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Use of high-spectral resolution airborne spectroradiometer data to map
hydrothermally altered rocks in the Gabbs Valley Range, Nevada

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TO MAP HYDROTHERMALLY ALTERED ROCKS IN THE GABBS VALLEY RANGE, NEVADA

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Introduction

A number of diagnostic mineral constituents of hydrothermally altered rocks exhibit characteristic, narrow spectral features which can be detected through the use of high-spectral resolution airborne spectroradiometer data. Evaluation of these spectroradiometer data can lead to the identification of minerals characteristic of hydrothermally altered rocks and the delineation of the areal extent of alteration. This approach provides an effective tool for carrying out rapid mapping of hydrothermally altered rocks, which can be used in conjunction with mineral exploration (Collins and others, 1981; 1984; Marsh and McKeon, 1983; Raines and others, 1984).

High-spectral resolution airborne spectroradiometer data were obtained for the Gabbs Valley Range, Nevada (fig. 1), a northwest-trending mountain range located near the western margin of the Basin and Range Province. The semi-arid climate of the region supports only a sparse vegetation cover which facilitates the direct detection of altered rocks and associated soils using airborne spectroradiometer data. The Gabbs Valley Range was chosen as a site for evaluation with the airborne spectroradiometer based on the results of a regional hydrothermal alteration study of the area using Landsat Multispectral Scanner (MSS) data (Rowan and others, 1980; Rowan and Purdy, 1984). The spectral response range of the MSS, 0.5 to 1.1 micrometers, allows the discrimination of hydrothermally altered rocks when limonite is present (Rowan and others, 1974; Blodget and others, 1978; Raines and others, 1978). For the regional study, the occurrence of limonite was mapped on digitally enhanced MSS images (fig. 1). This technique, however, does not distinguish between altered and unaltered limonitic rocks and therefore, considerable field checking is required. Furthermore, nonlimonitic altered rocks are not detected in MSS images. Some shortfalls of MSS data can be overcome with spectral information derived from the 2.0 to 2.5 micrometer region. Hydroxyl-bearing minerals common to alteration assemblages exhibit diagnostic spectral features in

this region (fig. 2) caused by Al-O-H and OH bonds (Hunt, 1979). Identification of these minerals can lead to improved recognition of hydrothermally altered rocks.

The Mark II airborne spectroradiometer acquired data for the Gabbs Valley Range in October of 1982 (fig. 3) in order to produce a more refined alteration map than was compiled from evaluation of MSS data. This instrument collected data in 64 channels in the 1.9 to 2.5 micrometer region with band widths of 6 to 8 nanometers. The data were acquired in a continuous line-profile with an instantaneous field of view of 20 meters-square from an altitude of 600 meters. Simultaneously acquired 35 mm photographs of the ground track were used for location purposes. The data were analyzed using a waveform analysis technique based on a best fit of Chebyshev polynomials (Collins and others, 1984) which facilitates the extraction of the spectral information required for mineral identification.

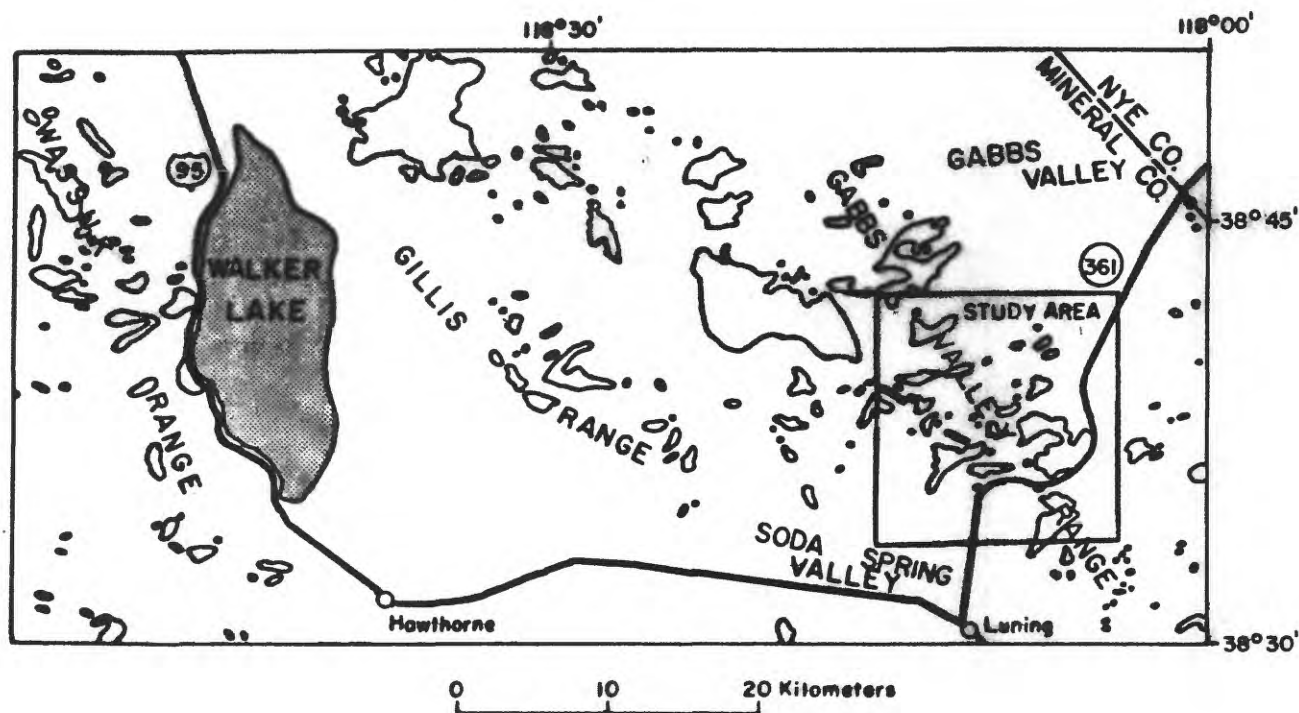


Figure 1— Map showing the distribution of limonite anomalies (irregularly outlined areas) identified by Rowan and others (1980) on a color-ratio-composite image produced from Landsat Multispectral Scanner data. The study area in the Gabbs Valley Range is outlined in the southeastern part of the map.

Geology

The Gabbs Valley Range lies along the Walker Lane (Locke and others, 1940; Albers, 1967) in west-central Nevada. The basement rocks in the region consist of Triassic to Jurassic marine sedimentary and volcanic rocks (fig. 4) which were deformed and later intruded by granitic to dioritic rocks during the Jurassic and Cretaceous (Ekren and others, 1980). The area is composed dominantly of Tertiary volcanic rocks, most of which are moderately to densely welded silic ash-flow tuffs. The regional structural style is right-lateral strike-slip faulting related to the northwest-trending Walker Lane. In addition, detachment faults occur at the base of the Tertiary section and at several horizons within it (Hardyman and others, 1975). Ekren and others (1980) believe that the ash-flow tuffs of the Gabbs Valley Range were erupted into a northwest-elongate trough which developed along the Walker Lane. They postulate that these ash-flow tuffs were erupted from depths too great to allow the formation of calderas.

The most intense hydrothermal alteration in the study area occurs within the Oligocene Benton Spring Group (fig. 4). This group consists of three cooling units of welded ash-flow tuff each of which grades from rhyodacite at the base to rhyolite or quartz-latite at the top (Ekren and Byers, 1978). The tuffs are relatively crystal-rich with from 20 to 40 percent phenocrysts, which consist of plagioclase, alkali feldspar, and quartz and less abundant biotite, hornblende, and pyroxene. The matrix is glassy and can be from moderately to densely welded with the occurrence of vitrophyres. The unaltered tuff is light red to reddish-gray, whereas the vitrophyres appear dark brown.

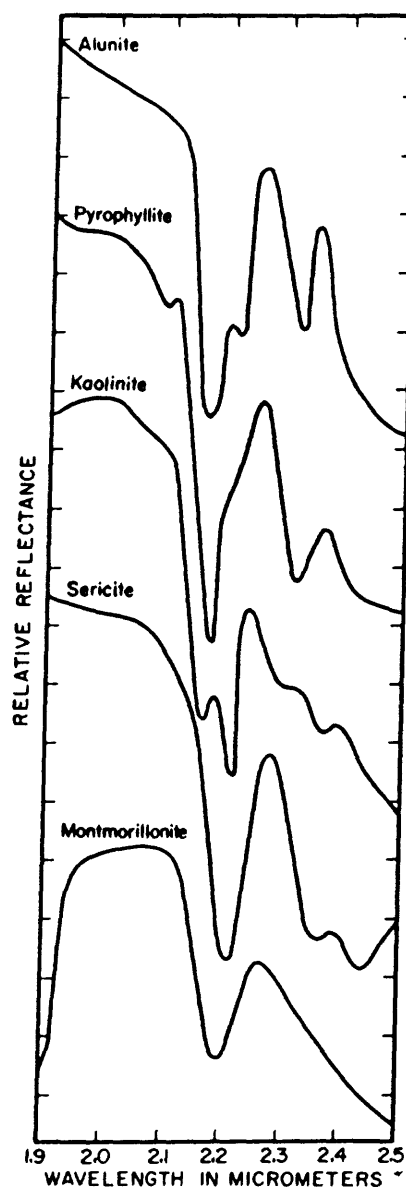
Hydrothermal Alteration

Alunite, kaolinite, sericite, and montmorillonite were indentified in the airborne spectroradiometer data. The distribution of the minerals shown in the data (figs. 3 and 5) has been confirmed through field evaluation and mineralogical identifications made using x-ray diffraction, laboratory spectral reflectance, and thin-section analyses.

The areas that are characterized by alunite in the spectroradiometer data consist of irregular, massive bodies of tuff which have been altered to quartz and alunite, commonly with a reddish surface stain. The matrix of the tuff has been largely replaced by quartz with minor fine-grained alunite. The feldspar phenocrysts and pumice lapilli have also been replaced by alunite. The rocks characterized by kaolinite in the spectroradiometer data range in color from pink to tan to yellow. Kaolinite pseudomorphs of feldspar phenocrysts are surrounded by a matrix that has been replaced by kaolinite and less abundant quartz. Jarosite is also present. Within this zone are near-vertical silicified ribs, 15 to 30 centimeters wide, that contain abundant pyrite. The ribs occur along faults and joints within the Benton Spring Group. This alteration zone overlaps with and grades into the zone that is dominated by sericite. The

rocks in the sericite zone are white to gray in color. Sericite occurs in the matrix of the tuffs as well as a replacement of both the feldspar phenocrysts and the pumice lapilli. Illite has also been identified in this zone. The propylitic zone, characterized by montmorillonite in the spectroradiometer data, is a less intense form of alteration which grades outward into unaltered rocks. Both chlorite and less commonly epidote occur in this zone as alteration products of mafic minerals.

Figure 2-- Reflectance spectra of alunite, pyrophyllite, kaolinite, sericite, and montmorillonite in the 1.9 to 2.5 micrometer range (from Lee and Raines, 1984). The spectra have been displaced vertically for added clarity. Tic marks on the ordinate are at 10 percent increments.



A crude pattern of mineralogical zonation recognized in the field shows quartz-alunite bodies scattered throughout the kaolinitic zone which in turn grades into a fringing sericitic zone. Beyond this is an outer zone of pervasive propylitic alteration. The quartz-alunite bodies generally occur along faults. A model that is consistent with this crude zonation and the types of alteration observed is that alteration occurred in a sulfataric environment characterized by acid sulfate solutions and base cation leaching. Migration of the solutions occurred most readily along faults. Highly acidic solutions, in the pH range of 3 to 4 (Diner, 1983), possibly derived from oxidation of sulphur to sulfate were responsible for the quartz-alunite alteration assemblages. As the solutions spread laterally away from the principle zones of porosity along the faults, reactions with the wallrocks decreased the hydrogen ion activity and increased the soluble ion concentration. As the fluids changed composition, the alteration assemblages changed progressively from quartz-alunite to kaolinite to sericite. This pattern of zonation is supported by the mineral stability relations in the $K_2O-Al_2O_3-SiO_2-H_2O-SO_3$ system (Hemley and others, 1969).

Conclusions

The data obtained from the high-spectral resolution airborne spectroradiometer facilitated the evaluation of hydrothermally altered rocks in the Gabbs Valley Range through the identification of zones of alunite, kaolinite, sericite, and montmorillonite. However it is difficult to interpret an overall pattern of mineralogical zonation in the airborne spectrometer data (fig. 3). In some areas a quartz-alunite to kaolinite to sericite pattern can be discerned, but in other areas different zonations are suggested. Several possible explanations can account for this. First, the pattern of zonation could have been disrupted through post-alteration faulting. Second, multiple alteration events may have occurred which could cause overprinting leading to the overlap of mineral assemblages. Third, the problem may lie in the line profile nature of the airborne spectrometer data. Even if a pattern is present, it could be difficult to discern because there is no information provided between flight lines. This problem could be remedied with the coverage that can be obtained with a high-spectral resolution airborne imaging system, such as the Airborne Imaging Spectrometer (AIS). Such an imaging system would not only permit the identification of alteration minerals but also allow the recognition of detailed patterns of mineral zonation when present. Image format data would be especially valuable in geologically complex terrains where lack of information between flight lines could lead to misinterpretation. Furthermore, the 10 meter spatial-resolution of AIS images provides a sampling density that is difficult to achieve over large areas with standard geologic and geochemical sampling techniques. The use of high-resolution sensors, whether imaging or line-profile systems, can provide valuable information to mineral exploration programs.

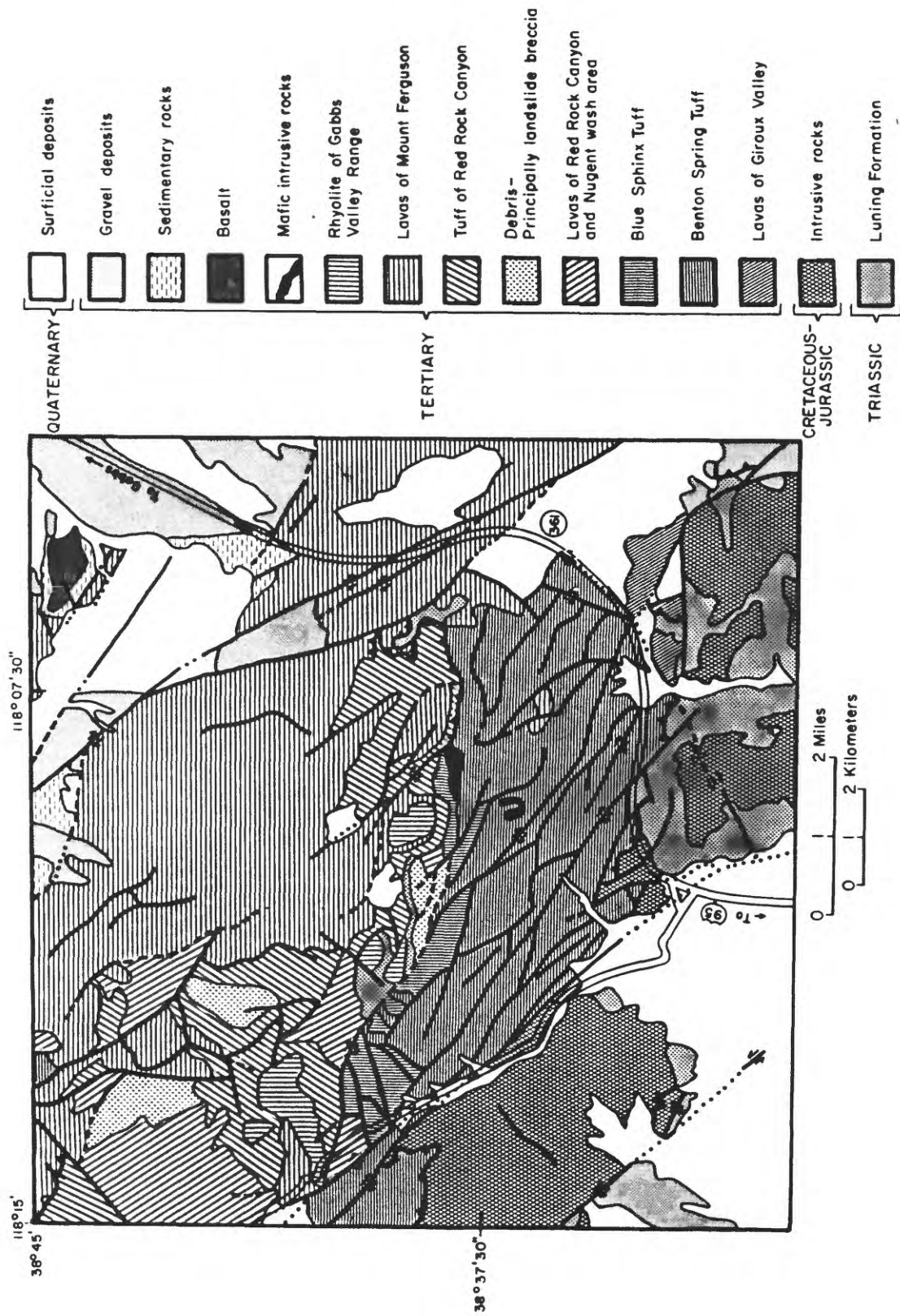


Figure 4-- Generalized geologic map of the study area (generalized from Ekren and Byers, 1978).

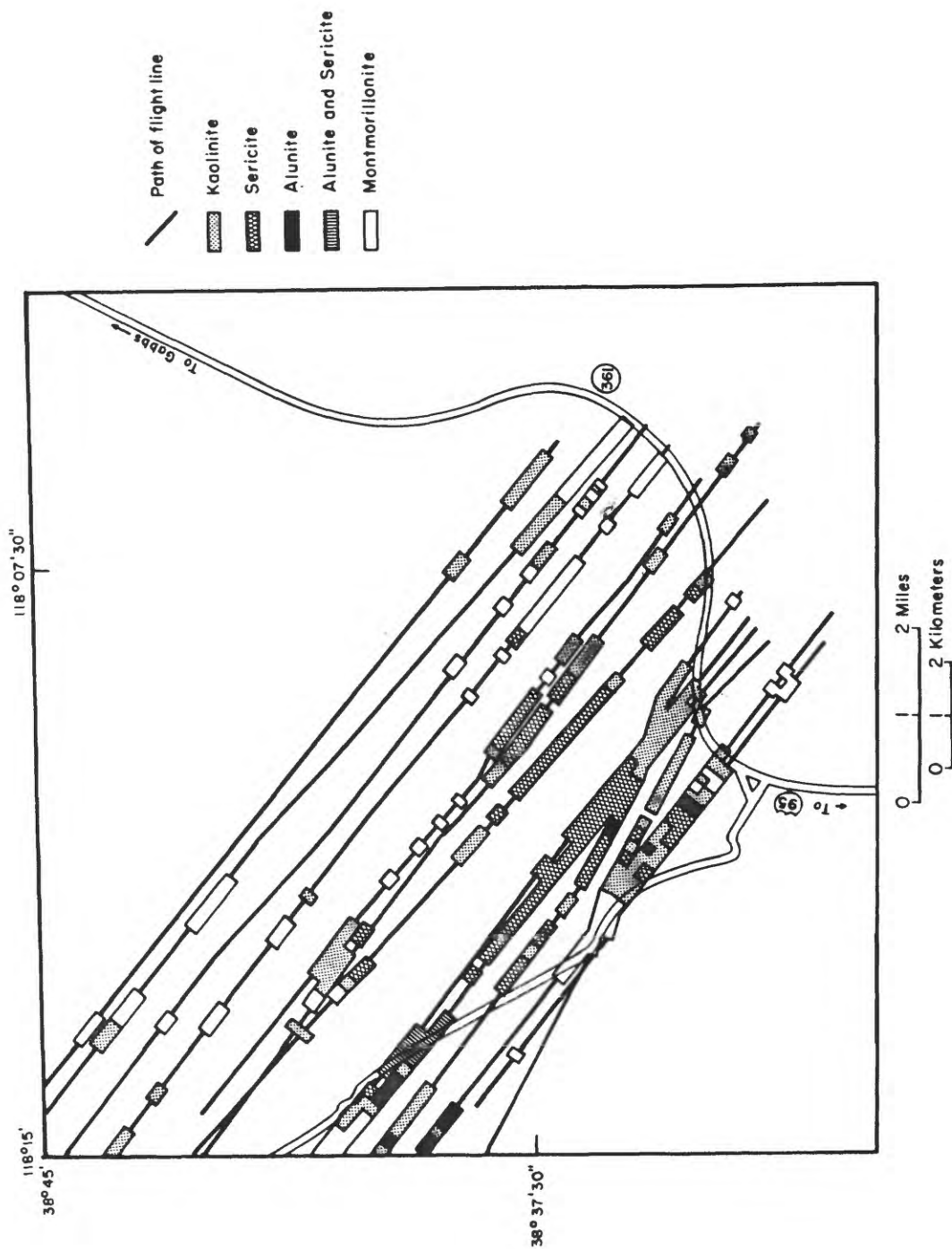


Figure 5-- Locations of the high-resolution airborne spectroradiometer flight lines in the study area showing the spectral identification of minerals along the lines. The parts of the flight lines that have no associated mineral identifications were considered to be background.

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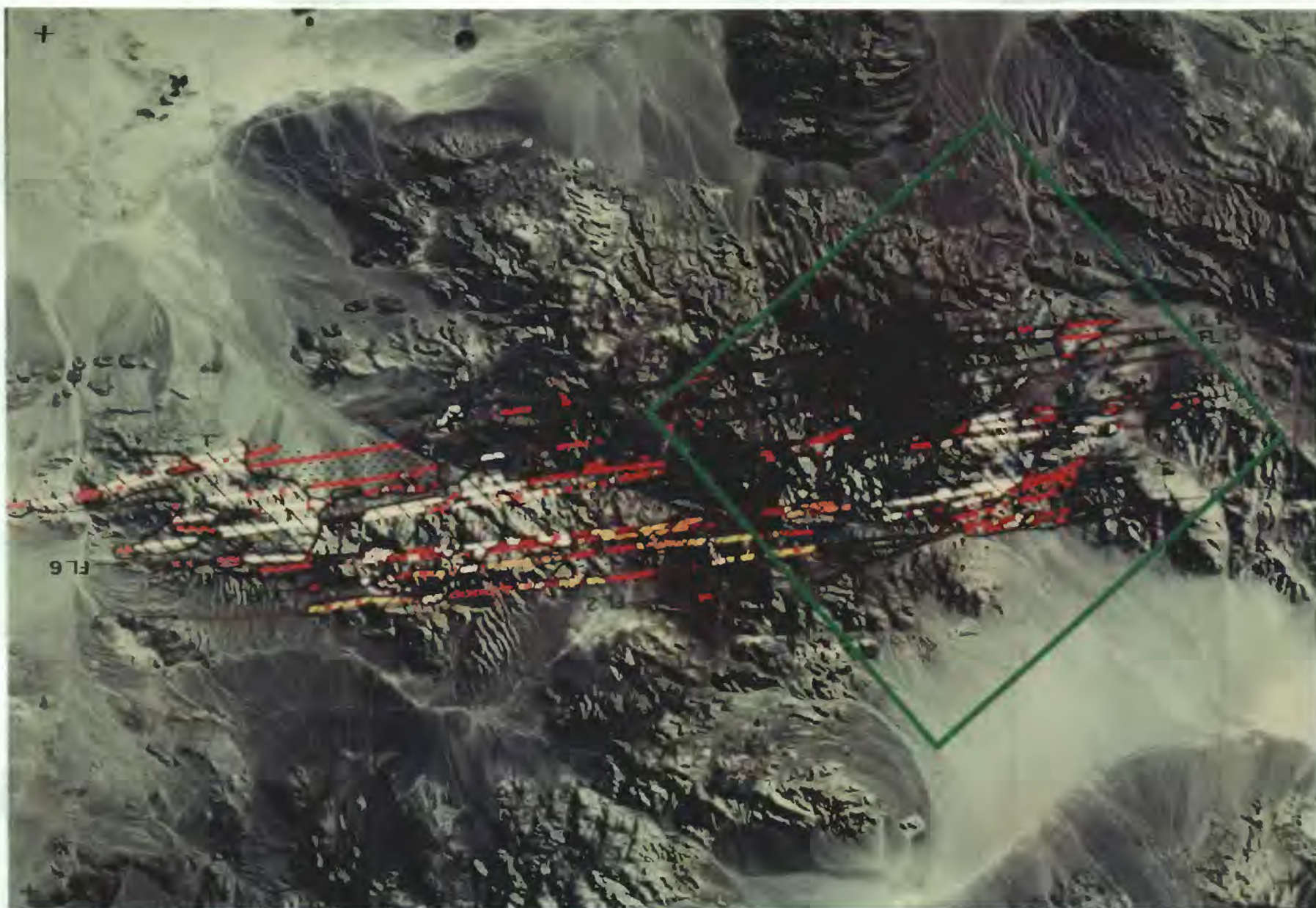






Figure 3-- Areal photograph showing the locations of the high-spectral resolution airborne spectroradiometer flight lines in the Gabbs Valley Range and spectral identification of alteration minerals. The study area is outlined in green.

KEY

Red:	kaolinite		extrapolation of kaolinitic zones between flight lines
White:	sericite		extrapolation of sericitic zones between flight lines
Yellow:	alunite		extrapolation of alunitic zones between flight lines
Orange:	mixed alunite and sericite		extrapolation of mixed alunite and sericite zones between flight lines
Brown:	montmorillonite		
Black:	background		