UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Center of Astrogeology
601 East Cedar Avenue
Flagstaff, Arizona 86001

November 29, 1966

MEMORANDUM:

TO : Assistant Chief Geologist for Engineering Geology

FROM : Chief, Branch of Astrogeology

SUBJECT : Monthly report for Director and Secretary

1. Highlights and noteworthy results

Astrogeologic studies

Cosmic chemistry and petrology

H. J. Gabe, N. J. Page, and M. H. Carr have obtained the first results from electron microscopic examination of particles collected by Litton Industries in the atmosphere at an elevation of 135, 400 ft. on a balloon-tethered high volume impactor. All the particles collected are less than 1 μ in diameter and most of the particles are in the size range 0. 05 to 0. 5 μ. Many of the particles are composed of two phases, an opaque non-reactive phase and a transparent deliquescent phase. The opaque phase appears to have formed nuclei around which the transparent phase has formed. Hydration of the transparent phase after collection has resulted in partial break-up of the opaque phase so that its boundaries are diffuse.

An attempt was made to obtain electron diffraction patterns on a group of 50 of the particles; 31 gave patterns of at least one spot. Eighteen of the patterns had a four-fold axis of symmetry, six had a two-fold axis and the symmetry of the rest of the patterns could not be determined. Each set of d-spacing was refined with a least squares technique based on spinel structure. The value of a_o for the majority of particles was between 8. 80 and 8. 97. This could correspond to a (Ni, Fe, Ti, Cr) spinel. The preliminary interpretation is that the particles consist of meteorite ablation debris around which has formed some material that originates in the stratosphere, possibly ammonium sulfate.

Surface planetary exploration

Geologic training for astronauts

Seven astronauts have been assigned by the Astronaut Office to participate in the evaluation of procedures in simulated lunar exploration exercises being conducted by the Surface Planetary Exploration Group, Astrogeology Branch. They are William A. Anders, Alan L. Bean, Joe H. Engle, Don L. Lind, Jack R. Lousman, Harrison H. Schmitt, and Paul J. Weitz. They will be directly involved in the field exercises as test subjects, and will also aid in retrieving and compiling geological and geophysical information as it is transmitted via radio, television, and telemetry to the Branch's Astrogeologic Data Facility from remote test sites. These activities will be coordinated with the Astronaut Training Program in Geology.

This participation began in November with Engle, Schmitt, and Weitz serving as observers and test subjects during the post-Apollo tests held in the Hopi Buttes volcanic field in eastern Arizona. The tests, which involve Apollo as well as the post-Apollo studies, are conducted several times each year for the purpose of developing methods, instruments, and equipment suitable for a program of geological exploration on the moon's surface.

4. Outside publications reported during month:

E. C. T. Chao, E. J. Dwornik, and Celine Merrill: Nickel-iron spherules in Aoelloul glass: Science, v. 154, p. 759-765.

Whitcomb, James H., 1966, Shear-wave detection in near-surface seismic refraction studies: Geophysics, v. 31, p. 981-983.

Swann, Gordon A., 1966, Apollo Applications Program Field Test 4, Technical Letter: Astrogeology 24.

5. Personnel

The following employees entered on duty

Flagstaff, Arizona

Pamela Dewey, Geologic Field Assistant
Irene E. Gedney, Administrative Assistant
Ivo Lucchitta, Geologist
Francis J. Schafer, Civil Engineer
Irving L. Wiser, Mechanic, Automobile

Menlo Park, California

Michael F. Donnelly, Geologic Field Assistant, WAE
Leroy Williams, Cartographic Aid, WAE
Pamela Wyman, Clerk-typist
Patricia E. Young, Cartographic Aid, WAE

Transfers

Ray H. Barnett, Electronic Engineer, transferred to U. S. Navy, Washington, D. C.
Anne A. Barnett, Clerk-typist, transferred to U. S. Geological Survey, Washington, D. C.
Stanley P. Lassiter, Electronic Dev. Tech., Denver, transferred to Lowry Air Force Base.

Resignations

John N. Bolles, Geologic Field Assistant, Flagstaff, Arizona
Cheryl Boettner Lamb, Physical Science Aid, Flagstaff, Arizona
Larry C. Starkey, Physical Science Aid

6. Scientific meetings and conferences attended at home or abroad

P. R. Brett attended the annual meeting of the Meteoritical Society in Washington, D. C., where he was chairman of the session on "The origin of meteorites."

E. C. T. Chao, Frank Cuttitta, and L. P. Greenland also attended the Meteoritical Society meeting.

P. R. Brett and G. A. Desborough attended a symposium sponsored by the S. E. G. on magmatic ore deposits at Stanford University.

J. J. Wooldridge visited the Lunar Orbiter screening team at Langley Research Center, and did albedo work, using one of the isodensitracers at Langley.

P. R. Brett visited T. E. Bunch, K. Keil, J. Short at Ames Research Center, Moffett Field, California, for a discussion of meteorites.

On November 17, Harold Masursky hosted a meeting in Menlo Park, California, to review potential Surveyor landing sites with representatives from the Surveyor Program and Project Offices, Jet Propulsion Laboratory, NASA Headquarters, Langley Research Center, and Bellcomm.

At the Geological Society of America meeting at San Francisco, California, E. C. T. Chao was co-chairman of the meteorite session, and also attended the Geochemical Society Council and business meetings; Harold Masursky co-chaired the session on Extraterrestrial Processes; J. F. McCauley attended the meeting for the purpose of examining the feasibility of starting a society of Astrogeologists. Frank Cuttitta, P. R. Brett, D. E. Wilhelms, D. J. Milton, M. H. Carr, K. A. Howard, H. J. Moore, N. J. Page, D. B. Burke, H. G. Wilshire, H. E. Holt and E. C. Morris also attended the meeting.

Progress in the design and manufacture of hand tools for Early Apollo lunar landings was discussed in a meeting held in Flagstaff, Arizona, with members of the Manned Spacecraft Center's Human Factors Section, Experiments Program Office, and Space Science Division. Included in the discussion were tool designs that were updated as a result of the August KC-135 airplane flights in which 1/6 gravity tests were held.

M. H. Hait and J. W. M'Gonigle conferred with personnel of the Northern Rockies Branch of Regional Geology in Denver, Colorado, on the problems involved in immediate analysis of geologic information gathered during the course of field work. Tentative plans were made for joint work to be done on the problems during the winter.

G. A. Swann attended a presentation at Grumman Aircraft Corporation, Bethpage, New York, concerning post-Apollo mission simulations for the purpose of human factors and biomedical studies to be carried out on Grumman's lunar surface model during the remainder of FY67.

G. E. Ulrich and G. A. Swann visited the Manned Spacecraft Center, Houston, Texas, for indoctrination in the A5L Apollo space suit and 1/6 gravity simulator.

Russell Wahmann was a guest of the Secretary of the Navy on an orientation cruise on board the USS Enterprise, largest nuclear-powered aircraft carrier, in the Pacific, from Alameda, California.

7. Talks or papers presented at meetings

Speaker and organization	Subject
E. M. Shoemaker American Meteoritical Society Smithsonian Institution Washington, D. C.	Air waves associated with large fireballs and the frequency distribution of energy of large meteoroids
E. M. Shoemaker Prescott College Prescott, Arizona	Scientific exploration of the moon and its impact on today's society
E. M. Shoemaker Orme School Mayer, Arizona	Scientific exploration of the moon
M. L. Troyer Arizona Chamber of Commerce Managers Association Wickenburg, Arizona	Work of the Center of Astrogeology
M. L. Troyer Business and Professional Women's Club Flagstaff, Arizona	Work of the Center of Astrogeology
H. J. Moore Las Crucas-El Paso Astronomical Society El Paso, Texas	The geology of the moon
N. J. Trask Research Society of America Palo Alto, California	Geologic exploration of the moon
Frank Cuttitta American Meteoritical Society Washington, D. C.	Georgia and Martha's Vineyard tektites: new chemical data
P. R. Brett and E. P. Henderson (U. S. National Museum) American Meteoritical Society Washington, D. C.	The occurrence and origin of lamellar troilite in iron meteorites
Frank Cuttitta Geological Society of America San Francisco, California	Georgia and Martha's Vineyard tektites: new chemical data

P. R. Brett and G. Kullerud (Geophysical Laboratory) Geological Society of America San Francisco, California	Melting relationships of galena-pyrite-pyrrhotite assemblages: a homogeneous sulfide melt at 718°C.
N. J. Page Geological Society of America San Francisco, California	Total iron variation during serpentinization at Burro Mountain, California
D. E. Wilhelms Astrogeology course San Jose State College San Jose, California	Lunar stratigraphy and structure (2 lectures)
P. R. Brett same course	Meteorites and tektites
N. J. Trask same course	Crater statistics and small lunar features

8. Visitors

Visitors	Visited and purpose
Solman Klapman Hughes Aircraft Los Angeles, California	J. D. Alderman and W. T. Borgeson--discussed imaging systems and application
Peter J. Cook Australian Bureau of Mineral Resources Canberra, Australia David P. Gold Pennsylvania State University University Park, Pennsylvania	D. J. Milton, H. G. Wilshire, D. J. Roddy--compared American and Australian cryptoexplosion structures
C. H. Marshall Lockheed Aircraft Corp. Sunnyvale, California	N. J. Trask--discussed impact frequency on the moon
T. E. Bunch Ames Research Center Moffett Field, California	P. R. Brett--discussed the origin of nodules in iron meteorites
Anthony Zendt U. S. Army Map Service Washington, D. C.	M. J. Grolier--sampled the Bonita Flow
D. L. Lamar and P. M. Merifield Earth Sciences Research Corp. Santa Monica, California	D. E. Wilhelms and Harold Masursky--discussed lunar geologic mapping
John Dietrich Manned Spacecraft Center Houston, Texas	D. E. Wilhelms and N. J. Trask--discussed lunar geologic mapping
Sam Steiger Congressman Elect for 3rd U. S. District Prescott, Arizona	Tour of Branch facilities conducted by E. M. Shoemaker, Russell Wahmann, A. H. Chidester and M. R. Brock
Bill Dickerson and his Physical Science Class Rehabilitation Project Northern Arizona University Flagstaff, Arizona	Tour of Branch facilities conducted by Russell Wahmann and J. A. Dushek
Fred J. Ketchum and Physical Science Class Rehabilitation Project Northern Arizona University Flagstaff, Arizona	Tour of Branch facilities conducted by Russell Wahmann and J. A. Dushek

Tosimatu Matsumoto and Peter Mollner Columbia University New York, New York	H. L. Krivoy--discussed the study of micro-earthquakes and conducted seismic experiments in Wupatki-Flagstaff areas, Arizona
John B. Hanley NASA Headquarters Washington, D. C.	Personnel of Surface Planetary Exploration--discussed lunar drill investigation and lunar instrument staff, and observed field and data center operations during the Advanced Systems Test 8
Homer Powers Marshall Space Flight Center Huntsville, Alabama	Personnel of Surface Planetary Exploration--attended Saturn Apollo Applications Investigations Test 8 and observed navigation system used in that test

General Information

Astrogeologic studies

E. C. T. Chao began investigating operational and design problems of carrying out mineralogical studies with petrographic and binocular microscopes behind the mock-up of a biological barrier. Specification of the mock-up was based on data available from the Army biological laboratory at Ft. Detrick, Maryland.

K. A. Howard reported that subdued relief features and abundant partly-filled basins in the Ptolemaeus quadrangle indicate that plains-forming material (Cayley Formation) was deposited over much of the terra there. Cayley deposition, interpreted to have been by fluid flows of low viscosity, spanned the period of formation of the craters Herschel and Arzachel. Lineaments of regional lineament systems appeared to be more prominent and more closely spaced on the rims of some fresh impact craters than in surrounding terra. The hummocky nature of the rims may reflect jostled bedrock.

H. A. Pohn found that preliminary studies of the photoelectric-photographic full moon albedo map did not seem to support the 1963 theoretical photometric function proposed by Hapke. There was no detectable limb brightening at large negative brightness longitudes. An almost circular distribution of constant brightness appeared along the limb.

J. D. Alderman announced that the Denver Area Topographic Division has released to the Branch a Wild phototheodolite to be used in the investigation of photogrammetric techniques as applied to terrestrial and oblique imagery as expected to be procured on Apollo missions. The techniques will involve the use of analytical and analogue methods for support of geological interpretations for such things as stratification, texture, fabric, and structure.

M. J. Grolier reported that scanning of the equatorial belt of the moon at a 1:500,000 scale, using Navy Plate No. 5818 (phase angle, g, is about 16 degrees and seeing resolution is better than 1.0 km) has been completed on the Isodensitracer. Tracings covering each of the quadrangles of the equatorial belt have been forwarded to the lunar mappers. The tracings of the upper quarter of the belt were contoured and also forwarded to the mappers, for comments and evaluation.

Environmental problems affecting the Isodensitracer have been evaluated. Solution of all these problems, which lie well within the guaranteed capability of the instrument, is relocation.

The Jarrell-Ash microdensitometer is being checked for accuracy of performance, and repetition of results. The coupler, in the digitizing unit which accompanies the instrument, was modified in the past to accommodate program requirements. These modifications are being analyzed, and an evaluation of the Jarrell-Ash presently in use is being made to determine its potential as an accurate single-scan microdensitometer.

A program for the photoclinometric reduction of spacecraft imagery is being prepared. Completion of the program is scheduled for December 1967.

Maurice Grolier announced that a three-dimensional model of the lunar surface, 37 feet x 80 feet, is to be built under a combined U. S. Army-NASA project. The model is to be displayed at the International Fair in Montreal in February 1967. The Branch of Astrogeology is acting as an advisor on the project.

Surface planetary exploration

Early Apollo investigations

A one-day field test was held in the San Francisco volcanic field northeast of Flagstaff where functional tests were made on early prototype models of lunar geologic hand tools, fabricated by the Manned Spacecraft Center, Houston, Texas. The equipment tested included a geologic hammer, soil scoop, sample grabber, soil sample drive tubes, gnomon, instrument staff, tool extension handle, and sample bags.

Minor failures developed on most of the tools, although the majority of these failures showed up after the equipment had been subjected to stresses somewhat greater than those anticipated during their use on the moon. Each failure will necessitate only minor changes in design or in use.

Mission planning

Preliminary geologic analysis of Lunar Orbiter Mission A moderate resolution photography of sites A-9.2 and A-4 were completed by T. N. V. Karlstrom. These site reports, being prepared by U. S. Geological Survey personnel, will be part of the geologic terrain section, for incorporation in the Screening and Evaluation report of Lunar Orbiter Mission A photography in the form of a Langley Research Center working paper.

Despite the general reconnaissance character of the Lunar Orbiter photography, the relatively high resolution imagery provides significant photogeologic data, heretofore unavailable, that will prove highly useful in selecting the most critical areas for scientific surface exploration and analysis of lunar geology.

LUNAR GEOLOGIC MAPS

REPORT FOR MONTH OF November

	PRELIMINARY MAPS								FINAL MAPS							
	ACIC Bases Received	Author's Geological Work in Progress	Cartography - Scribing & Assembly in Progress	1st Composite Completed	1st Explanation Completed	Map in Technical Review (Branch)	2nd Composite Completed	2nd Explanation Completed	Geology Revision in Progress	Cartography - Final Map Prep	Map in Technical Review (Branch)	Submitted to APU	Director's Approval Received	Map Materials Transmitted to BTI	Transmitted to BMR	Published
Equatorial Belt																
ARISTARCHUS LAC 39	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BYRGIUS LAC 92	X	X	X	X	X	X	X	X								
CLEOMEDES LAC 44	X	X	X	X	X	X	X	X	X	X	X					
COLOMBO LAC 79	X	X	X	X	X	X	X	X	X	X						
COPERNICUS LAC 58	X	X	X	X	X	X	X		X	X	X	X				
FRACASTORIUS LAC 97	X	X	X	X	X	X	X	X								
GRIMALDI LAC 74	X	X	X	X	X	X	X	X	X							
HEVELIUS LAC 56	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
JULIUS CAESAR LAC 60	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
KEPLER LAC 57	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LANGRENUS LAC 80	X	X	X	X	X	X	X	X								
LETRONNE LAC 75	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MACROBIUS LAC 43	X	X	X	X	X	X	X	X	X	X	X					
MARE HUMORUM LAC 93	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
MARE SERENITATIS LAC 42	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MARE UNDARUM LAC 62	X	X	X	X	X	X	X	X								
MARE VAPORUM LAC 59	X	X	X	X	X	X	X	X	X	X	X					
MONTES APENNINUS LAC 41	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MONTES RIPHAEUS LAC 76	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PETAVIUS LAC 98	X	X	X	X	X	X	X	X								
PITATUS LAC 94	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PTOLEMAEUS LAC 77	X	X	X	X	X	X	X	X	X							
PURBACH LAC 95	X	X	X	X	X	X	X	X								
RUPES ALTAI LAC 96	X	X	X	X	X	X	X	X	X							
SELEUCUS LAC 38	X	X	X	X	X	X	X	X	X	X	X					
TARUNTIUS LAC 61	X	X	X	X	X	X	X	X	X							
THEOPHILUS LAC 78	X	X	X	X	X	X	X	X	X	X	X					
TIMOCHARIS LAC 40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Northern Hemisphere (32°N - 64°N)																
ARISTOTELES LAC 13																
CASSINI LAC 25		X	X	X	X	X										
EUDOXUS LAC 26																
GEMINUS LAC 27																
J. HERSCHEL LAC 11		X	X	X	X											
PLATO LAC 12		X	X	X	X											
RUMKER LAC 23		X	X	X												
SINUS IRIDUM LAC 24		X	X	X	X	X	X	X								
Southern Hemisphere (32°S - 64°S)																
CLAVIUS LAC 126		X	X	X												
HOMMEL LAC 127		X	X	X												
MAUROLYCUS LAC 113		X	X	X	X	X										
RHEITA LAC 114		X	X	X												
SCHICKARD LAC 110																
SCHILLER LAC 125																
TYCHO LAC 112		X	X	X												
WILHELM LAC 111																
North Polar Cap																
ANAXIMANDER LAC 2																
BAILLAUD LAC 1																
METON LAC 4																
PHILOLAUS LAC 3																
South Polar Cap																
BAILLY LAC 136																
CABEUS LAC 144																
MANZINUS LAC 138																
NEWTON LAC 137																
HELMHOLTZ																

LUNAR GEOLOGIC MAPS
Scale 1:500,000

REPORT FOR MONTH OF November

PRELIMINARY MAPS

AIC NUMBER	Preliminary AIC Base Received	Published AIC Base Received	Author's Geological Work in Progress	Cartography - Scribing & Assembly in Progress	1st Composite Completed	1st Explanation Completed	Map in Technical Review (Branch)	2nd Composite Completed	2nd Explanation Completed
57C	xxxxxx		xxxxxx						
57D	xxxxxx		xxxxxx						
58C	xxxxxx	xxxx	xxxxxx						
58D	xxxxxx	xxxx	xxxxxx						
59C	xxxxxx	xxxx	xxxxxx						
59D	xxxxxx	xxxx	xxxxxx						
60C	xxxxxx	xxxx							
60D	xxxxxx	xxxx	xxxxxx						
61C									
61D	xxxxxx	xxxx	xxxxxx						
75A	xxxxxx		xxxxxx						
75B	xxxxxx		xxxxxx						
76A	xxxxxx		xxxxxx						
76B	xxxxxx	xxxx	xxxxxx						
77A	xxxxxx	xxxx							
77B	xxxxxx	xxxx	xxxxxx						
78A	xxxxxx	xxxx	xxxxxx						
78B	xxxxxx	xxxx							
79A	xxxxxx	xxxx	xxxxxx						
79B									

Advanced systems

Advanced Systems Test 1 was held at the Hopi Buttes test site using the Mobile Geological Laboratory (MGL). The Land Navigation System with gyrocompass and location plotter, which worked so well on the Trespasser vehicle in SAA Test 8, was mounted in the MGL, but due to a power-train breakdown in the MGL during the test, reliability of this system was not determined. However, a periscopic aircraft sextant mounted in the roof of the vehicle proved valuable in determining location by resection from known topographic features. This permitted personnel at the Astrogeologic Data Facility to know the location and vehicle heading as well as elevation at the geologic stations. Vertical angles and map distances were used to check elevations of geologic contacts and topographic features with fair results.

A set of screen sieves and an arm balance were used to determine bulk density and the percent by weight particle size distribution of grains in soils of geologic units sampled. Because of recent snow in the test area, however, the soil samples were too moist to obtain accurate results.

The Jet Propulsion Laboratory's nondispersive Alpha K Alpha Spectrometer and supporting electronics were mounted in the MGL for the test, and a NaI (Tl) detector was suspended from the floor of the vehicle for natural gamma counting. Results: The spectrometer data requires computer analysis to be of value during the test. The natural gamma experiment was not sensitive enough to show a spectrum significantly different from background. Shock mounting to all electronics was adequate to stand the MGL motion.

A decision was made to eliminate experimental neutron activation work as a part of the Advanced Systems program because of the excessive weight required for proper shielding for sample analysis during manned missions and the cost of outfitting a laboratory for testing of neutron activation techniques: $60,000 to $80,000.

Saturn Apollo applications investigations

Saturn Apollo Applications Test 8 was held at Hopi Buttes test site utilizing astronauts Paul J. Weitz, Joe H. Engle, and Harrison H. Schmitt as field test subject and as evaluators in the Flagstaff data center. Geology of a 50 square kilometer area was mapped in reconnaissance fashion during the testing of the Arma-Brown gyrocompass navigation system supplied by Marshall Space Flight Center Astrionics Laboratory which was mounted on the Trespasser vehicle. The equipment proved very successful in field checking the geology compiled on aerial photographs and transferred to a topographic base (scale 1:24,000) prior to the test.

Supporting projects

Time data was collected on tasks performed during the field tests held in the Hopi Buttes area by personnel of the Saturn Apollo Applications and Advanced Systems programs.

Installation of a building housing Branch radio and microwave relay equipment and an antenna tower was completed on Mt. Elden near Flagstaff.

Two documentary films covering field exercises in simulated lunar exploration were completed. One titled "Early Apollo Investigations Test 8" in color with sound is 12 minutes in length. The second film "Apollo Applications Program Test 6" is a 26-minute color and sound film. This film had its first showing at the School of Earth Sciences, Stanford University, on November 21.

Geophysics

Fourier analyses of relatively long time-windows of seismic records indicate that a new approach to attenuation studies may be possible, whereby the spreading factor may be determined as part of the computer analyses rather than being assumed. The result is a product of an attempt to make use of "whole record" analysis rather than initial arrivals.

A final report on the nuclear cavity detection project was presented to Advanced Research Projects Agency, Department of Defense.