

UNITED STATES
DEPARTMENT OF THE INTERIOR
BRANCH OF ASTROGEOLOGY
GEOLOGICAL SURVEY
Box 1906
Flagstaff, Arizona

May 31, 1964

MEMORANDUM

To: V. R. Wilmarth

From: E. M. Shoemaker

Subject: Monthly report for Director and Secretary

1. Highlights and noteworthy results

Lunar and Planetary Investigations

Evidence of modification of lunar features by either erosion or burial has been found in the Timocharis region by M. H. Carr. The evidence is provided by comparison of Copernicus and Eratosthenes secondary craters and by the examination of rills. Copernicus secondary craters have distinct outlines, well defined rim crests and commonly have cusped outlines whereas Eratosthenes secondaries have indistinct outlines that are never cusped, have rounded rim crests and are shallower than equivalent Copernicus secondaries. As Eratosthenes is demonstrably older than Copernicus the Eratosthenes secondaries are thought to be a degraded form of Copernicus secondaries. Similar differences are seen between Rima La Hire I and Rima La Hire II. Rima La Hire II has a

distinct outline and steep walls. Rima La Hire I is indistinct, has rounded walls and is very shallow. Hence Rima La Hire I is thought to be an older degraded rill.

Cosmochemistry and Petrography

The following new analytical techniques are being developed in order to analyze individual meteorite chondrules, metallic spherules in tektites and small samples of impact glasses:

X-ray spectroscopy--Frank Cuttitta and H. J. Rose are engaged in an intensive study on major element analyses on small samples by a combined solution--Pelleting technique. A series of 14 standard silicate samples using sample portions ranging from 4 milligrams to 7 milligrams produced linear curves for Al, Fe, Ca, K, Ti, and Mn. The lowest measurable amounts being Al = 150 μ g; Fe = 20 μ g; Ca=10 μ g; K = 5 μ g; Mn or Ti = 2.5 μ g. Preliminary observations on analyzing samples of less than 4 milligrams have also indicated much promise for silicates and sulfides.

Emission spectroscopy ("Plasma Arc")--After several months, work was resumed on solution analyses with a "Plasma Arc" by Charles Ansell and A. W. Helz. The technique requires about 0.5 ml solution containing 0.25 milligrams or less of sample. A new design of the graphite cathode was used in conjunction with the medium bore rather than the small bore Beckman Atomizer. The flow of He and Ar siphoning gas was adjusted to flow rates giving maximum stability of the Arc. The results for the

for the determination of Al, Ca, Fe, Mg, and Ti as major and minor constituents appears very encouraging. The determination of these elements is made more precisely with a Co internal standard similar to the method previously reported for the rotating disc--high voltage spark method. The "Plasma Arc" method appears more advantageous than the rotating disc method for the determination of these five elements because of its greater precision and no solution spatter.

Space Flight Projects

The astronaut training program in Principles of Lunar and Terrestrial Geology continued in May with three 2-hour classroom lectures and a field trip. The lectures were given by D. E. Wilhelms, on lunar geologic mapping, by A. H. Chidester, on terrestrial geologic mapping and by M. F. Kane, on geophysical measurements.

All 29 astronauts attended the third field trip of the course, which was given in two sections. On May 29, 30, and June 1, and again on June 20 and 21, the men observed the Moon in groups of 6 at Kitt Peak National Observatory in Tucson under the direction of D. E. Wilhelms and Harold Masursky. Wilhelms and Masursky pointed out stratigraphic and structural relations on the Moon that the astronauts had been studying in class. On May 30 and June 1, and again on June 21 and 22, the astronauts traveled from Tucson to Flagstaff and spent one day each, again in groups of 6, observing the geologic features of the San Francisco volcanic field from light planes, and mapping basalt flows and cinder cones on the ground at

Sunset Crater National Monument. The fly-around was conducted by J. F. McCauley and E. M. Shoemaker, and the astronauts observed four kinds of circular geologic structures from the air--a caldera, a number of maars, cinder cone craters, and Meteor Crater. The mapping at Sunset Crater was conducted by E. D. Jackson, A. H. Chidester, and Jerry Harbour. The problem included stratigraphic problems of multiple flows, flow-cinder relations and recognition of flow surface structures, bombs, xenoliths, etc.

A field test at the Bonito Flow, Flagstaff, Arizona, of the two existing "engineering test models" of the proposed Surveyor Lunar Roving Vehicle was conducted on May 5, 6, and 7 under the direction of L. V. Divone of the Jet Propulsion Laboratory and J. F. McCauley. Considerable information on the guidance, mobility, and imagery problems was obtained which will be incorporated into later designs.

A final report by E. M. Shoemaker and J. F. McCauley on the topographic mapping experiment for the proposed Surveyor Lunar Roving Vehicle was submitted to the Jet Propulsion Laboratory on May 25. The Phase I study has shown that a "Rover" is feasible but that improvements in the imaging system must be made before useful photogrammetric information can be obtained.

2. Significant changes

Field work for the In Situ Geophysical Studies was begun during the week of May 18. During the remainder of the month, the crew was trained in operation of equipment; various charge sizes and charge depths were evaluated, and refraction profiles of selected field sites were run to determine thickness of rubble and aa lava.

Three sites northeast of Flagstaff have been selected for study this fiscal year. R. A. Loney is presently mapping sites (a fourth on Kaibab limestone is being used for comparison of results).

Professional staffing of the project is virtually complete with the addition of J. H. Whitcomb who will join the project this summer after completion of a Master's degree at Oregon State.

The selected sites are:

1. Kana-a flow is a basaltic aa flow which emanated from the north-east side of Sunset Crater. Much of its surface is covered by ash to estimated depths of 40 feet. Both outcrops and ash are being sampled for petrographic examination. A drilling contract is planned for next month which will provide one deep core (up to 100 feet) through the flow and four to six shallow cores (30 to 40 feet) of the flow rock. Seismic refraction profiles have been shot in order to determine thickness of the ash.

Lithology and structure of the flow rock appear similar to those of the Bonito Flow which has been used for astronaut study and Rover testing.

2. Ash dunes northeast of Sunset Crater have been selected for the determination of physical properties of unconsolidated material. The area was reconnoitered but active investigations were not begun during the report period.

3. The S. P. Flow is a basaltic flow characterized by polygonal jointing. As a result of the jointing, the surface is covered with a thick rubble of polygonal blocks whose maximum dimension generally ranges from 6 to 12 inches. The thickness of the flow ranges from less than 50 feet to a maximum of about 200 feet. The depth of the rubble will be determined by seismic refraction next month.

Samples have been collected from the surface and sides for petrographic examination. A bulldozer will be required to grade a road up the side and on the top to provide accessibility for the instrument truck and drill rig. Preliminary seismic investigations have been conducted on the flow using equipment carried to the top by hand.

An area of exposed Kaibab limestone near S. P. Crater is being used as a control area. The simple and relatively homogeneous geology makes it a near ideal place for testing seismic operational procedures.

3. New projects

Planning for a mission simulation test of the Apollo science program mission profile study began in May with Jerry Harbour as test co-ordinator. The objectives of the mission simulation are to evaluate geological activities and procedures of the proposed mission profile, and to test real-time television monitoring of the ground-based activities. The mission simulations will take place between June 8 and 12.

C. H. Roach and G. R. Johnson have started a program to study the effects of high vacuum and different gaseous elements on the thermoluminescence of various rocks and minerals.

5. Personnel

Priscilla Mount, Physical Science Technician, entered on duty in Washington on May 15.

Richard E. Hoffman, Physical Science Aid, GS-3, entered on duty in Flagstaff, Arizona, May 19.

Jerry Harbour, Geologist, GS-12, on loan from Military Geology, Washington, is working on Apollo science mission studies and on the final compilation of the Terrain Map of the Lunar Equatorial Belt, at Flagstaff, Arizona.

6. Conferences and scientific meetings attended at home or abroad

The field geology team for the early Apollo science program met in Denver May 28 to discuss scientific objectives for field work on the Moon. The members of the team are J. H. Mackin, University of Texas; A. C. Waters, University of California at Santa Barbara; E. N. Goddard, University of Michigan; and E. M. Shoemaker, U. S. Geological Survey, team chairman.

E. D. Jackson, A. H. Chidester, D. E. Wilhelms, and M. F. Kane conferred with V. C. Fryklund in Washington on May 11 on the accomplishments of the Houston office and on plans for future training of astronauts in geology.

E. D. Jackson, A. H. Chidester, D. E. Wilhelms, M. F. Kane, G. A. Swann, and D. J. Milton of the Houston project, joined by G. D. Robinson, C. G. Pillmore, and G. D. Bath of Geologic Division and by U. S. Clanton, E. A. King and T. H. Foss of NASA, met at Philmont Scout Ranch, New Mexico, the week of May 25-29 to prepare for the fourth astronaut field trip.

E. C. T. Chao attended an organizational meeting of the consulting panel on mineralogy and petrology of the Apollo mission of the National Aeronautics and Space Administration at Princeton, New Jersey. Those present on the panel include H. H. Hess, Clifford Frondel, and Eugene Cameron.

E. C. T. Chao participated in a half-hour radio panel discussion of Baltimore radio station WBAL "Quiz the Scientists". The topic of discussion was tektites. Participants besides Chao were John O'Keefe of NASA and Roy Clarke, Jr., of the U. S. National Museum.

Kenneth Watson and E. C. Phillippi met with P. Damrel, Texas Instruments, to discuss the use of the Germanium Bolometer in infrared emission studies.

E. C. Phillippi and Kenneth Watson discussed the application of imaging systems to the lunar environment with F. Salgo, President of General Electrodynamics Corporation.

Kenneth Watson met with B. C. Murray and R. L. Wildey of California Institute of Technology to discuss instrumentation for the lunar infrared studies.

E. M. Shoemaker participated as a member of an ad hoc committee of the Space Science Board of the National Academy of Sciences on Scientific Qualifications of Scientist-Astronauts in Washington, D. C.

E. C. Morris, R. M. Batson, and G. A. Swann met with Manned Spacecraft Center personnel and explained techniques that are being developed to utilize data from unmanned spacecraft for support of the manned spacecraft program.

C. H. Roach and S. P. Lassiter met with Don Curly and John Salsgiver of Perkin-Elmer Instrument Company, Auburndale, Massachusetts, to discuss and see demonstration of the Atomic Absorption Spectrophotometer model 303.

C. H. Roach and S. P. Lassiter met with D. Segre and M. Simon of Raytheon Corporation, Waltham, Massachusetts, to discuss possibilities of using lasers in solid state investigations.

J. T. O'Connor and G. A. Swann met with Messrs. Lewis, Handin, Heard and Friedman, Shell Development Company, Houston, Texas, to observe results of electron microscopic and X-ray studies of deformed rocks and to correlate our work with that of Shell Development work on ARPA contract.

C. H. Roach and S. P. Lassiter met with Bill Calhoun and John Ung of Jarrell-Ash Company, Waltham, Massachusetts, to discuss and see operation of the atomic absorption/flame spectrometer and the laser microprobe.

M. H. Carr met with Dr. P. Mueller, California State Health Department, to discuss technique of separating submicron particles and Dr. Schwerdt, Microbiology Department, Stanford University to discuss techniques of ultra-centrifugation.

7. Talks or papers presented at meetings

- R. M. Batson "Photogrammetric Mapping"
Civil Engineering Class
Arizona State College
Flagstaff, Arizona
- E. M. Shoemaker "Geology of the Moon"
Carnegie Institute of Technology
Pittsburgh, Pennsylvania
- E. M. Shoemaker "Geology and History of the Imbrium Basin"
American Astronautical Society
New York, New York
- E. M. Shoemaker "History of the Moon"
American Institute of Mining and
Metallurgical Engineers
University of New Mexico
Albuquerque, New Mexico
- E. M. Shoemaker "The USGS Program in Lunar Science"
Southwest Metals and Minerals Conference
Los Angeles, California
- Charles Annell "Minor Elements in Selected Australasian
Tektites" by Charles Annell, Frank Cuttitta,
E. C. T. Chao, and Janet Fletcher.
American Geophysical Union
Washington, D. C.
- Frank Cuttitta "Some Physical Properties and the Major
Chemical Composition of Selected
Australasian Tektites" by Frank Cuttitta,
E. C. T. Chao, M. D. Carron and Janet
Littler.
American Geophysical Union
Washington, D. C.
- H. J. Moore "The Lunar Mapping Program"
Eastbay Astronomical Society
Oakland, California.

H. J. Moore

"The Moon"
Fifth Grade Class
Green Gables School
Palo Alto, California

8. Visitors

Visitor and Affiliation	Visited and Purpose
Dr. J. W. Salisbury G. R. Hunt Lunar-Planetary Research Air Force Cambridge Research Laboratories Bedford, Massachusetts	Kenneth Watson to discuss lunar infrared emission studies.
C. D. Cochran J. A. Fountain Marshall Space Flight Center Huntsville, Alabama	Kenneth Watson to discuss experimental techniques for thermal conductivity measurements of powders in vacuum.
M. E. Malin J. R. Lambert R. E. Schlier Mr. Cornetti AVCO Corporation Wilmington, Massachusetts	E. M. Shoemaker and J. F. McCauley to discuss the use of telescopically collimated laser beams to measure the roughness of selected parts of the lunar surface.
G. R. Taylor Chief Science Assistant The British Broadcasting Corporation Television Outside Broadcasts London, England	E. M. Shoemaker and E. C. Morris to discuss the Branch of Astrogeology programs.
Howard Tashjian, Computer Branch NASA Ames Research Center Moffett Field, California	H. J. Moore and R. V. Lugin to discuss contouring of data with computers.
R. B. Lewis, Director of Exhibits Lawrence Hall of Science University of California Berkeley, California	H. J. Moore to discuss exhibits for the Planetary Science Section of the Lawrence Hall of Science
Lorin R. Stieff United States Air Force, AFTAC Washington, D. C.	M. H. Carr to discuss progress in setting up clean room facilities and techniques to be used for studying cosmic dust.

Paul Fillo
Office of Mineral Exploration
San Francisco, California

V. E. Barnes
University of Texas
Austin, Texas

Jerry Wasserburg
H. J. Lippolt
California Institute of Technology
Pasadena, California

A. J. Cohen
University of Pittsburgh
Pittsburgh, Pennsylvania

Robert Fleischer
General Electric Corporation

Dean Chapman
Frank Centolanzi
Ames Research Center, NASA
Moffett Field, California

Hugh Taylor
California Institute of Technology
Pasadena, California

Charles Sclar
Battelle Memorial Institute
Columbus, Ohio

Donald Doran
V. G. Gregson
Standord Research Institute
Palo Alto, California

Raymond Alger
Preston Butler
Naval Radiological Laboratory
San Francisco, California

Harold Masursky to discuss proposed drilling in the Cortez, Nevada, area.

E. C. T. Chao to discuss the Ivory Coast tektite localities

E. C. T. Chao to discuss the Bosumtwi glass and Sr/Rb isotopic analyses; and shock transformation of minerals

E. C. T. Chao to discuss the Ablated moldavites and Ivory Coast Tektites

E. C. T. Chao to discuss fission track dating of Bosumtwi glass and Ivory Coast tektites.

E. C. T. Chao to discuss tektites in general

E. C. T. Chao to discuss Oxygen isotope analysis of Ivory Coast tektites.

E. C. T. Chao to discuss Comparison of crystal habit of synthetic and natural stishovite.

C. H. Roach and G. R. Johnson to tour Solid State Laboratory and discuss wrok being done by SRI for Project 7.9.

C. H. Roach to discuss FY 1964-65 budget and tour laboratories

R. Seibert
Perkin-Elmer Corporation
Auburndale, Massachusetts

Otto Muller
Max Plank Institute for
Nuclear Physics
Heidelberg, Germany

Elbert King
National Aeronautics and Space
Administration
Houston, Texas

Otto Muller
Max Plank Institute for
Nuclear Physics
Heidelberg, Germany

J. T. O'Connor to instigate evaluation
of X-ray diffraction topography equip-
ment and technique

Frank Cuttitta to discuss analytical
techniques concerning geologic
materials and the problem of
obtaining analyzed materials.

E. C. T. Chao to discuss tektites

E. C. T. Chao to discuss
meteorite research

General Information

Space Flight Projects

Surveyor Field Test #2 originally planned for April has been rescheduled for June because of delays in obtaining the 4. 2. 2 Surveyor TV camera from Hughes Aircraft Corporation. Until the receipt of the camera and equipment for the test, work will be directed towards preparing for Field Test #3. Work accomplished during April was directed toward developing techniques for reduction evaluation and interpretation of the Surveyor TV data.

D. W. Dodgen has begun work on a preliminary design of a special stereoscope for viewing spherical mosaics. A prototype instrument will be built in the instrument shop of the Branch of Astrogeology to test the feasibility of the design.

Photometric measurements of Field Test #2 site made by D. P. Elston from camera position #2 of the simulated Surveyor spacecraft, have been plotted on 360° graphs preparatory to determining the photometric function of the surface materials of the test site. Preliminary examination of the graphs indicate that photometric measurements taken at elevations below 30° show interference by shadows and reflections of the spacecraft. Photometric measurements of near field material will not be valid if made at the same sun angles as those during which Elston made his measurements.

A contract was let to the General Electrodynamics Corporation for a slow scan television system which will be used to simulate the Surveyor

television system in training exercises and in developing techniques and procedures for scientific interpretation and evaluation of television data received from the lunar surface. Delivery is scheduled for mid-July.

G. A. Swann, E. C. Morris, and R. M. Batson prepared an oral report on the Surveyor camera system at the request of the Space Environment Subdivision, Manned Spacecraft Center, and gave the report before a group of NASA engineers and geologists on May 22.

A cartographic method of presenting the photometric slope information derived in the lunar terrain analysis has been devised by Jerry Harbour and J. F. McCauley. The resulting integrated slope distribution maps will permit a more quantitative separation of terrain units.

Cortez Quadrangle

The copper, silver-lead-zinc geochemical anomaly west of Cortez, Nevada, outlined by Erickson, Masursky, Marranzino, and Oda will be drilled this summer by American Exploration Company. The drilling should provide structural information about the Roberts thrust zone as well as testing the mineralization in the area.