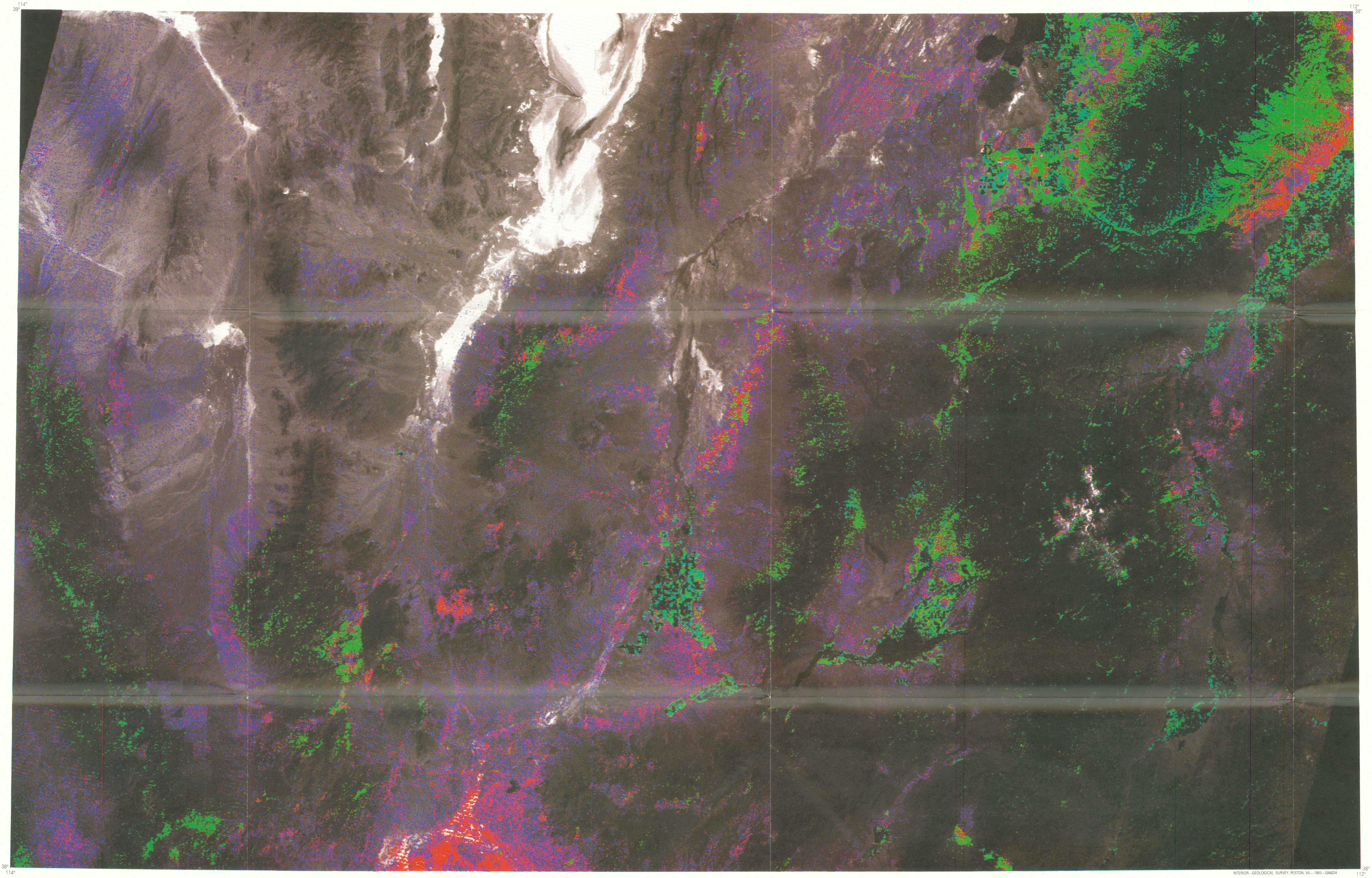
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1574

EXPLANATION

- Strong limonite
- Weak limonite
- Limonite and sparse vegetation
- Limonite and dense vegetation



DISCUSSION

This image map of the Richfield, Utah 1° x 2° quadrangle, which shows several categories of limonite, is the result of a digital classification of Landsat multispectral scanner (MSS) band-ratio data superimposed on an MSS band 5 image. Ground resolution of each picture element (pixel) is 79 m. The map was produced as a means of rapidly mapping the distribution of limonitic materials in a mineral assessment program for the quadrangle. Limonitic rocks, which are possible indicators of hydrothermally altered rocks (Rowan and others, 1974), are defined by Blanchard (1968) as rocks containing a wide range of ferric iron oxide, oxyhydride, and sulfate minerals, including hematite, geothite, lepidocrosite, and jarosite, among others. Although the map was prepared to delinate potential areas of hydrothermally altered rocks it also may be used in conjunction with a geologic map to study the areal extent of limonite within specific geologic units.

Two adjacent Landsat scenes were required to cover the majority of the Richfield quadrangle (fig. 1). Figure 2 shows an index map of prominent physiographic features and towns. Although the two scenes (ID's 1699–17353 and 10699–17355) were collected on the same day (June 26, 1974) along the same flight path, they were processed from archival high-density tape to computer-compatible tapes by the National Aeronautics and Space Administration (NASA) several years apart. During the interim period, NASA changed its MSS calibration reduction procedures. Hence, the radiometry of the two scenes was different. Radiometry was corrected to a first approximation by using histogram normalization techniques (Condit and Chavez, 1979) on the overlapping 240 scanlines between the two scenes. Scanline destriping (Condit and Chavez, 1979) then was applied to both data sets using the same parameters for both scenes to remove the modulo–6 striping common to Landsat MSS data. However, some residual striping is still present and is evident most in the classification results for the southern part of the quadrangle.

Landsat MSS ratios 4/5, 4/6, 5/6, and 6/7 were used as variables in a supervised Euclidian Distance classifier (Turner and others, 1978). A color-ratio composite image (Rowan and others, 1974) was used as an aid in defining training areas necessary for a supervised classification. Spectral signatures were derived for 12 training sets of limonitic rocks, including some with varying vegetation cover. Based on the geology of known areas and the relative mean values in the ratios for these areas, the limonitic rocks in the training sets were divided into four categories (fig. 3):

1) Strong ferric-iron absorption – rocks with a low 4/5 ratio and a relatively lower 4/6 ratio. The 5/6 ratio also generally is lower than for rocks showing weak ferric-iron absorption. The 6/7 ratio completely overlaps with several of the other categories. These band ratios are characteristic of strong concentrations of goethite, hematite, and jarosite (Hunt and Ashley, 1979). Training sites were selected in limonitically and argillically altered areas in the southern Shaunite Hills and southern San Francisco Mountains. (Stringham, 1963).

2) Weak ferric-iron absorption – rocks with higher 4/5, 4/6, and 5/6 ratios than category 1. The 4/5 and 4/6 ratios are of about equal value. The 6/7 ratio shows a wider range of values, including the range of 6/7 values of category 1. Training sites were selected in the same areas as category one and in silicically and limonitically altered rocks in the Beaver Lake Mountains (Barosh, 1960).

The broad range of 6/7 values may be due to inclusion of two different groups of limonitic materials into this category that were not recognized at the time of this classification.

Lower concentrations of the limonitic minerals hematite, goethite, and jarosite could exhibit weaker absorption at 0.5 um and 0.85 um, thus producing higher digital values in MSS bands 4 and 7 than higher concentrations of these limonitic minerals. Hence, 4/5 band ratio values will be larger for this category. The higher MSS band 7 values also will produce the lower values within the range of the 6/7 ratio for this category.

A ferrihydrite type mineral (Chukhrov and others, 1973) also could show the same weak contrasts in its 4/5, 4/6, and 6/7 ratios as low concentrations of hematite, goethite, and jarosite. However, the contrast between bands MSS 6 and MSS 7 is even weaker for ferrihydrite, (Lee and Raines, 1984). Thus, the 6/7 ratio value could be higher for ferrihydrite than the same ratio for low concentrations of hematite, goethite, or jarosite and may be the cause of the higher values in the range of 6/7 values for this category.

3) Limonitic rocks with sparse vegetation cover—rocks which have 4/5 ratios comparable to the strong ferric-iron absorption of category one, but whose 4/6 and 5/6 ratios are lower, reflecting the influence of vegetation. Inspection of aerial photographs for several areas classified in this category reveals coniferous and deciduous forest cover as high as 20–30 percent in the mountains. No estimates were made for areas in the lowlands covered by grasses or shrubs. Training sites for categories three and four were located on the east flank of the Pahvant Range, on limonitic units of the Triassic Moenkopi and Tertiary Flagstaff Formations

4) Limonitic rocks with dense vegetation cover – rocks which have 4/5, 4/6, and 5/6 ratios similar to category three above, but have lower 6/7 ratios. Examination in the field and on aerial photos indicates denser vegetation cover than category three; cover typically is from 30–50 percent. Because of the limited number of training sites in categories 3 and 4, they are combined into one group in figure 2, but are retained as separate categories on the image in order to portray variations in vegetation density cover on limonitic rocks. No attempt was made to differentiate between strong and weak ferric-iron absorption in categories 3 and 4.

Twelve training sets representing non-limonitic rocks were defined for comparative purposes. These were assigned to the non-limonitic category portrayed in figure 3. Efforts were not as exhaustive in defining all possible non-limonitic classes. So some areas remained unclassified, including bright playa surfaces and dense vegetation. For purposes of location on the image map, the MSS band 5 image data were substituted in place of the non-limonitic category and unclassified areas. Typically, dark areas in the upland are covered by dense coniferous and deciduous forests. Dark areas in the valleys are primarily cultivated crops or reservoirs. Several dark areas in the lowlands between Beaver and Cover Fort, Utah, and in the Sevier Desert are basaltic shield volcanoes and cinder cones.

The classification scheme was transferred to line printer maps at 1:24,000 and other scales (see Podwysocki and Segal (1980a, b) for examples) to locate limonitic areas in the field. Efforts were concentrated in bedrock areas, although limonitic colluvium and alluvial fans in the valleys often form patterns that pointed upslope to a locus of limonitic rocks in the uplands where vegetation masks possible limonitic rock outcrops. Field checking was done during the 1980–1982 field seasons, resulting in a map of hydrothermally altered rocks and mineral occurrences for the Richfield 1° x 2° quadrangle (Podwysocki and others, in preparation).

Generally, all known hydrothermally altered limonitic rocks fall into the strong ferric-iron absorption category. However, numerous unaltered limonitic rocks also fall into this category, such as igneous rocks stained with limonite formed by weathering processes, pink tuff, purple quartzite, hematitically stained limestone, and red, orange, and yellow aeolian sand and sandstone.

The weak ferric-iron absorption category is associated primarily with rocks containing less limonite than the strong ferric-iron absorption category. Many areas classified as showing strong ferric-iron absorption are fringed by zones showing weak ferric-iron absorption, reflecting a decrease in the amount of limonite away from the source. Such areas on the ground are pale yellow, orange, and pink and are related to hydrothermal alteration processes. Other areas showing weak ferric-iron absorption are underlain by tan to brown rocks and soils that are related to weathering of unaltered rocks.

The mixed limonite and vegetation categories were very useful in isolating areas of limonitic rocks in the vegetated upland terrains. These categories aided in the identification of extensive areas of hydrothermally altered rocks in the southwestern part of the quadrangle. When viewed on the ground, the bedrock in these areas typically had the characteristics of category one, that is, they appeared to have strong concentrations of hematite, goethite, or jarosite in the rocks. Just as in category one, both altered and unaltered rocks contained one or more of these limonite minerals.

Because of the inability to distinguish between limonite minerals of altered and unaltered rocks in Landsat MSS data, field checking, examination of available geologic data, and studying the spatial relationships of the limonitic areas were necessary to make a judgement as to their economic significance.

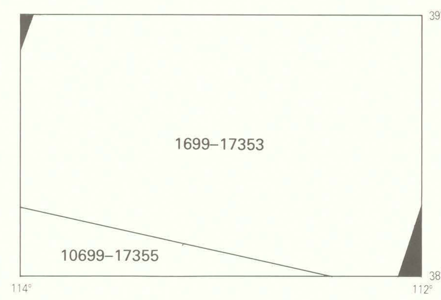


FIGURE 1.—Index map of the Richfield 1° X 2° quadrangle showing areas covered by the Landsat MSS images used in the analysis. The black areas in the northwest and southeast corners of the quadrangle indicate no data.

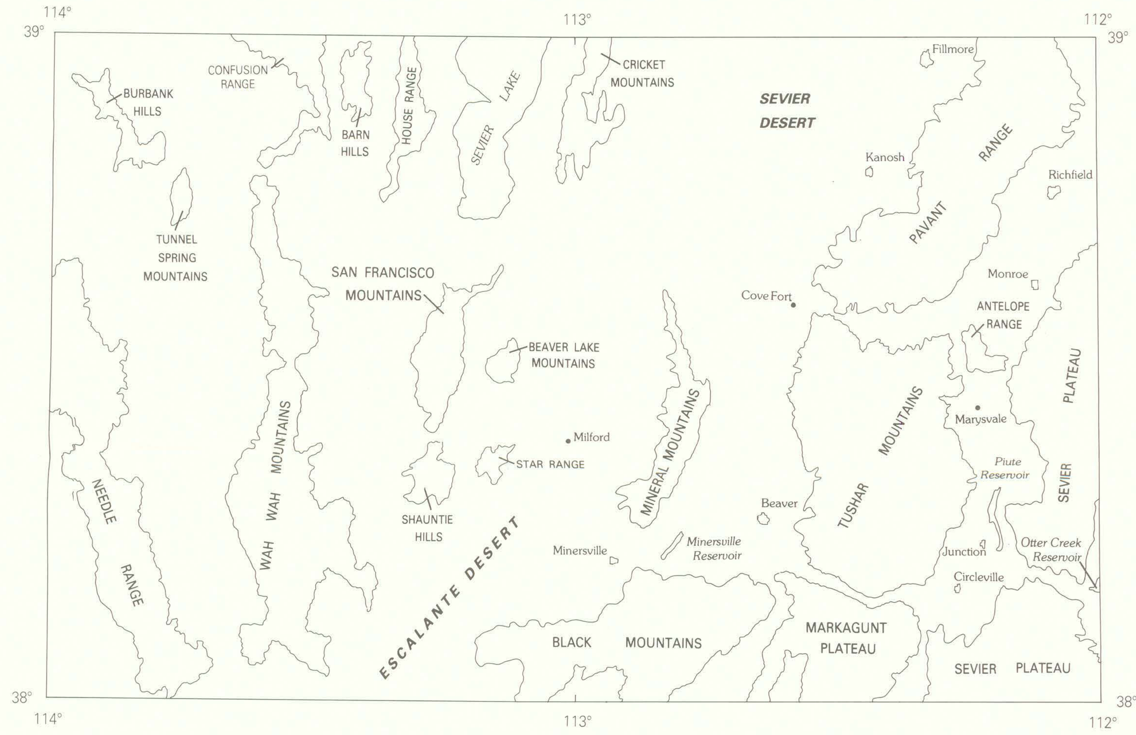


FIGURE 2.—Index map of the Richfield 1° X 2° quadrangle showing prominent physiographic features and towns.

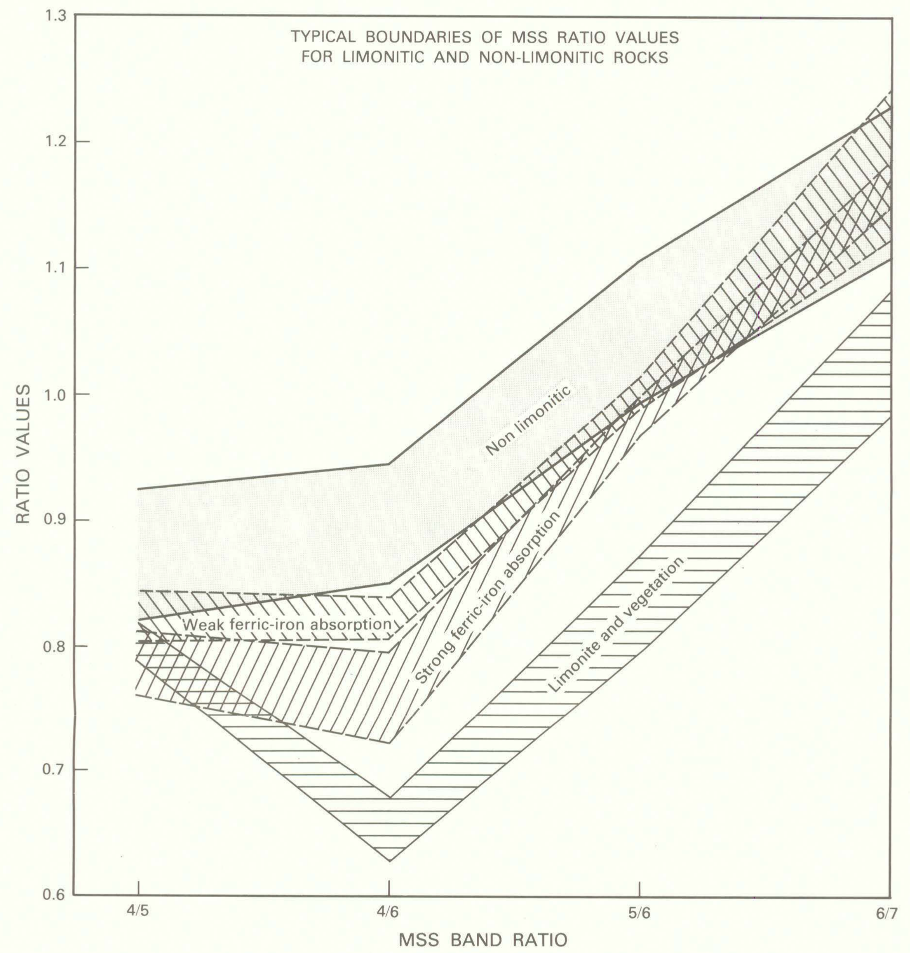


FIGURE 3.—Plot of the range of mean ratio values for the various classes of limonitic and selected non-limonitic materials.

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LANDSAT IMAGE MAP SHOWING THE DISTRIBUTION OF LIMONITIC ROCKS, RICHFIELD 1° X 2° QUADRANGLE, UTAH

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1985

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