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A Technique Using Diazo Film for Isolating Areas of Spectral Similarity

by

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Abstract

A masking technique using diazo film was devised to isolate areas of spectral similarity from image data for an area of hydrothermal alteration near the Marysvale, Utah, mining district. The technique provides a rapid and inexpensive alternative to thematic classification methods commonly used to locate and extract from image data geographic regions having specific spectral absorption features. An example is shown using band-ratio data derived from the airborne NASA (U.S. National Aeronautics and Space Administration) 24-channel Bendix scanner in the wavelength region between 0.48 and 2.39 microns.

Introduction

This paper describes a masking technique using diazo transparencies to isolate geographic regions that show specific spectral features. This technique is particularly important in areas where film products may be readily available and digital processing is an unaffordable luxury. Diazo transparencies are diazonium salt-based film positives, which are available in a variety of colors. In image processing, diazo transparencies are commonly used to construct color-composite images from black-and-white film by the color subtractive process. These color-composite images are constructed by using a different color transparency for each black-and-white film image and overlaying the diazos. The resulting image commonly displays a continuous gradation of colors.

Once an image is produced that meets the requirements of the analyst, extraction of thematic information may be accomplished either visually or by computer-assisted (supervised or unsupervised) digital classification. Photo-interpretive extraction of thematic information is relatively fast and inexpensive. However, the technique is subjective, because of both variations in color perception and the gradational nature of colors in the image. Location accuracy also may be jeopardized during the transfer of data from image to base maps.

Computer-assisted digital classification for thematic extraction is precise and reproducible; however, it is expensive, as it normally requires iterative processing of the data and, more importantly, access to a digital processing facility is required. In addition, the type of classifier used and the stringency of the limits imposed on it by the user will affect the results.

The utility of the diazo masking technique lies in the fact that once a satisfactory series of black-and-white images (and the corresponding color-composite image) are produced, a mask can be created directly from those same black-and-white images without digital processing. The method was devised during the process of defining areas of hydrothermal alteration in the Marysvale, Utah, mining district. The study area is outlined in figure 1.

Multispectral scanner data recorded between 0.48 and 2.39 microns were derived from the airborne NASA (U.S. National Aeronautics and Space Administration) 24-channel Bendix Scanner. These data were analyzed to identify 1) rocks containing ferric-iron-bearing and hydroxyl-bearing minerals, 2) rocks containing hydroxyl-bearing minerals but lacking ferric minerals, and 3) rocks containing ferric-iron-bearing minerals and lacking significant hydroxyl-mineral content.

Data from the presently operating Landsat Multispectral Scanner (MSS) allows the identification of ferric-iron-bearing rocks and bright regions, both of which may be associated with hydrothermal alteration. However, ferric-iron-bearing rocks and bright regions are not unique to altered rocks (Rowan and others, 1974, 1977). The presence of hydroxyl-bearing minerals, such as alunite, potash-rich micas, pyrophyllite, and kaolinite is also characteristic of hydrothermally altered rocks (Hemley and Jones, 1964). Consequently, the ability to detect concentrations of these minerals should be useful for mapping altered rocks that do not have ferric iron staining and for identifying ferric-iron-stained unaltered rocks that lack hydroxyl-bearing minerals (Rowan and others, 1977; Rowan and Lathram, 1980; Abrams

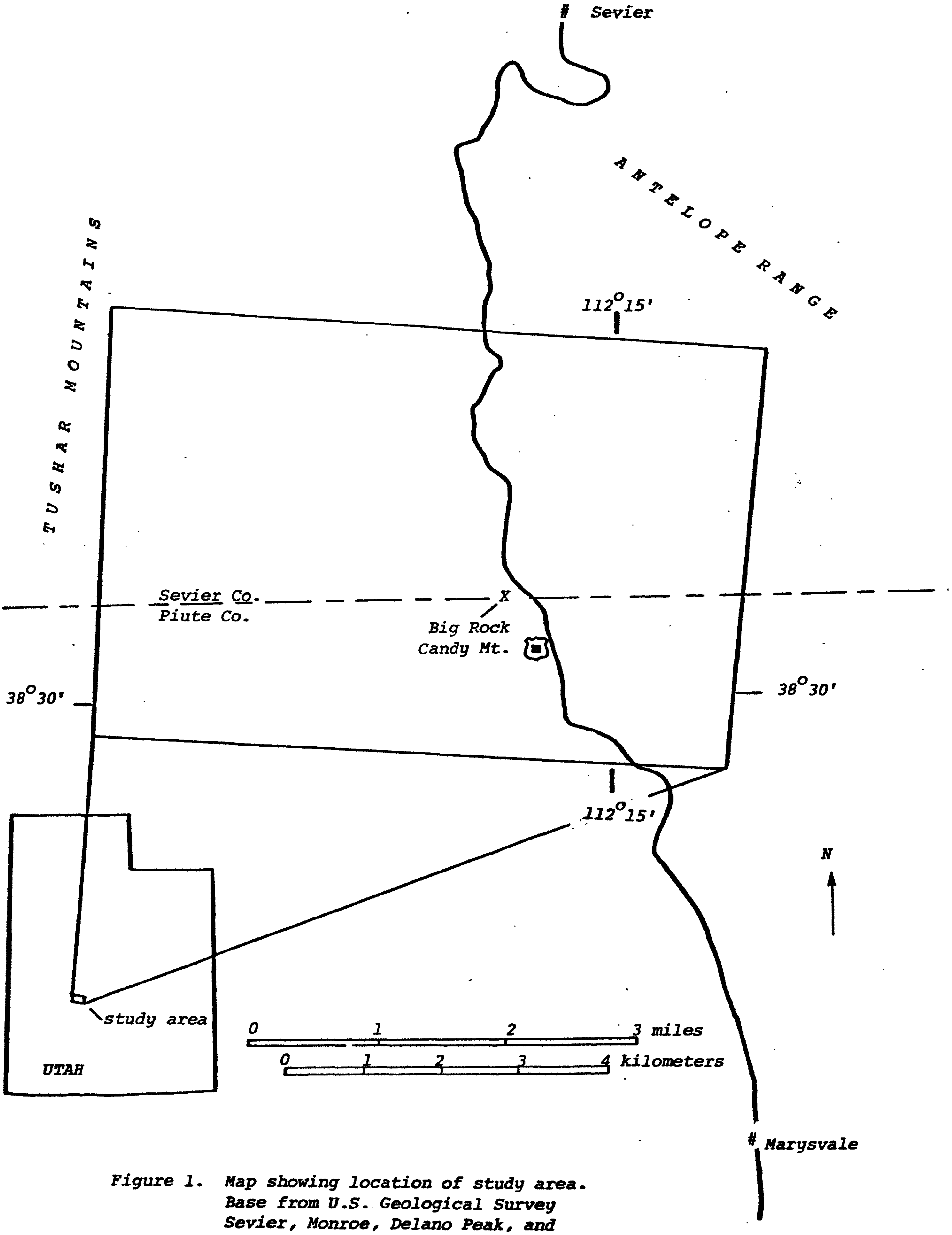

Figure 1. Map showing location of study area. Base from U.S. Geological Survey Sevier, Monroe, Delano Peak, and Marysvale 15-minute quadrangles.

and others, 1977).

Data from the airborne 24-channel Bendix scanner were used because some of the spectral bands approximate those of the proposed Landsat D Thematic Mapper, especially in the regions of hydroxyl and ferric-iron absorption. Table 1 shows the pertinent parts of the approximate reflective spectral-band coverage of Landsats 1-3 (MSS) and the NASA 24-channel scanner (MSDS) and pertinent parts of the coverage proposed for the Landsat D Thematic Mapper (TM). Specific spectral bands were ratioed because ratioing has been shown to be an effective way to emphasize subtle spectral-reflectivity differences while minimizing radiance variation due to topography and albedo (Rowan and others, 1974).

Example

Blanchard (1968) defined limonite as a general term to include ferric-iron-bearing minerals such as goethite, jarosite, lepidocrosite, hematite, and others. Color-composite images of Landsat MSS ratioed data have been used to map the distribution of limonitic rocks in semi-arid and arid regions, where they are possible indicators of hydrothermal alteration (Rowan and others, 1974). The major limitations to this method are that 1) the spectral signatures of bright nonlimonitic altered rocks are not distinctly separable from signatures of some bright sedimentary and silicic volcanic rocks, and 2) limonitic unaltered rocks are not distinguishable from limonitic altered rocks in enhanced Landsat images (Rowan and others, 1977; Abrams and others, 1977).

Analysis of field and laboratory spectra of altered and unaltered volcanic and related intrusive rocks in the 2.15-2.25-micron region shows an intense absorption band characteristic of but not unique to hydrothermally altered rocks (Hunt and Salisbury, 1970). This absorption band, which is due to O-H and Al-O-H bond stretching and bending in clays, alunite, dioctahedral micas, and pyrophyllite, shifts slightly depending upon the exact composition of the

Landsat 1-3 (MSS)

band	*um*
4	*0.5-0.6*
5	*0.6-0.7*
6	*0.7-0.8*
7	*0.8-1.1*

NASA 24-channel Bendix scanner (MSDS)

band	*um*
3	*0.46-0.50*
4	*0.53-0.57*
5	*0.59-0.64*
6	*0.65-0.69*
7	*0.72-0.80*
8	*0.76-0.80*
9	*0.82-0.87*
10	*0.98-1.04*
12	*1.53-1.67*
13	*2.12-2.39*

Landsat D (TM)

band	*um*
1	*0.45-0.52*
2	*0.52-0.60*
3	*0.63-0.69*
4	*0.76-0.90*
5	*1.55-1.75*
6	*2.08-2.35*

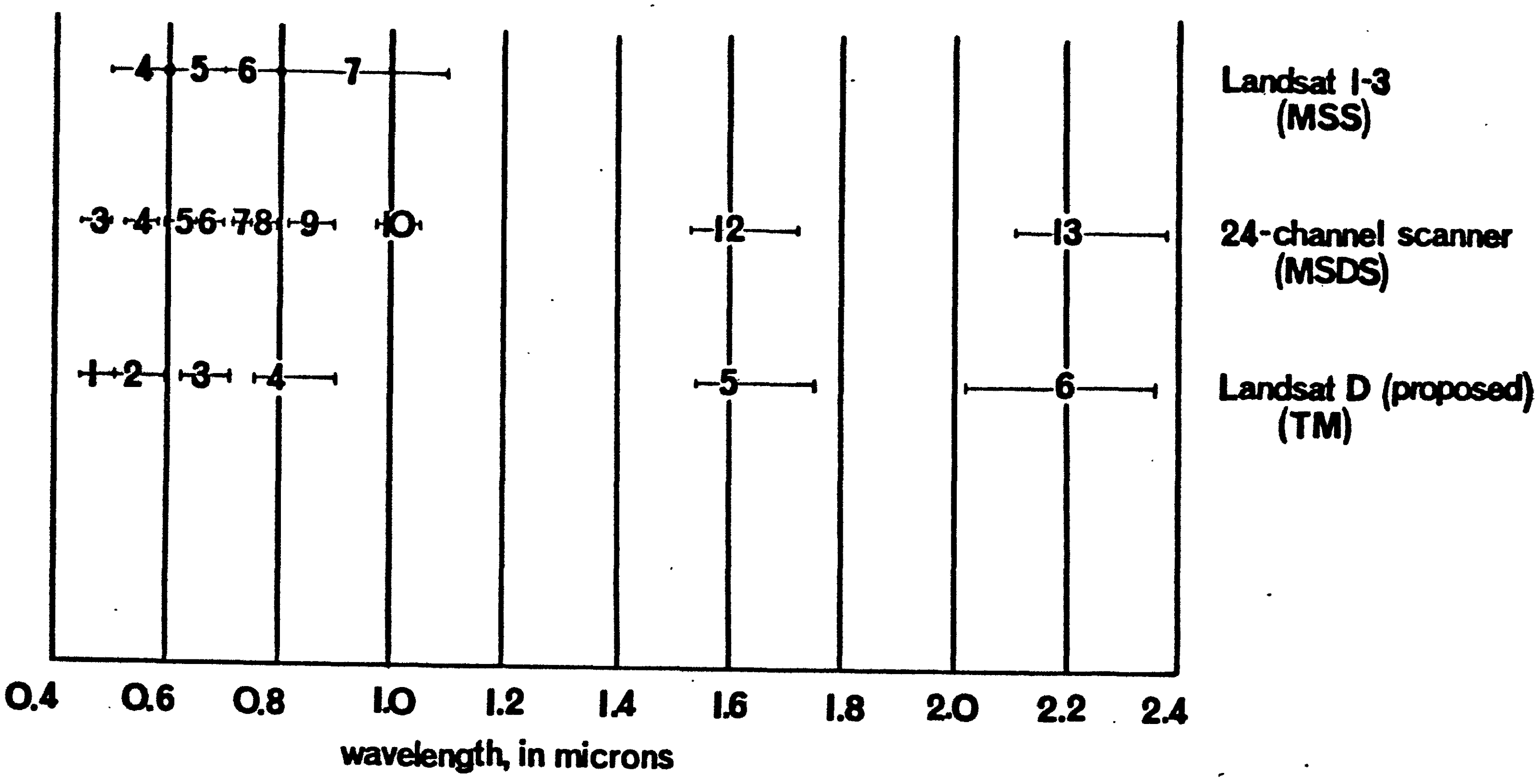

Table 1. Charts showing approximate spectral band coverage of Landsat 1-3 (MSS), the NASA 24-channel scanner (MSDS), and those bands proposed for the Landsat D Themmatic Mapper (TM).

hydrous mineral and is weak or absent in most fresh unaltered rocks (Hunt and others, 1973). Because most altered rocks attain maximum spectral reflectance near 1.6 microns, the ratio of spectral bands centered in the 1.6-micron and 2.2-micron regions can be used to identify rocks containing hydroxyl-bearing minerals. The limitations of Landsat MSS data mentioned above are thereby overcome (Abrams and others, 1977). However, additional spectral bands must be used in order to distinguish altered rocks and vegetation, because intense water-absorption features centered near 1.3 and 1.9 microns cause similar spectral contrast in vegetation (Allen and Richardson, 1968).

Figure 2 is a graph showing field spectra of a ferric-iron-bearing hydrothermally altered rock (solid line) and typical vegetation (dashed line). In the hydrothermally altered rock spectrum, the minima at 0.4-0.55 micron and 0.9-1.0 micron represent absorption due to limonite. Hydroxyl absorption is shown by a minimum in the 2.2-micron range. The vegetation spectrum shows chlorophyll absorption in the 0.4-0.7-micron range (Knipling, 1970) and low reflectance in the infrared beyond 1.3 microns due to the presence of free water in the leaf.

Method - Construction of Color Ratio Composite

Because vegetation exhibits chlorophyll absorption in the 0.5-0.7-micron range and a relatively high reflectance in the 0.8-1.1-micron range, a ratio of 24-channel scanner bands centered at 0.6 and 1.0 microns (MSDS 6/10) will be low for vegetated areas (see fig. 2, table 1). In an image, these low digital numbers (DNs) will be shown as dark picture elements (pixels) on positive film.

Similarly, because both hydrothermally altered rock and vegetation show a relatively high reflectance in the 1.5-1.7-micron region and low reflectance in the band centered at 2.2 microns, a ratio using bands centered at 1.6 and 2.2 microns (MSDS 12/13) will exhibit high DNs for areas of hydroxyl-bearing minerals and vegetation. These high DNs will appear as light pixels on

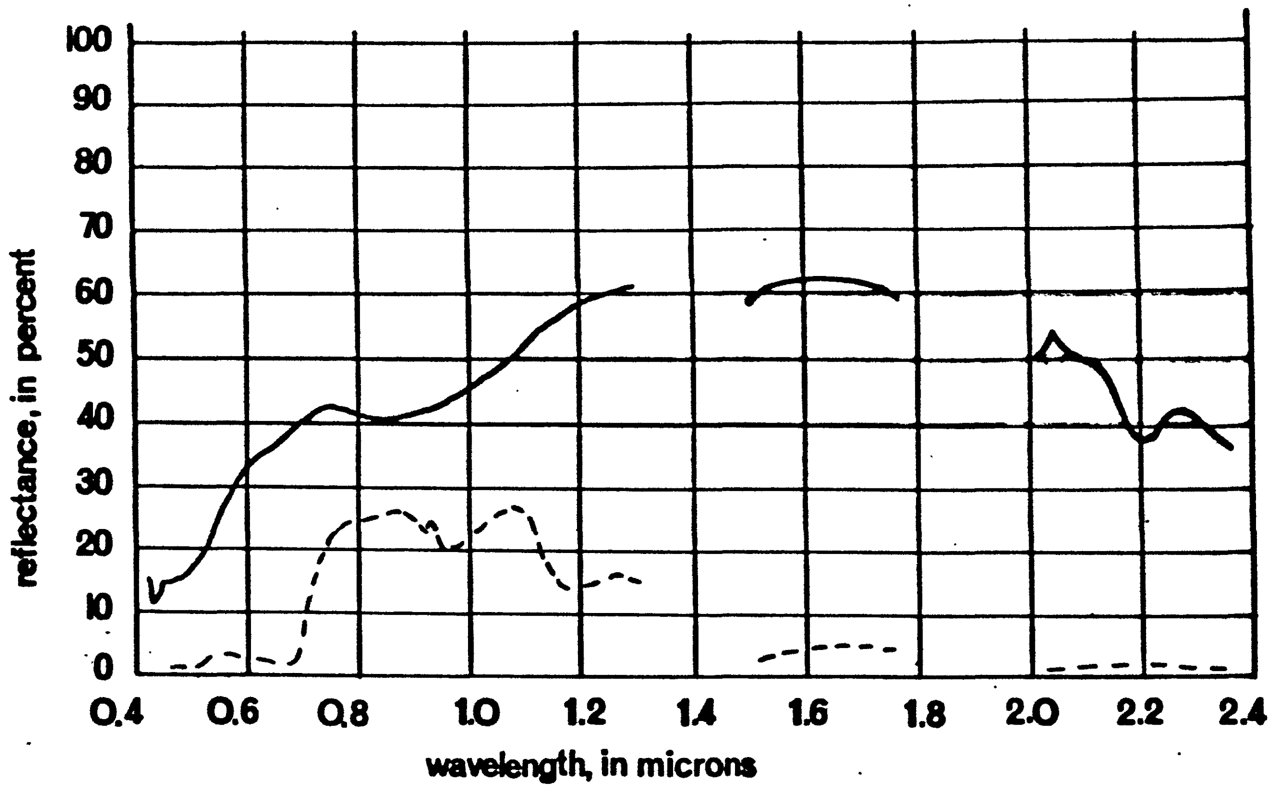

Figure 2. Field spectrum of a ferric-iron-bearing hydrothermally altered rock (solid line) from Goldfield, Nevada (courtesy of L.C. Rowan), and typical vegetation spectrum (dashed line) of Pinus monophylla (single-leaf pinyon, from Milton, 1978). In the rock spectrum, minima at 0.4-0.55 micron and at 0.9-1.0 micron represent ferric-iron absorption; minimum at 2.2 microns is due to hydroxyl absorption. The vegetation spectrum shows chlorophyll absorption in the 0.4-0.7-micron range and low reflectance in the infrared beyond 1.3 microns due to the presence of free water in the leaf.

positive film.

Because the spectrum of hydrothermally altered rock (fig. 2) shows ferric iron absorption in the 0.4–0.55-micron range and high reflectance in the 1.5-1.7-micron region, a ratio of bands centered at 1.6 and 0.48 microns (MSDS 12/3) will also be high for areas containing ferric-iron-bearing limonitic materials. These DNs will appear as light pixels on positive film.

Figure 3 is a color-ratio composite (CRC) image of the study area constructed by use of 24-channel scanner MSDS band ratios 6/10, 12/13, and 12/3. The band ratios were linearly stretched (see Condit and Chavez, 1979), and saturation cutoffs for the low and high ends of the distribution, respectively, are as follows: 6/10 ratio 22.4%, 9.4%; 12/3 ratio 1.8%, 3.4%; 12/13 ratio 3.8%, 8.1%.

Choice of stretch parameters and saturation levels is dependent upon both scene contrast and the spectral characteristics of the materials to be enhanced. The saturation limits were chosen in order to meet the requirements defined above. The ratios, diazo-color scheme, and exposure times used to produce the CRC are shown in table 2.

Areas of hydroxyl-bearing and limonitic rocks in this CRC (fig. 3) are displayed as white. Yellow represents rocks containing hydroxyl-bearing minerals lacking ferric iron. Limonitic non-hydroxyl-bearing rocks appear as blue. Vegetation appears as shades of magenta or purple, and green areas are spectrally flat.

Method - Construction of Diazo Mask

The diazo mask is produced from the same positive film images used to construct the color-ratio composite. Because the 6/10 ratio shows the presence (dark pixels) or absence (light pixels) of chlorophyll and because the 12/13 ratio depicts the presence (light pixels) or absence (dark pixels) of absorption due to hydroxyl, irrespective of its origin, vegetation can be masked out by

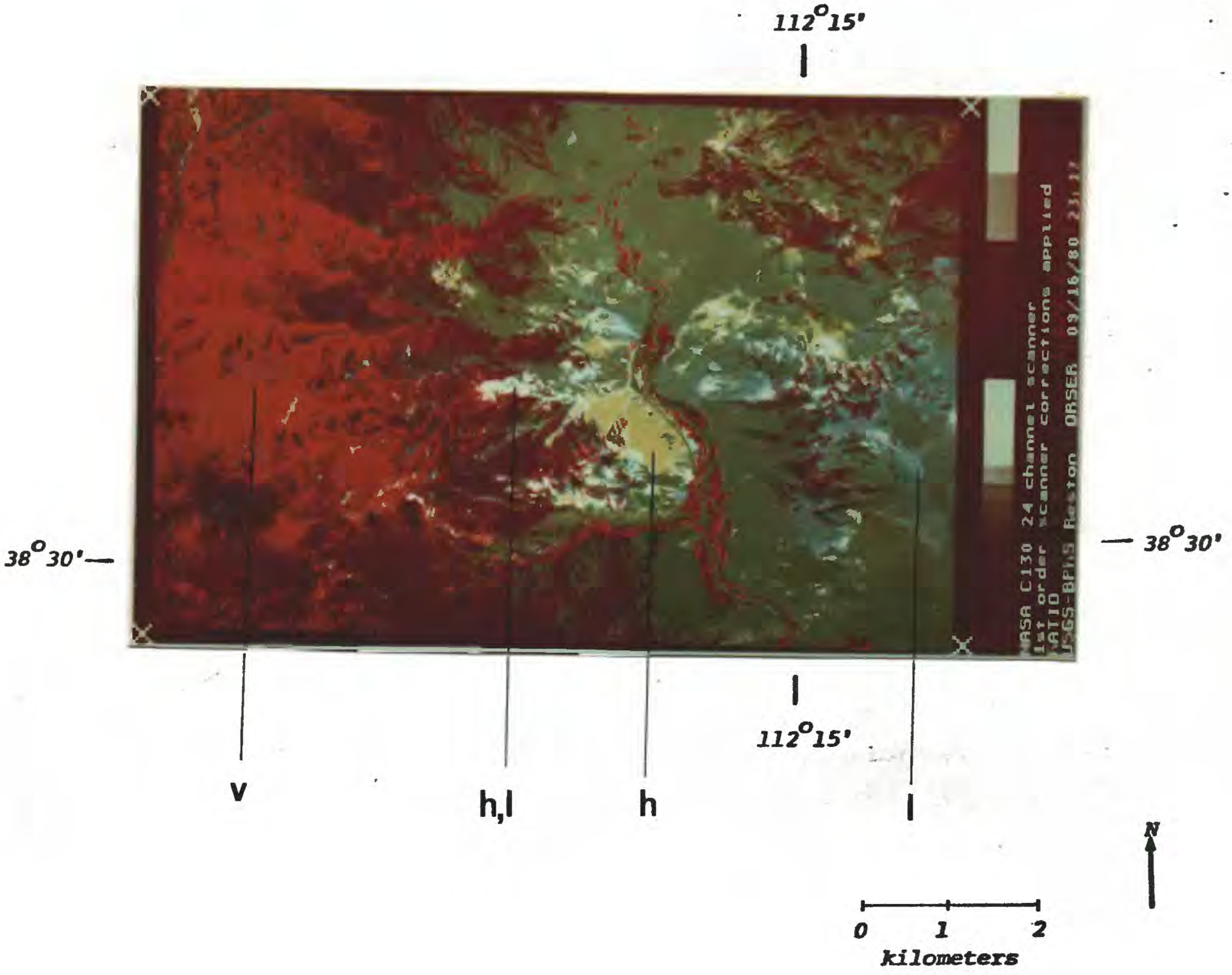

Figure 3. Color-ratio composite image of the study area outlined in figure 1. This image was constructed by use of MSDS band ratios 6/10, 12/3, and 12/13 shown respectively as magenta, yellow, and cyan.

Explanation

h - hydroxyl-bearing minerals (yellow)
v - vegetation (magenta or purple)
l - limonitic materials (blue)
h,l - hydroxyl-bearing and limonitic materials (white)

Table 2. MSDS channel band-ratios, diazo colors, and exposure times used to produce the color-ratio composite image shown in figure 3.

MSDS band-ratios	*Diazo color*	*Exposure time**
6/10	*magenta*	*90 units*
12/3	*yellow*	*75 units*
12/13	*cyan*	*120 units*

* *Arkwright Escochrome Diazo film, Arkwright Model 101 printer.* *1 unit = approximately 3 secs.*

developing an image such that all pixels having a low 6/10 ratio appear black. If all pixels that show high DNs in the 12/13 ratio are developed as transparent (white) on the image, an overlay mask created by use of the 6/10 and 12/13 band ratios will show only the hydroxyl that is not related to vegetation.

A mask constructed from band ratios 6/10 and 12/13 on double-coated black Escochrome diazo film is shown in figure 4. Areas of hydroxyl-bearing minerals appear white. Figure 5 was constructed by overlaying black and white transparency masks of the 6/10, 12/13, and 12/3 band ratios. Figure 5 shows areas of hydroxyl- and limonitic-bearing minerals as white. Note the correspondence between the yellow and white areas of figure 3 and the white areas of figure 4 and the correspondence between the white areas of figure 3 and those of figure 5.

Double-coated black Escochrome diazo film is preferable for maximum contrast; however, any single color may be used. Exposure time for figures 4 and 5 was 60 units (approximately 180 seconds). These times may vary and should be tested by overlaying the diazo masks on the previously constructed CRC image.

The masking technique described in this example is not limited to the isolation of hydroxyl- and limonite-bearing rocks. For instance, by combining positive film images of the 12/3 and 6/10 ratios, one can isolate the areas having anomalously high ferric iron content. In addition, by overlaying a contact negative of the 6/10, 12/3, and 12/13 ratio mask on positives of the 6/10 and 12/3 ratio mask, one can isolate all areas high in ferric iron but low in hydroxyl-bearing minerals.

In general, this masking procedure can be used on virtually any image data set that can be displayed as a color-composite image. Areas that appear as one of the original (primary) colors used to construct the color-composite image can be isolated by use of a diazo mask created from film positives. Colors resulting from some combination of primary colors can be isolated by use of diazo masks created from film negatives of the bands that were combined to form that color.

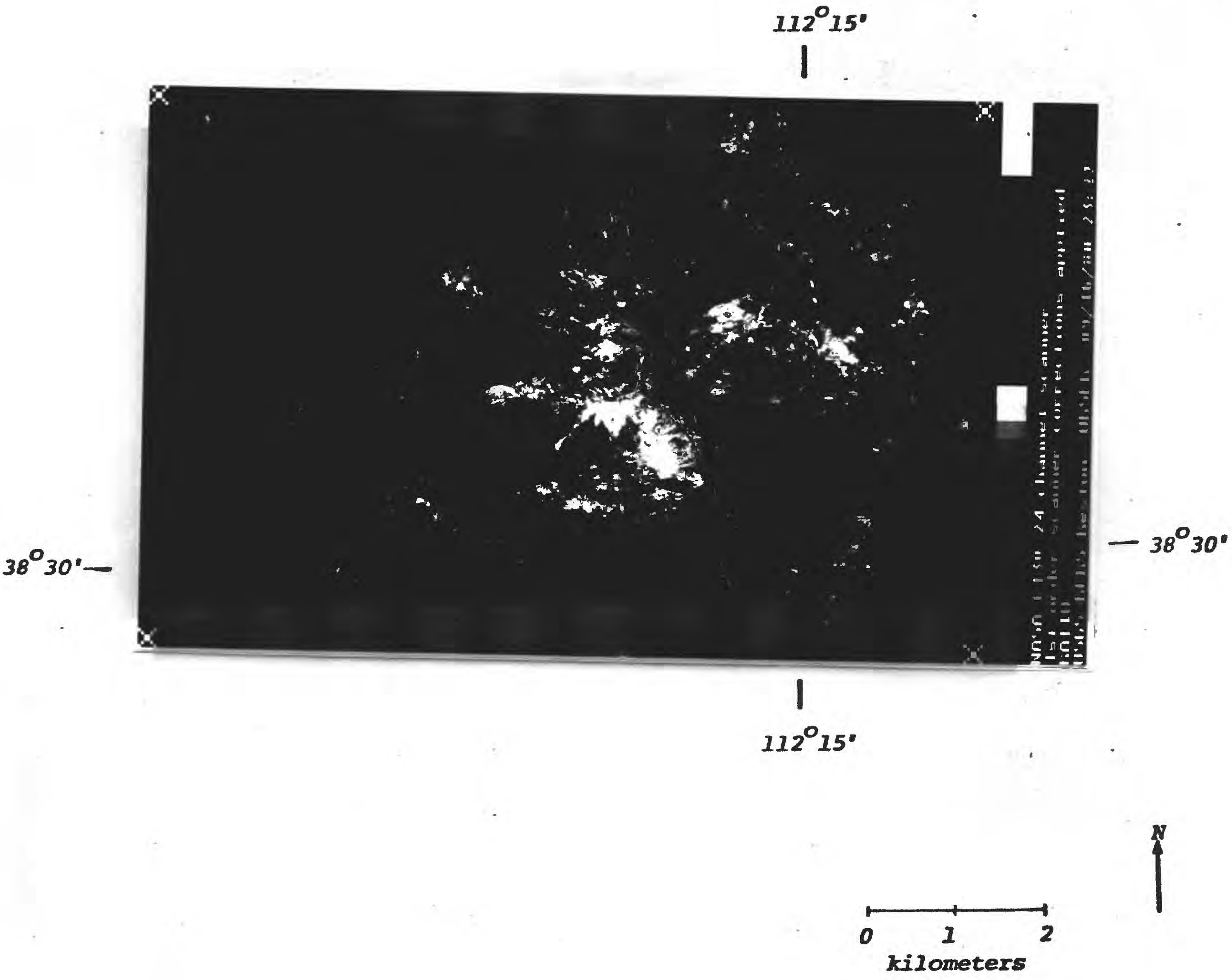

Figure 4. Diazo mask of figure 3 showing areas of hydroxyl-bearing minerals as white. Produced from MSDS band ratios 6/10 and 12/13 on double-coated black Escochrome diazo film.

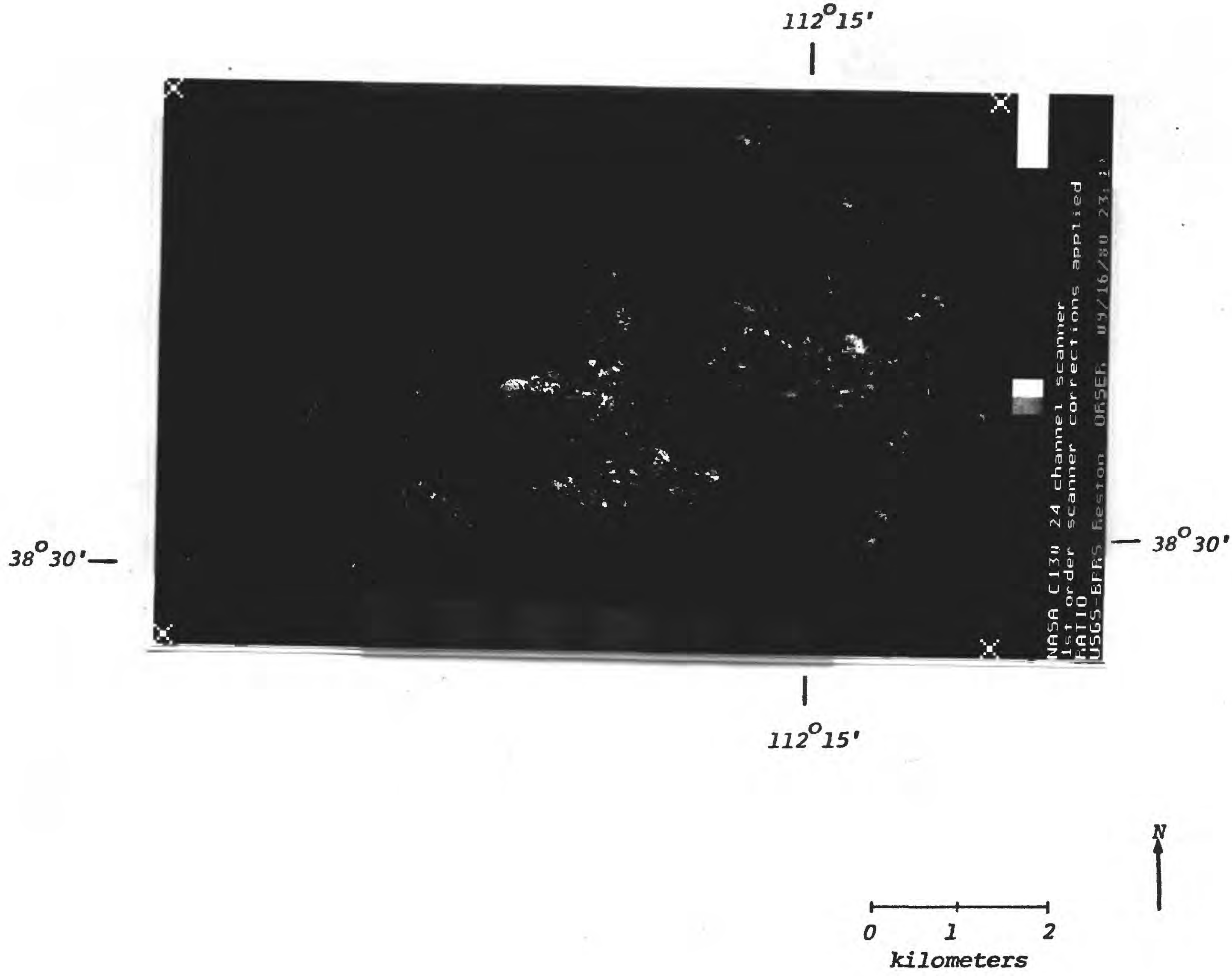

Figure 5. Diazo mask of figure 3 showing areas of hydroxyl-bearing limonitic minerals as white. Produced from MSDS band ratios 6/10, 12/3, and 12/13 on double-coated black Escochrome diazo film.

Thus, if one is given a complete set of film positives and negatives, any resulting color can be extracted from the composite image.

Summary

Selective ratioing of spectral bands can be used effectively to isolate and locate materials that have specific spectral absorption features. Although color-composite images contain a wealth of information, locating and extracting, either manually or by computer the desired features, is often time consuming. As shown in the example in this paper, diazo masking of specific band ratio images can eliminate absorption features that are in the same spectral region but that arise from different sources. This elimination by masking is possible only if one of the sources has two distinct and separable absorption features, of which one can be effectively ignored.

The success of the masking technique is based on four primary factors: 1) knowledge of the spectral characteristics of the materials in question, 2) proper selection of bands and/or band ratios such that non-unique absorptions can be eliminated, 3) proper choice and construction of positive and negative diazo film images such that the primary and resulting secondary subtractive colors may be isolated, and 4) proper registration and exposure of diazo film. This process provides a fast and inexpensive non-digital alternative to computer-assisted thematic classification schemes.

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