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The use of Landsat data in exploration for limonitic outcrops in the Circle quadrangle, Alaska

by

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Introduction

This report describes the use of Landsat data in exploration for limonitic anomalies in a heavily vegetated, sub-Arctic terrain, the Circle 1° x 3° quadrangle, Alaska. Landsat data have been used successfully in sparsely vegetated, arid and semi-arid regions to locate limonitic alteration associated with sulfide mineralization (for example, Rowan and others, 1974; Ballew, 1977; Vincent and Rouse, 1977). The ability to use Landsat data for exploration in non-arid regions is severely limited by the vegetation cover, simply because the rocks and soil are hidden from view. Farris (1977), for example, used Landsat data unsuccessfully in the northwestern Canadian mountains in exploration for limonitic anomalies. The results here are similar to Farris' results--unsuccessful.

Topography, geology, and vegetation of the Circle Quadrangle

The Circle three-degree sheet lies in the hilly Yukon-Tanana upland and is centered at lat 65°30' N. and long 145°30' W. Foster and others (1973) have described the regional geology of the area. Most of the hills in the upland have rounded, smooth summits at 2,000-4,000 ft, but the Lime Peak and Prindle Peak areas in the western part of the quadrangle have more rugged topography and rise to 5,200 ft. The region is underlain by discontinuous permafrost, and stone polygons, stone stripes, and solifluction lobes are well developed. The area is unglaciated except for Pleistocene alpine glaciation in the higher valleys. The central and southern parts of the quadrangle are underlain by deformed metamorphic rocks of late Precambrian to Paleozoic(?) age. The metamorphic rocks have been intruded by Mesozoic and Tertiary granitic batholiths and smaller plutons which are more resistant to erosion and underlie the higher knobs in the quadrangle. The metamorphic foliation trends from west-southwest to east-northeast across the quadrangle. The metamorphic rocks grade from schistose in the northwest to gneissic in the southeast. The metamorphic province is bordered on the north by the Tintina fault, a major right lateral zone of offset which parallels the Denali fault zone further south. The Yukon River and associated sediments cover the northeast edge of the quadrangle, and the Yukon Flats lie directly north of the study area.

Mineralization in the Circle quadrangle is associated with the margins of the granitic intrusions. Prospects of antimony, gold, copper, monazite, lead, and zinc associated with quartz veins are present in widely scattered localities in the upland (Cobb, 1972). Limonitic outcrops are rare. Active placer gold mines are widespread in the Circle quadrangle. The absence of gold lodes sufficient to explain the abundance of placer gold suggests that the gold was derived from rocks already eroded away.

The Circle quadrangle has a dense cover of vegetation. Forest, predominantly yellow birch and black spruce, covers the land below about 3,000 ft. Birch trees dominate on the south-facing slopes, and black spruce prefer the north-facing. A dense, springy tundra mat of low shrubs and grasses covers the ground elsewhere, except along active talus slopes, stream banks, landslide scars, and at the highest elevations. Inactive talus slopes are commonly covered by orange, green, and black lichen. The birch trees, grasses, blueberry and bearberry bushes, and other low shrubs undergo an autumn color change beginning after the first freeze. The birch trees turn bright yellow, blueberry and other shrubs turn bright red, and the grasses turn a golden-brown straw to reddish-brown color. These color changes typically commence in early August.

Landsat data

A Landsat multispectral scanner (MSS) image recorded on August 23, 1977 was used in this work (ID 2944--00835, sun elevation angle = 33°). This was not an optimal image to use because of the low sun angle with consequent shadows due to surface terrain roughness, but no cloudfree images from mid-summer cover the entire Circle quadrangle.

Two different methods were used to extract spectral information from the Landsat data for limonite detection--1) a color- ratio composite image, and 2) a MSS 4/5 grayscale dotprint. Both procedures used ratios of Landsat digital numbers to subdue the effects of surface topography and to enhance the presentation of spectral information in the data. The color-ratio composite (CRC) image was created at 1:800,000 scale with the 4/5, 4/6, and 6/7 ratios in red, blue, and green, respectively. This is apparently similar to the procedure used by Farris (1977) in northwestern Canada. A CRC image was made before and after a path radiance correction (Vincent, 1973; Kowalik, 1981) to subdue the residual topographic effect and to minimize any false anomalies on well-illuminated topographic slopes. The final correction was chosen by modifying it slightly until the topographic pattern present in the ratio dotprints was minimized. In this manner, the path radiance correction was also finely tuned to minimize false anomalies on poorly illuminated surfaces, a problem which arises if too large a correction is applied. The path radiance correction was small (5,3,1,0 digital values in bands 4,5,6, and 7, respectively), and was found to have little visible effect upon the CRC. A black-and white-print of the 4/5 ratio appeared somewhat flatter after the correction--that is, it had subdued topography. Limonitic areas appear green on similarly constructed CRC's of arid regions. The author identified 7 anomalous-appearing green and blue areas on the CRC. The anomalies range from

1-10 km in diameter.

In the second processing method, the individual, path radiance corrected 4/5 ratio was printed in a gray scale rendition at 1:63,360-scale, the scale of the inch-to-a-mile maps in the Circle quadrangle. The same path radiance correction as was used in bands 4 and 5 on the CRC had a very apparent effect of subduing the tendency for anomalies to occur preferentially on well-illuminated slopes. Pixels with the lowest 4/5 values were printed in black. For the black pixels, the satellite measured a larger radiance in band 5 than in band 4 because of stronger absorption of green light (band 4) than red (band 5) by the surface material. The black pixels are ostensibly more limonitic in character than the gray or white pixels on the dotprints. The dotprints have the advantage that small anomalies only several pixels in size (1 pixel = 79x79 m) can be selected and accurately located on the topographic maps. The ability to extract small anomalies was considered crucial, because of the minimal outcrop area and lack of known alteration in the Circle quadrangle. The 4/5 dotprints were more intensely searched for anomalies within and adjacent to the granitic plutons, because mineralization in the quadrangle is known to be associated with the margins of the plutons. Thirty-six clusters of black pixels (2 pixels and larger) were identified and numbered as anomalies. Areas with low 4/5 values which are restricted to well-illuminated or to poorly illuminated slopes, and which also lay in unison with the pattern of brightness generated by illumination of the topography during imaging were not considered as anomalies. Such 4/5 values can be caused by a path radiance correction which is respectively either locally too small or too large. When choosing anomalies, a band 5 grayscale dotprint was overlaid upon the 4/5 dotprint to identify and eliminate from consideration such false, topographically controlled anomalies.

Checking of anomalies and Results

Color-infrared airphotos from August 1980 at about 1:62,000-scale were obtained for 35 of the total 44 anomalies. The airphotos showed that many of the anomalies were likely due to lower vegetation density. Other anomalies showed no apparent color or textural contrast with the surroundings on the photos.

U.S. Geological Survey data (Foster, 1981, oral communication) from previous field seasons in Circle quadrangle were studied for those anomalies which lay adjacent to field stations. A field station near anomaly No. 27 mentioned iron staining near a contact of schist and granite. Another field station near anomaly 15A indicated highly iron stained quartzite and schist. For seven other anomalies near field stations, the field notes did not mention iron staining.

Subsequently, 14 of the 44 areas were visited by helicopter between August 26 and 29, 1981. The season of the field trip corresponds to the date of the satellite image, 4 years earlier on August 23. None of the anomalies visited were caused by limonitic rock or soil. Table 1 is a list of anomalies visited and their cause. The iron-staining near anomaly 15A was not located, but iron-staining was not the cause of that Landsat anomaly. The other anomaly (No. 27) with field notes indicating nearby iron-staining, was not visited due to helicopter malfunction.

Discussion

The anomalies visited are all caused by a relative lack of "greenness" of the vegetation compared to the surroundings. The lack of greenness can be subdivided into two cases: 1) low vegetation density caused by a larger percentage of outcrop and rubble due to high altitude or because of a previous fire burn; 2) autumn colors intensely developed in local patches of shrubs (brilliant-red blueberry and bearberry bushes) and straw-brown to reddish-brown grass in meadows.

Figure 1 shows five spectral curves which help explain the negative results of this exercise. These five curves are intended to show the relative spectral characteristics of five key surfaces involved in this work: 1) straw-brown to reddish-brown grass from anomaly No. 49, 2) an autumn-red blueberry leaf from anomaly No. 45, 3) a healthy green leaf, 4) the weathered surface of a non-limonitic granite from anomaly 43, and 5) the limonitically weathered surface of an ultramafic rock from southwestern Oregon.

These are individual curves recorded in the lab on a Beckman Model 5270 spectrophotometer [1]- not in the field in vivo. Plant samples 1 and 2 were recorded 1 week after returning from Alaska. The samples may have dried out somewhat during that week, but no visible changes occurred in the plant samples during that time. Sample 4 is a maple leaf showing typical green leaf reflectance characteristics. It was picked from outside the laboratory in Denver just prior to the spectral run. Sample 5, a limonitically weathered surface of an ultramafic rock from the Josephine ultramafic complex of southwestern Oregon, shows typical iron-oxide absorption features. These 5 samples are by no means a statistical sample of the 5 surfaces in the Circle quadrangle, but they provide a useful tutorial base from which to proceed in the absence of field spectrometer data.

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[1]The use of brand names or trademarks in this report are for descriptive purposes only and do not necessarily constitute endorsement by the USGS.

The four Landsat band passes are labeled on figure 1, and the 4/5, 4/6, and 6/7 ratios for these five spectral curves are listed in table 2. The reflectance values were calculated by weighting the reflectance curves with the Landsat filter response values. The reflectance ratios show why the CRC and 4/5 dotprints provided false anomalies. In terrain sparsely dotted with green vegetation (green-colored in nature due to chlorophyll absorption of the red and blue light), pixels of limonitic rocks will have the smallest 4/5, among the smallest 4/6, and the largest 6/7 ratios in the scene. Because 6/7 is commonly printed in green on a Landsat CRC image, the limonitic rocks will appear green on a CRC of such sparsely vegetated terrain. In the Circle quadrangle, the reddish-blueberry bushes and the straw-brown to reddish-brown grass have very low 4/5 and 4/6 ratios, and their 6/7 ratios are not very different from that of the green leaf. The reddish blueberry bushes and brownish grasses, therefore, appear green on the CRC because relatively less red and blue are printed in those pixels than in the surroundings which are spectrally more akin to the green (in vivo) leaf. Farris (1977) also found numerous false anomalies due to yellow-brownish colored grass in northwestern Canada.

The areas of lowest vegetation cover in the Circle quadrangle occur at high altitude (3,500 ft+) and appear as large, topographically controlled, fields of light blue on the CRC. Small, scattered areas of light blue due to local outcrops, also occur at lower elevations and appear anomalous (for example, anomaly No. 50, in table 1) in contrast to the greens and oranges of the surrounding vegetated terrain on the CRC. The light-blue color occurs because the areas of sparse vegetation cover have notably larger 4/6 ratios (blue, table 2, non-limonitic granite) than do the vegetated surfaces.

On the 4/5 dot prints, any limonitic rocks would likely have larger 4/5 ratios than the reddish blueberry bushes or the brownish grass (table 2). A search of the 4/5 dotprints for the lowest 4/5 ratios was thus a useless methodology to follow for this data set. If restricted to one ratio and this Landsat data, a better method would be to find the pixels having the largest 6/7 ratio, because absorption in the .85-1.00 μm region (band 7) caused by ferric and ferrous iron (Hunt and Ashley, 1979; Hunt and Evarts, 1981) is absent in the non-limonitic and the three different vegetation spectra.

Conclusions and recommendations

The heavy vegetation cover in the Circle quadrangle and the use of Landsat data from after the autumn color change contributed significantly to the failure of this exploration effort. Landsat data from midsummer, prior to the vegetation color change, and at the highest possible sun elevation angle (about 47°) should be used. This will eliminate anomalies caused by the autumn-colored vegetation and will minimize the deleterious effect of shadow caused by surface roughness elements.

A mask of the vegetated areas using the 5/7 or 4/7 ratio (Podwysocki and Segal, 1981) would lucidly display the large area in the Circle quadrangle which is too heavily vegetated to be considered in a limonitic exploration program via Landsat. Data processing could then be tailored to maximize the extraction of information from the remaining areas of low vegetation cover in the quadrangle. The 6/7 ratio of the CRC should be stretched to enhance the upper end of the 6/7 range because any limonitic pixels should lie in that spectral region.

To improve the chances of locating small anomalies amongst those small areas not covered by vegetation, a series of large-scale (ca 1:63,360) CRC images could be used. This would combine the advantages of using three ratios in color with the dotprint's advantage of being able to specify and accurately locate small anomalies several pixels in size.

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References

Cobb, E. H., 1972, Metallic Mineral Resources of the Circle Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-391.

Ballew, G. I., 1977, Alteration mapping at Goldfield, Nevada, by cluster and discriminant analysis of Landsat digital data: in Proceedings of the II Int. Symposium on remote sensing of Env., p. 783-790.

Farris, J. H. D., 1977, Field exploration, using Landsat I maps for lead-zinc and uranium, northwestern Canadian mountains, Abstract in Program of the Third Annual Wilbram T. Pecora Memorial Symposium, Sioux Falls, South Dakota, October 30-November 2.

Foster, H. L., and Weber, F. R., Forbes, R. B., and Brabb, E. E., 1973, Regional geology of the Yukon-Tanana upland, Alaska, in Arctic Geology, American Association of Petroleum Geologists Memoir 19, p. 388-395.

Hunt, G. R., and Ashley, R. P., 1979, Spectra of altered rocks in the visible and near infrared: in Economic Geology, v. 74, p. 1613-1629.

Hunt, G. R., and Evarts, R. C., 1981, The use of near-infrared spectroscopy to determine the degree of serpentinization of ultramafic rocks: Geophysics, v. 46, no. 3, p. 316-321.

Kowalik, W. S., 1981, Atmospheric correction to Landsat data for limonite discrimination: Ph. D. Thesis, Stanford University, Stanford, California, 365 p.

Podwysocki, M. H., and Segal, D. B., 1981, Use of multispectral scanner images for assessment of hydrothermal alteration in the Marysvale, Utah, mining district: in IEEE Proceedings, Washington, D. C., p. 595-596.

Rowan, L. C., Wetlaufer, P. H., Goetz, A. F. H., Billingsley, F. C., and Stewart, J. M., 1974, Discrimination of rock types and detection of hydrothermallty altered areas in South Central Nevada by the use of computer enhanced ERTS images: U.S. Geological Survey Professional Paper 883, 35 p.

Vincent, R. K., 1973, Ratio maps of iron ore deposits Atlantic City District, Wyoming: Symposium on Significant Results, Obtained by the ERTS-1, p. 379-386.

Vincent, R. K., and Rouse, G., 1977, Landsat detection of hydrothermal Alteration in the Nogal Canyon Cauldron, New Mexico: 11th Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, p. 579-590.

Table 1.--List of spectral anomalies from the Circle quadrangle that were visited in the field

Anomaly No.	Found on 4/5 Dotprint or CRC?	Cause of Anomaly
15A,B	Dotprint	Reddish brown grass, tundra cover
14A	Dotprint	Reddish tundra cover
14B	Dotprint	Non-limonitic granitic outcrop, low vegetation density.
16	Dotprint	Nothing different from surroundings
52	CRC	Low vegetation density due to altitude(?).
28	Dotprint	Low vegetation density, granite boulders with black lichen.
10	Dotprint	Reddish blueberry and bearberry bushes.
43	Dotprint	Low vegetation density due to white-colored granite outcrops at altitude.
45	Dotprint	Reddish blueberry and bearberry bushes.
50	CRC	Bare outcrops of quartzitic schist on ridge top.
46	Dotprint	Nothing different from surroundings.
49	CRC	Straw-brown to reddish brown grass.
53	CRC	Low vegetation density due to forest fire burn.
51	CRC	Low vegetation density due to forest fire burn.
48	CRC	Straw brown to reddish brown grass

Table 2.--Ratios of Landsat bands for the five spectral curves in figure 1

	4/5 Red	4/6 Blue	6/7 Green
Straw-brown to reddish-brown grass	.60	.41	.78
Reddish blueberry leaf	.28	.15	.89
Healthy green leaf	1.52	.22	.79
Non-limonitic granite	.93	.89	.96
Limonitic ultramafic rock	.69	.60	1.03

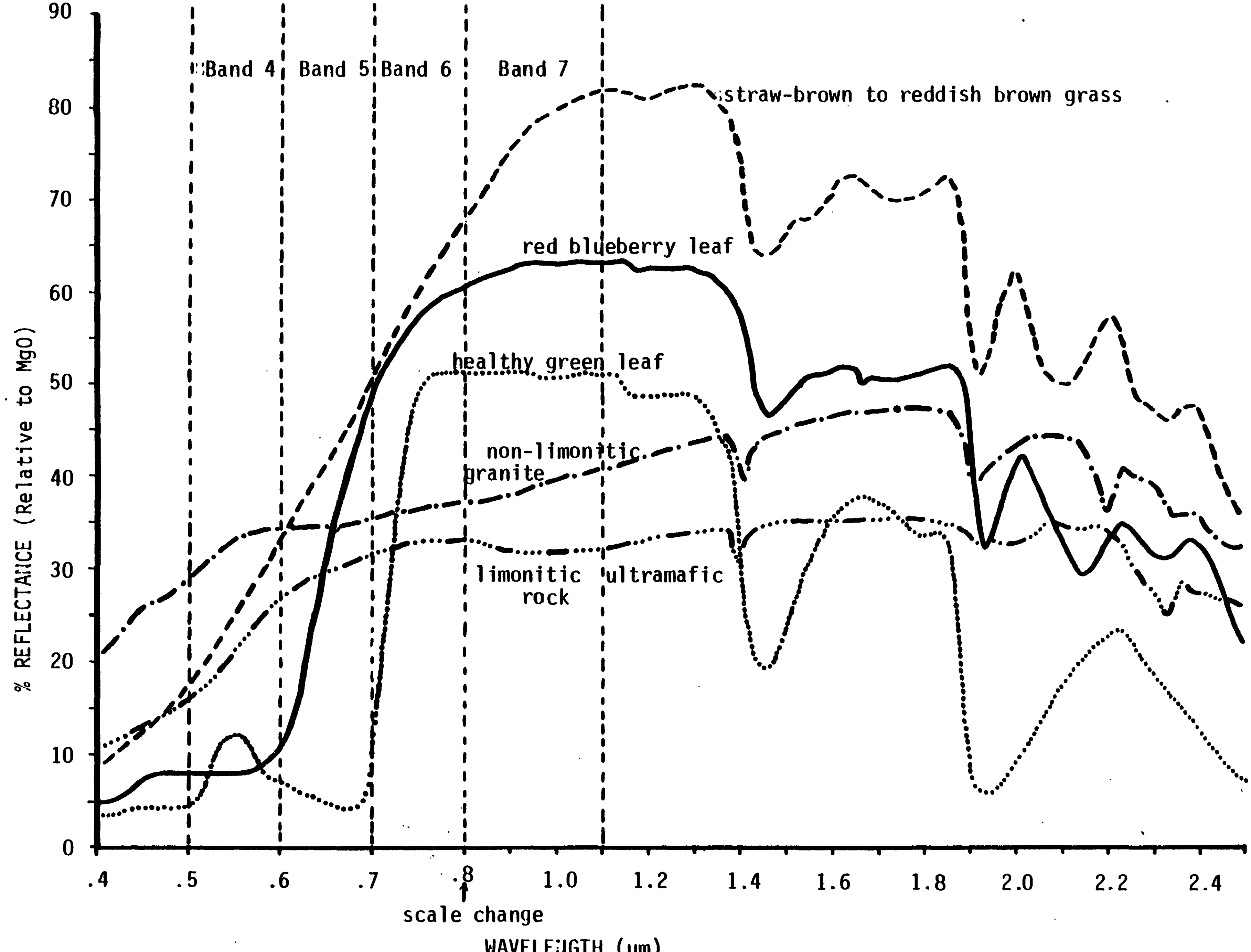

Figure 1. Laboratory spectral reflectance curves for 5 surface types. The presence of the brownish grass and the reddish blueberry shrubs on the Circle Quad