NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

*Technical Memorandum 33-810*

# *Detection of Alteration Associated With a Porphyry Copper Deposit in Southern Arizona*

(NASA-CR-152677) DETECTION OF ALTERATION ASSOCIATED WITH A PORPHYRY COPPER DEPOSIT IN SOUTHERN ARIZONA (Jet Propulsion Lab.) 10 p HC A02/MF A01 CSCL 08G

N77-22740

Unclas

G3/46 25138

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

February 1, 1977

TECHNICAL REPORT STANDARD TITLE PAGE

| 1. Report No. 33-810 | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 4. Title and Subtitle<br>DETECTION OF ALTERATION ASSOCIATED WITH A PORPHYRY COPPER DEPOSIT IN SOUTHERN ARIZONA | | 5. Report Date<br>February 1, 1977 |
| | | 6. Performing Organization Code |
| 7. Author(s) M. J. Abrams, B. S. Siegal | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>JET PROPULSION LABORATORY<br>California Institute of Technology<br>4800 Oak Grove Drive<br>Pasadena, California 91103 | | 10. Work Unit No. |
| | | 11. Contract or Grant No.<br>NAS 7-100 |
| 12. Sponsoring Agency Name and Address<br>NATIONAL AERONAUTICS AND SPACE ADMINISTRATION<br>Washington, D.C. 20546 | | 13. Type of Report and Period Covered<br>Technical Memorandum |
| | | 14. Sponsoring Agency Code |
| 15. Supplementary Notes | | |

16. Abstract

The author has identified the following significant results. Alteration associated with a known porphyry copper deposit, Red Mountain near Patagonia, Arizona, has been delineated using spectral reflectance data, acquired by Landsat, a field spectrometer, and by NASA's Bendix 24-channel Multispectral Scanner (MSDS).

Computer processing of Landsat MSS data was performed using contrast stretching and band-to-band ratioing. A false color ratio composite picture showed color anomalies which coincided with known areas of alteration on and about Red Mountain. A helicopter survey of the study area was undertaken using the Jet Propulsion Laboratory's portable field reflectance spectrometer. One hundred and fifty-six spectra were obtained in the 0.4 to 2.5 μm wavelength region. The spectra were digitized and contour maps for 24 wavelength intervals were produced: no spectral anomalies were evident for the known altered areas. A contour map produced from the 1.6 and 2.2 μm ratio generally delineated the alteration areas. The 1.3, 1.6, and 2.2 μm wavelength data were canonically transformed using a transformation empirically derived from discriminant function analysis of altered and unaltered materials for the Goldfield, Nevada region, and a contour map was produced for the first canonical variable. The known areas of alteration were clearly defined on

| 17. Key Words (Selected by Author(s)) | 18. Distribution Statement |
|---|---|
| Geosciences (General)<br>Earth Resources | Unclassified -- Unlimited |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 5 | |

# PREFACE

The work described in this report was performed by the Planetology and Oceanography Division of the Jet Propulsion Laboratory.

# ABSTRACT

The author has identified the following significant results. Alteration associated with a known porphyry copper deposit, Red Mountain near Patagonia, Arizona, has been delineated using spectral reflectance data, acquired by Landsat, a field spectrometer, and by NASA's Bendix 24-channel Multispectral Scanner (MSDS).

Computer processing of Landsat MSS data was performed using contrast stretching and band-to-band ratioing. A false color ratio composite picture showed color anomalies which coincided with known areas of alteration on and about Red Mountain. A helicopter survey of the study area was undertaken using the Jet Propulsion Laboratory's portable field reflectance spectrometer. One hundred and fifty-six spectra were obtained in the 0.4 to 2.5 μm wavelength region. The spectra were digitized and contour maps for 24 wavelength intervals were produced; no spectral anomalies were evident for the known altered areas. A contour map produced from the 1.6 and 2.2 μm ratio generally delineated the alteration areas. The 1.3, 1.6, and 2.2 μm wavelength data were canonically transformed using a transformation empirically derived from discriminant function analysis of altered and unaltered materials for the Goldfield, Nevada region, and a contour map was produced for the first canonical variable. The known areas of alteration were clearly defined on the contour map. Spectral reflectance imagery in the 0.4 to 2.5 μm wavelength region was obtained with NASA's Bendix 24-channel MSDS. A false color ratio composite was created using the following ratios: 1.5/.82, 1.5/.46 and .65/.46, chosen to give the maximum differences between altered and unaltered rock. The alteration

areas in and around Red Mountain were identifiable. Good separation was observed between limonitic alteration centered on Red Mountain and alluvial fans shed northward, and areas of silicic, non-limonitic alteration to the east.

This paper presents the results of a joint Jet Propulsion Laboratory-Continental Oil Company-Kerr McGee Oil Company project to develop remote sensing exploration techniques for identifying hydrothermal alteration zones associated with porphyry copper deposits. The study area centers around Red Mountain in Southern Arizona, near the town of Patagonia. Red Mountain, a 3 x 4 km mountain, consists of hydrothermally altered Tertiary rhyolitic rocks, and overlies a large unmined porphyry copper deposit. Tertiary alluvial fans, derived from Red Mountain, extend 2.5 km to the north. Other lithologies exposed locally include Tertiary and Mesozic extrusives and intrusives, and Paleozoic sediments.

Three types of data were analyzed in an attempt to delineate the areas of hydrothermal alteration: 1) Landsat MSS imagery; 2) Helicopter-acquired reflectance spectra; and 3) MSS imagery acquired with NASA's Bendix 24-channel scanner. Computer processing algorithms, developed during a study of alteration at Goldfield, Nevada, were applied to the data.

Two sets of Landsat MSS computer tapes were acquired for the test area, E-1156-17280 (December 26, 1972) and E-1678-17210 (June 1, 1974). Preliminary computer processing of both sets of tapes was performed to remove noise, correct dropped data lines, and rectify geometric distortions resulting from the Earth's rotation and satellite motion. Pictures were produced from each set of tapes for the four MSS spectral bands. Examination of the December pictures indicated excessive seasonal vegetative cover and extreme shadowing due to low sun angle. These factors rendered the pictures unsatisfactory for further study.

Vegetative cover and shadowing were less on the June pictures. Band-to-band ratios were constructed from the digital data. (Ratio images remove, to the first order, variations in brightness due to topography, and thus gave a truer picture of the spectral characteristics of a material.) Three ratio positive transparencies (4/5, 5/6 and 6/7) were combined on an additive color viewer to produce a false-color composite picture. Ratio 4/5 was projected as blue, 5/6 as green, and 6/7 as red. A subtle but noticeable red color anomaly centered on Red Mountain was observed. Other less obvious red color anomalies observed in the vicinity of Red Mountain were: 1) an area adjacent to the northwest of Red Mountain, coinciding with the alluvial fans flanking Red Mountain; 2) an area about 8 km to the northwest; and 3) an area about 5 km east of Red Mountain. These three areas also correspond to areas of known hydrothermal alteration.

In order to obtain a better understanding of the spectral characteristics of the altered rocks at Red Mountain, a field reconnaissance of the test area was undertaken and samples were collected from three sites of known hydrothermal alteration. Laboratory measurements of the spectral reflectivity in the 0.5 to 2.5 μm wavelength region (see Figure 1) revealed prominent absorption bands at 0.85 μm, 1.4 μm, 1.75 μm, 1.9 μm, and 2.15 μm. The 0.85 μm absorption band is associated with ferric iron, a constituent of limonite, hematite, and goethite, which are minerals characteristic of alteration. Absorption bands at 1.4 μm and 1.9 μm are characteristic of adsorbed water of hydrous minerals such as limonite. The 1.75 μm and 2.15 μm absorptions are assigned to the $OH^-$ stretching of clay minerals, which are also characteristic of hydrothermal alteration.

In the wavelength region spanned by the Lanisat MSS, 0.5 $\mu$m to 1.1 $\mu$m, only the absorption band at 0.85 $\mu$m due to ferric iron can be detected. The influence of this absorption band is to strongly depress the reflectance of altered rocks in MSS bands 6 and 7, and is inferred to be the cause of the color anomaly seen in the false color ratio composite picture.

As part of a broader research program to determine the optimal wavelength regions for identifying hydrothermal alteration, an aerial survey of the test area was performed using the Jet Propulsion Laboratory's portable reflectance spectrometer. The spectrometer measures reflectivity in the range of 0.4 to 2.5 $\mu$m. Measurements were acquired by helicopter for a 9 x 10 km area about Red Mountain. One hundred fifty-six spectra, each covering a 9 x 25 m area, were obtained based on a rectilinear sampling grid with 80 m spacing. The spectra were digitized at 0.05 $\mu$m intervals for the wavelength region of 0.4 to 1.0 $\mu$m and 0.10 $\mu$m intervals thereafter. Contour maps were produced for each of the 24 intervals; no spectral anomalies were evident for the known alteration areas.

Based on previous analysis of spectra of hydrothermally altered and unaltered materials in Goldfield, Nevada, a contour map was produced from the ratio of the 1.6 $\mu$m and 2.2 $\mu$m wavelength region. High ratio values are indicative of hydrothermally altered materials. The highest ratio values on the contour map of Red Mountain delineated, in general, the known altered areas. The 1.3, 1.6 and 2.2 $\mu$m wavelength spectral data for Red Mountain were canonically transformed using a transformation which was empirically derived from discriminant function analysis of hydrothermally altered and unaltered materials in the Goldfield, Nevada region. A contour map was produced for the first canonical variable data. In general, the contour map delineated the altered zones within the test area.

Multispectral reflectance imagery for the test area were obtained by NASA's 24-channel MSDS in the wavelength region of 0.4 to 12.5 $\mu$m. A false color ratio composite was produced by projecting the ratios 1.5/.82, 1.5/.46, .65/.46 in blue, green and red, respectively. These ratios were chosen after analysis of the field spectra, in order to provide the maximum differences between altered and unaltered materials. (Due to sensor malfunction, the 2.2 $\mu$m image was not available.)

Due to the heavy vegetation cover, Red Mountain appears green and yellow. Limonitic alteration on Red Mountain appears yellow in those areas which are less heavily vegetated. The northward shed alluvial fan composed of limonitically altered debris appears red on the imagery. The non-limonitic, silicically altered areas to the east of Red Mountain appear blue. All the altered areas are distinct in color with respect to both the unaltered areas and the heavily vegetated areas.

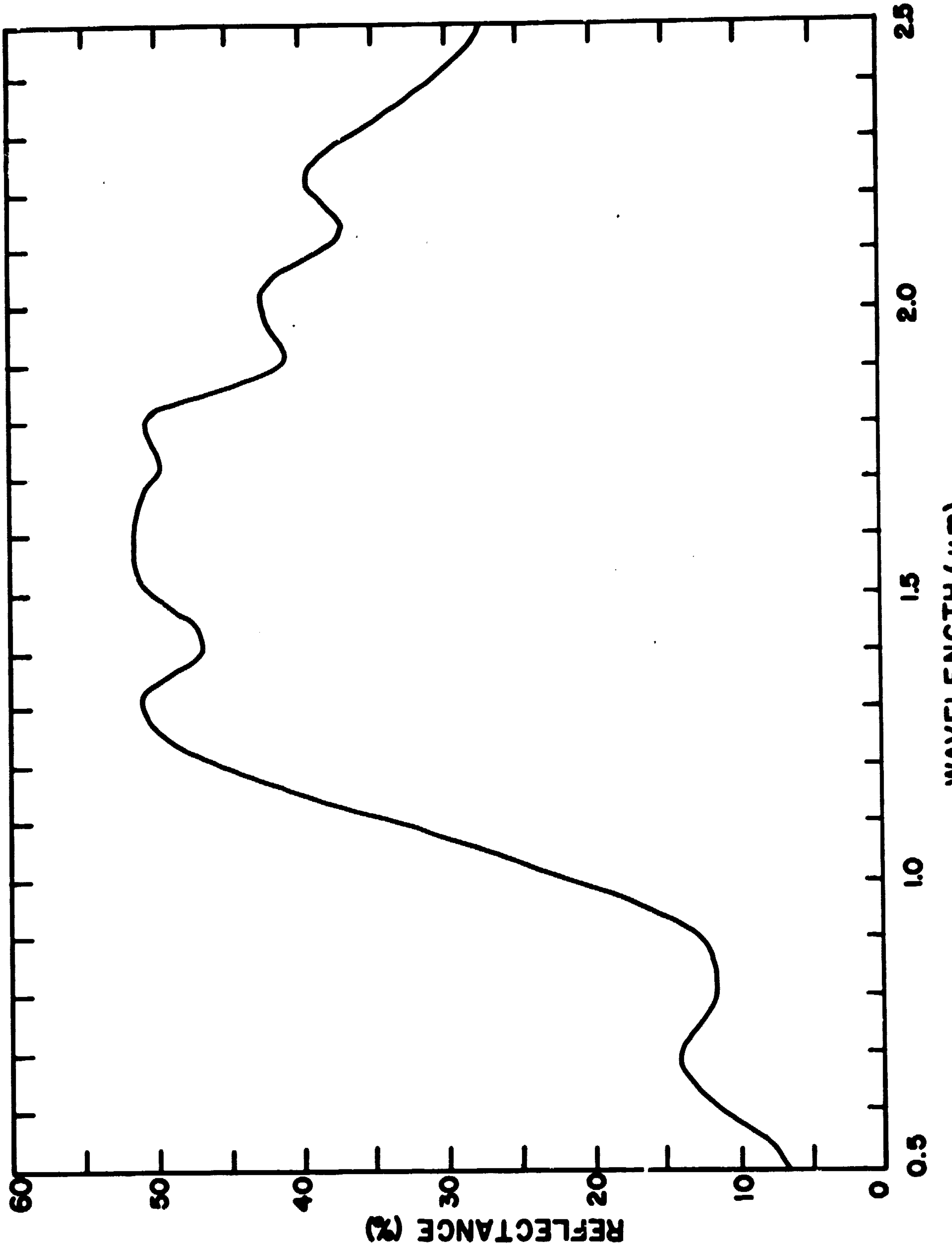


Figure 1. Spectral reflectance of altered material at Red Mtn., Arizona.



NASA-JPL-Coml. L.A. Calif