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UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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TECHNICAL LETTER NASA-5

PRELIMINARY RESULTS OF AERIAL INFRARED SURVEYS AT PISGAH CRATER, CALIFORNIA [*]

by

W. A. Fischer, J. D. Friedman and

T. M. Sousa

[*] Work performed under NASA Contract No. R-146

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Technical Letter
NASA - 5
April 22, 1965

Dr. Peter C. Badgley
Chief, Advanced Missions
Manned Space Science Division
NASA Headquarters
Washington, D. C. 20546

Dear Peter:

Transmitted herewith are 25 copies of:

TECHNICAL LETTER NASA-5

PRELIMINARY RESULTS OF AERIAL INFRARED SURVEYS AT PISGAH CRATER, CALIFORNIA*

by

W. A. Fischer **
J. D. Friedman **
T. M. Sousa **

Sincerely yours,

R. M. Moxham

R. M. Moxham
Chief
Branch of Theoretical Geophysics

---

*Work performed under NASA Contract No. R-146

**U. S. Geological Survey, Washington, D.C.

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PRELIMINARY RESULTS OF AERIAL INFRARED SURVEYS AT PISGAH CRATER, CALIFORNIA [*]

by

W. A. Fischer,[**] J. D. Friedman,[**] and T. M. Sousa [**]

Initial surveys utilizing the NASA remote sensing aircraft were undertaken from February 9 to February 17, 1965, at Pisgah Crater, San Bernardino County, California. Sensors aboard the aircraft utilized in these surveys included a Reconofax 4 infrared scanner operating in the 8-13μ part of the spectrum, and a AAS-5 scanner filtered so as to record energy in the 4.5-5.5μ part of the spectrum.

Pisgah Crater rubble cone and adjoining lava flows (figs. 1,2,and 3) were selected as the site of the initial surveys for the following reasons:

1) The rocks are relatively fresh and largely unaffected by weathering.

2) The area is largely devoid of vegetation.

3) Rocks having similar chemical composition occur here in a variety of physical conditions (rough and smooth surfaces, consolidated and loose).

4) The area is free of snow for most of the year.

5) The area is readily accessible by land and air.

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[*] Work performed under NASA Contract No. R-146

[**] U. S. Geological Survey, Washington, D. C.

6) Geologic maps of the area are available.

7) Support facilities, such as photographic laboratories, are available at nearby NASA installations.

The principal objectives of the initial surveys were testing the airborne and related field monitoring equipment under operational conditions and developing field methods for describing the surface of various rock units in a statistically valid manner and in terms meaningful to the interpretation of the infrared records.

The initial surveys and related field studies have also contributed to several long-range objectives of our program by permitting:

1) an assessment of the value of infrared records in measuring the differences in thermal-inertia of various earth materials and relating these observations and measurements to differences in consolidation and surface irregularity of the various materials;

2) an assessment of the effects of different angles of view on infrared records and relating these observations to surface irregularity;

3) an assessment of the geologic value of simultaneous observations of solar absorption and infrared emission;

4) a preliminary assessment of the geologic value of observations of the spectral distribution of infrared energy emitted by various rock types present in the area; and

5) a preliminary appraisal of the effects of altitude on infrared records.

In preparation for the remote-sensing surveys, aerial photographs were taken at a scale of 1:4000-1:8000, control points were established and targeted, and topographic profiles of selected areas were compiled at scales of 1:600. The targeted control points were used in the preparation of the topographic profiles and will be of additional value in calibrating the various sensing instruments and in relating various remote-sensing images to one another.

During the period of aircraft flight, the temperature of each of the major rock units was recorded (seven gross lithologic units were studied in the Pisgah area). These units were:

1) aa, rough-surfaced or granular basaltic lava;

2) pahoehoe, basaltic lava having a relatively smooth or vesicular surface;

3) desert pavement mosaic of basalt fragments and areas covered with loose fragments of basaltic lava;

4) cinders, blocks, and ash of rubble cone;

5) surficial materials, chiefly calcareous silt and quartz sand;

6) alluvial-fan material ranging from silt to boulders, of diverse composition; and

7) playa deposits, mostly silt and clay.

These units (figs. 3, 4, and 5) were monitored to provide calibration for the aerial infrared images and basic information relating to the thermal properties of the rock units themselves. These measurements demonstrate that the various units differ from one another in thermal properties.

Cinders, for example, are characterized by low radiant temperature during night-time hours; a rapid rate of change in temperature at dawn, signifying low thermal inertia; and relatively high radiant temperature in daylight hours. These characteristics contrast strongly with characteristics of aa and pahoehoe lavas, which have lower rates of change and radiant temperatures more nearly approaching the temperature of the air surrounding them. Close examination of the temperature records suggests that each of the units is distinguishable and possibly identifiable by analysis of its thermal behavior.

The radiant temperatures of each of these units were recorded several times on aerial infrared images during the period of time represented in figure 4. Although only preliminary analyses of these records have been made, these analyses suggest that the thermal properties of the various units may be deduced from sequential airborne infrared images, provided appropriate thermal reference is available from ground control or possibly from an instrument calibration system. Some preliminary results of the analysis of the airborne infrared records are also shown in figure 4.

In addition to monitoring the temperatures of various units during periods of aircraft flights, measurements were made and samples collected to provide data relevant to other parameters which may affect the way in which various surfaces are registered on infrared images. Profiles of segments of the surface were among the data obtained in the field. These profiles were measured in two directions at a spacing of 4 feet in a rectangular grid system of 236 ft.^2 for each lithologic unit (fig. 6). To date, estimates of the surface irregularity or microrelief were made for each sample location in five lithologic units by measurement of the profile surface length (figs. 7 and 8) and estimation of the total surface area. The ratio of surface area of sample to the area of an equidimensional plane is considered here an index of surface irregularity. The mean surface irregularity of 16 samples of each lithology was plotted against change in infrared image density per degree of arc (fig. 9) to determine the relationship between surface irregularity and image density.

These relationships suggest that, in general, the total radiating surface, and hence the total energy visible to the detector at any one instant of time, diminishes more rapidly for irregular surfaces than for relatively smooth surfaces with increasingly oblique angles of view.

To evaluate possible geologic significance of observations of the relationship between solar absorption and infrared emission, the film density of the infrared images of the various units was contrasted with their absorption of visible light as determined by colorimetric measurement (fig. 10). The preliminary results of this investigation are shown in figure 11. These observations show that the unconsolidated deposits, cinders and silt, emit significantly more infrared energy when exposed to sunlight than the consolidated lavas, although the cinders and silt reflect more (absorb less) solar energy than the lavas. The data likewise suggest that the irregularly surfaced aa (fig. 10) emits more radiation relative to its absorption of solar energy than the somewhat less irregularly surfaced pahoehoe.

Sensor flights were undertaken at altitudes of 1,500 feet and 5,000 feet above terrain to obtain preliminary data relating to the effects of increasing altitude on our ability to distinguish various materials. At present these images are unevaluated; they will be studied to determine the effects of successively higher flight altitudes.

The spectral distribution of emitted infrared energy in the 5-15μ range was measured in the field with a spectrometer-interferometer (fig. 12). Strong signals and clear records were obtained that seemingly show significant differences in the spectral distribution of energy emitted by the various lithologies. The recorded signals are being processed by a co-adder, computer, and wave analyzer, to determine which of the processing instruments and techniques yield the most meaningful results.

SUMMARY OF INFRARED SURVEYS

Pisgah Crater and adjoining lava flows, California, were selected for the initial surveys undertaken with the NASA remote sensing aircraft. These surveys were primarily intended to test equipment under field conditions and to provide infrared imagery of the test site at various times of day and from various spatial positions. Field control stations were surveyed and targeted on the surface of the test site to facilitate development of topographic profiles at a scale of 1:600 and to assist in relating various sensor records to one another.

Field measurements of surface temperatures, microrelief, and laboratory measurements of reflectance were contrasted with measurements of film density on infrared images acquired at various times of day. Measurements of microrelief were also contrasted with film densities of various materials imaged at increasingly oblique angles.

Contrast of these various functions suggests that unconsolidated materials possess a lower thermal inertia than consolidated materials, that unconsolidated materials emit larger quantities of infrared energy than consolidated materials when both are subjected to similar quantities of solar radiation, and that the film densities with which objects are recorded on infrared imagery differ with angle of view; commonly the differences are greater for rough surface than for smooth. These studies also suggest that these relative quantities and changes in relative quantities of radiation may be observed from airborne platforms.

ILLUSTRATIONS

Figure 5. Monitoring a thermistor array system to determine ground temperatures during infrared aerial survey of Pisgah Crater area, February 12-14, 1965.

6. Taping 16 x 16 ft. sampling grid, totaling 236 ft.^{2} to obtain preliminary hand specimens of Pahoehoe surface material for laboratory study.

7. Sections selected for each lithology are those most closely approximating the mean surface area of all samples for each lithology.

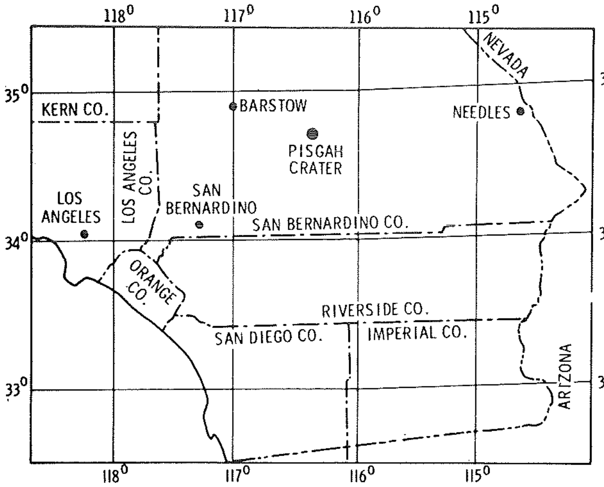
8. Angular, vesicular basalt fragments distributed in rough polygonal patterns on mud-cracked calcareous silty-clay surface of Lavic Lake playa.

9. Range in change of image density away from centerline of image of several lithologies, plotted against surface irregularity (ratio of mean surface area of approximately 16 samples of each lithology to area of an equidimensional plane). Determined from selected infrared images flown February 13-14, 1965, and preliminary interpretation of data.

10. Reflectance of lithologic units in the visible spectrum.

11. Relationship of the reflectance of various materials to relative infrared emission.

12. Interferometer spectrometer used for field measurement of the spectral energy distribution of infrared radiation (5-15µ) emitted from various rock surfaces.



INDEX MAP SHOWING THE LOCATION OF THE PISGAH CRATER AREA, CALIFORNIA

Fig 1

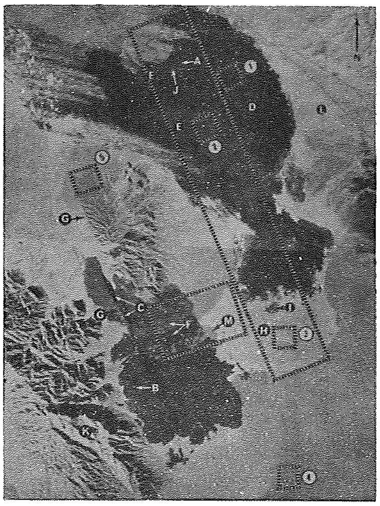


Fig. 2

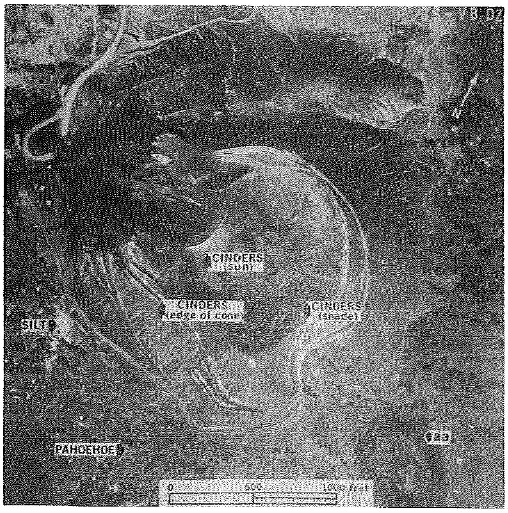


Fig. 3

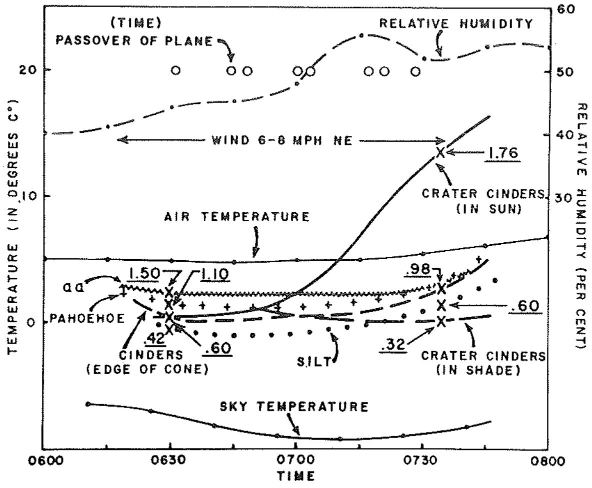


Fig. 4

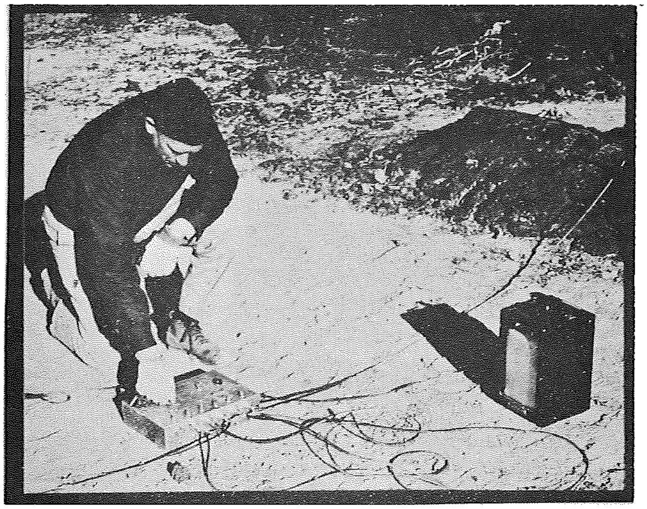


Fig. 5

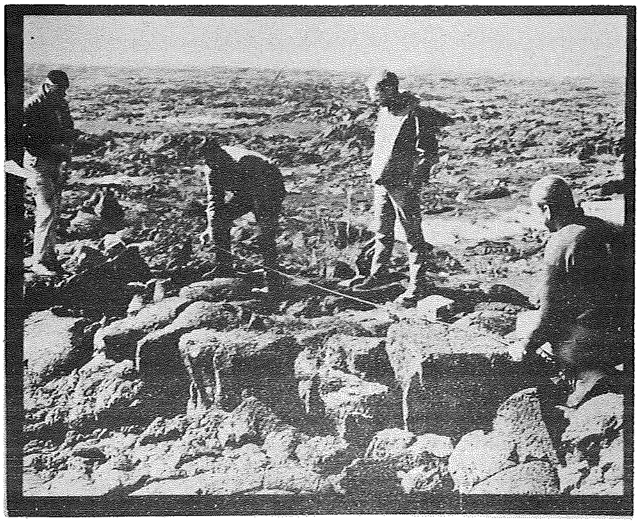
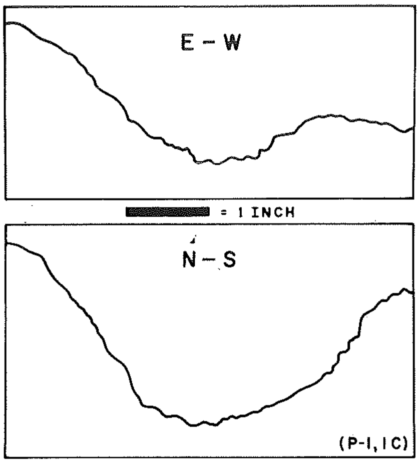
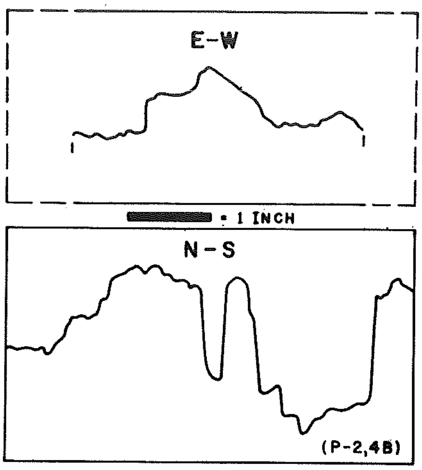


Fig. 6

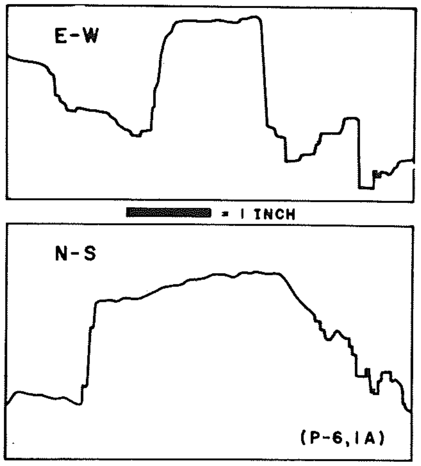


TYPICAL PAHOEHOE SURFACE

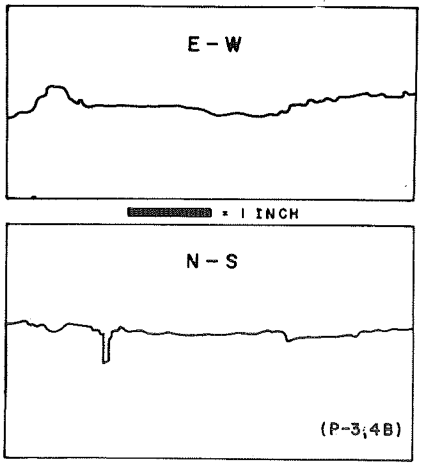


TYPICAL aa SURFACE

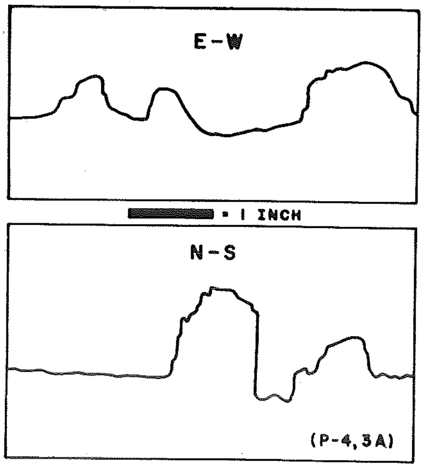
Fig 7



TYPICAL VOLCANIC EJECTA SURFACE



TYPICAL SILTY CLAY OF PLAYA SURFACE



TYPICAL FRAGMENTS ON PLAYA SURFACE

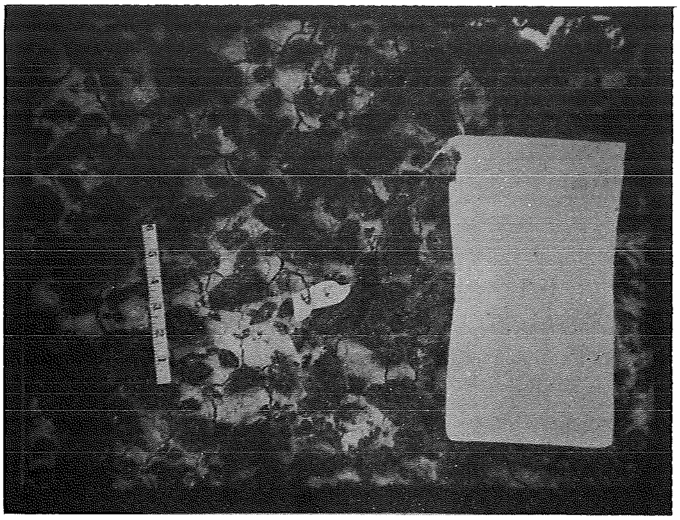


Fig. 8

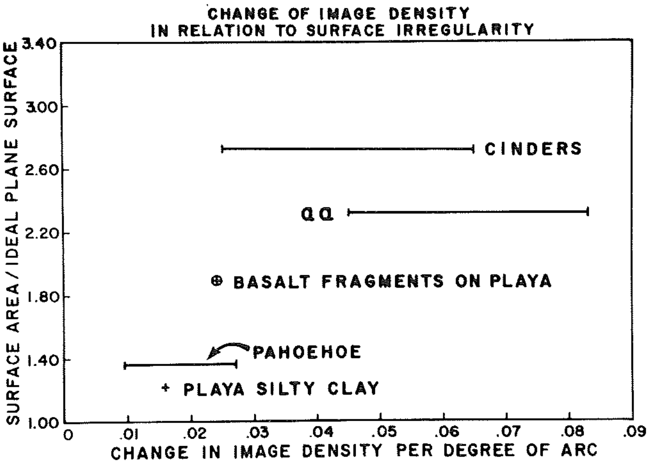


Fig. 9

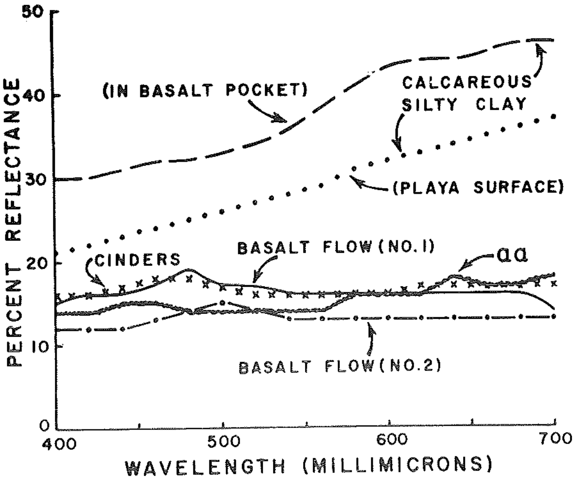
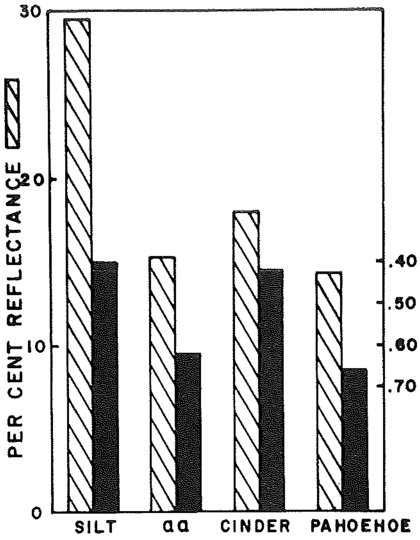


Fig. 10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PER CENT REFLECTANCE ▨
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Fig. 11

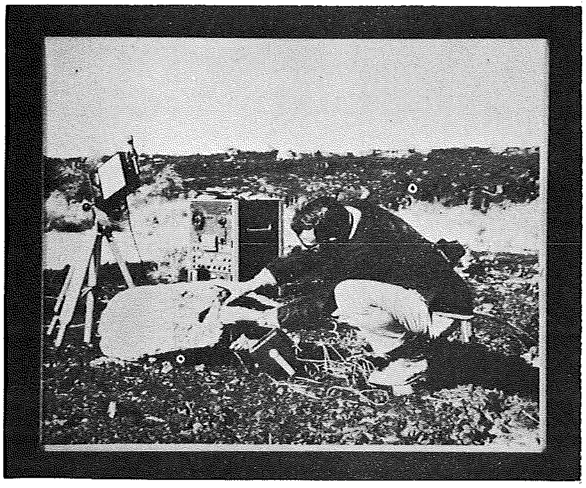

Fig. 12