| Average time/activity | 1 min 34 sec | 39 sec  | 42 sec  | 1 min 04 sec | 1 min 32 sec |              |
| Average percent of time spent at activity during traverse | 10      | 4       | 2       | 6       | 5       |              |
|                      | 56 sec  | 30 sec  | 12 sec  |         |         | 33 sec       |
| Mean Standard deviation |         |         |         |         |         |              |
### C. Grab sampling

(samples were placed into sample bags after being described)

<table>
<thead>
<tr>
<th>No. of times carried out</th>
<th>11</th>
<th>13</th>
<th>8</th>
<th>11</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time spent at activity</td>
<td>8 min 48 sec</td>
<td>10 min 29 sec</td>
<td>6 min 54 sec</td>
<td>8 min 44 sec</td>
<td>2 min 18 sec</td>
</tr>
<tr>
<td>Average time/activity</td>
<td>48 sec</td>
<td>48 sec</td>
<td>52 sec</td>
<td>49 sec</td>
<td>15 sec</td>
</tr>
<tr>
<td>Average percent of time spent at activity during traverse</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Mean</td>
<td>38 sec</td>
<td>31 sec</td>
<td>23 sec</td>
<td></td>
<td>31 sec</td>
</tr>
<tr>
<td>Standard deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### D. Sampling surface or near-surface materials

(A scoop was used to gather samples and to place them into sample bags after they were described)

<table>
<thead>
<tr>
<th>No. of times carried out</th>
<th>8</th>
<th>9</th>
<th>7</th>
<th>8</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time spent at activity</td>
<td>5 min 49 sec</td>
<td>8 min 57 sec</td>
<td>6 min 08 sec</td>
<td>6 min 58 sec</td>
<td>3 min 25 sec</td>
</tr>
<tr>
<td>Average time/activity</td>
<td>44 sec</td>
<td>1 min 00 sec</td>
<td>53 sec</td>
<td>52 sec</td>
<td>26 sec</td>
</tr>
<tr>
<td>Average percent of time spent at activity during traverse</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Mean</td>
<td>14 sec</td>
<td>24 sec</td>
<td>20 sec</td>
<td></td>
<td>11 sec</td>
</tr>
<tr>
<td>Standard deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19 sec</td>
</tr>
</tbody>
</table>
Table 2.—Times spent by test subjects in different activities—Continued

<table>
<thead>
<tr>
<th></th>
<th>Suited</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subject A</td>
<td>Subject B</td>
<td>Subject C</td>
<td>Average</td>
<td>Shirt-sleeved</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Outcrop sampling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Samples were broken by hammer, briefly described, and placed into sample bags]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of times carried out</td>
<td>11</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total time spent at activity</td>
<td>9 min 13 sec</td>
<td>9 min 15 sec</td>
<td>8 min 38 sec</td>
<td>9 min 02 sec</td>
<td>2 min 12 sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average time/activity</td>
<td>50 sec</td>
<td>1 min 19 sec</td>
<td>1 min 14 sec</td>
<td>1 min 05 sec</td>
<td>22 sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average percent of time spent at activity during traverse</td>
<td>7</td>
<td>6</td>
<td>9</td>
<td>7</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>18 sec</td>
<td>13 sec</td>
<td>21 sec</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17 sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Collecting oriented samples from outcrops</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Subjects scratched a mark on sample and photographed it before removing sample from outcrop]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of times carried out</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total time spent at activity</td>
<td>6 min 44 sec</td>
<td>3 min 08 sec</td>
<td>4 min 08 sec</td>
<td>4 min 40 sec</td>
<td>2 min 53 sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average time/activity</td>
<td>2 min 15 sec</td>
<td>1 min 34 sec</td>
<td>2 min 04 sec</td>
<td>2 min 00 sec</td>
<td>43 sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average percent of time spent at activity during traverse</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
G. Photography

[Staff used for camera mount and to determine bearing and inclination. A brief description of object photographed was made.]

<table>
<thead>
<tr>
<th>Suited</th>
<th>Subject A</th>
<th>Subject B</th>
<th>Subject C</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of times carried out</strong></td>
<td>11</td>
<td>24</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td><strong>Total time spent at activity</strong></td>
<td>5 min 53 sec</td>
<td>16 min 21 sec</td>
<td>8 min 55 sec</td>
<td>10 min 23 sec</td>
</tr>
<tr>
<td><strong>Average time/activity</strong></td>
<td>32 sec</td>
<td>41 sec</td>
<td>30 sec</td>
<td>35 sec</td>
</tr>
<tr>
<td><strong>Average percent of time spent at activity during traverse</strong></td>
<td>4</td>
<td>11</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>10 sec</td>
<td>24 sec</td>
<td>15 sec</td>
<td></td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td></td>
<td></td>
<td></td>
<td>15 sec</td>
</tr>
</tbody>
</table>

H. Use of penetrometer to measure bearing strength of ground surface

[The depth of penetration of penetrometer point was measured on a scale]

<table>
<thead>
<tr>
<th>Suited</th>
<th>Subject A</th>
<th>Subject B</th>
<th>Subject C</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of times carried out</strong></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total time spent at activity</strong></td>
<td>5 min 21 sec</td>
<td>3 min 54 sec</td>
<td>2 min 39 sec</td>
<td>3 min 58 sec</td>
</tr>
<tr>
<td><strong>Average time/activity</strong></td>
<td>1 min 04 sec</td>
<td>59 sec</td>
<td>53 sec</td>
<td>1 min 00 sec</td>
</tr>
<tr>
<td><strong>Average percent of time spent at activity during traverse</strong></td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 3.--Time spent by test subjects in performing various activities during the seismic experiment

<table>
<thead>
<tr>
<th>Activity</th>
<th>Subject A</th>
<th>Subject B</th>
<th>Subject C</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Sec</td>
<td>Min</td>
<td>Sec</td>
</tr>
<tr>
<td>Plugging seismic line into LSEP</td>
<td>1</td>
<td>48</td>
<td>2</td>
<td>47</td>
</tr>
<tr>
<td>Plugging line into staff</td>
<td>1</td>
<td>17</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Walking 20 meters paying out line</td>
<td>39</td>
<td>1</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Placing first detector</td>
<td>1</td>
<td>49</td>
<td>1</td>
<td>48</td>
</tr>
<tr>
<td>Walking 50 meters paying out line</td>
<td>1</td>
<td>44</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Placing second detector</td>
<td>1</td>
<td>50</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Walking 50 meters paying out line</td>
<td>1</td>
<td>34</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>Placing third detector</td>
<td>2</td>
<td>21</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>First thumper firing</td>
<td>40</td>
<td>13</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Walking 5 meters waiting for thumper firing</td>
<td>8</td>
<td>42</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>record (20 times)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking 20 meters</td>
<td>1</td>
<td>17</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total time of test</td>
<td>23</td>
<td>41</td>
<td>27</td>
<td>28</td>
</tr>
</tbody>
</table>
Description of distant features and of terrain in the immediate vicinity of the subject consumed an average of 20 percent of the total time spent on the geologic traverses, whereas during the shirt-sleeve simulation 29 percent of the subject's time was spent in description of near and far geologic features. This difference may be a reflection of the difficulty of talking in the suits; frequently the subjects had to shout to be heard through the suit radios above the noise of air movement in the suits. Although more total time was spent in near-field description under shirt-sleeve conditions, the ratio of time spent on individual description events (suited:shirt-sleeve) is approximately 1:1. There were more stops for far-field description in suits than in shirt sleeves, probably because the suited subjects tended to make distant descriptions while resting.

Various types of sampling averaged 23 percent of the subject's time during the geologic traverses. Under shirt-sleeve conditions 19 percent of the test subject's time was spent in sampling. The subjects found bagging the samples in the small canvas bags difficult. Sampling required almost three times as much time in a suit as it did in shirt sleeves. Sampling in a suit required on the average 49 seconds for a grab sample (fig. 16), 52 seconds for a surface or near-surface sample, 65 seconds for an outcrop sample which involved breaking off a portion of material (fig. 17), and 2 minutes for an oriented sample which, in addition to breaking or loosening the sample, required that its orientation be noted.

Taking photographs with a staff-mounted camera involved sighting the object to be photographed through the finder, snapping the shutter, and reporting the orientation of the camera at the time the picture was made along with the photo number and a brief description of the object photographed.

During the geologic traverses the subjects knelt an average of 11 times each. The geophysical seismic traverse required kneeling 4 times. Using the staff-mounted television camera and the magnetometer did not require kneeling.
Summary

Far-field descriptions are probably most useful in supplementing information obtainable from photography, and would be the only possible method of observation if emergence from the LEM were inadvisable for any reason, such as the hazard of a high radiation or particle flux at the landing site.

The test shows that Apollo type (foot traverse) techniques seem to be virtually restricted to the investigation of a few selected features in detail. Although suited test subjects cannot traverse terrain nor perform geologic operations as rapidly as a person in shirt sleeves, techniques of automatic tracking, data handling and analysis, and map compilation by a CDRA team, will largely offset these restrictions, so that it will probably be possible to equal or better the speed with which conventional geologic field work can be accomplished by a single geologist. And it appears that, given a particular problem to solve, and with due regard for difficulties of mobility, a suited geologist can produce the required results as accurately as can a geologist in shirt sleeves.
A. Comments from Test Subjects

Suits

Need increased mobility--probably by modifications to hip joint. Should be able to raise leg higher, and also be able to lock knees backward when resting.

Vibram-type soles (as on mountaineering boots) would greatly improve traction and should provide some thermal insulation as well.

Boots should have better ankle support and good pressure contact with surfaces.

Experimental outer boots used by subject A on first day made walking difficult; the lack of foot sensitivity in soles was especially bad.

Finger dexterity of gloves is surprisingly good and should be retained in thermal overgloves. It is important to keep finger diameter as small as possible. The rigid bar across palm makes prolonged gripping difficult.

Movement of arms around face area is restricted and requires a large effort.

Thermal garment should be snug against the suit crotch.

Torso-collapse strap should be made easier to use or eliminated by redesign.

It would help if subject could bend at waist more easily and farther, as it is better to work from kneeling position (both hands are then free) than on hands and knees.

The bubble helmet is the better of the two, but the neck ring is uncomfortable.

If cooled underwear does not decrease face-plate fogging, then another means to do so should be designed.

Equipment

Sample bags are hard to reach and to use.

Sample carrier should be balanced, made stronger, and have a better handle.

Provision should be made for mounting the staff horizontally on top of the carrier.
Traverse 1, Subject A
(Suited; thermal garment not worn)

I am standing in the bottom of a small draw about a meter deep and maybe 3 or 4 meters wide at the top. Bottom of the draw appears to be sandy with a few small cobbles and boulders. I think you can probably see them in the television. Most of the boulders and cobbles are a dark-colored material with a few lighter colored fragments such as this one by my staff. I will attempt to sample these things.

I won't describe it since I am bringing it home with me. Sample 259 is one of the dark-colored, pebble-sized fragments of the black material. Sample 261 is of the white material.

The next sample is the sandy material that covers most of the bottom of the wash. This is sample 262.

I will now dig a little hole down below the surface. Sample 263 is some of the sandy material from about 4 cm below the surface.

I cannot push the penetrometer through the crust without pushing the red ring all the way down. I will break through the crust on the surface then take a penetrometer reading. Penetrometer reading 2.3.

I will take a photograph of the hole that I just dug with the hammer in it for scale. I can't get a clinometer or sun compass reading due to the steep angle.

I will proceed up the gulley.
Traverse 1, Subject A--continued

Transcript

I am at the junction of two small gulleys of about equal size that join to form the gully that I have just been walking up. The difference in these two gulleys is the size of the material in the bottom of the gully. The bottom of the gully to my left as I face upstream away from the LEM has a large number of cobbles and boulders, some gravel covering 40% of the surface.

I will take a photograph of each. The first photograph will be the gully to my left. The azimuth of this photo is 345°. The vertical angle is -7.

The azimuth is 290°, vertical angle -30°. Better make this a station; I have given a lot of description here.

I will go up the gully to my left, the one that has the larger number of boulders in it.

On the left side of the gully as I look up is a boulder of tuffaceous or agglomerate material. It appears to be volcanic. I will take one sample of it. This is sample 260.

This boulder that I have broken up is not typical of the boulders on the surface. Most of them are this black, more basaltic looking material.

I will proceed on up this gully. I see a bank ahead of me that I would like to get a soil sample from.

I am standing here looking at a cut bank. The bank is almost a meter high. It has some layering (?) exposed in it. These aren't soil profiles or anything. They seem to be channel fills: small cobbles and large pebbles and small gravel channel fill.

I will take a photograph of this bank. Azimuth 289, vertical angle approximately -13°. I moved the camera some so it's pretty approximate.

I will go over and sample this. A few of these fragments I forgot to mention are a fine-grained sandy material, probably sedimentary, possibly tuffaceous.
**Traverse 1. Subject A--continued**

**Transcript**

The sample I am taking contains soil with some of the finer fragments in it.

I will take a penetrometer reading of the gulley at the top of the bank. I broke through a second crust here 3 or 4 cm below the surface. The first reading is 0.8°. The next attempt I broke through this second crust again. This reading is 0.6°.

I will climb out of here and go over to the other gulley which is more devoid of boulders and give a brief description there.

Here, looking directly away from the LEM, is a small hill maybe 6 or 8 meters high. The hill is marked with dark, basaltic-looking material with one large boulder that is dark brown. Looks like different material but I don't think I will climb up there and sample it.

Let's make that a station. Maybe you can plot that hill. It probably has 60 or 70% basalt covering. You can probably map that with your air photos. As I come into this gulley, the side I am facing is much more sharply cut than the side I just came down.

The soil on that side of the gulley is sandy with very few fragments of pebble-size material in it, and very few boulders and cobbles. I will take a sample from the side of this gulley. Better make this a station.

Penetrometer reading is 4.5

The surface appears to be very similar to.... (lost communication)

Station ll--Description of outcrop

I will take a sample of this gypsum. That is sample 267.

I am returning back toward the LEM.

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44
I am proceeding away from the LEM here crossing a small gulley about 30 yards away from the LEM. I am proceeding toward a large dike which is about 50 yards away. This dike is a black dike; it is a linear feature which seems to be continuous for several hundred yards. It rises out of the low alluvial surface, here a wall about 30 feet high.

The rock itself is polygonal jointed. The individual joints are rounded. They resemble...structures from a distance.

I see a contact near the base of this dike with some red and whitish rock which looks quite a bit different from the dike rock itself. I will try and go down close to this contact.

I'm going to wait here until my faceplate unfogs.

The dike here, about 1 meter thick, consists of a dense black rock with sparse phenocrysts with some vesicles. The vesicles seem to be concentrated in the Bake zone about a few inches thick near this margin of the dike. The central zone of this dike is a mottled greenish rock. The mottling takes the appearance of devitrification type of phenomenon. The outside of the rock seems to be blacker than the rock inside. I can see now about three zones from here these are from the outside in a black possibly chill zone, a vesiculated zone about 2 inches thick just inside the black zone, a denser nonvesicular zone inside that and in the middle of the dike a mottled, possibly devitrified zone. I can see above me that the vesicular zone is repeated on the other side of the mottled devitrified zone. I will try to take a couple of photographs of this area.

The first photograph at this station is of the inner zone and outer zone and possibly some of the dense intermediate zone. There is a scriber in the photo for scale. The azimuth of this photo is 323° and the vertical angle is 23°.
I am taking another photograph, this time of the contact zone. This photo has an azimuth of $337^\circ$ and a vertical of $26^\circ$.

I will take a sample of this rock. The first sample I will take is an oriented sample. The sample horizontal line will have an azimuth of $353^\circ$ and will be oriented vertically. This marking is made on the left side of the dike looking away from the LEM. The marking is on the outside of the dike. The photo is of the vesicular zone, possibly a little bit of the outside bake zone. That was sample 327.

I will take a grab sample of the mottled zone of the dike. The rock appears to have some alteration. This is sample 326.

The rock in contact with this dike to the left looking away from the LEM area appears to be a sandstone. It is white at the contact; about a foot away from the contact it is red. It looks like the rocks in the lower part of a cliff directly behind the LEM area.

I will collect a sample of the light sandstone right next to the dike. This appears to be a very fine-grained sandstone, some mottling with red. This is sample 323.

I will now move along the dike and describe and sample it further along its extent. The trend of the dike is approximately $249^\circ$ and it is essentially vertical.

The rock here rises about 30 or 40 feet above the ground. It is polygonally jointed with large joint blocks about up to a foot and a half in diameter and these are in turn jointed into smaller blocks. I will take a photograph of this area of the wall and then go to the wall to sample. I am about 10 feet from the wall.

The azimuth of this photo is $283^\circ$ and the vertical angle is $-1^\circ$.

The rock here is very black; it is evidently primarily the outer, probably chill, zone of this dike.
I see some phenocrysts which appear to be biotite in this rock. I also see some elongate vesicles filled with a light-colored mineral which may be calcite. I am not sure; I can't tell from here. I will not take a reading on these vesicles except to note their angle within the trend of the dike. These vesicles drop down away from the LEM at an angle of 34°.

I will try to take an oriented sample at this point. The strike and dip of this sample is marked on the outside wall of the dike. The strike is right in the line of the dike. I can't get a reading on it because it is in shadow. The dip is about vertical. Because of the size of the sample I'm going to drop it into the bin rather than into one of the numbered sample bags.

I will now proceed along the strike of the dike to a place where it appears I can cross the dike and once more observe the texture of it.

At this point the dike is broken or offset slightly. It changes its strike slightly and I can see that it does it again further along the dike, perhaps as many as three times further down. I will take an oriented photograph of the dike and then describe and sample the dike at this location.

The azimuth is 323°; the vertical angle is 0°.

I will proceed along here just a little further and try to get an oriented sample.

The dike appears to have the same zonation here. I can see it particularly on the opposite side of the dike from where I am. There is a black dense zone, a vesicular zone, a dense, grayish-greenish-black zone, and a central mottled devitrified zone. The vesicles do still seem to be filled with a cream to brownish mineral. I can't tell just what that mineral is.
Traverse 2, Subject B--continued

**Transcript**

I will not orient this sample. It is a sample from the dense zone in the center. It seems to have some phenocrysts in it. This is sample 319.

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<td>to LEM</td>
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Traverse 3, Subject C

(Suited)

**Transcript**

I am walking directly away from the LEM, behind it. I am going toward a low prominence which appears to be capped by some sort of dike which runs off to my right. The ground in the immediate area is a sandy, silty, reddish-brown soil--looks like it is wind blown with slight vegetation cover. There are some cobbles and pebbles of black rock which appear to have come down from the feature I am approaching.

The feature here appears to be a black basaltic dike. It trends away from me with an orientation of $223^\circ$ and approximately vertical. I can see that the strike changes as you go along. It seems to change in several places. It may be offset farther along. I will proceed along the dike and describe it as I go.

The dike at this point appears to be a matter of a foot or two wide. It is a dense black rock with some vesicles. The vesicles seem to be oriented parallel to the trend of the dike. The central portion of the dike where it increases to more than 2 feet appears to be mottled and similar in appearance to the central portion of the dike described this morning.

I think I will make a station here and describe this rock and take a sample from it. I have taken a representative sample of the dike. It is a dark grayish to black aphanitic rock. It has a few glassy phenocrysts a few millimeters in diameter. The phenocrysts appear to be pyroxenes.
At this location I cannot see any evidence of zonation that we observed in the dike this morning. There is some mottling but the dike is very thin. There is evidence of contact with a whitish sedimentary rock in the soil zone at my feet. I will now take a sample of the ... zone which is very poorly exposed. (Taking sample on narrow ridge from kneeling position.)

The sample number is 308.

I will take an oriented photograph of the dike along the trend from here. This photo has an orientation of 237° and vertical angle 0°.

I am proceeding along the trend of the dike. The rock along here is similar in color, strewn with platy small fragments over reddish-brown silty material. There is a little gap in the outcrop of the dike here. It appears to terminate as it cuts through, and the ground does not have much in the way of basalt on it; primarily the reddish-brown sandy material of the area itself. (Climbs very steep hill to Station 2.)

The dike at this point which I will make Station 2 increases in thickness to approximately 3 or 4 feet. It has a very well displayed zonation. On this side we have the chill margin we saw this morning. It has a vesicular layer several inches thick and a denser material, a spotty mottled devitrified material. Some of the vesicles are filled with a brownish or whitish material but these are in a minority. There is a zone of anomalous platy material right at the contact and is probably sandstone. I will collect some of this material and will make a couple of photographs of the layers in the dike and small changes in strike which occur just beyond this.

The first sample is a piece of the sandstone from the end near the contact of the dike with the country rock. This contact is not exposed.... This is sample 269.

The first photograph taken has an azimuth of 312°, vertical angle -8° from a distance of approximately 4 feet of the outside of the dike. It shows the vesicular zone. It shows the interior zone. There is nothing in the photograph for comparison.
Traverse 3, Subject C--continued

The second photograph taken at an azimuth of 253°, vertical angle of +3° and shows the changes in strike along the contact.

I will take one more photograph of the bluff behind the dike which is a sandstone material layered with... capped by a lava flow. This outcrop is about 300 to 500 yards away. The picture was taken at an azimuth of 280°, vertical angle of +8°.

I will now move along the dike to the next break in slope and will sample the dike at that point.

There are quite a few vesicles in the dike in this area. The vesicles are elongate at an angle of about 2° to the vertical in the trend of the dike.

There is quite a bit of polygonal jointing in here, both on large scale and small. I will make a quick photo here. I also see an inclusion here. The inclusion is about 4 inches long. I will take a photograph that shows both the polygonal jointing and the inclusion. The azimuth is 332°, vertical angle of -7°.

The dike at this point is about 2 1/2 to 3 feet thick. It is still vertical and has very good zona- tion. The outer zone, the chill zone appears to have a thickness of about 1 centimeter. The vesic- cles in the next zone are filled with a brown-to-whitish material. The interior zone is not strongly mottled or devitrified.

I will take a sample and make this station 3. There are a minor number of phenocrysts in the rock. The phenocrysts appear to be a pyroxene a few millimeters in diameter. The vesicles in the vesicular zone appear to be elongate along the trend of the dike. I will sample this. This is sample 335.

There are some inclusions in the rock that are fairly well altered. One cannot tell what they are.
Traverse 3, Subject C--continued

**Transcript**

They do not look like parts of the immediate country rock.

I will take a photograph of one of the altered inclusions which is about 2 1/2 inches in diameter. The azimuth of this photograph is 323°, vertical angle -35°.

Along the direction of my traverse this dike separates as if it was by fault. However, by looking at the next section of the dike it obviously thins down. It appears very black and comes to a thickness of 2 or 3 feet.

I will take a photograph here and then go and look at it. This photograph has an azimuth of 238° and a vertical angle of -8°.

The rocks at this point do not look like they have been cut by a fault but that this dike has come up initially in parallel joints. The... along the direction I was traveling thins noticeably and loses its zonation as you come into the area of the break. It then goes past the other part of the dike... (lost communication)

I will now return to the LEM area.

---

**Traverse 4, Subject B**

(Suited)

**Transcript**

I am standing on an outwash shoulder of a wash here. The material I am standing on is primarily silty, brownish-red sand. It appears to be material which has washed down from the immediate hillside and possibly hillsides behind the LEM on the bluff. There are some pebbles of black volcanic material mixed in with this. There are quite a few cobbles of black rock mixed in with this. There appears
Traverse 4, Subject B—continued

Transcript

a veneer of rock lying on the surface of a hill in front of me. The bedrock here appears to be pre-dominantly a muddy-looking sand. It is partly.... It forms the approach to a badlands topography and there are many shoots of black angular-looking material coming down across this hillside. I will go over and sample some of the material on that hillside and some of the material here on the alluvial flat.

Walking to first station 2 05
Kneels 2 33

Using part of a recent sample hole in the surface I see that the bedrock is a fissile shale. It has some grayish-green stringers running vertically in it and some spots in it. Part of the material in these stringers appears to be crystalline. Looks like a secondary material. There is a white deposit on the surface of some of the material here. The material right opposite appears to be mud which has been derived locally but not at the point of its present location. It is mudcracked and there is a scattering of smaller pebbles of black rock lying on top of it.

I will take a sample here of the shale. Sample number is 363.

I will take another sample here. It will be of the material from the flat itself. It is mudcracked and looks very much like the other. It seems to have been disaggregated and is now slightly reconstituted, either through moisture cementation or possibly the same material that is forming the efflorescence on the walls at this location. (Second sand sample.) That is sample 354.

I will now take a photograph of this area in an attempt to show the distribution of various rock types. (Photo from kneeling position.) Azimuth 330°, declination about 0°.

In the rocks above me about 25 feet is a stringer of white rock. It looks very much like the rock which I have described, except for the change in color. It does form a slight ledgy deposit and goes up the gulley from me.
I will go on up and describe and photograph some of the relationships we see in these rocks.

The wash continues to be covered with a veneer of boulders. The rock here appears to be an aphanitic volcanic rock with sparse, scattered phenocrysts. The matrix is also black. It has some deposits on joint surfaces, with some weathering rind. It weathers to a brown-to-blackish color with some green. And there appear to be some vesicles which appear to be filled with a whitish or brownish mineral. (Pausing along the way to describe various features.)

On the bluff behind the LEM toward which I am walking up this wash is a dark black rock which at this point appears to be continuous. There are some other... of black rock which appear to be discontinuous across the face of the bluff.

(Pause) These are much more jumbled and less oriented than the...and appears that they may be derived from the....

(Pause) There is a homogeneous sequence of layered rock underneath this. The distinctive color is grayish green. They have some reddish-brown colors in them. The layers appear to be measured in 10's of feet thick. Many layers usually separating units of different color about a foot thick or so which are lighter in color, gray and they form very small thin ledges maybe 10 centimeters thick or so.

This unit goes down to the very prominent ledge forming material which caps the unit

(Pause) forming a very distinctive cliff. This cliff may be about 10 or 20 feet high overlying some softer material forming a badlands unit.

I think I will photograph this area from here and try and get a panoramic view along the bluff. The first photograph has an azimuth of 214°. Vertical angle of about +4°.
Traverse 4, Subject B--continued

Transcript

...taken of the photographic sequence to my right as we go up the wash. There is a covered zone then to the left of this photograph. The next photograph of this panorama will be of this zone. Azimuth 230°, inclination 0°.

Continuing around with an azimuth of 242° of the same zone.

Continuing around with an azimuth of 255° to pick up this unit again and showing some of the blocks of the caprock down from the skyline.

Continuing at an azimuth of 270° of this same interval but a little to the left.

And finally coming to an azimuth of 287° this shows the cliff and the upper unit and one of the major slump blocks coming down from above.

(Pause) I have a little spur veneered with this black aphanitic coming out here. The stream is deflected around it. I will cross this and go down into the stream and continue up to the left. There is some drainage coming down from the right from the areas of the first picture at the last point.

Looking up the gulley from this area I believe I can see a contact in the reddish sandstone which I have been sampling and the materials from the badlands underneath the cliff. I shall take a photograph of that.

Photo azimuth 292°.

In front of me I see some pebbles of black rock and also some light-colored rock which may correspond to some of the material either in the ledge former or possibly in some of the units above the ledge in the light gray small ledge-forming units in the upper part of this formation.

I will make this station and take a couple of samples. (Sampling with scoop.) The light-colored stuff looks like siltstone. It could be tuffaceous. It is white.
I will take some pebbles of these and the alluvium. I will take a few other pieces of the alluvium here too, some of the black volcanic rock. And I see some other pebbles, pieces of gypsum and a couple of other things scattered around here. This will be sample 365.

(Sampling still using scoop.) The piece of basalt that I picked up is not quite as aphanitic as it looked. It has moderately abundant black phenocrysts which look like pyroxene. And some lighter colored... possibly phenocrysts. It is black with some greenish cast, possibly alteration. I will put it in with the other.

I saw some gypsum around here but I don't see it now and I won't waste time trying to find it.

(Rises from kneeling position.)

Now I will go up the wash here a ways. The wash now is sandier and is hemmed in on both sides primarily by the sandy reddish material on the other side by black basaltic rock.

(Pauses) 10 to 15% of the material appears to be in units pretty much... by its....

Most of these fragments of this 10% that seems to come from the units of basalt and red sandstone look very much like those pieces that I collected from the alluvium at the previous station.

I will take a photograph here of the material that is scattered in a little spur between two drainages. It has the flag in it for scale. Azimuth 250°, vertical angle fairly steep I would say 15 or 20°.

I will proceed up this drainage to some extent.

I see a very large amount of very worthwhile rocks right here and I think I shall establish a new station at this point and proceed to sample as much of this material as possible for a few minutes.

First a piece of siliceous-looking rock with convoluted-looking bedding. I am going to throw all these into the bin. It does not appear to be a very common rock.
Traverse 4, Subject B--continued

**Transcript**

The second is a piece of aphanitic basalt.

Another piece of phophryritic basalt with pyroxene crystals with brownish to grayish matrix.

Here is a piece of greenish basalt with a number of vesicle fillings. This also is not a common rock type.

Right underneath me if I can get it is a piece of fragmented tuffaceous rock with what looks like... in it and a grayish-green matrix.

A piece of basalt, possibly fragments. It does look like it is fragmental. It has a reddish cast. Somewhat scoraceous in appearance with reddish vesicles. Some greenish vesicle fillings.

Here is a piece of what looks like a tuffaceous sandstone perhaps with a very brilliant white filling on the upper parting.

A piece of baked fragmental rock that has fairly good phenocrysts in it. It doesn't appear to have a homogeneous matrix. But possibly particulate with some rock fragments.

A piece of greenish basalt, mottled, very much like the interior zone of the dike.

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Traverse 5, Subject C
(Suited)

**Transcript**

I am standing at what appears to be a contact between alluvial material that may well be the flood plain of a small stream, a dry wash and some material of a somewhat steeper slope whose angle I would estimate is maybe... degrees. I will start up this slope and try to give you an idea of the terrain I am traversing as I am traversing it.

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You should be able to see some of the coarse basaltic material which tends to litter the low slopes. Pebbles and cobbles--dominantly cobbles--and small boulders of this material generally reasonably well rounded to subrounded and in a few cases, subangular. I think you will note a... material. There is a mixture of finer material, both basaltic sand and fine-grained, light-brown silty material.

I shall attempt to show you a large boulder with a coating of desert varnish. You can see this boulder is subrounded with a coating of desert varnish. Its color is greenish gray. You might be able to notice in this associated boulder the glint of phenocrysts in this otherwise aphanitic material. Let me show you some more of this surface in detail. You should see pebbles of basaltic material, subangular to subrounded. A few millimeters to 1 or 2 centimeters in diameter. Mixed with silt, light brown in color.

Here is a boulder of yet another type of material. It appears to be an agglomeritic tuff; perhaps I should call it an agglomerate. Lighter patches on here are for the most part lichens.

I am panning over the stream where I started. You should be able to see the little... with vegetation growing densely along it. You should be able to see its....

As I look at an azimuth of approximately 218° I see a small dike. Looking off at the hill in the background you should be able to see light and dark sedimentary rocks; these are somewhat intricately dissected by erosion. There are occasional slides of talus of which this is probably a good example. Exposed is a bench of even more resistant rocks. Can you pick it out?

This bench is very near the contact between these darker rocks and rocks of lighter tone which appear to be... by a lava flow. This is an intriguing light-colored
Traverse 5, Subject C--continued

Transcript

zone beneath the lava flow. Can you see that?

If you look over here again you can probably see that resistant bench again beautifully exposed. Above that the pearl-colored beds capped by what probably here is slump basaltic material. Above that a series of grass-covered slopes. Finally, above the grass-covered slopes a basaltic cap 10 to 20 meters thick.

Can you see the boulder I am aiming at? Working to focus camera; I would like to get a feel for the width of field of this lens. Does the large boulder occupy the entire field of your monitor screen?

This is a brownish-colored boulder of agglomeratic material. I want you to see the whole thing to compare it to the other materials on the slope. I am moving closer to it and will try to let you look at the thing in detail.

Can you see anything? You will see material ranging from a few millimeters to a few centimeters in grain size. Some of this material appears to be vesicular and other parts appear to be glassy. I think you should be able to pick out some of the pyroxene phenocrysts in the agglomerate material.

Using staff camera for panorama of far field, I am going to try some distant shots and try to give you the big picture because it is too hard to focus down close.

Across the alluvial flat you will probably see an impressive series of surfaces with hummocky hills that appear to be remnants of former higher surface. There appear to be at least three surfaces, maybe more. You may be able to pick out some higher hills that look distinctly volcanic. A couple of them, most notably this one over here, very much like a volcanic....

In the foreground is the dike which I looked at earlier, whose azimuth I described. This dike swings across the
foreground. There is a series of irregular fingers rising 10 or 15 meters above the alluvial material.

...what appear to be flat-lying sedimentary beds with a lava cap on top of it. Exposed very nicely over here apparently a series of flat progressive stages of dissection. In the foreground is what appears to be an erosional remnant of one of these sloping surfaces. There are similar sloping surfaces behind them, many of them rubble strewn. They might very well be pediments because they appear to truncate the horizontal bedding of these sedimentary rocks.

As I glance around and look up hill more I see the sedimentary beds, the... colors at the bottom, the rubble-strewn slopes, horizontal bedding distinctly transected...of cobbly and bouldery material which may very well be either dissected slumps or sort of a lag residue from a lava cap, and up at the top again the lava cap.

Looking off at an azimuth of about 248° I see hummocky remnants...

...of a dissected pediment surface. The reason I am inclined to think of this as a pediment is because one can see fragmentary remnants of different colored bands which strongly suggest sedimentary bedding in this poorly consolidated rock. Again up here you can see a lava cap way up at the top. The gully is dissecting the upper light-colored sedimentary unit from the lower darker colored unit.

Can you see the boulder with the phenocrysts in it? This would appear to be a typical basalt boulder in this rubble-strewn surface. You will probably be able to see the glint of phenocrysts, actually black; the host rock is a greenish-gray color when weathered and apparently a deeper gray color when fresh.

Here is some more basaltic material. It has some very small subspheroidal fragments. These fragments probably give rise to much of the debris that mantles the surface.
Traverse 5, Subject C--continued

Transcript

This appears to be another tuff... fragments of pumice and here little chunks of either a pyroxene or an amphibole. They are a millimeter or so across and appear from here to be subhedral. They constitute perhaps 1% of the rock... tan and brown and reddish tones. It's a lovely thing.

This is a boulder of basaltic material, green in color; aphanitic. The reason I selected it to show you is because it is covered with a thin coating of caliche probably a millimeter thick. Let's try the other extreme, again looking out. I think maybe you can see very nicely exposed a slump block beneath the lava cap on the mesa. The slump block is an interpretation. It appears reasonably certain that this material is detached...

the lower level in the basalt sedimentary contact exposed in the wash....

There is a little stream over here... filled with what would appear to be a light-brown silty material that we have been seeing all along down on these lower levels.

... the path of the stream is gently sinuous. There is a good possibility that...

it would be very difficult with the narrow field of view of this camera to get a feel for how linear some of these stream segments are. The one which I am in now is distinctly linear, running approximately parallel to the mesa edge at an azimuth of about 240°. Another linear segment is about perpendicular to the first. I read its azimuth as 330°.

---

Traverse 1, Subject C
(Shirt-sleeve)

Transcript

I have walked across a surface composed of silty

Activity | Min | Sec
---|---|---
Walking from LEM to gulley | 0 | 20

Description
material. It appears to be alluvium. It is light brown in color. The grain size appears to be predominantly silt. I am standing in a small draw which forks upstream at a distance of perhaps 10 meters from me. I will describe the forks of the gulley as I approach them. The portion on which I am standing here is a very fine silty material light brown in color. It appears to be calcareous in places and contains swatches of lighter colored material. In places there is a surface crust which is vaguely mudcracked.

I am taking two samples of basaltic material which is common to the floor of the wash. This will be sample 368. I will take one sample of sandy material which will be sample 369. The sandy material contains coarse basaltic sand which is also present in the actual part of the wash. A subsurface sample (digging). I will take sample 372 which is a subsurface sample taken from a few centimeters below the present floor of the wash.

The penetrometer reading will be taken approximately about 1 centimeter below the surface. The material is very hard and I get a reading of 3.6. The second reading a few centimeters away from the first is 4.3.

I will take a photograph here of the gulley bottom. In the area from which I took the subsurface sample and one of the surface samples you will be able to see mudcracking as well as some of the coarse basaltic material. The azimuth reading is approximately 286 and the inclination approximately 18°.

I am now proceeding upstream in the gulley walking up to the junction between two tributaries. At this point there is some white tuffaceous material which I won't sample because I am not supposed to. Again there is coarse basaltic sand, grain size a few millimeters in the actual portion of the stream where fast flow took place. The surface here is quite hard.

The gulley on the left is characterized by having abundant bouldery basaltic detritus, subrounded, and subangular cobbles and boulders dominantly of dark basaltic material with an occasional chunk of what appears to be a pumice tuff much lighter in

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<td>Kneels</td>
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<tr>
<td>Sample</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Penetrometer reading</td>
<td>2</td>
<td>46</td>
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<tr>
<td>Photo</td>
<td>3</td>
<td>24</td>
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<tr>
<td>Walking</td>
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</table>
Traverse 1, Subject C, shirt-sleeve, continued--

Transcript

color and containing distinct... pumice a centimeter or so across.

I will take a couple of photographs here to show the contact between the two branches of the gulley. The first photograph was taken at an azimuth of 258, inclination +2. The second photograph looking up the more southern gulley was taken at an azimuth of 191° and an inclination of +2. The second gulley is considerably more sandy than the first. I will describe as I traverse it a little further on.

I am now walking along the floor of this gulley again. There is considerable basaltic sand in the part where apparently there is a fast flow. I will stop here and take a couple of samples of the surface material.

Let me take a photograph here showing some of the basaltic cobbles which contain phenocrysts and also a tuffaceous boulder lying along what appears to be the top of a natural levee here. This photo has an azimuth of 329, an inclination of approximately 0.

I will take a sample of this tuffaceous boulder up here which is somewhat more interesting than the basaltic stuff. This will be sample 372.

I shall continue up the gulley, and again the floor of the gulley is fine basaltic material--light-brown-colored material. There are subangular cobbles and boulders ranging in size from granules a few centimeters across up to large rounded boulders some 30 to 40 centimeters across. The walls here are somewhat steeper. They expose a fair bit of cobbly material intermingled with silt and other finer detritus.

The bank here exposes a cross section of the alluvial material very nicely. There are stringers of coarse basaltic sand and fine pebbles. Dominantly subangular. There is some inclusion of what appears to be a white tuff stuff that we have seen strewn along the gulley previously, as well as some larger cobbles up to about 15 centimeters across.

I'll photograph this with an azimuth of approximately 191° and an inclination of about 6. This photograph shows the silty material in the bank. I haven't left a scale but my distance from the bank is approximately a meter or a meter and a half.
I will take a soil sample from the bank. This will be sample 369 with some of the silty material from the top of the bank.

And I will take a penetrometer reading here. This material is very soft, probably a surface crust, so the reading may be atypical, but I get a reading of 0.4.

I shall now traverse out of the gulley and proceed across the drainage divide to the more southern gulley. I am walking here across what may be debris. There is considerable basaltic cobbles and pebbles mixed with finer material again, much of it the fine silt we have seen everywhere else.

I am standing directly in front between the LEM and a small bank that looks like it might be a remnant of a higher erosion or depositional surface. It is a bit hard to see what the underlying material is but it is veneered with boulders and cobbles and coarse sand of basaltic material with a matrix of the light-brown silty material. There is one typical large boulder on top of the hill that looks like it may be an agglomerate. It is somewhat brownish in color and its texture is apparently less homogeneous than the basalt.

I shall now traverse across to the second gulley, the more southern gulley, and attempt to describe it. Here I am out in the silty material again with only occasional coarse... composed of basaltic material.

I will take a sample of the material in the bottom of the gulley. This again appears to be dominantly fine silt with occasional linear deposits of basaltic material and an occasional gypsum fragment. This will be sample 369.

I will take a penetrometer reading in the bottom of the gulley. I will brush away the surface material. I am actually removing only a fraction of a centimeter here and I get a penetrometer of 4.6. The soil is rather well consolidated a short distance below the surface.

I shall now proceed back down the drainage toward the LEM. There are fine scaly mudcracks here in the floor of the gulley. They are very very thin,
Traverse 1, Subject C, shirt-sleeve, continued--

<table>
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<tr>
<th>Transcript</th>
<th>Activity</th>
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<td>less than a millimeter I would judge, and in plan only a centimeter or so across.</td>
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<tr>
<td>They tend to curl up in very delicate little fragments. There are some larger mud cracks a couple of centimeters across again all curled up. I am traversing here what may be a partially eroded stringer of basaltic material.</td>
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<td>And here I am standing before a small outcrop which looks as if it might be the material that would be the source for the light-brown silty material that we see everywhere. I take a sample of this. This material contains gypsum and I will sample some of this gypsum as well, I trust, as the other material. This sample will be sample 369.</td>
<td>Sample</td>
<td></td>
<td>13 03</td>
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<tr>
<td>I shall now proceed back down the gulley to the LEM. The total depth of the incision here is only 20 centimeters or something like that and it is only local. Here the gulley has gently sloping sides with only a very narrow central zone—flow zone 20 centimeters or so across. I am proceeding now across the silty material—light-brown material—toward the LEM. This material is unconsolidated on the surface.</td>
<td>Walking</td>
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<td>13 51</td>
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Traverse 2, Subject C (Shirt sleeve)

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<th>Activity</th>
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<tr>
<td>I am again traversing the apparently alluvial surface silty material, light-brown, totally unconsolidated on the surface. I am approaching this small wash which I described on the previous traverse. The wash is a total of about 2 meters across, although the actual flow zone that is preserved here is only 10 or 20 centimeters, and only a few centimeters deep. The flow zone is characterized by having coarse basaltic sand in contrast with the silty material present elsewhere in the wash. This material is again the silty, apparently alluvial, material, pretty well unconsolidated.</td>
<td>Walking</td>
<td></td>
<td>0 43</td>
</tr>
</tbody>
</table>
I am approaching here a small dike which appears to rise above the topography about 5 meters at the highest point. It is very irregular in cross sectional outcrop. I will descend this small gulley which has a nicked point right here on the dike and sample the dike up close.

The dike appears to be composed of basaltic rock. It is dark in color and is aphanitic. It apparently can be divided into several zones. There appears to be an outer chill zone here nicely defined in its contact with the fine sandy country rock, which, along the contact, is bleached white in contrast to its reddish-brown color elsewhere. The contact zone is approximately 2 or 3 millimeters thick. Then there is a zone of vesicles which appear to be elongate parallel to the dike. These vesicle zones are approximately 3 to 5 centimeters thick. Then there appears to be a more massive central zone which goes on for another several tens of centimeters, approximately 40 centimeters. I can't be sure of the entire extent here. The vesicles are (some of them) filled with amygdaloidal material, others are empty. As I say, they are elongate, with axial ratio of approximately 2 to 4 to 1. The width of the vesicles is about a millimeter and their length varies from a millimeter to 3 or 4 millimeters.

I'll take an oriented sample here. This will be from the chill zone in the dike. This will be sample 369 from the chill zone.

I'll try also to sample the vesicular zone. Here's a sample of that. This will be sample 370.

I'll take a photograph of the dike here. I think with the pick in it for scale. The vesicular and chill zones will be apparent from the photograph. The azimuth of this photo is approximately 334°; its inclination approximately 15°.

I'll also take a couple of samples from the contact zone. The country rock here appears to be a fine-grained sandstone. I'll describe the color contrast. Near the dike it is apparently bleached out. And its color further away from the dike is a reddish brown.

I'll try to sample both of these materials. They will be distinct on the basis of color. Sample 369.
Traverse 2, Subject C, shirt sleeve, continued--

Transcript

I'll sample some of this unconsolidated material on which I am treading which appears to be directly derived from the country rock. It appears to be fine, sandy. Further examination will make this clear.

I'll proceed along the dike now, walking along the strike, which is approximately 26° although it's sinuous both in plan and in section. There are little markings here which look like extrusion markings, and also there are delicately plumose grooves a millimeter or so deep and a millimeter or so across. They are quite irregular in plan and look very much like dendritic drainage pattern. My first thought was that they might be plumose joint markings on the surface, but on second thought they look rather different from this, because they are distinct grooves. I won't speculate as to their origin because I don't know what caused them.

I'll proceed along the dike to the second station where I think I can see beautifully exposed polygonal jointing, which seems to be very characteristic of this dike.

There are relatively large polygons. Several tens of centimeters across, perhaps 30 or 40 centimeters across. The number of sides is irregular, perhaps 4 or 5 sides, but these larger polygons are divided into two smaller sets of polygons. One set is about 10 centimeters across which in turn is further subdivided into little polygons just a centimeter or 2 or 3 or 4 centimeters across.

I'll photograph these. I am about 2 meters away from the dike so you can get a feel for scale from that. The azimuth of the photo is about 291, the inclination very nearly 0.

There are also xenoliths in the dike here. There is one near my head. It is roughly rectangular, roughly square, in fact, in outline. It appears to be a fine-grained sedimentary rock. It is tannish in color and is approximately 4 centimeters square. The surface directly above my head has a brownish staining that doesn't appear to be present elsewhere along the dike. It might be a weathering phenomenon, or it might be an alteration phenomenon. It is localized along the contact.
Traverse 2, Subject C, shirt sleeve, continued--

**Transcript**

I'll take an oriented sample here from the dike itself. This should be good contact zone material. It should be nicely indicative of some of the relations. The strike of this material is that of the trend of the dike. The dip is essentially vertical. It is too close to vertical to measure the discrepancy with any ease. I'll sample this as sample 368.

I'll walk along the dike now. I am walking across a reddish-brown country rock or at least a reddish-brown soil which appears to correspond to the country rock I've seen elsewhere. Here the cross section of the dike is very nicely exposed. I'll try to give you a detailed description and do some sampling here.

First, I'll take a photograph to give you a general feel for the appearance of the dike at this point. The azimuth of this photo is 319; its inclination is approximately -14.

I'll try to take an oriented sample from the dike itself and another from the contact zone which will be a little bit difficult to sample here because it is not too well exposed. The strike of this sample is parallel to the trend of the dike which here is approximately 35° and the dip line on the sample is approximately vertical.

The surface of the dike here appears to be coated with a material that might very well be caliche. It is a whitish material. This will be sample 368. It is an oriented sample from near the contact of the dike showing the fine-grained contact zone and the vesicular material immediately within.

I'll try to sample some of the country rock here. I appear to be getting only into basalt. Here is a sample which may be only highly altered contact rock or basalt. I guess it is actually basaltic material. It is pretty big so I'll toss it in the bin.

Here again the dike shows several clearly developed zones. A very finely aphanitic contact zone, a vesicular zone approximately 5 centimeters thick with elongate vesicles very similar to those described previously and then a massive zone extending for perhaps 50 centimeters. On the far side of the dike another vesicular zone; it's a little hard to pick up the contact zone here, but the vesicles are beautifully developed. They are a millimeter or so across, 3 to 4 millimeters long.
characteristically, and filled with amygdaloid material that may be calcite or quartz. It is white and glassy in appearance. There is a little book of what appears to be biotite here too, included in the vesicular zone. I am not sure of the presence of a contact zone on the far side but I think there is probably one here, finely aphanitic and 2 or 3 centimeters thick. The contact with the country rock on this side of the dike appears to be quite sharp, almost knife sharp. On the other side it is a little hard to pick but I would guess it is sharp too.

I am now traversing along the far side of the dike. I should come back into view of the television monitor shortly. Here again the polygonal jointing is apparent and is beautifully developed, and it appears here that the vesicular zone or some sort of zone is split away from the central zone that from here looks somewhat more dense. There is evidence of calichification across the surface, extending about 10 centimeters above the present ground level and running parallel to the present topography along the surface of the dike. The dike continues directly ahead of me; again it is very sinuous. There appears to be a series of offsets which, as I look at them from here, are right lateral in plan. It is impossible to say at this stage whether they are tectonic or a phenomenon of en echelon intrusion. I am back on the alluvial surface again. Here it is veneered with patches at most a meter or so across, consisting of coarse basaltic sand as well as a mixture of a great number of relatively widely scattered subangular cobbles, most of them less than 10 centimeters in dimension. Again footprints and vehicle tracks appear to penetrate to a depth of approximately a centimeter, giving a feel for the compaction of the surface material. Here is a nice series of little mud cracks. They are very, very curly, and are about 2 millimeters thick, and some of them have curled through an angle of more than 180°. There is one that has curled through an angle of 240°. Typically the edges are curled through at least 90°. In plan the things are about 3 to 5 centimeters across.
I am traversing the silty alluvial material, approaching the dike, walking more or less perpendicular to the trend. I'll follow along the dike describing it as I go. At this point the dike does not appear to break through the surface at all. Here's the first real evidence of outcrop, although the slopes on both sides of this little hill are abundantly littered with apparently basaltic material. The material here appears to be aphanitic. Cursory examination reveals no phenocrysts, although I might see some in looking more closely at it.

At this point the dike does stick up 30 or 40 centimeters above the surface. Its trend is about 164°.

I'll take a photo of the dike looking along its trend. The azimuth of this photo will be about 171, which is again very nearly the trend of the dike; its inclination is about 0°.

I'll sample the massive central zone of the dike here which I haven't sampled previously. It tends to fracture into little pebbles a few centimeters across, one of which will be sample 372.

I'll continue walking along the dike. It rapidly fades into oblivion again. It is exposed only here. Here I see no more definite outcrop, just a bunch of detritus mantling the surface. Very densely packed subangular pebbles a few centimeters in dimension actually touching one another as sort of a lag gravel on top of this silty alluvium material. No outcrop at all here. I am walking into a small gully, and in this area, as you can probably pick out on your photos and your monitor, there is essentially no basaltic detritus at all. It begins just a short distance up the hill. The hill is very abundantly littered with basaltic detritus, both pebbles a few centimeters in dimension, most of them subangular, and cobbles subangular to subrounded, ranging from a few centimeters, taking over continuously from the pebble range right up into large cobbles or boulders 20 or 30 centimeters in dimension, roughly equidimensional. Here is apparently the first real outcrop, and I will stop up here and try to sample it in more detail.
Traverse 3, Subject C, shirt sleeve, continued--

Transcript

The dike here again appears to be divided into several zones which we have seen previously. It has a rather nice contact zone which here contains small phenocrysts ranging from a few millimeters to about a centimeter in dimension. It is hard to identify the lithology of the phenocrysts, and they appear here to be confined just to the contact zone extending only a few centimeters into the dike -- let's say 3 centimeters. Then there is a nice vesicular zone which again is about 3 or 4 centimeters thick, dominantly elongate oval in plan. Vesicles have no amygdaloidal filling at all. And then the massive zone of the dike extending about 30 centimeters into another vesicular zone, whose thickness I can't be sure of, but about 5 centimeters again; and again the vesicles are elongate with axial ratios of about 1 to 2 or 3 and dimensions on the order of a few millimeters.

I'll sample the dike here and take a couple of photos. Here's a sample of some of the vesicular material and part of the contact zone. This will be sample 372.

I will photograph the dike here. I think you will be able to see both the contact zone and the vesicular zone. The photo has an uncorrected azimuth of 285 and an inclination of about 40°.

I'll take another photo looking along the trend of the dike. I'm approximately 4 meters from the central part of the photo, to give you a feeling for scale. You can see some rather large vesicles a couple of centimeters across, which may be the result of coalescence of other vesicles. This photo has an azimuth of 189 and an inclination of -2.

I shall also photograph a series of what appears to be flat-lying sedimentary beds exposed in a cliff on the edge of a lava-capped mesa, at an azimuth of 204 and an inclination of 0°.

These beds appear to be divisible into several formations. There is a series of relatively dark reddish-brown beds with white stringers running through them. I can't comment on the continuity of the stringers. They may be discontinuous. From here most of them I see appear to be relatively continuous over a scale of at least some tens of meters. Above this reddish formation, in fact divided by a whitish band, is a
Traverse 3, Subject C, shirt sleeve, continued--

paler pink formation which may be divided from still a third unit by a relatively resistant ledge which will certainly show up in the picture. I can't estimate the thickness of the ledge from here, but it is quite distinct in the photograph. It serves as a little bench which impedes the downward progress of talus from above. Above this ledge there is a series of pale beds: pale browns and tans, and also apparently greenish-gray colors, many of them mantled by talus. At the very top of this is a lava cap, which I would guess is 10 to 15 meters thick. It appears that this lava cap rests on some sort of alteration zone. There is some distinctly different lithology from the pale rock immediately underlying it. So the sequence again from the top down is: lava cap, alteration zone with a question mark, pale beds, resistant bench, pale pinkish bed, and at the very bottom, the dark red-brown bed with the white stringers.

I'll continue along the dike a little further. There are nicely exposed polygonal joints a little further along and I will try to get a picture of them too. These polygonal joints are rather similar to those exposed earlier, except that the lower orders are not as well developed.

Here I am about 3 meters away from the dike and the lower orders are exposed as sort of a hackly weathering phenomenon, although not quite at the same place as the rest of the dike. Azimuth of the photo is 246, inclination is -2; about 3 meters from the dike.

Here the chill zone appears to be anomalously thick. It is about 3 or 4 centimeters thick. The contact would appear to be knife sharp—very, very sharp; and then as you go into the dike from the chill zone, there is again a vesicular zone with rather larger vesicles here. The zone appears to be about 5 centimeters thick. It contains some amygdaloidal materials.

I'll try to sample some of the chill zone here. Here is a sample and it will be sample 372. This is a sample of the chill zone of the dike.

I'll take an oriented photo of the dike here, looking along the dike, and showing this right lateral en echelon type of separation which I commented on?
Traverse 3, Subject C, shirt sleeve, continued--

**Transcript**

earlier. I can probably describe it in somewhat greater detail standing right there. The azimuth of this photo is 159, its inclination is about -10°.

The offset, as I say, is right lateral in trend. It must be about 2 or 3 meters from where I am standing to the other portion of the dike off on my left. It looks here as if it would most probably be a phenomenon related to the mechanical extrusion, rather than a tectonic separation because this portion of the dike thins down. Here it appears to be only about 10 centimeters thick, and apparently largely vesicular throughout. I'm pretty sure I'm standing in country rock here. The dike there appears to be thin too, so it looks as if it is a series of en echelon intrusions separated by these 2 or 3 meters. This seems to be characteristic all along the dike, and the trend seems to be pretty consistent. There is no real evidence of faulting at all. In fact the dikes overlap.

I shall return to the LEM along the dike wall. There are little extrusion markings along the dike wall here, which slope upward at an estimated angle of 60°. There are also some of these little micro rill structures and tabular xenoliths of white, fine-grained material in the dike.

I am traversing a relatively steep slope now, which is clad with basaltic material, much of which is coated with a very thin layer of what may be caliche. It is whitish in color, and it has this micro texture characteristic of caliche.

The material is relatively basaltic material, pebbles and coarse sandstone; and out here I am out in silty material with no basalt at all.

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Traverse 4, Subject C
(Shirt sleeve)

**Transcript**

I am standing here at a contact between some colluvial material and what appears to be alluvial material in
Traverse 4, Subject C, shirt sleeve, continued--

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<td>the bed of a stream. There is almost no lithologic difference between the materials. It is all a light-brown silt, but there is a rather distinct break in slope which probably shows up nicely in the photographs. Also, the upper slope appears to be mantled with a lag gravel of basaltic material, both very coarse sand and fine cobbles. The fragments are sort of hackly, and seem to be derived from some hackly weathered portions of the basalt. I'll take a couple of samples here.</td>
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<tr>
<td>I'll sample some of the colluvial material as sample 316,</td>
<td>Sample</td>
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<td>47</td>
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<tr>
<td>and I'll grab a sample of some of the basaltic material as sample 355,</td>
<td>Sample</td>
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<td>00</td>
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<td>and I'll try to get a sample of the bedrock material itself, which is poorly exposed here and tends to break into sort of hackly material, and has a couple of little subvertical joints of some sort in it.</td>
<td>Sample</td>
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<td>16</td>
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<td>I'll take a photo of the slope that will show essentially what I have been sampling. You can see this joint system, and you can see the splotches and little coated subvertical veinlets of this pale-greenish material in contrast to the reddish color of the bedrock. The azimuth of the photo is approximately... and its inclination is approximately -130°.</td>
<td>Photo</td>
<td>1</td>
<td>37</td>
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<td>I'll now walk upstream a short distance to my left. I think you can pick out the break in slope and tone in the photograph. The stream here appears to have an unusually large concentration of basaltic cobbles and pebbles or cobbles and boulders. Most of them are subangular to subrounded. They appear to be fairly uniformly phorphyritic, with phenocrysts perhaps of amphibole or pyroxene; I can't tell which. The samples will reveal this. The sides of the stream are rather sharply incised, at least locally. There is a place over here where there is a series of stringers of coarse basaltic... exposed, interlayered with the fine, light-brown silt.</td>
<td>Walking</td>
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<td>The little ridge which I am approaching here is veneered with basaltic sand again, and with pebbles and cobbles. There might very well be bedrock underneath it. I guess this reddish bedrock appears to be characteristic everywhere. There is some nice tuffaceous material here which I haven't seen exposed before.</td>
<td>Description</td>
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Traverse 4, Subject C, shirt sleeve, continued--

**Transcript**

I'll take a few samples of it. There appear to be two types of tuff because there's a white, very porous, very low density tuff, and also a pumice tuff, and I'll grab a sample of this basaltic material, too, and I'll throw all these into the scintillator bin as I did last time.

This is an alluvial flat and sort of a point between the confluence of a couple of tributaries. The more southern tributary will probably be light on your photograph, because it is largely filled with bleached-out tumble weed.

I'll proceed up the rubbly gulley, the more northward gulley, and do some sampling there. I forgot to sample the streambed I photographed that time down there so I'll photograph it here. I'm looking at the stream bed. I should be taking a photo of the cut bank I described down there. It caught my fancy before. The azimuth of the fake photo will be 72, its inclination about -16.

I'll get a sample of the sandstone.

I am proceeding along the drainage here. The stream itself is not very wide, less than a meter across. The main channel where the last flow took place would appear to be no more than a few centimeters deep.

This seems to be an appropriate place to sample both sandstone and basalt. I'm standing in a stream bed here directly beneath a cliff; a white stringer is present above my head. I don't quite know what the nature of it is, but it appears to be fine grained, as is the rest of the material. It differs dominantly only in color.

I'll take a picture. This is azimuth 357 and its inclination very nearly 0°. It's intended to show you the contact between this white stringer and the reddish material.

There are some nice mud cracks in the stream here. They aren't curved very much, and tend to be somewhat flat; and in fact they seem to be somewhat convex upward. They are a bit thicker than some of the other mud cracks we have seen. Some of them approaching a centimeter in thickness. Although there appears to be a second generation of mud cracks on their surface which are thinner, scaly and concave upward. These are only a millimeter or so thick.

**Activity** | **Min** | **Sec**
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3 Samples | 4 | 11
Description | 4 | 30
Photo | 4 | 48
Sample | 5 | 46
Walking | 6 | 09
Description | 7 | 00
Photo | 7 | 20
Traverse 4, Subject C, shirt sleeve, continued--

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<td>The larger, thicker mud cracks have dimensions and plan of a few centimeters, the maximum being about 8 to 10 centimeters, and they are nicely polygonal, and some of them are rather uniformly curved rather than having straight sides.</td>
<td>Description</td>
<td>8</td>
<td>04</td>
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<td>I'll continue on up the stream bed here, again over this silty material, across fragments of very abundant basalt as well as a few sparse fragments of gypsum or a white tuffaceous material. I'll continue up a relatively steep slope here, which again is veneered with coarse basaltic sand and abundant cobbles and pebbles. There is a fairly unusual agglomerate here which I will sample.</td>
<td>Walking</td>
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<td>00</td>
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<tr>
<td>I will take a picture of this rubble-veneered slope. Azimuth is 309°.</td>
<td>Photo</td>
<td>9</td>
<td>42</td>
</tr>
<tr>
<td>I am also in a favorable position to take pictures of resistant ledge ahead of me. This photo will have azimuth 261, inclination +8.</td>
<td>Photo</td>
<td>10</td>
<td>09</td>
</tr>
<tr>
<td>The beds are nicely exposed here. The lower beds are composed of a reddish-brown, fine-grained material, then a pale-pink material, then a ledge a couple of meters thick. Above this ledge are the pale beds of tans and browns, and these appear to be capped here by coarse basaltic material, very probably a slump. I can see blocks somewhat jumbled in their orientation. Somewhat higher up the hill there is a basalt cap. The thickness of the cap is probably 10 or 15 meters.</td>
<td>Description</td>
<td>11</td>
<td>34</td>
</tr>
<tr>
<td>I shall continue up this little ridge across the basaltic material overlying the silt. I get a nice panoramic view looking across the flat on the other side of the LEM shelter.</td>
<td>Walking</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>I shall photograph a large butte that protrudes in perhaps 500 feet of relief. It has a lava cap and a dike at an azimuth of roughly 40°. I'll photograph this. Photo azimuth about 91, inclination +2.</td>
<td>Photo</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>I'll take a few more samples here of the basaltic detritus on the slope; it appears to be the thing to do. A fine-grained sample and a sample of hackly fragments as sample 362.</td>
<td>Samples</td>
<td>13</td>
<td>11</td>
</tr>
</tbody>
</table>