

MAPPING MINERALS AT THE COPPER FLAT PORPHYRY, NEW MEXICO, USING AVIRIS DATA

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ABSTRACT

The Copper Flat porphyry is a Laramide copper deposit in southwest New Mexico. High-altitude AVIRIS data were acquired over the site in 1998. Limonite minerals, carbonates, some phyllosilicates, epidote, gypsum, and tremolite/talc have been preliminarily mapped based on AVIRIS data. The results indicate a fairly regular zonation of hydrothermal alteration minerals around the porphyry that is consistent with classic models of alteration from porphyry copper deposits. Verification of the preliminary results is on-going. X-ray diffraction analyses and laboratory spectral analyses will be performed on samples from the area in order to confirm the results of mineral mapping.

1.0 INTRODUCTION

The Hillsboro mining district is located in the Animas Mountains in Sierra County, New Mexico, approximately 180 miles south of Albuquerque (Figure 1). The district lies on the eastern edge of the Laramide Arizona-Sonora-New Mexico porphyry-copper belt. The district contains six types of mineral deposits: the Copper Flat porphyry, polymetallic fissure veins that radiate from the porphyry, carbonate replacement deposits, weakly mineralized skarn deposits, jasperoids, and placer gold deposits derived from the fissure veins.

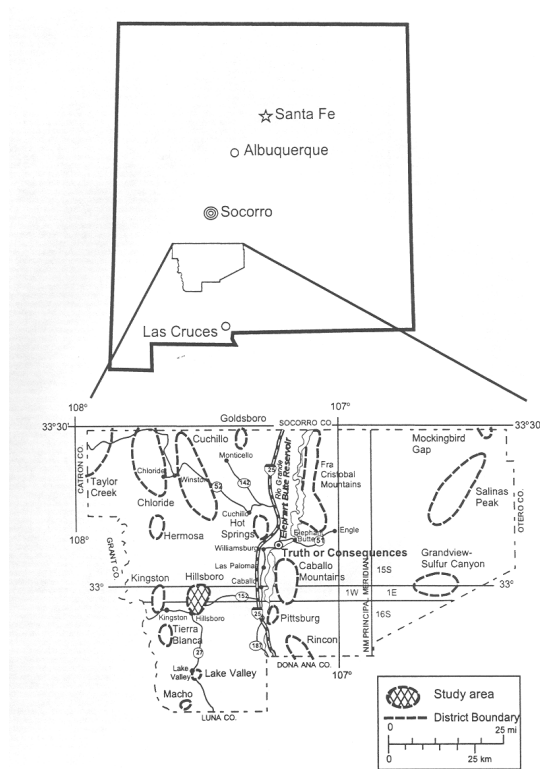


Figure 1--Location of the Hillsboro mining district (McLemore et al., 1999).

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High-altitude Airborne Visible Infra-Red Imaging Spectrometer (AVIRIS) data were collected over the site during the summer of 1998. This type of remotely sensed data has a spatial resolution of approximately 17 meters and measures spectral radiance in 224 channels from 0.38 to 2.5 micrometers. AVIRIS data have been used with success many times in the past to produce maps of minerals occurring on the surface. The Hillsboro district provides a good location to study the use of AVIRIS data to map hydrothermal alteration because of the variety in deposit types and alteration types within the district.

2.0 RESEARCH OBJECTIVE

The objective of this research is to evaluate AVIRIS data as a tool for mapping hydrothermal alteration in the Hillsboro district. The research is aimed at answering two questions. The first is, what is the distribution of alteration minerals within the Hillsboro district? The second is, how well can this distribution be mapped from AVIRIS data?

3.0 GEOLOGY OF THE HILLSBORO MINING DISTRICT

Figure 2 is a generalized geologic map of the Hillsboro district. The Animas Mountains are composed of Cretaceous andesites erupted from the Copper Flat volcano. The Copper Flat quartz monzonite porphyry was emplaced in the vent of the volcano. The circular outcrop of andesite surrounding the porphyry measures approximately six kilometers in diameter and is at least 830 meters thick (Figure 2) (McLemore et al., 1999). Thirty-four latite dikes radiate outward from the porphyry into the andesite, many of which are associated with polymetallic veins. The circular andesite outcrop is surrounded by Paleozoic carbonates and alluvial deposits. Skarn deposits occur in the carbonates to the north and south of the andesite. In addition, jasperoid bodies, which replaced some of the carbonates, are found to the south of the andesite. The Warm Springs quartz monzonite intrudes the flank of the andesite to the south of Copper Flat, and there is another quartz monzonite in the northern part of the district (McLemore et al., 1999). Pliocene basalts cap some of the peaks in the region.

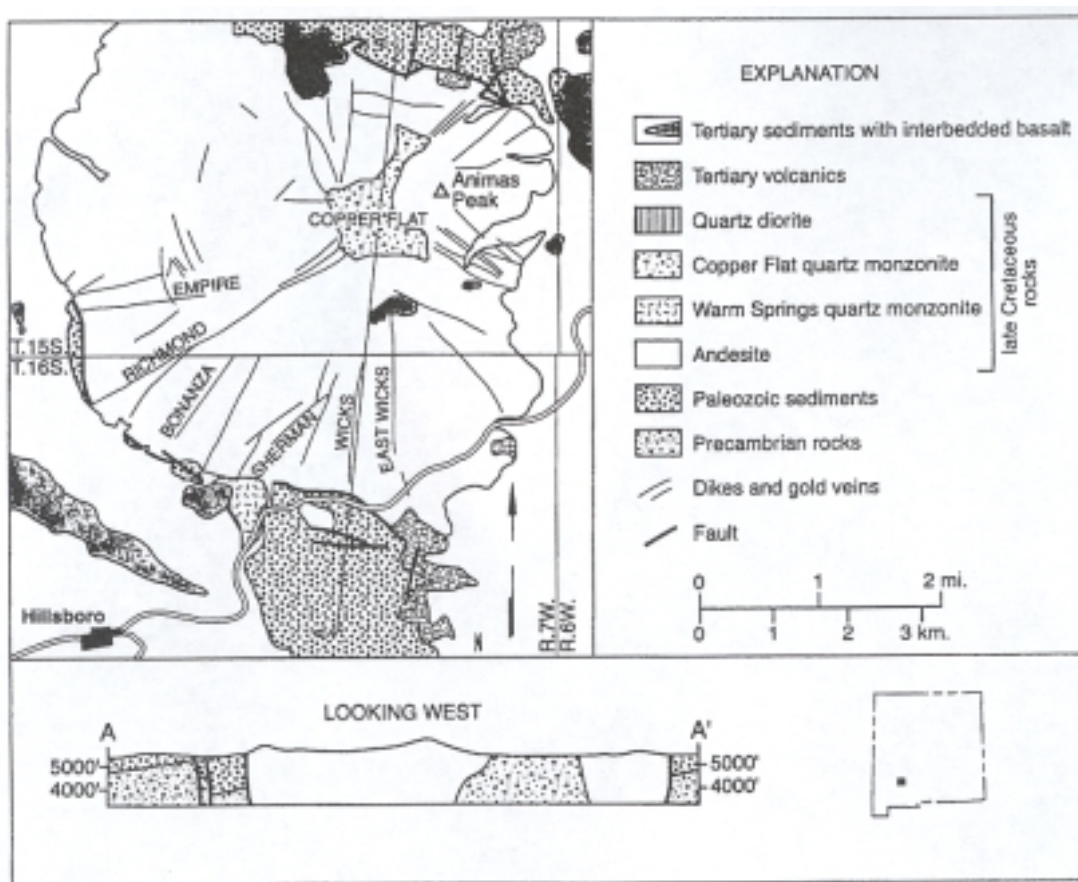


Figure 2--Generalized geologic map of the Hillsboro mining district (McLemore et al., 2000).

The andesite is composed of volcanic flows, flow breccias, and volcanoclastic rocks. It is usually dark gray to greenish gray and porphyritic. It is composed of plagioclase, orthoclase, hornblende, and magnetite, with lesser amounts of biotite, clinopyroxene, quartz, rutile, apatite, and zircon (McLemore et al., 1999). The andesite also contains epidote and is propylitically altered near the Copper Flat quartz monzonite and the polymetallic veins (Fowler, 1982).

The quartz monzonite is light gray to pinkish gray and contains large euhedral potassium feldspar crystals, euhedral to subhedral plagioclase, quartz, biotite, and hornblende (Fowler, 1982).

The dikes are gray to tan to white and vary in thickness from 1 to 38 m (McLemore et al, 2000). They contain feldspar phenocrysts in a groundmass of feldspar and quartz. Small amounts of biotite and hornblende are present locally. Three types of dikes have been mapped: quartz latite, latite porphyry, and latite (Fowler, 1982).

Skarns occur in the limestones to the north and south of the andesite. The skarns are small and contain garnet, epidote and magnetite. Carbonate replacement deposits, which are either Ag-Mn or Pb-Zn dominant, are developed in the Paleozoic limestones and dolomites (McLemore et al., 1999). Jasperoids have replaced large portions of the carbonates to the south of the andesite. The jasperoids are white to reddish brown and brecciated. They contain primarily quartz, iron oxide, and manganese oxide. Lesser amounts of weathered pyrite, dolomite, calcite, magnesite, sericite, fluorite, and altered feldspar are also present (McLemore et al., 2000).

4.0 HYDROTHERMAL ALTERATION

Alteration is a change “in the chemical or mineralogical composition of a rock, generally produced by weathering or hydrothermal solutions” (Bates and Jackson, 1984). Hydrothermal alteration assemblages within the Hillsboro district are prevalent, varied and well characterized. McLemore et al. (2000) summarized the alteration types as shown in Table 1.

Table 1--Summary of alteration types (McLemore et al., 2000)
[Minerals in boldface type may be identified with AVIRIS data.]

Host Rock/Mineral Deposit Type	Alteration Type	Alteration Mineral Assemblage
Quartz monzonite/porphyry copper deposit	Biotite-potassic	Biotite, K-feldspar, quartz, pyrite
	Potassic	K-feldspar, chlorite , quartz, pyrite
	Sericitic	Sericite , quartz, pyrite
Andesites adjacent to the latite dikes and polymetallic veins	Propylitic	Epidote, chlorite, sericite , pyrite, magnetite
	Argillic	Sericite, calcite, chlorite , quartz, pyrite
	Propylitic	Chlorite, kaolinite, sericite, calcite , quartz, pyrite
Latite dikes associated with the polymetallic veins	Propylitic	Quartz, K-feldspar, pyrite, epidote, chlorite
	Sericitic	Quartz, sericite, chlorite , pyrite
Limestones, dolostones	Skarn	Garnet, epidote , magnetite, quartz
	Marble	Marble, recrystallized limestone
	Jasperoid	Quartz, iron oxides , manganese oxide

A model for hydrothermal alteration around porphyry copper deposits was developed by Lowell and Guilbert (1970). In this model, alteration progresses outward from a central core of potassic alteration to a phyllic alteration zone, then to an argillic zone, and finally to a propylitic alteration zone along the periphery. Potassic alteration is characterized by biotite and orthoclase. Phyllic alteration consists of quartz, sericite and pyrite. Argillic

alteration minerals include kaolinite and montmorillonite. Typical propylitic alteration minerals include epidote, calcite, and chlorite. A schematic cross-section through an idealized copper deposit is illustrated in Figure 3.

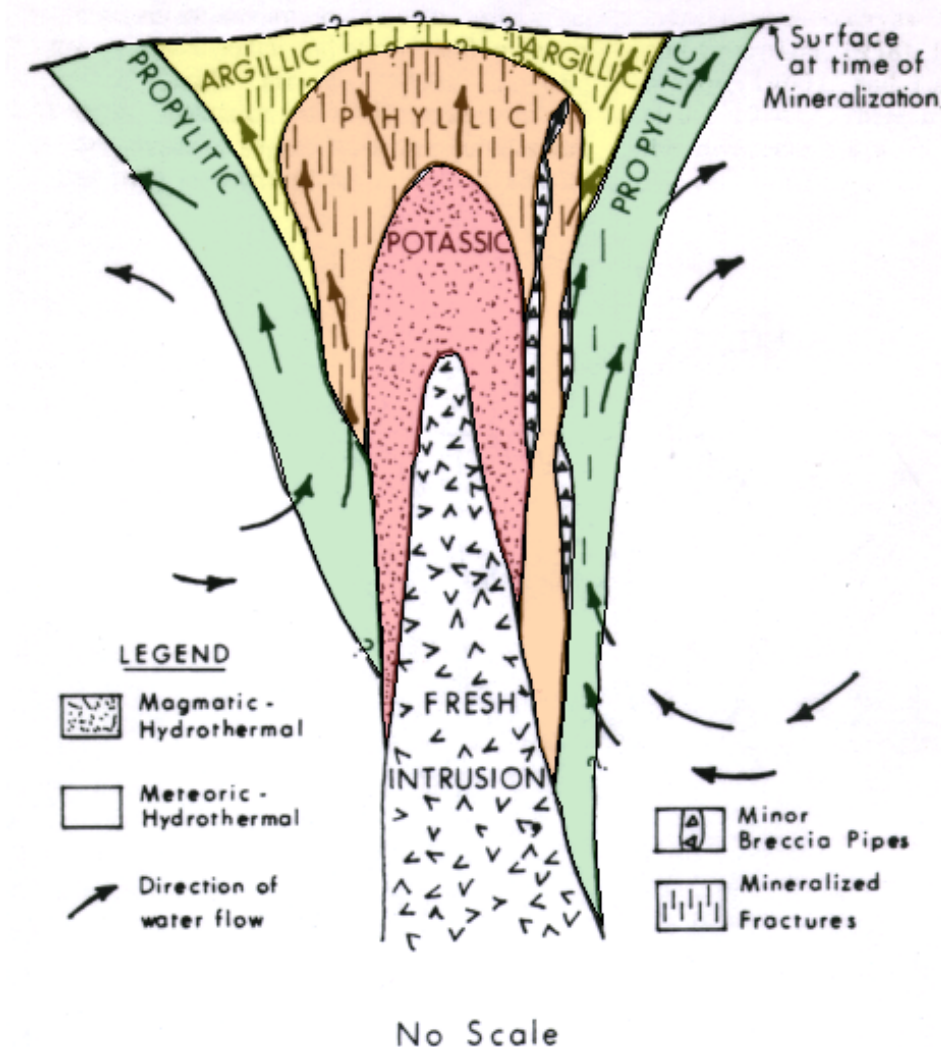


Figure 3--Model for hydrothermal alteration around a porphyry copper deposit. Modified from Hollister (1978).

In addition to hydrothermal alteration, deuteric alteration is also prevalent in the Hillsboro district. Deuteric is defined as “referring to reactions between primary magmatic minerals and the water-rich solutions that separate from the same body of magma at a late stage in its cooling history” (Bates and Jackson, 1984). In the Hillsboro district, deuteric alteration is responsible for the widespread replacement of feldspar phenocrysts by sericite, replacement of groundmass minerals by sericite and chlorite, and replacement of hornblende by biotite, hematite, and chlorite (McLemore et al., 2000).

5.0 METHODOLOGY

This research project consists of four steps:

1. Preparation of mineral maps from AVIRIS data;
2. Field checking of mineral maps combined with field mapping of alteration in critical areas such as the porphyry itself and an anomalous area in the andesite to the northwest of the porphyry;
3. X-ray diffraction (XRD) analysis of samples to support the identification of clay minerals;
4. Laboratory spectral measurements and analysis of samples.

The AVIRIS data were calibrated to spectral reflectance by personnel at the Mineral Resources Team at the USGS in Denver. Additional pre-processing is unnecessary. The image is georeferenced, facilitating combination with other geospatial data sets, such as geochemical or geophysical data. The data scene encompasses the six mineral deposit types within the Hillsboro district.

Mineral maps of the Hillsboro district have been prepared with ENVI[®] software using the continuum removal/spectral feature fitting[™] technique. This procedure begins by selecting diagnostic electromagnetic absorption features for the minerals being mapped. These absorption features were obtained from the USGS Tetracorder 3.5 command file. Spectra from the USGS Digital Spectral Library (Clark et al., 1993) have been used as references.

The spectral range of an absorption feature is isolated in every pixel within the scene by spectrally subsetting the image. Individual features from various pixels must then be normalized in order to compare them to the reference spectrum. The normalization process consists of (1) drawing a straight line between the endpoints of a given absorption feature (the straight line is referred to as a “continuum”) and (2) dividing the value of the reflectance spectrum by the value of the continuum at many points along the line.

Following continuum removal of both the reference spectrum and the image spectra, absorption features in the reference spectrum can be compared with spectra from the image. This is the “spectral feature fitting” portion of the procedure. Two statistics are calculated that indicate how well the spectrum of an individual pixel matches an absorption feature in the reference spectrum. The first is dubbed “RMS” and is simply the root mean square error between the spectrum of an individual pixel and the reference spectrum. Low RMS values indicate pixels with spectra that have shapes similar to the reference spectrum in the spectral range of the absorption feature being considered. Theoretically, the RMS value can be used to determine the presence or absence of the material.

The second statistic is called the “scale.” It is a measure of the depth of the absorption feature seen in individual pixels. A pixel with a high scale value has a strong absorption in the spectral range being considered. Theoretically, the scale value is proportional to the abundance of the material within the pixel.

A third statistic, the “fit,” can be derived from the two calculated statistics. The fit is simply the scale value divided by the RMS value. A high scale value and low RMS value (both indicative of a good match with the absorption feature seen in the reference spectrum) will result in a high fit value. For mapping purposes, the fit statistic is particularly useful, because it highlights those pixels in which the material is not only present, but is also abundant.

Mineral maps are prepared by selecting a threshold value for the fit statistic. All pixels with fit values greater than the cutoff are classified as containing the mineral being mapped. This process is subjective, because different individuals will probably choose different thresholds. They would therefore produce different mineral maps. Selection of the threshold values is the most difficult, and probably the most important, step in the mineral mapping process. A seemingly effective approach to creating reliable mineral maps is to field map critical areas to verify the remote sensing results. For minerals that may not be readily identified with the naked eye, e.g., many clay minerals, samples collected in the field can be analyzed with a technique other than spectroscopy, e.g., XRD, to support the spectroscopic results. The results of analyses from these samples will provide control areas within the image where certain minerals are known to be present or absent. The areas may help in determining appropriate threshold values and may facilitate the refinement of mineral maps.

6.0 RESULTS

Mineral maps have been prepared for limonite minerals, carbonates, some phyllosilicates, epidote, gypsum and tremolite/talc. Figure 4 illustrates the distribution of sericite, kaolinite-montmorillonite, montmorillonite, epidote, chlorite, gypsum, and tremolite/talc. This map indicates that the distribution of hydrothermal alteration minerals immediately surrounding the Copper Flat porphyry is similar to the zonation pattern illustrated in Figure 3. Potassic alteration has not been mapped, however, because of the indistinct spectra of the characteristic minerals biotite and potassium feldspar. A propylitic alteration assemblage, consisting of epidote, chlorite and calcite, has been mapped around the porphyry. This assemblage is also prevalent in the andesite to the northwest of the porphyry. Sericite alteration adjacent to the polymetallic veins has been mapped from AVIRIS data. Gypsum has

also been mapped; it is actively precipitating from the pond in the center of the porphyry. This map has been only primarily field checked, and additional work will be aimed at verifying and improving the remote sensing results.

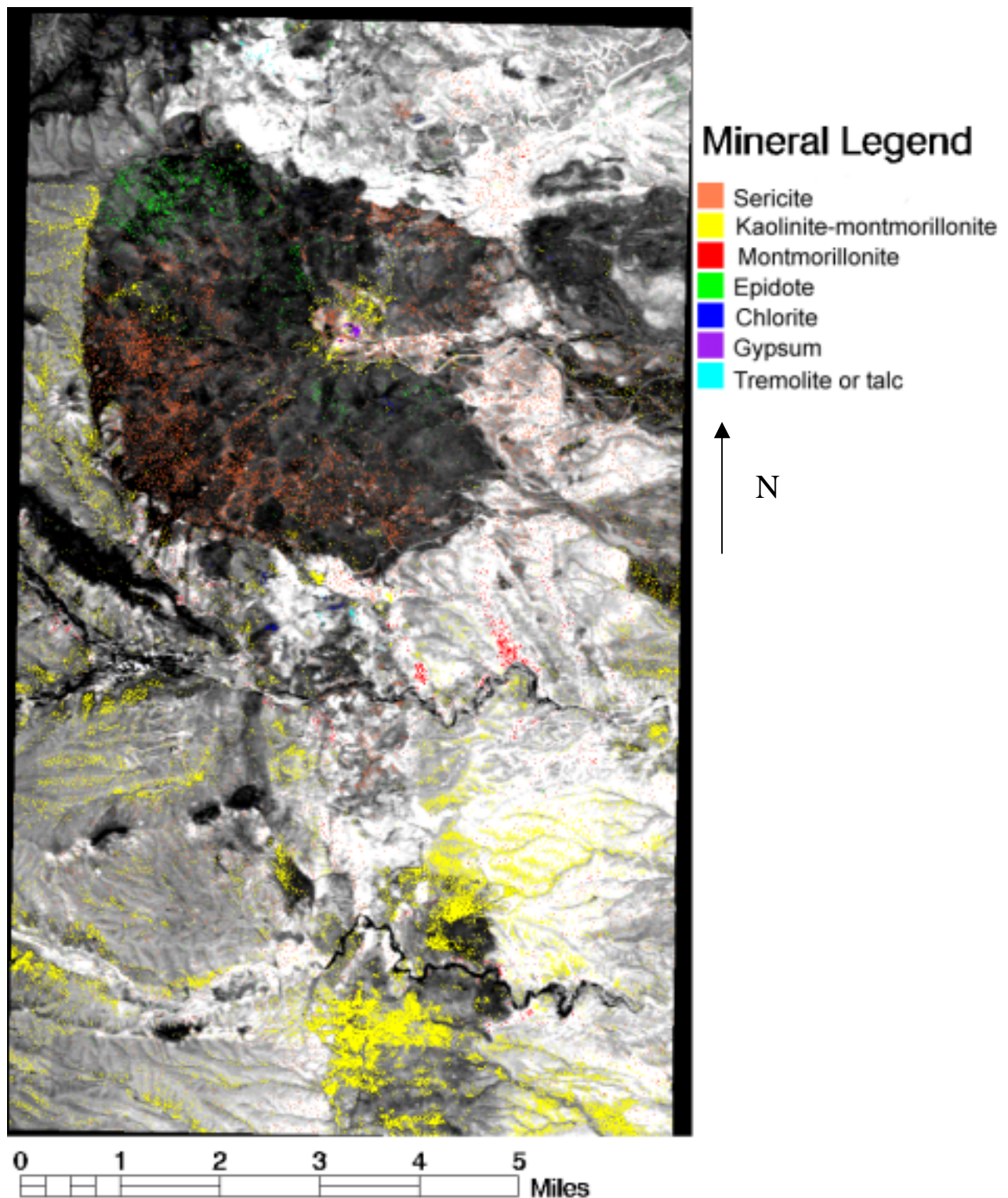


Figure 4--Preliminary map of selected minerals in the Hillsboro mining district.

7.0 REFERENCES

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