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Iron-Absorption Band Analysis for the Discrimination of Iron-Rich Zones

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Washington, D.C. 20244

10 July 1973

Type II Progress Report for Period 1 January 1973 - 30 June 1973

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Greenbelt, Maryland 20771

NOTICE

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16. Abstract

Study has concentrated on the two primary aspects of the project, structural analysis through evaluation of lineaments and circular features and spectral analyses through digital computer-processing techniques. Several previously unrecognized lineaments are mapped which may be the surface manifestations of major fault or fracture zones. Two of these, the Walker Lane and the Midas Trench lineament system, transect the predominantly NNE-NNW-trending mountain ranges for more than 500 km. Correlation of major lineaments with productive mining districts implies a genetic relationship, the 50 circular or elliptical features delineated suggest a related role for Tertiary volcanism.

With regard to spectral analysis, color-ratio composites have been used to identify limonitic zones and to discriminate mafic and felsic rock by combining diazo color transparencies of three different ratios (blue for 0.5-0.6/0.6-0.7μm, yellow for 0.6-0.7/0.7-0.8μm, and magenta for 0.7-0.8/0.8-1.1μm). EROS Data Center scene identification number for color composite in this report is ER 1 CC 500. Refinement of enhancement procedures for the ratio images is progressing. Fieldwork in coordination with both spectral and structural analyses is underway.

17. Key Words Suggested by Author
Structural Analysis
Computer processing
Rock discrimination
Ratioing

18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
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Figure 2A. Technical Report Standard Title Page. This page provides the data elements required by DoD Form DD-1473, HEW Form OE-6000 (ERIC), and similar forms.

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Type II Progress Report
ERTS-A

a. Title: Iron-absorption band analysis for the discrimination of iron-rich zones.

ERTS-A Proposal No.: 9648

b. GSFC ID No. of P.I.: I 345

c. Problems relating to progress:

Spring snowfall caused a 1 month delay in initial field study, but this work was carried out between April 30 and May 4. Prior to the field week, the spectroradiometer needed to measure spectral reflectances in the field broke down, necessitating a second field trip when the instrument was again functioning. The ground spectral data were finally collected the week of June 4. These measurements have not yet been received for analysis because of necessary preliminary processing. The additional problem of gathering spectral measurements from a platform intermediate to ERTS and ground level is being examined.

A digital computer-processing technique has generated a viable set of ratio images for analysis of spectral differences among MSS bands. Although an atmospheric correction factor has been applied to the ratio images without loss of data, the process seems to overemphasize the scan lines. An averaging technique by which the scan lines were smoothed out was attempted, but the resulting degradation in image quality offset the benefits. Problems with enhancement methods, such as stretching the ratio images and color filtering and compositing several of the ratio images, are being evaluated. Density histograms seem to be a necessary accompaniment to the ratio image in order o decide more efficiently which part(s) of the image should be stretched. In addition, viewing the ratio images in an I^2S Mini-Adcol Viewer has been found more restrictive than producing color-ratio composites with a diazo machine.

Scale differences among computer-processed images, published maps, and available aerial photographs have posed problems. Valuable time has been spent bringing much of the data to one scale. Completion of a geologic map of Nevada at 1:5000,000, an ideal scale for this project, by the U.S. Geological Survey and Nevada Bureau of Mines seems to be several months in the future.

Statistical analyses of major and minor lineaments have been delayed because of the limited availability of pertinent existing programs and of problems in storing the spatial data on magnetic tape for future use.

Ground coverage of the test site from ERTS-I has been scant for passes in February through May because of heavy cloud cover. Hence, although older data suffice for present analysis, very few new data have been available. In addition, older data marred by Newton rings still have not been replaced. Repetitive coverage has proven to be extremely useful because seasonal variations such as snow cover and changes in water distribution have brought to notice valuable structural information.

. Accomplishments:

A series of overlays using an ERTS image mosaic of Nevada as a base (scale 1:1,000,000) has been completed. These overlays include:

1) Information derived from individual ERTS frames
   - a) major lineaments
   - b) minor lineaments
   - c) circular and elliptical features

2) Known information
   - a) separate overlays of metal-mining districts
   - b) volcanic centers and calderas
   - c) hot springs
   - d) earthquake epicenters
   - e) gravity data
   - f) aeromagnetic data

Although some mafic and a few felsic rocks can be discriminated on unenhanced MSS images, spectral contrast within the images is not adequate to identify rock type with any degree of confidence, therefore ratio images have been generated from ERTS computer compatible tapes (CCT'S) through a digital-processing technique and are currently being analyzed. The ratioing process is carried out by dividing, pixel by pixel, the values of corresponding pixels from two bands. The generated values are fed into a flying-spot cathode ray tube which converts the numbers into a photographic transparency. The new image represents the spectral differences between the two original bands.

Examination of several methods of enhancement is underway because contrast in the original ratio images is minimal. Thus far, stretching and color-ratio compositing techniques have been utilized. The stretching process involves eliminating a part of the dynamic range and expanding the remaining part of the range to a fully expanded gray scale of 255 steps. More spectral information is thereby discernible because of the increased number of gray levels in that one part of the spectrum.

The most effective color-ratio composite for a study area in south-central Nevada has been determined. The following diazo color separate and ratio combination was used: blue for 0.5-0.6/0.6-0.7μm, yellow for 0.6-0.7/0.7-0.8μm, and magenta for 0.7-0.8/0.8-1.1μm. Color variations seen in these ratio composites represent spectral reflectance differences.

Plans include:

1) Further work with ratio images and enhancement procedures. Histograms will be generated to determine the amount and positioning of the stretch. Several geologic overlays using the color-ratio composite of south-central Nevada as a base will be completed soon. When the best digital and enhancement procedures have been established, images of other areas will be processed.

2) Continued fieldwork in coordination with spectral analysis. Subtle color variations in the color-ratio composites will be evaluated in the field. In addition, some means of calibrating these spectral reflectance differences must be developed.

3) Comparison of radiance in the ERTS imagery of south-central Nevada with analyses of spectral reflectances gathered in the field with a spectroradiometer and of spectral data generated in a laboratory from rock samples of the study area.

4) Statistical analysis of the overlays of the Nevada mosaic (scale 1:1,000,000) to determine correlation of lineaments and circular features with metal-mining districts and volcanic centers. Trend-surface analyses will be carried out on the major and minor lineaments and on metal-mining-district distribution.

e. Significant results during the reporting period:

Study has concentrated on the two primary aspects of the project, structural analysis through evaluation of lineaments and circular features and spectral analysis through digital-computer-processing techniques. Both analyses are aimed toward refining new techniques for descrimination of known metallogenic areas with a natural extension towards discovering new areas for mineral exploration.

A. Lineament analysis

Lineament analysis of the study area was initiated on individual images and then expanded areally by the use of mosaics at the 1:1,000,000 scale. Principal trends are NE, NW, NNE-NNW, and ENE. Several previously unrecognized lineaments are mapped which may be the surface manifestations of major fault or fracture zones.

Three lineaments are especially noteworthy. Two of these, the Walker Lane and the Midas Trench lineament system, transect the predominantly NNE-NNW-trending mountain ranges for more than 500 km. A third major lineament, formed by the alinement of several topographic escarpments 10-20 km long, is orthogonal to the Midas Trench lineament. This lineament is marked by a distinct positive magnetic anomaly for approximately 200 km. (Mabey,1966; Robinson,1970)

Further visual analysis of ERTS images has resulted in the delineation of 50 circular or elliptical features which are presumed to be volcanic or intrusive centers. A comparison with the 78 Tertiary volcanic centers mapped in the study area by Albers and Kleinhampl (1970) indicates some good agreement between the proposed and known volcanic centers. Eight of the 21 proposed centers which do not correlate at all with the Tertiary data of Albers and Kleinhampl appear to be major centers. Alinements of centers in the Walker Lane and along the northeastern part of the Midas Trench lineament zone are reasonably convincing. Many centers, however, seem to have no obvious relationship with the main lineaments.

The coincidence of some major lineaments and productive ore bodies, namely gold , silver, copper, lead, and zinc as compiled by Jerome and Cook (1967), implies a genetic relationship. Productive districts occur preferentially along the ENE-trending lineaments in the Walker Lane and along the northeastern part of the Midas Trench lineament zone. In addition, the intersection of three previously unmapped lineaments in northwestern Nevada is the location of a highly productive metallogenic district. Some Tertiary volcanic centers appear to localize the ore deposits. Where centers are situated along lineaments, however, assessment of the role of Tertiary volcanism is more difficult because of the strong correlation of mines and lineaments.

Expansion of these preliminary results through fieldwork and through statistical analysis of recently completed overlays of Nevada should provide a clearer understanding of the complex and economically important terrain of Nevada.

References Cited

Albers, J.P., and Kleinhampl, F.J., 1970, Spatial relation of mineral deposits to Tertiary volcanic centers in Nevada: U.S. Geological Survey Prof. Paper 700-C, p. C1-C10.

Jerome, S.E., and Cook, D.R., 1967, Relation of some metal mining districts in the western United States to regional tectonic environments and igneous activity: Nevada Bur. Mines Bull. 69, 35 p.

Mabey, D.R., 1966, Regional gravity and magnetic anomalies in part of Eureka County, Nevada, in Mining Geophysics, v.1, Case Histories: Tulsa, Okla., Soc. Exploration Geophysicists, p. 77-83

Robinson, E.S., 1970, Relations between geological structure and aeromagnetic anomalies in central Nevada: Geol. Soc. America Bull., v.81, No. 7, p. 2045-2060.

B. Spectral Analysis

A combination of digital computer processing and color compositing of ERTS multispectral scanner (MSS) images has been used to identify limonitic zones and to discriminate mafic and felsic rock types in south-central Nevada. Although rocks with large albedo differences, such as basalt and the silicic volcanic and intrusive rocks, can be seen in the individual MSS images, the limonitic zones are not apparent in these images; they are detectable only locally in conventional color composites. However, ratioing of two MSS bands results in black and white transparencies which show subtle spectral differences and concurrently minimize radiance variations due to topography.

Relative spectral reflectance curves for most major rock types, vegetation, and limonitic alteration zones can be deduced from comparison of the six black-and-white ratio images of the study area. These ratios are 0.5-0.6/0.6-0.7μm (G/R), 0.5-0.6/0.7-0.8μm (G/IR_1), 0.5-0.6/0.8-1.1μm (G/IR_2), 0.6-0.7/0.7-0.8μm (R/IR_1), 0.6-0.7/0.8-1.1μm (R/IR_2), and 0.7-0.8/0.8-1.1μm (IR_1/IR_2).

If the gray areas of no change on a ratio image are assigned a value of 1, the whiter areas are those in which the numerator is greater than the denominator for the ratio. Conversely, the denominator is greater than the numerator for dark-gray and black areas of the ratio. By examining the tonal changes among and within the six ratio images for a discrete geologic material, a general relative curve may be constructed for that material.

The critical ratio for limonitic alteration areas is IR_1/IR_2 in which they appear very light. The fact that they are light implies that the IR_1 radiance is greater than the IR_2 radiance, indicating the fall-off in reflectance in the near infrared (minimum at 0.92μm) so characteristic of limonite. On the other hand, rhyolites in the ratio images provide a spectral reflectance curve characteristic of felsic rocks of increased spectral reflectance from 0.6 to 1.1, with no indication of a fall-off radiance (i.e., $G < R < IR_1 < IR_2$).

Additional enhancement is achieved by preparing color composites from these transparencies. Color variations seen in these ratio composites represent spectral reflectance differences and increase the discrimination potential. The choice of ratios and colors depends on the spectral reflectance properties of the rocks to be discriminated. For south-central Nevada, the most effective composite (fig.1) was prepared using the following diazo color separate and ratio combination: blue for 0.5-0.6/0.6-0.7µm, yellow for 0.6-0.7/0.7-0.8µm, and magenta for 0.7-0.8/0.8-1.1µm.

Basalts, appearing white on the color ratio composite, are easily distinguished from the silicic volcanic rocks that appear pink. For example, the color-ratio composite shows that a substantial exposure of the underlying rhyolite is in the center of a basalt-capped mesa southwest of Goldfield. Fieldwork confirms this. On published geologic maps, however, this exposure is not mapped. In addition to basalt/rhyolite discrimination, subtle color variations among the silicic rocks permit subdivisions which in several areas agree well with geologic maps.

Limonitic-alteration zones appear green on the color ratio composites but have subtle yellow variations which are apparently related to the type of alteration. Field observations substantiate that all the green areas on the color-ratio composite are altered, some areas more than others. The mineralized area east of Goldfield is notably green. Although the limonitic alteration zones can be discerned on the black and white ratio images, one must first know where to look. Colors allow discrimination of altered areas on a regional basis without prior knowledge of their existence.

The critical ratio IR_1/IR_2 is responsible for the green color of the limonitic zones on the color-ratio composite. It is important to realize at this point that the color transparencies are exact replicas of the black and white transparencies; that is, the light areas remain light with very little or no color, and the dark areas become appropriately colored. Therefore, as the limonitic areas in the ratio IR_1/IR_2 are very light (numerator > denominator), there is no magenta contribution to the color-ratio composite in those areas. However, blue and yellow (= green) are contributed to these areas by the G/R and R/IR ratios, respectively. On these individual ratio transparencies, the limonite zones are dark (denominator > numerator) and therefore pick up color.

The few green areas tinged with yellow may be similarly explained. In the typical limonite spectrum, a secondary fall-off in radiance occurs at about 0.65μm, included in the MSS band 0.6-0.7μm. Only in some alteration zones is this fall-off recorded. In these zones, the 0.5-0.6/0.6-0.7μm (G/R) ratio increases, thereby becoming lighter and absorbing less color (blue), whereas the 0.6-0.7/0.7-0.8μm (R/IR_1) ratio decreases, thereby becoming darker and absorbing more color (yellow). The type of limonitic alteration that more strongly reflects this secondary fall-off in radiance will therefore contain more yellow on the color-ratio composite.

The two radiance minima centered at 0.65μm and at 0.92μm only occur in the limonite spectra. Hence, the green and yellow/green areas on the color-ratio composite can only be limonitic areas because the limonite spectral reflectance curve is unique. Although mafic and silicic rocks are also distinguishable, the same degree of confidence cannot be applied to them as to limonitic alteration zones. Nevertheless, although this technique is in the initial stages of development, it already appears to have considerable potential for mineral exploration and regional geologic mapping.

f. Reports:

The following reports were prepared during February and submitted for publication to the ERTS-1 Symposium, March 5-9, 1973.

1) Rowan, Lawrence C., and Wetlaufer, Pamela H., 1973, Structural geologic and radiometric analysis of ERTS-1 images of Nevada and southern California (abs.).

2) Rowan, Lawrence C., and Wetlaufer, Pamela H., 1973, Structural geologic analysis of Nevada using ERTS-1 images: A preliminary report.

g. Changes in operation:

None

h. Changes in standing order forms:

None

i. ERTS Image Descriptor forms:

Attached

j. Data Request forms:

no changes

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	volcanics	playas	>20%snow	important mineral-ized areas	major fault zones	>60%cloud cover
1109-18061	✓			✓	✓	✓
1109-18064	✓		✓			
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1129-18172			✓			
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1124-17502		✓				
1126-17594	✓			✓	✓	✓
1126-18001		✓	✓	✓	✓	
1126-18003	✓			✓		
1126-18010	✓	✓	✓	✓		
1126-18012	✓					
1127-18053			✓	✓		
1127-18055		✓		✓		
1127-18062	✓		✓	✓		
1127-18064	✓		✓			

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*All imagery 70 mm MSS (4 bands)

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1143-17560		✓				
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1144-18010	✓	✓	✓	✓		
1161-17541	✓	✓				✓
1161-17543	✓			✓		
1161-17550	✓	✓				
1161-17552		✓				
1159-17442						

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1163-18054		✓	✓	✓		
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1163-18063	✓		✓			
1164-18105				✓		
1164-18112		✓		✓	✓	
1164-18114				✓		✓
1165-18164	✓					
1165-18170						

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1178-17501						
1179-17552		✓				✓
1179-17554		✓				✓
1180-17592	✓		✓	✓	✓	
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1182-18112		✓	✓	✓	✓	
1182-18114			✓	✓		✓
1183-18164	✓		✓			

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS		
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1197-17542	✓	✓	✓			
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1197-17551	✓	✓	✓			
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1214-17503		✓				✓
1215-17541	✓		✓	✓	✓	
1215-17543	✓	✓	✓			✓
1215-17550	✓		✓	✓		

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1217-18065	✓		✓			
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1232-17504		✓				✓
1237-18174						✓
1236-18122				✓		
1233-17542						✓
1233-17560		✓				✓

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1234-18000						✓
1234-18003						✓
1234-18005			✓			✓
1234-18012	✓	✓	✓	✓		
1235-18055			✓	✓		
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1250-17501		✓		✓	✓	
1250-17504	✓					
1251-17551						✓
1251-17553	✓	✓				
1251-17560		✓				
1251-17562		✓				
1252-18000						✓

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

*All imagery 70 mm (4 bands)

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NASA GSFC
GREENBELT, MD. 20771
301-982-5406

FC 37-2 (7/72)

DATE July 10, 1973

PRINCIPAL INVESTIGATOR Lawrence C. Rowan

GSFC I 345

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N ______
ID ______

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS		
	volcanics	playas	>20%snow	important mineral-ized area	major fault zones	>60%cloud cover
1252-18005						✓
1252-18012	✓	✓		✓		
1253-18055				✓		
1253-18061		✓		✓		✓
1253-18064	✓			✓	✓	✓
1253-18070	✓		✓			
1254-18113			✓	✓		
1254-18120		✓	✓	✓	✓	
1254-18122			✓	✓		
1267-17445						
1255-18172	✓		✓			
1255-18174			✓			
1269-17542						✓
1269-17544						✓
1269-17551						✓
1269-17553	✓	✓		✓		
1269-17560		✓				

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS		
	volcanics	playas	>20%snow	important mineral-ized area	major fault zones	>60%cloud cover
1269-17562		✓				
1268-17501		✓		✓	✓	
1268-17504		✓				
1270-18000						✓
1270-18003						✓
1270-18005						✓
1270-18112	✓	✓		✓		✓
1271-18054						✓
1271-18061						✓
1271-18063						✓
1271-18070	✓		✓			
1273-18171	✓					✓
1273-18174			✓			
1272-18113				✓		
1272-18115		✓		✓	✓	
1272-18122			✓	✓		
1285-17445						

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*All imagery 70 mm (4 bands)

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ID

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS		
	volcanics	playas	>20%snow	important mineral-ized area	major fault zones	>60%cloud cover
1286-17500		✓		✓	✓	
1286-17503		✓				
1287-17541	✓	✓				✓
1287-17543						✓
1287-17552	✓	✓				
1287-17555		✓				
1287-17561		✓				
1289-18054				✓		
1289-18060		✓		✓		
1289-18063	✓			✓	✓	
1289-18065	✓		✓			
1290-18112				✓		
1290-18115		✓		✓	✓	
1290-18121			✓	✓		
1291-18170	✓					
1291-18173						
1303-17444						

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS		
	volcanics	playas	>20%snow	important mineral-ized area	major fault zones	>60%cloud cover
1305-17542						✓
1305-17545						✓
1305-17551						✓
1305-17554						✓
1305-17560						✓

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Fig.1 -- Color-ratio composite of south-central Nevada showing limonitic zones (green to yellowish green), playas (light to medium blue), basalts (white), silicic volcanic and intrusive rocks (pink), and vegetation (orange). Prepared in cooperation with the Jet Propulsion Laboratory, Pasadena, California.

EROS Data Center scene identification number is ER 1 CC 500.