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APOLLO APPLICATIONS PROGRAM

FIELD TEST 5

By

G. A. Swann, N. G. Bailey, and R. D. Regan

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ABSTRACT

Apollo Applications Program Field Test 5 was held March 14-18, 1966, in the Hopi Buttes area, Arizona. The objectives of the test were to 1) evaluate techniques of field checking a moderately complex photogeologic map--techniques potentially useful for lunar geologic exploration; 2) test the feasibility of using a vehicle-mounted magnetometer and applying the magnetometer results to real-time geologic mapping and interpretation; and 3) evaluate the use of a petrographic microscope as a possible analytical tool for lunar exploration. The test results indicated that for real-time mapping at a station remote from the fieldwork, persons working in the field and at the remote station must be trained as a team, and that the use of a vehicle-mounted magnetometer and a petrographic microscope in lunar exploration should be thoroughly investigated.

INTRODUCTION

Apollo Applications Program (AAP) Field Test 5 was held March 14-18, 1966, near French Butte in the Hopi Buttes area, Arizona.[1/] Methods of field checking a moderately detailed photogeologic map of a geologically complex area were tested under shirtsleeve (i.e., without space suit) conditions. This report describes and evaluates the procedures followed during the test.

The test site was chosen because its geology is moderately complex. Also, because parts of the area are not readily accessible

[1/] This test was a "follow-on" to AAP Test 4, held at Meteor Crater, Ariz., which was designed to test the feasibility of field checking, by reconnaissance traverses, a photogeologic map of a geologically simple area. The results were reported by Swann (1966).

to vehicular exploration, test subjects wearing space suits had to study and describe inaccessible areas from a distance, thereby simulating one of the conditions of lunar exploration.

ACKNOWLEDGMENTS

We are grateful to the Navajo Tribe for allowing us to conduct our field tests on their reservation, and to the Branch of Astrogeology personnel who participated in the test.

OBJECTIVES

The objectives were to test the following:

1. Feasibility of--
   a) Field checking a moderately complex and detailed photogeologic map and defining the rock materials that make up the photogeologic units, by methods which have potential use in AAP lunar surface missions.
   b) Using remote description techniques to solve the problem of identifying materials of inaccessible photogeologic units.
2. Feasibility of conducting detailed magnetic surveys from a vehicle and using the results in real-time geologic mapping and interpretation.
3. Use of petrographic techniques for cursory examination of samples of the major rock units and for definition of the problems involved in cataloging petrologic information.

TEST CONSTRAINTS

The test was conducted for 5 days. Instead of the usual method of taking written notes and compiling maps in the field, all descriptions and cartographic location data were transmitted via portable radio and television link to a data reception and analysis facility (CDRA) where the information was used to compile maps.

GEOLOGY OF TEST SITE [2/]

The French Butte test site lies within the Hopi Buttes volcanic region of the Colorado Plateau in northeastern Arizona, at an elevation of about 6,000 feet; the site is on the Navajo Indian Reservation, and about 30 miles northeast of Winslow. Within the test area, isolated volcanic plugs and lava-capped mesas rise several hundred feet above intervening alluvial flats. Several levels of alluvial terraces reveal a complex history of deposition and erosion during Pleistocene time.

The oldest rocks exposed in the test area are reddish-brown siltstones and cherty limestones of the Chinle Formation, of Triassic age. The overlying Wingate Formation, also of Triassic age, consists of reddish-brown siltstones and crossbedded reddish-brown and white sandstones. Calcareous lacustrine siltstones, claystones, and tuffs of the Bidahochi Formation of Pliocene age overlie the Triassic beds with slight angular discordance. Within the test area, basaltic lavas

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[2/] Taken from Swann and others (1966).

and agglomerates lie on a nearly horizontal surface on top of the Bidahochi lake beds. Pipes and dikes of basaltic rock and of tuff-breccia intrude both the older sandstones and the Bidahochi lake beds. Coarse colluvium covers slopes and terrace remnants, and silty alluvium is widespread at lower levels.

TEST FACILITIES

Test operations were centered at the northern edge of French Butte. The maximum distance of operation from this center was about $1\frac{1}{2}$ miles.

A mockup of the LEM-Shelter was mounted on the bed of a truck parked near the base of the butte. The LEM-Shelter served as a small analytical laboratory in which were housed a petrographic microscope and petrographic thin-sectioning apparatus. A fast-scan surveillance TV camera with a zoom lens was mounted on a pan-and-tilt head on top of the LEM-Shelter.

A small 10-wheel cross-country vehicle, the Trespasser, was used as a simulated Local Scientific Survey Module (LSSM) for transporting the two test subjects and their field equipment to various parts of the test site.

Facilities for monitoring and plotting the test subjects' activities were set up at the test site in a van called the field Communication, Data Reception, and Analysis facility (CDRA). The CDRA was equipped with a two-way radio for communication with the test subjects. Tape recorders in the CDRA recorded all converations between the test subjects and CDRA personnel. A unit for controlling the pan, tilt, magnification (zoom), and focus of the surveillance TV camera was mounted in the CDRA.

A truck-mounted a-c generator supplied power to all but the portable electronic equipment. An electronics van was used as a repair shop and transmitter station.

GEOLOGIC TOOLS AND INSTRUMENTS

The equipment used by the test subjects included a surveying staff on which were mounted a 35 mm camera and manually operated sun-compass and clinometer, and a tool-and-sample carrier.

A TV camera mounted on a petrographic microscope was used to relay an image of the microscope field to the CDRA. Petrographic thin sections were prepared with a semiautomatic apparatus called a Petralab (Schaber, 1966).

A Varian Rubidium Vapor magnetometer mounted on the Trespasser (Regan, 1966) was used for 1 day during the test.

TEST SITE PROCEDURES

The geological, geophysical, and analytical operations performed during the test differed from those usually employed in field and laboratory studies chiefly in the methods of recording and compiling information. Instead of the usual method of recording data in the field, bringing it to the laboratory or office for reduction and compilation, then returning to the field to continue the fieldwork that the initial data indicate is necessary, the field data collected during the test were transmitted to the CDRA via portable radio and reduced at the CDRA in near real-time. Thus, the CDRA could transmit pertinent results from the data back to the test subjects, who could then plan the remainder of their fieldwork without taking time for the intermediate data-reduction process.

The two test subjects performed the role of astronauts on an AAP mission. Two geologists served as test subjects except during the magnetometer traverse, when a geophysicist and a geologist were the test subjects.

Two geologists in the CDRA monitored the test subjects' activities and plotted their traverses, a third controlled the surveillance TV cameras and studied the TV images, a fourth conducted all communications between the test subjects and CDRA personnel, and a fifth coordinated these activities and saw that descriptions of the photogeologic units were compiled on the photogeologic map during the test.

Geological Procedures

The first objective, to test the feasibility of field checking a moderately complex and detailed photogeologic map by methods that have potential use for AAP missions, was carried out in real-time and near real-time by adding appropriate information to the map in the CDRA, as it was received from the subjects during the test. As the test progressed, succeeding traverses were planned on the basis of information received and compiled during the previous traverses.

The test subjects transmitted all descriptions via portable radios to the CDRA, where they were recorded on magnetic tapes.

Descriptions were supplemented by black-and-white photographs taken with the staff camera.

During one short exercise, a staff-mounted TV camera, aimed by the test subjects, transmitted the TV image to the CDRA in real-time. The test subjects aimed the camera at features they described in the vicinity of a station and at features at some distance away. The TV monitor image from both the surveillance TV and staff TV cameras was photographed by Polaroid camera, and the 4 x 5-inch photographs were studied in the CDRA and annotated.

Azimuth angles were measured with the staff sun compass, and slope and dip angles were measured with the staff clinometer.

Monitoring personnel in the CDRA noted parts of test subjects' descriptions which were especially pertinent to the map compilation and used the information to complete the map. The CDRA test communicator occasionally asked the test subjects to clarify descriptions that were ambiguous or distorted by radio interference, and at times asked the test subjects to identify or describe features seen on the TV monitor.

Samples were collected, related to their geologic environment by the test subjects' description, and placed in prenumbered sample bags. The sample bag number was reported to the CDRA, where the description was cross-referenced to it.

Locations of description, sample, and photographic stations were transmitted to the CDRA by a surveying crew, which performed the function of an automatic tracking system. A rodman followed the test subjects and erected a stadia rod at stations that they indicated.

A surveyor plotted the position of the stations on coordinate paper and relayed the coordinates of each station to the CDRA. The map and map explanation were then revised and amplified to reflect the test subjects' descriptions. Because of the limitations imposed by this type of "automatic tracking," no attempt was made to adjust or refine the photogeologic unit contacts, or to subdivide the photogeologic units on the basis of field observation. To have done this would have required far more stations than the surveyors could have supplied in the time available and would have seriously limited the area covered and descriptions supplied by the test subjects. The resulting map is shown on plate I.

Geophysical Procedures

A Varian Rubidium Vapor total field magnetometer was mounted on a retractable boom on the Trespasser, and the power supply/readout and digital frequency counter were mounted between the two seats. (See Regan, 1966, for a more complete description of this system.) Traverses were designed to trace the subsurface expression of the partly exposed dike in the Finger Rock area (pl. 1). Three traverses were conducted at right angles to the apparent strike of the dike, and two traverses parallel to the apparent strike to connect the three right-angle traverses. Two test subjects in the Trespasser transmitted all pertinent data to the CDRA by radio. Personnel in the CDRA plotted profiles of magnetic intensity during the traverses and occasionally advised the test subjects to alter course in order that more significant data might be obtained. No corrections were applied to the data in the field. However, the profiles were accurate enough to indicate the presence or absence of the dike.

Analytical Procedures

Petrographic thin sections were made on the Petralab in the LEM-Shelter from samples collected on the traverses. The purpose was to further test the use of TV images of the microscope field (Schaber, 1966) and to define some of the problems of cataloging detailed sample information. No attempt was made to quantify the petrographic results and apply them to the geologic map and the planning of succeeding traverses.

The test subjects advised the CDRA via radio which samples should be studied by petrographic techniques. Upon return to the LEM-Shelter at the end of each traverse, the test subjects were told by the CDRA communicator which samples they had previously selected for study with the microscope. The samples were then sorted and thin sectioned in the LEM-Shelter. After preparation, the thin sections were studied by a test subject and described to the CDRA personnel via radio while the TV microscope image was being displayed in the CDRA.

POST-TEST PROCEDURES

Post-test procedures consisted primarily of compiling notes that were made on the photogeologic map in the CDRA during the test, coordinating the test communicator's tabulated notes with the map explanation, and drafting the map shown on plate 1. The map units were then placed in the explanation by the compilers and test subjects, with the youngest units at the top of the explanation.

TEST EVALUATION

The map shown on plate I is essentially the same as the photogeologic map prepared before the test and used to plan the traverses; the only significant difference is the addition of an explanation, which defines the materials in the map units and shows the approximate age relationships of the units.

Geological Procedures

The staff-mounted TV camera enabled the test subjects to show the CDRA personnel the features that were being described. Descriptions accompanied by TV views were much easier to understand than those without TV coverage. However, there was no provision for accurately sighting the TV camera, and it was more difficult than anticipated for the monitoring personnel to pick out in the camera field of view the feature that was being described.

The surveillance TV camera helped place the test subjects' descriptions into the context of the general environment, as has been found during previous tests (e.g., Swann and others, p. 35). The surveillance camera was most useful when the Trespasser was less than half a mile from the LEM-Shelter. At greater distances it was very difficult to see the test subjects on the TV monitor and thus difficult to relate their descriptions to the environment.

The Polaroid photographs of the TV image were of very limited use, largely because the geologic features were too small to be seen in detail on the photographs and because the resolution of the system was not sufficient to produce high-quality photographs. However, a higher resolution system capable of producing larger scale photographs of the TV monitor could be useful for detailed analysis and annotation of selected TV images in near real-time. After the annotation, the selected images could be passed on to the map plotters, who could study details derived from a different vantage point and at a larger scale than the initial aerial photographs and maps.

Sampling and definition of materials constituting the photogeologic units progressed rapidly where the units were readily accessible. This technique supplied a factual map explanation which, except for age relationships, required little interpretation on the part of the plotters. The materials defined in the photogeologic map units visited on traverses were extrapolated during the test to other areas which had the same albedo and geometric relationships on the aerial photographs. On extended tests (or lunar missions), these extrapolations would be useful in final planning of succeeding traverses. In that way, the areas of confident extrapolation need not be checked or might be checked in a cursory way if they happened to lie along the planned traverse route; those areas of a slightly more questionable extrapolation could be briefly checked, and traverses could then be planned to study in detail the areas into which extrapolations were questionable or impossible.

This test as well as previous tests (Swann and others, 1966; Schleicher, 1966; Swann, 1966) show that continuous, automatic tracking of the vehicle and of the test subjects on foot would enable precise placement of all geologic data points (including observations made while driving the Trespasser) on the map, thus improving the quality and accuracy of the map. This system would undoubtedly facilitate compilation of the map and would thus allow the test-subject--data-compilation team to cover a larger area in less time.

Geophysical Procedures

Interpretation of the magnetic profiles across the dike yields a depth to the magnetic poles of 20-30 feet on all traverses. This is consistent with a near-surface dike which dips steeply to the west. The peaks of magnetic intensity in the areas south of the last outcrop of the dike (pl. 1) showed that the shape of the top of the dike is complex and that in this area it may possibly branch into several distinct dikes. No expression of the dike appeared on any of the traverses run parallel to it 200-300 feet away on either side. Thus the dike was generated at a great depth, and there is no indication of an associated magma chamber. Interpretation of the traverse results agreed with the pretest surveys and analysis. An illustrated and more detailed account of the magnetometer procedures used on this and related tests was presented by Regan (1966).

The frequency of the stops at stations to take magnetic readings, and the nearly constant use of the radio to relay the readings and station locations to the CDRA, prohibited the gathering and transmission of any significant amount of surface geologic data during the magnetic traverse, and also greatly reduced the time available for real-time interpretation of the geophysical data in the light of geological data.

Analytical Procedures

As previously stated, no attempt was made to utilize the petrographic data in the geologic map compilation or traverse planning.

The TV image of the microscope field in the CDRA was very useful to the monitoring petrographers. The test subject had only to point out a sample of each type of mineral in the field of view, and the monitoring petrographers could then identify nearly every grain in the field of view and study their textural relationships from the TV image. The monitoring petrographers' mineral identifications were cross-checked against the test subject's and found to be reasonably accurate. This is significant in that a video tape record of the TV images can be used to obtain modal analyses of the samples, with the test subject supplying only a brief first-hand description.

These results agree with those from AAP Test 3 (Schaber, 1966). Future tests are planned in which modal analyses using video tape records will be made and quantitatively compared with analyses made at the microscope, using standard point-counting techniques.

The greatest problem in using the petrographic data apparently consists in cataloging and cross-referencing laboratory-type data with field data (such as field location, field sample description, and relationship of sample to environment) in an easily accessible form in a data retrieval system. If this can be accomplished, the data collected can be fully utilized in planning succeeding traverses; if not, much of the data will only serve as a cumbersome library for postmission analysis. This problem will become more complex as more instruments, both laboratory and field, are used in the tests.

CONCLUSIONS AND RECOMMENDATIONS

1. As indicated by previous tests (AES Test 1, AAP Test 2 and 4, and others), a geologic map can be compiled in near real-time from data telemetered to a CDRA-type facility remote from actual fieldwork. The quality of the resulting map and the area covered are directly proportional to the precision and quantity of descriptive data. The quality and quantity of data obtained depend in part on cooperation between the CDRA and field personnel; thus, the importance of training and teamwork cannot be overemphasized. The lack of an automatic tracking-navigation system with telemetry to the CDRA limited the quality and quantity of map information more than any other single factor.
2. A video tape record from the hand-held TV camera would be a useful supplement to detailed post-test analysis of audio tapes and returned samples and camera film. The hand-held TV camera and video tapes would provide a useful record from which detailed analysis of inaccessible areas could be made during and after the test (or mission).

3. The possibility of mounting a surveillance TV camera on the Trespasser should be investigated and, if practical, the feasibility of using this camera on an LSSM should be tested.
4. Taking measurements at closely spaced stations with a vehicle-mounted instrument such as the magnetometer, and the determination of these station locations, are purely mechanical; when these operations must be repeated frequently, they tend to interfere significantly with the more scientific aspects of the traverse, such as interpreting the reduced geophysical data in the light of geological observations. Therefore, the performance of these mechanical operations on a lunar mission should be automated as much as possible; for example, magnetometer readings could be continuously telemetered to earth for real-time data reduction, thus freeing the astronauts to utilize fully the results of the traverse as it progresses.
5. Tests to date (see Regan, 1966) indicate the feasibility of mounting a magnetometer on the vehicle so that readings can be taken without leaving the vehicle. This method should be thoroughly investigated for lunar surface vehicular missions.
6. The petrographic microscope has long been established as one of the tools most useful in geological description and interpretation. This test supports the contention that the petrographic microscope with TV camera attached should be investigated for potential use in AAP missions.

The two major problems to be solved are:

1. Adaptation of a high-resolution TV camera to a microscope, and real-time image transmission to earth of routine parts of the analyses.
2. Development of a device for automatically preparing usable petrographic thin sections in the LEM-Shelter.

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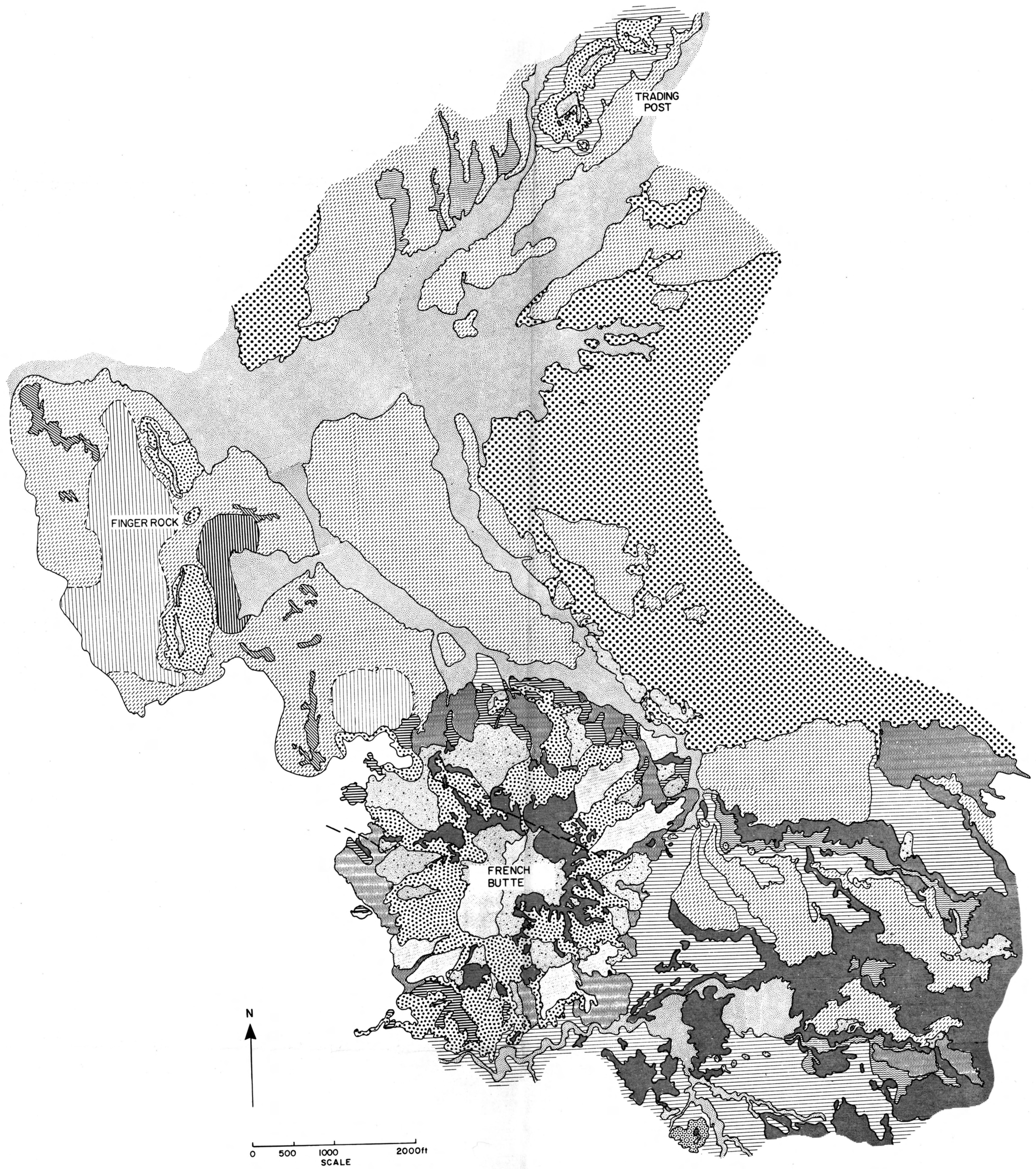

GEOLOGIC MAP AAP TEST 5
HOPI BUTTES AREA, ARIZONA
PLATE 1

EXPLANATION

Alluvial deposits in latest mainstream channels: sand and gravel, derived chiefly from basalt and sandstone, and pebbles, cobbles and boulders of basalt. Includes undivided low alluvial terrace remnants adjacent to streams.

Talus: mainly basalt fragments; thin to thick mantle over flat-lying sedimentary bedrock on steep and unstable slopes of French Butte and the Finger Rock and Trading Post Dikes. Photometric characteristics: dark tone, rubbly appearance, highly dissected to expose abundant light tone "slope stripes" of bedrock.

Talus: fine and coarse basaltic material undivided. Occurs on hummocky slopes on French Butte. Photometric characteristics: variable light and dark tone.

Mafic intrusive and extrusive rocks, undifferentiated. Basalt plug and lava flows capping French Butte: basalt dikes on north and west sides of French Butte; and complex dense basalt, basalt breccia, tuff agglomerate, and sedimentary breccia dikes in Finger Rock and Trading Post Dike areas.

Sandstone and siltstone: well-bedded red, red-brown, and brownish-white sedimentary rock. Minor green or gray siltstone and claystone exposures east of French Butte. Sandstone-siltstone sequence on French Butte and mesa to east has at least two conspicuous ledge-forming resistant layers of gray-white massive rock, probably tuff. Glitter of surface near base of mesa wall exposures suggests presence of platy gypsum.

Sandstone: gray-white, fine-grained and conspicuously cross-bedded on a large scale. Contains petrified wood. Surrounds Finger Rock Dikes.

Colluvial deposits of slope wash and slump debris mantling valley walls along upper reaches of latest main stream channels. Includes undivided alluvial deposits in stream channels.

Talus: relatively fine-grained basaltic material. Mostly sand to small pebbles with occasional cobbles and boulders. On smooth, stable lower slopes of interfluve areas on French Butte. Photometric characteristics: light tone and smooth texture generally bounded on upper side by break in slope.

Talus: relatively coarse-grained basaltic material predominantly pebble to boulder sizes and subordinate tuffaceous blocks around basalt caprock and stable upper slopes of interfluve areas on French Butte. Also mantles isolated hummocks of bedrock and alluvium east of French Butte and chain of probable pediment remnants north of French Butte. Photometric characteristics: dark tone and smooth to rubbly texture.

Tuff: forms cone southeast of French Butte. Dark gray to gray-brown. Exact stratigraphic position unknown.

Claystone: caps tuff cone southeast of French Butte. Contains fossils. Exact stratigraphic position unknown.

Alluvial fans in valleys: principally developed around base of French Butte. Consists of sand, gravel, cobbles and boulders derived chiefly from basalt and sandstone with subordinate amounts of tuffaceous material.

Colluvium mantling generally gentle slopes: sand and gravel derived from adjacent alluvial-surface remnants or steep bedrock and talus slopes. Coarser debris in areas of heavy slope wash and slump. Surfaces are weakly dissected. Aggradation nearly equals and may in places, exceed degradation.

Alluvium: commonly mud-cracked, containing abundant coarse sand-sized basalt fragments, capped by red-brown sandy to clayey soil on undissected upland remnants of northwest-sloping surface.

Marsh or pond deposits in sharply bounded area of clayey and silty soil southeast of Finger Rock. Partly covered by alluvial fan produced by spillover of dammed stream nearby.

Alluvium: brown, sandy to clayey, in interfluve areas, fine to medium sand and gravel in stream channels on erosional surface in early stage of dissection.

Sand hummocks: surficial layer of windblown sand in large flat hummocks held by vegetation. Northwest of French Butte and west of Finger Rock Dikes.