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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Technical Letter
NASA - 14
May 1966

Dr. Peter C. Baugley
Chief, Natural Resources Program
Office of Space Science and Applications
Code SAR, NASA Headquarters
Washington, D.C. 20546

Dear Peter:

Transmitted herewith are 3 copies of:

TECHNICAL LETTER NASA-14

SUMMARY OF SIGNIFICANT RESULTS OF

REMOTE SENSING STUDIES IN 1965*

by

W.D. Carter**

Sincerely yours,

William A. Fischer
Research Coordinator for
USGS/NASA Natural Resources Program

*Work performed under NASA Contract No. R-09-020-013
**U.S. Geological Survey, Washington, D.C.

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-14

SUMMARY OF SIGNIFICANT RESULTS OF REMOTE SENSING STUDIES IN 1965*

by

W. D. Carter

April 1966

These data are preliminary and should not be quoted without permission

Prepared by the Geological Survey for the National Aeronautics and Space Administration (NASA)

*Work performed under NASA Contract No. R-09-020-013

U. S. Government Agencies and Contractors Only

Contents

Summary of Significant Results of Remote Sensing Studies in 1965

by

W.D. Carter

Introduction

Since inception of the U.S. Geological Survey cooperative agreement with NASA in 1964, to investigate the feasibility and applications of remote sensing to geologic studies, twenty (20) scientific documents have been transmitted to NASA, reporting the results of geologic and instrument investigations. Ten (10) of these have been in the form of Technical Letters and ten (1) have been published as formal reports of the Geological Survey and outside scientific organizations. In addition, three (3) instrument oriented spaceflight experiment proposals have been submitted by Survey members for studies in the fields of infrared, spectroscopy, ultraviolet luminescence and magnetism. Similar proposals to evaluate and utilize space acquired photography and infrared data have either been submitted or are in preparation. Each of the latter proposals intend to study at lease 21 areas or regions of the earth's surface and presently involve approximately 50 Survey scientists. A list of the documents mentioned above are appended to this letter (APPENDIX I) along with a list of 12 similar reports that are presently in preparation as a result of more recent investigations (APPENDIX II); a list of spaceflight experiments submitted and in hand are also listed (APPENDIX III).

The purpose of this Technical Letter is to summarize the more significant scientific results of studies conducted during 1965. It is intended that this summary will be published as part of Professional Paper 550 A entitled, "Geological Survey Research 1966", and will appear as follows:

General Statement

During 1965, the Geological Survey broadened its cooperative agreement with the Natural Resources Program of the Office of Space Science and Applications of the National Aeronautical and Space Administration (NASA). Prior to 1965, the Survey had been participating in the determination of the feasibility of using remote sensing devices mounted in earth orbiting spacecraft as tools to study the geology and hydrology of the earth. Scientists of other government agencies, universities and non-profit research institutes have also been invited to participate in this multi-discipline experiment which not only includes geology and hydrology, but also geography, cartography, oceanography, agriculture and forestry.

The experiment is based on the premise that spacecraft flying at orbital altitudes and speeds, and equipped with remote sensing instruments, offer man an unusual opportunity to study his surroundings and help solve some of the

serious problems, such as scarcity of food, water and mineral resources, that are being compounded by the population explosion. Realizing the potentialities of such an experiment as well as the required multidiscipline effort essential to attack the problems, the Geological Survey has appointed a group of individuals responsible for Survey participation in the various disciplines. W.A. Fischer is responsible in the geologic fields, C.J. Robinove in hydrology, W. Sibert in cartography, and A.C. Gerlach in geography.

The bulk of the effort to date has been in the geologic field, and the Geologic Division established a Remote Sensing Evaluation and Coordination Staff (RESECS). This staff is coordinating feasibility studies of many instruments in various types of geological environment, on the ground, in low flying NASA aircraft and, soon, high flying aircraft to determine what geologic parameters can be measured from spacecraft. The remote sensing tools under consideration represent various portions of the electromagnetic spectrum and include black-and-white, and color photography, radar and infrared imaging and non-imaging systems, microwave imagers and radiometers, magnetometers and gravimeters. Many of these tools are well developed but their capabilities in air and spacecraft are untested. Data, obtained from small areas by the various sensors mounted in low flying aircraft, will be evaluated by Survey geologists by on-the-ground mapping, employing geophysical and geo-chemical methods. Studies of larger areas to be overflown by high altitude aircraft and space-vehicles will be largely empirical.

A major responsibility of the Geological Survey, in this program, is to assist in training a sufficient number of people, from within the entire geologic community, that will be capable of handling and interpreting the data to be received from orbit. Current estimates indicate that a minimum of at least 400 geologists will be needed within the next three years.

A few of the major geological problems of worldwide scope that will be approached from orbit are: 1) convective heat flow of the earth's crust and its relation to volcanism; 2) lateral-shift strain fault zones of the world and earthquakes; 3) ecology and distribution of reef building organisms and their relation to ocean currents; 4) seasonal variations of sediment loads and sediment distribution of the world's major river effluents; 5) magnetic variations of the earth's crust; 6) metallogenic provinces. A few of the major hydrologic problems are: 1) measurement of gross evapotranspiration; 2) identification of areas of ground water discharge; 3) water pollution; 4) runoff and water retention characteristics of drainage basins.

Investigations of principles and processes

Geologic applications of remote sensing data

Feasibility studies of remote sensor data obtained from ground observations and aircraft-borne instruments have been studied to determine their applications to geologic research. Such studies included analysis of black-and-white, color, near-infrared and multiband photography, radar and infrared imagery from sites representing a variety of geologic features or problems.

Photographic studies

R.J. Hackman made a study of time-variant phenomena and their affects on image interpretation. These studies indicated, 1) that subtle topographic forms are better expressed when photographed at low angles of illumination; 2) that differences in photographic tone are more easily recognized on photographs taken at high angles of illumination, 3) that variations in representation of terrain features with angle of illumination may effect interpretation of some images produced with imaging systems that employ variable angles of illumination, such as side looking radar systems.

Studies of Gemini photography

Approximately 200 hyper-altitude color photographs from Gemini IV, V, VI, and VII space missions have been distributed to geologists for identification, study and comment. Initial returns indicate that such photography can be of great utility in reconnaissance geologic mapping of gross structural and lithologic features of little known regions and compiling small scale maps.

Analyses of color fidelity and tonal variations of Gemini color photography, taken over the southwestern U.S., were compared with ground observations by Roland W. Tabor. He found that certain soils and rock types can be mapped from such photographs with considerable accuracy.

James Seitz, USGS/USAID, LaPaz, Bolivia, annotated the regional geology and geography of the Bolivian Altiplano on a copy of a single photograph extending between Lake Titicaca and Lake Poopo and covering an area of approximately 75,000 square kilometers. The potential utility of such photographs for regional geologic synthesis appears to be great.

During a preliminary examination of a Gemini satellite color photograph, Robert F. Johnson discovered a large wrench fault in the Precambrian of northwestern Saudi Arabia. Although the area was covered by a photomosaic at ten times the scale of the Gemini photo, the fault was not apparent on the mosaic.

Studies of Nimbus I imagery

James Burns, Mario Conti and Edward Hasser (Military Geology) conducted studies of Nimbus I High Resolution Infrared Radiometer (HRIR) imagery and Advanced Vidicon Camera Systems (AVCS), respectively, evaluating them for geologic purposes. The Nimbus I Meteorological Satellite was put into elliptical near-polar orbit in August 28, 1964, and was in operation until September 23. The height of the satellite ranged from 423 to 932 km above the earth's surface.

Burns and Conti found that the infrared imagery was not useful for geologic mapping purposes. It was, however, useful in detecting certain features indicated by thermal patterns. Among the more important features are ice sheets, terrain-thermal reversals, thermal soil patterns and thermal fields.

Hasser found that of approximately 1000 frames of vidicon photography, 200 were suitable for geologic study. A frame, showing parts of Baja California and western Sonora, was selected for initial study. Recognizable tonal variations and lienaments were plotted and compared with existing maps showing bedrock geology and structure. Little correspondence, however, was noted. The image was then compared with an airphoto mosaic, reduced to the same scale as the image, to compare tonal variations. Shadow patterns (a function of sun angle and topography) and cultivated patterns were identified as the major factors influencing tonal variation. Other possible factors are under study.

Analyses of Multiband photography: Carrizo Plains, California

Robert E. Wallace compared enhanced multiband photographs with black-and-white and aerial Ektachrome photographs of the Carrizo Plains area of the San Andreas Fault Zone, California. He found the multiband photograph was useful in distinguishing between several types of surficial materials, each having different particle size.

Caliente Range, California

An enhanced multiband aerial photograph of the Caliente Range was compared with an Ektachrome photograph of the same area by J.C. Vedder and E.W. Wolfe. The Ektachrome photography was considered extremely valuable for mapping unknown terrain where rocks have contrasting colors. The multiband photograph indicated that certain rock types, such as white arkosic sandstone and olivine basalt flows were markedly enhanced, suggesting that the method could be used as an analytical tool in the study of stratigraphic facies.

Radar imagery studies of the Oregon Coast

P.D. Snavely, Jr. and H.C. Wagner found that radar imagery effectively "defoliated" the Oregon Coast enhancing the topographic and tonal expressions of certain Tertiary rock units. Miocene basalt flows show the highest reflectivity as expressed by the lightest tones, sandstones gave intermediate tones, and marine mudstones gave the lowest radar returns of any of the Tertiary rocks. Faults and lineaments that cannot be identified on conventional black-and-white aerial photography were recognized on radar imagery.

Evaluation of radar imagery in volcanic terrain

Evaluation of radar imagery in volcanic terrain of the High Cascade Range, Oregon, by Donald A. Swanson, revealed that heavy cloud cover tends to absorb radar energy giving the image a washed-out or blurred appearance. In hazy areas over volcanic terrain, radar imagery clearly shows viscous dacite lava flows and domes, cinder cones and craters. Radar did not, however, indicate differences between such rock types as andesite and basalt because of their similar composition and topographic characteristics. Fault zones, lakes and water-saturated meadows stood out as black areas.

Radar imagery of the Hart Mountain area, Oregon

George E. Walker found that side looking radar imagery of the Hart Mountain area revealed a large number of the structural features (mainly faults) that had been found by earlier surface mapping. Certain surficial features, especially water-saturated sediments, were easily distinguished from radar imagery.

Radar imagery of Jackson Hole, Wyoming

Side looking radar imagery of the Jenny Lake area, Jackson Hole, Wyoming was studied by A.B. Campbell who found that such imagery was especially effective in distinguishing surficial features (moraines, outwash plains, knob and kettle areas) of glacial origin as well as certain fault zones.

Infrared imagery of the San Andreas Fault System, California

R.E. Wallace and R.M. Moxham found that infrared images (8-13μ band) clearly displayed the trace of the San Andreas Fault system through most of the Carrizo Plain area of California. Factors influencing visibility of the fault in the infrared imagery are 1) variations in soil moisture caused by the water-barrier characteristics of the fault zone and 2) vegetation differences related to soil moisture and microtopography. Ancient offset segments of stream channels disrupted by movement along the fault,

landslide terrain, and numerous soil and Tertiary bedrock units. Imagery obtained one to two hours before sunrise is considered most useful for the fault studies.

Infrared surveys of the Taal Volcano, Luzon, Philippine Islands

R.M. Moxham and A. Alcaraz made infrared scanner (8- to 14-μ) surveys of the Taal Volcano area, two weeks after the September 1965 eruption. Two principal areas of abnormal thermal activity were defined: (1) a fumarole area which has been active for many years on the north flank of the volcano's main (1911) crater and (2) anomalies around the summit and on the southeast flank of Mt. Binintiang Malaqui on the northwest tip of the island. Thermal activity at this crater may be more widespread than previously supposed.

Far-infrared (Wavelengths of 1 to 3 millimeters) investigations

A feasibility study undertaken by the Block Engineering Company for the U.S. Geological Survey suggests that the spectral distribution of emitted energy in the 1 to 3 millimeter wavelength part of the spectrum may be observed by interferometric techniques. Observations of the spectral distribution of energy at these wavelengths could provide information regarding the composition of certain gases and liquids and would provide a valuable method of correlating spectroscopic observations made by optical techniques with similar observations made using radio techniques.

Ultraviolet absorption and luminescence investigations

W.R. Hemphill found that 1) reflectance differences among many rock types are greater in the ultraviolet than in the other parts of the electromagnetic spectrum, thus far investigated; 2) line scan images recording reflected ultraviolet energy show some features, such as craters, in striking contrast with their surroundings, 3) images showing the distribution of luminescing minerals have been produced at distances of more than 200 feet, using a newly developed "active" ultraviolet imaging device.

Earth orbital magnetometer experiments

I. Zeitz, L.C. Pakiser, E.R. King, W. Geddes and E.G. Lidiak examined the significance of the long-wavelength end of the crustal magnetic spectrum to determine the feasibility of conducting crustal and subcrustal magnetic experiments from earth orbiting spacecraft. They analyzed a series of parallel transcontinental aeromagnetic profiles across the U.S.A. spaced at five mile intervals and found that by applying a high-pass filtering process to the data, they could recognize anomalies with spatial wavelengths of several tens to several hundreds of miles, and amplitudes of up to or in some cases exceeding 1000 gammas. The anomalous patterns so developed were found to be spatially related to seismic velocity and heat flow distributions that evidentally originate in the deeper portion of the crust or in the upper mantle. Extrapolation of these data to orbital altitudes indicates that such anomalies can be recognized and mapped from spacecraft.

Surface studies

In preparation for remote sensing studies by aircraft overflight in the Northwestern Yellowstone Park area, Kenneth L. Pierce made a detailed chart of properties of surficial materials that are considered to be critical to remote sensing imagery. The chart describes the surficial material, its texture below the surface and at the surface, its moisture retention characteristics near the surface, thickness of the unit, its slope and local relief (i.e. surface roughness), composition, compaction and vegetative cover. The chart will be used as reference for comparison of radar, microwave, and infrared images of the area.

J.D. Friedman made detailed compositional studies of older aa and younger pahoehoe porphyritic olivine basalt flows at Pisgah Crater, California in support of airborne infrared surveys to determine what kind of analytical information might be most useful for infrared interpretation. Chemical and mineralogical differences between the two were slight but the surface of the older aa flow was richer in Fe_2O_3 and MnO than the pahoehoe. Iron and manganese oxides occur as desert varnish on both rock types but are more abundant on the aa because it is older and has greater surface-to-volume ratio. The minor variations in composition recorded in this study are considered too small to affect the emissivity and thermal inertia of the rock. More significant are the wider-ranging differences in surface-to-volume ratio and vesicularity.

Hydrologic applications of remote sensing data

Color and infrared color photography were studied by H.E. Skititzke and C.J. Robinove to determine the applications of certain airborne remote sensing techniques to lake surveying. They assessed the depth penetration of water by photographing targets submerged at increasing depth with color film employing various filters; they also determined the diurnal variation in temperature over land and water surfaces with an airborne infrared radiometer at Lake Cachuma, California. Color and infrared color photography were used to map the mixing of pollutants in the Great Lakes, to identify water surface color and bottom features of Great Salt Lake, and to map the staged eutrophication of Florida lakes. Similar studies were conducted at the Prairie potholes of North Dakota, Sand Hill lakes of Nebraska, the Salton Sea and lakes in Minnesota.

South Cascade Glacier, Washington

M.F. Meier, W.J. Campbell (Water Resources Division) and R.H. Alexander (Office of Naval Research) report that airborne remote sensing tests were carried out at South Cascade Glacier as part of a NASA/ONR/AFCRL/USGS program to determine the potential of obtaining glaciological data from earth-orbiting spacecraft. Near-infrared photography (both color and black-and-white) differentiated snow from

ice and firn most effectively and pointed up wetness contrasts. Short wavelength visible light effectively differentiated ice from moraine. Subtle moraine structures were emphasized with color-infrared. Thermal infrared scanning showed interesting moraine and lake temperature patterns, but in this preliminary work did not show emissivity differences on the ice and snow.

C.J. Robinove suggests that infrared photography and radiometry have many other applications to hydrologic problems. Infrared photography has been found to be particularly useful in shoreline mapping. Infrared imagery is being employed in water resources studies to identify surface and subsurface thermal anomalies, to identify submarine springs along coasts, to measure temperature differences along streams as indicators of effluent seepage of ground water and to determine the circulation of heated water discharged from power plants into streams and cooling ponds.

Cartographic applications of remote sensing data

W. Sibert and L. Starr of the Topographic Division conducted cartographic studies of Gemini VII photograph of the Cape Kennedy area by comparing it with corresponding portion of the Orlando, Florida 1:250,000 scale topographic map, published in 1955 and revised in 1962. The photograph clearly showed new highways, roads, airports and urban development indicating that space photography will have great value in accelerating revision of published maps as well as in mapping uncharted regions of the world.

Geographic applications of remote sensing data

Studies to evaluate remote sensor imagery for geographic purposes were conducted in the Asheville Basin, North Carolina, by D.E. Harrell, N. Crawford and R.W. Peplies of East Tennessee State University and at Phoenix, Arizona and Chicago, Illinois by D.F. Marble and E.N. Thomas of Northwestern University on contract with the Office of Naval Research. Preliminary results indicate that infrared color photography is useful in distinquishing historical features such as old roads, trails, mines and house sites. Multispectral photography shows promise of being useful to studies of urban development and transportation systems. During 1966, these and new evaluation studies in geography will be monitored by the Bureau Geographer, A.C. Gerlach, for the Survey and NASA.

APPENDIX I

Scientific Documents

Altenhofen, R.E., Oman, J.K., and Sousa, T.M., 1965, Topographic studies of Pisgah Crater, California: U.S. Geol. Survey, Tech. Letter NASA-7

Dibblee, T.W., Jr., 1965, Preliminary geologic map - Pisgah Crater and vicinity, California: U.S. Geol. Survey, Tech. Letter NASA-4

Fischer, W.A., 1964, Information regarding Vindicator Mtn., Nevada, as a possible test site for NASA remote sensing program - also - Information on proposed route of Naval Research radar craft: U.S. Geol. Survey, Tech. Letter NASA-1

Fischer, W.A., and Daniels, D.L., 1964, Interim report of ultraviolet absorption and stimulated luminescence investigations being undertaken in cooperation with the National Aeronautics and Space Administration - Part II - Spectral distribution of ultraviolet stimulated luminescence: U.S. Geol. Survey, Tech. Letter NASA-3

Fischer, W.A., and Gerharz, R., 1964, Interim report of ultraviolet absorption and stimulated luminescence investigations being undertaken in cooperation with the National Aeronautics and Space Administration - Part III - Measurement of ultraviolet reflectance: U.S. Geol. Survey, Tech. Letter NASA-3

Fischer, W.A., Moxham, R.M., Polcyn, F., and Landis, G.H., 1964, Infrared surveys of Hawaiian Volcanoes: Science, v. 149, No. 3645, p. 733-742

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Fischer, W.A., Friedman, J.D., and Sousa, T.M., 1965, Preliminary results of infrared surveys at Pisgah Crater, California: U.S. Geol. Survey, Tech. Letter NASA-5

Fischer, W.A., Davis, D.E., and Sousa, T.M., 1966, Fresh water springs of Hawaii from infrared images - Hydrologic Atlas 218

Friedman, J.D., Lyon, R.J.P., Beattie, D.A., and Downey, J., 1966, Lunar ground data required for interpretation of A.E.S. orbital experiments: Advances in the Astronautical Sciences: Proc. 11th ann. symposium, Am. Astronaut. Soc., Chicago

Gawarecki, S.J., 1964, Geologic reconnaissance report of the Pisgah Crater, California, area: U.S. Geol. Survey, Tech. Letter NASA-2

Gawarecki, S.J., Lyon, R.J.P., and Nordberg, William, 1965, infrared spectral returns and imagery of the earth from space, and their applications to geologic problems: Proc. Third Goddard Mem. Symposium, Am. Astronaut. Soc., in press

Gawarecki, S.J., and Moxham, R.M., 1966 (in prep.) Infrared survey of Irazu Volcano and vicinity, Costa Rica (CONFIDENTIAL)

Hemphill, W.R., and Gawarecki, S.J., 1964, Interim report of ultraviolet absorption and stimulated luminescence investigations being undertaken in cooperation with the National Aeronautics and Space Administration - Part 1 - Ultraviolet video imaging system: U.S. Geol. Survey, Tech. Letter NASA-3

Hemphill, W.R., and Carnahan, S.U., 1965, Ultraviolet absorption and luminescence investigations progress report: U.S. Geol. Survey, Tech. Letter NASA-6

Hemphill, W.R., et al, (in press), Ultraviolet investigations for lunar missions, Proceedings American Astronautical Society, Chicago, May 4-6

Hemphill, W.R., Fross, C.R., Boynton, G.R., Philbin, P.W., and O'Neal, Maston, III, 1966, Laboratory test of the Reconofax IV - Infrared imaging system: U.S. Geological Survey, Tech. Letter NASA-10 (CONFIDENTIAL)

Kistler, R.W., 1965, Preliminary geologic map of the Mono Craters quadrangle, California: U.S. Geol. Survey, Tech. Letter NASA-9

Moxham, R.M., Crandell, D.R., and Marlatt, W.E., 1965, Thermal features at Mount Rainier, Wash., as revealed by infrared surveys: in Geol. Survey Research, 1965: U.S. Geol. Survey Prof. Paper 525D, p. D93-D100

Moxham, R.M., and Alcaraz, A., 1965, Infrared surveys at Taal Volcano, Philippines (CONFIDENTIAL). (Proc. 4th symp. on remote sens., Univ. of Mich. - pending clearance)

Wallace, R.E., and Moxham, R.M., 1966, Use of infrared imagery in study of the San Andreas fault system, California (CONFIDENTIAL) (Proc. 4th symp. on remote sens., Univ. of Mich. - pending clearance)

APPENDIX II

Reports in preparation

Space Flight Experiments

Hemphill, W.R., Geologic Studies of planetary surfaces by ultraviolet absorption and stimulated luminescence

Scientific Documents

Betz, H. and Vickers, R. (IITRI), Comparative study of ultraviolet instrumentation suitable for orbital remote sensing experiments

Betz, H. (IITRI), Technical memorandum: Examination of an active terrestrial UV system (2200-2900 Å)

Daniels, D.L., Effects of long term ultraviolet irradiation of luminescent minerals: U.S. Geol. Survey Tech. Letter NASA-

Friedman, J.D., Geologic map of the Mono Craters area, California: U.S. Geol. Survey Tech. Letter NASA-12

Friedman, J.D., Composition of basalt flows of Pisgah Crater, California: Preliminary data, U.S. Geol. Survey Tech. Letter NASA-20

Gerharz, R., and Fischer, W.A., Reflectance measurements in the 0.6 to 2.5 micron part of the spectrum: U.S. Geol. Survey Tech. Letter NASA-8

Hackman, R.J., Time, shadows, terrain and photointerpretation: U.S. Geol. Survey Tech. Letter NASA-22

Hemphill, W.R., Interpretation of ultraviolet imagery of the Mesquite sedimentary test site and Meteor Crater, Arizona: U.S. Geol Survey Tech. Letter NASA-

Irwin, W.P., Geologic appraisal of radar imagery of southwestern Oregon: U.S. Geol. Survey Tech. Letter NASA-

Senftle, F., Spectral distribution of ultraviolet reflectance (2000-3000 Å) of selected rocks and rock-forming minerals: U.S. Geol. Survey Tech. Letter NASA-

Skibitzke, H.E. and Robinove, C.J., Lake surveying techniques in the Geological Survey - Progress Report: U.S. Geol. Survey Tech. Letter NASA-21

Snavely, Jr., P.D. and Wagner, H.C., Geological evaluation of AN/APQ-97 radar imagery, Oregon coast: U.S. Geol. Survey Tech. Letter NASA-16

Swanson, D.A., Geologic evaluation of radar imagery of the central part of the Oregon High Cascade Range: U.S. Geol. Survey Tech. Letter NASA-19

Tabor, Rowland, Photogeologic interpretation of satellite color photographs, Gemini IV: U.S. Geol. Survey Tech. Letter NASA-24

Vedder, J.G. and Wolf, E.W., Evaluation of Ektachrome and multiband photography in Caliente Range, California: U.S. Geol. Survey Tech. Letter NASA-17

Walker, George W., Evaluation of radar imagery of highly faulted volcanic terrane in southeast Oregon: U.S. Geol. Survey Tech. Letter NASA-25

Wallace, R.E., Evaluation of enhanced multiband photography of San Andreas fault zone, Carrizo Plain, California: U.S. Geol. Survey Tech. Letter NASA-18

Watts, H., (IITRI) Laboratory measurement of ultraviolet reflection (2200-7000 Å) and stimulated emission of rocks and rock-forming minerals: U.S. Geol. Survey Tech. Letter NASA-

Wise, W., Geologic map of the Pisgah and Sunshine lava flows, San Bernardino County, California: U.S. Geol. Survey Tech. Letter NASA-11

APPENDIX III

Spaceflight experiments and reports submitted or in preparation

Earth Orbital Spaceflight Geologic Experiments
(Proposed by U.S. Geological Survey members)

Instrument Studies

1) A scanning spectral radiometric experiment for geophysical studies from an earth orbit, by R.M. Moxham and G.W. Greene

2) A.A.P. manned earth orbiter magnetometer experiment, by I. Zeitz

3) Geologic studies of planetary surfaces by ultraviolet absorption and stimulated luminescence, by W.R. Hemphill

General Geologic Studies

General geologic studies to analyze and test the applications of remote sensor data have been or are being proposed in the following documents:

1) Geologic utilization of photography acquired from orbit, by W.A. Fischer (Coordinating Investigator) (Transmitted to NASA December 1965)

2) Experiments to study the use of infrared imagery and non-imaging data in geologic and hydrologic investigation of the earth, by W.D. Carter (Coordinating Investigator) (In final preparation)

Note: Each of the above experiments contain descriptions of areas for geologic studies presently underway or contemplated to study the applications of orbital data. The titles, areas, and responsible investigators are listed below:

a) Geologic interpretation of space photographs of the Colorado Plateau area, by R.J. Hackman

b) Applications of remote sensor data to the geology of the Middle Appalachian region, by J.P. Minard, D.L. Southwick, A.A. Drake, Jr.

c) Geologic mapping and interpretation in the central to northern part of the Atlantic Coastal Plain, by J.P. Minard and J.P. Owens

d) Application of remote sensing data to studies of marine and brackish water environment, Pamlico Sound, North Carolina, by H.L. Berryhill, Jr.

(cont'd)

e) Applications of space data to interpretation of southern Appalachian Tectonics, by J.C. Reed, Jr.

f) Geomorphic studies of the northern parts of the Mississippi alluvial plain, by L.L. Ray

g) Applications of photography and other remote sensor data to the study of the geology of island arcs (greater Antilles) in tropical areas, by R.P. Briggs

h) Applications of remote sensor data in geologic studies of Oregon and adjacent states, by P.D. Snavely, Jr.

i) Applications of remote sensor data to studies of volcanic and arctic regions - Alaska, by G. Gryc and others

j) Applications of remote sensor to studies of the geology, hydrology, and mineral deposits of the Andes Mountains, South America, by W.D. Carter and others

k) World wide study of coral reefs, by S.O. Slanger

l) Effluents of the world's major rivers, by R.H. Meade

m) Tectonic features of island arcs (Mariana and western Caroline Islands of the western Pacific Ocean), by Gilbert Corwin

n) Remote sensor applications to studies of the structural habit of batholithic complexes, western North America, by D.A. Brew

o) Applications of remote sensor data to studies of strain in earthquake belts, especially San Andreas, California, by R.E. Wallace

p) Analysis of infrared imagery of the San Andreas Fault zone and related faults of the western U.S., by R.D. Brown, Jr.

q) Analysis and applications of remote sensor data to studies of the geology of Baluchistan and adjacent areas, West Pakistan, by W.R. Hemphill and R. Schmidt

r) Analysis and application of remote sensor data to regional geologic problems, Preston 2^{o} Quadrangle, Idaho/Wyoming, by S.S. Oriel

(cont'd)

s) Analysis and application of remote sensor data to studies of recent volcanic features (Lunar analogues) of northwestern Sonora, Mexico, by G.E. Ulrich and others

t) Application of earth orbiter remote sensing techniques to geologic discover of new ore districts in northeastern (Elko County), Nevada, by D.R. Shawe

u) Infrared studies of thermal anomalies of Iceland, by J.D. Friedman and others

v) Analysis and application of remote sensor data to studies of the Tectonics, Northern Appalachian Mountains of New England and adjacent areas, by E.L. Boudette and others.