DEPARTMENT OF THE INTERIOR

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Preliminary Description of a Mineral-Bound Ammonium Locality in the Cedar Mountains, Esmeralda County, Nevada

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Abstract

A zone of mineral-bound ammonium that extends over 10 km in length has been discovered in the southern half of the Cedar Mountains in Esmeralda County, Nevada. The zone initially was depicted on a Landsat Thematic Mapper image and is centered on an unnamed 6931 ft (2113 m) peak composed of two Tertiary silicic ash-flow tuffs. The zone as mapped by an airborne scanner extends in a narrow swath along the west side of the Cedar Mountains through Tertiary volcaniclastic rocks and sediments and appears to be structurally controlled. Ammonium concentrations of a few samples associated with the spectral anomalies are near 0.20 wt % $(NH_4)_2O$.

Introduction

During the course of geologic investigations to assess the mineral resources of the western United States, a large zone of mineral-bound ammonium was discovered in the southern Cedar Mountains, in Esmeralda County, Nevada. To date, this zone is the largest known occurrence of inorganic ammonium mapped in volcanic rocks. Ammonium-bearing silicate minerals were first recognized in the early 1960's; they continue to be found in small isolated occurrences in several geologic environments. Ammonium-bearing minerals are distinctive mineralogically, because they incorporate organic chemical components into an inorganic crystal structure. They are of interest in economic geology, because they tend to occur in association with base-metal and precious-metal mineral deposits. The Nevada National Guard (also known as the Nevada Military Department) has issued a proposal to withdraw or partially withdraw a parcel of land in southern Nevada greater than 500,000 acres for military training purposes. The Cedar Mountain locality is located entirely within one of the two major parcels proposed for withdrawal. This open-file report is being released to provide additional geologic information for the public commentary provisions of the Environmental Assessment by the Nevada National Guard, dated September, 1989, for the proposed Reserve Component Training Center (RCTC).

Background

Ammonium-bearing silicate minerals were first recognized by White and Roberson (1962) from an active hot spring site in northern California that was mined for mercury. The mineral was named buddingtonite and is described as a potassium feldspar, like sanidine, where NH_4^+ replaces K^+ or Na^+ within the crystal structure (Erd and others, 1964). Subsequently NH_4^+ has been found to replace K^+ in other minerals, including mica, alunite, and leucite. In addition to hot spring deposits, ammonium minerals are known from disseminated gold deposits, sedimentary-exhalative lead-zinc deposits, organic-rich shales, phyllitic metamorphic rocks, and granitic igneous rocks. In the mid-1980's, diagnostic spectral absorption features were first observed in the near-infrared wavelengths for ammonium minerals (Krohn and Altaner, 1987). Subsequent work showed that ammonium minerals could be mapped utilizing these spectral absorption features (Krohn and others, 1988).

Geologic Setting

The Cedar Mountains, situated 50 km northwest of Tonopah, NV, are one of the ranges in the Basin and Range physiographic province (Figure 1). The geology of the Cedar Mountains recently has been mapped as part of the U.S. Geological Survey's mineral-resource assessment of the Tonopah 1^{o} x 2^{o} quadrangle (Whitebread and Hardyman, 1987). The oldest rocks in the range are deformed Palezoic and Mesozoic sedimentary and volcaniclastic rocks, such as the Mina Formation (Speed, 1977). While Mesozoic intrusives are present in other ranges, they are not present in the Cedar Mountains. Most of the range is composed of Tertiary volcanic and volcaniclastic rocks. The older Tertiary rocks of early Oligocene age are generally of intermediate composition. Several large rhyolitic flows and welded and non-welded ash-flow tuffs of middle Oligocene to early Miocene age are present along the west side of the range. One of these rhyolitic ash-flow tuffs, the Royston Hills tuff, has been dated at 26.0 and 29.1 m.y. $\pm$ 0.9 m.y. (McKee and John, 1987). Volcanic rocks younger than early Miocene are composed predominantly of intermediate to mafic flows plus some rhyolitic flow domes. The area is capped by Quaternary landslide, alluvium, and dune sand deposits.

Mining districts are present in the three ranges surrounding the Cedar Mountains (Figure 1). Gold deposits and one silver-lead deposit are present in the Gilbert district to the south in the Monte Cristo range. Gold occurs in quartz veins that are hosted in Tertiary lavas near the contact with rhyolitic intrusive rocks (Albers and Stewart, 1972). Mercury is noted from this district. In the Royston Hills to the east, turquoise is the main economic mineral, but silver, lead, copper, and gold values have been reported. Mercury with some small amounts of gold, silver, and copper is present in the Sodaville district to the west in the Pilot Mountains (Ross, 1961).

Discovery

The ammonium anomaly in the Cedar Mountains, Nevada was originally depicted on a Landsat Thematic Mapper (TM) satellite image, but was incorrectly identified at first. A color-ratio composite image was produced to map hydrothermally altered rocks for the U.S.G.S.'s mineral resource assessment of the Tonopah 1^{o} x 2^{o} quadrangle (Purdy and others, 1985). The sensor configuration of the TM permits iron- and clay-bearing minerals, two principal oxidation products of hydrothermal alteration, to be mapped remotely. Clay minerals are detected based on a spectral absroption feature near 2.2 microns that are related to Al-OH molecular bonds. Band 7 on the Landsat TM satellite is a broad channel centered on 2.2 microns designed to map the Al-OH spectral absorption feature (Figure 2). The near-infrared spectrum for the ammonium feldspar, buddingtonite, shows two major absorption minima at 2.02 and 2.12 microns (Figure 2). The hatchured area in Figure 2 represents the portion of the ammonium spectral absorption features that is detectable by the Landsat TM sensor.

Two principal areas in the Cedar Mountains were mapped on the color-ratio composite image as having absorption features for TM band 7. The largest area encompassed the unnamed 6931 ft peak in the middle of the range as shown on the 1971 revised Tonopah 1:250,000 quadrangle (Figure 1); scattered small areas also were depicted in the southern part of the range. Near-infrared laboratory spectra of the bleached volcanic tuff collected from both areas showed the 2.02 and 2.12 micron absorption features of ammonium-bearing minerals.

Preliminary Outcrop Description

High spectral resolution airborne data were acquired over the Cedar Mountains to map in detail the distribution of ammonium-bearing minerals in the Cedar Mountains. A 63-channel imaging spectrometer from Geophysical Environmental Research, Inc. (GER)* was flown over the Cedar Mountains in August, 1988. Because 31 of the 63 channels of the instrument are in the range between 1.9 and 2.5 microns, ammonium-bearing minerals can be distinguished from clay-bearing minerals. The data were processed using the Spectral Analysis Manager (SPAM) software written at the Jet Propulsion Laboratory. A preliminary interpretation of the GER airborne data combined with limited field seasons in 1988 and 1989 indicates two distinct settings for the zone of ammonium-bearing minerals; a large exposure of ammonium-bearing minerals is located at the unnamed 6931 ft peak and corresponds to the area mapped on the Landsat image (hatchured area, Figure 1); a narrow swath of ammounium-bearing minerals extends for over 10 km along the west side of the Cedar Mountains (heavy line, Figure 1).

The unnamed 6931 peak in the preliminary geologic map is primarily composed of two welded crystal-rich rhyolitic ash-flow tuffs; the Royston Hills tuff is present at the base and two unnamed members of the tuff of the Cedar Mountains are present at the top (Whitebread and Hardyman, 1987). Principal phenocrysts are K-feldspar, plagioclase, and quartz accounting for between 30 - 50 % of the total composition with minor amounts of biotite and some amphiboles. The lower Cedar Mountain tuff has fewer phenocrysts, lesser ammounts of mafic phenocrysts, and a larger number of lithic fragments than the upper member. Present field observations differ from the preliminary geologic map. The lower north-west flank of the peak is interpreted as Royston Hills tuff, not the Permian Mina Formation as shown on the preliminary geologic map (Whitebread and Hardyman, 1987). Mina Formation is observed north of the major east-west drainage to the north as presented on the geologic map.

In the preliminary mapping, ammonium-bearing minerals are found throughout the outcrops of Royston Hills tuff and upper Cedar Mountain tuff that form the bulk of the flanks of the 6931 peak. More than 400m (1300 ft) of section is exposed, depending upon the dip of the volcaniclastic units. Previously, the deepest measurement from drillcore of ammonium minerals in volcanic rocks was approximately 100 m (320 ft) deep (Krohn and others, 1988). Ammonium concentrations from a few samples along the flanks were measured using an ion selective electrode. Values are generally near 0.20 wt % $(NH_4)_2O$ for samples exhibiting ammonium spectral features.

A narrow swath of ammonium-bearing minerals is portrayed on the GER airborne data extending south from the 6931 peak to the southern part of the range (Figure 1). Cross sections across this narrow swath could be observed at several steep canyons and man-made excavations along the range front. The ammonium-bearing minerals were mapped in outcrop using a hand-held ratioing radiometer (Krohn and others, 1988). Ammonium-bearing minerals appear to be concentrated in a zone approximately 100 m wide. The west side of the zone appears to be a fairly sharp contact controlled by a set of west-dipping fracture surfaces; the eastern contact is gradual and no definitive contact has yet been observed. Internally, the zone appears to be characterized by sets of non-linear iron-stained anastamosing fractures. Cross-cutting the west-dipping fractures are a set of well-developed east-dipping fractures that generally trend northwest. This east-dipping fracture system is presumably younger than the one marking the edge of the zone of ammonium-bearing minerals.

Discussion

The zone of ammonium-bearing minerals in the Cedar Mountains is a unique geologic discovery. The 10 km length of the zone makes it 100 times the size of any previously mapped ammonium-mineral locality in volcanic rocks. The Cedar Mountain locality is the first documented example of ammonium-bearing minerals that were depicted by satellite, proving that the bandpass of the Landsat TM band 7 sensor is sufficiently broad to detect the ammonium absorption feature at 2.1 microns. Other clay-bearing areas depicted on Landsat are now also targets for ammonium-bearing minerals. Prior to the airborne flight, no previous mapping technique had identified this zone, in spite of over

100 years of intense exploration for ore deposits. Moreover, the Cedar Mountains are located in the Walker Lane, a major zone of strike-slip faulting and mining districts in western Nevada. Because the zone of ammonium-bearing minerals cross-cuts several of the ash-flow tuffs along the west side of the Cedar Mountains, the ammonium appears to have been emplaced after the extrusion of the 29 m.y. rhyolitic ash-flow tuffs. The ammonium feldspar, buddingtonite, has previously been associated with mercury/gold-bearing epithermal systems in igneous rocks at McLaughlin, California, and Ivanhoe, Nevada. Like the distribution of ammonium-bearing minerals from other epithermal systems, their distribution at the Cedar Mountains seems to be structurally-controlled. Loss of access to this locality should be considered prior to withdrawing the land for the Reserve Component Training Center (RCTC).

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* Brand names are for descriptive purposes only and do not imply an endorsement by the U.S. Geological Survey.

List of Figures

Figure 1. - Outline map of the mountain ranges northwest of Tonopah, Nevada showing the location of the zone of ammonium-bearing minerals in the Cedar Mountains photointerpreted from the GER 63-channel airborne data, flown in August, 1988.

Figure 2. - Near-infrared spectra between 1.9 and 2.5 microns showing relation of the 2.1 micron spectral absorption feature for the ammonium-bearing feldspar, buddingtonite, to the 2.2 um absorption feature for clay minerals, such as kaolinite. Bandpass for Landsat Thematic Mapper band 7 is shown at the top of the figure. Hatchured area represents the portion of ammonium spectral absorption feature that is detectable from the Landsat TM sensor.

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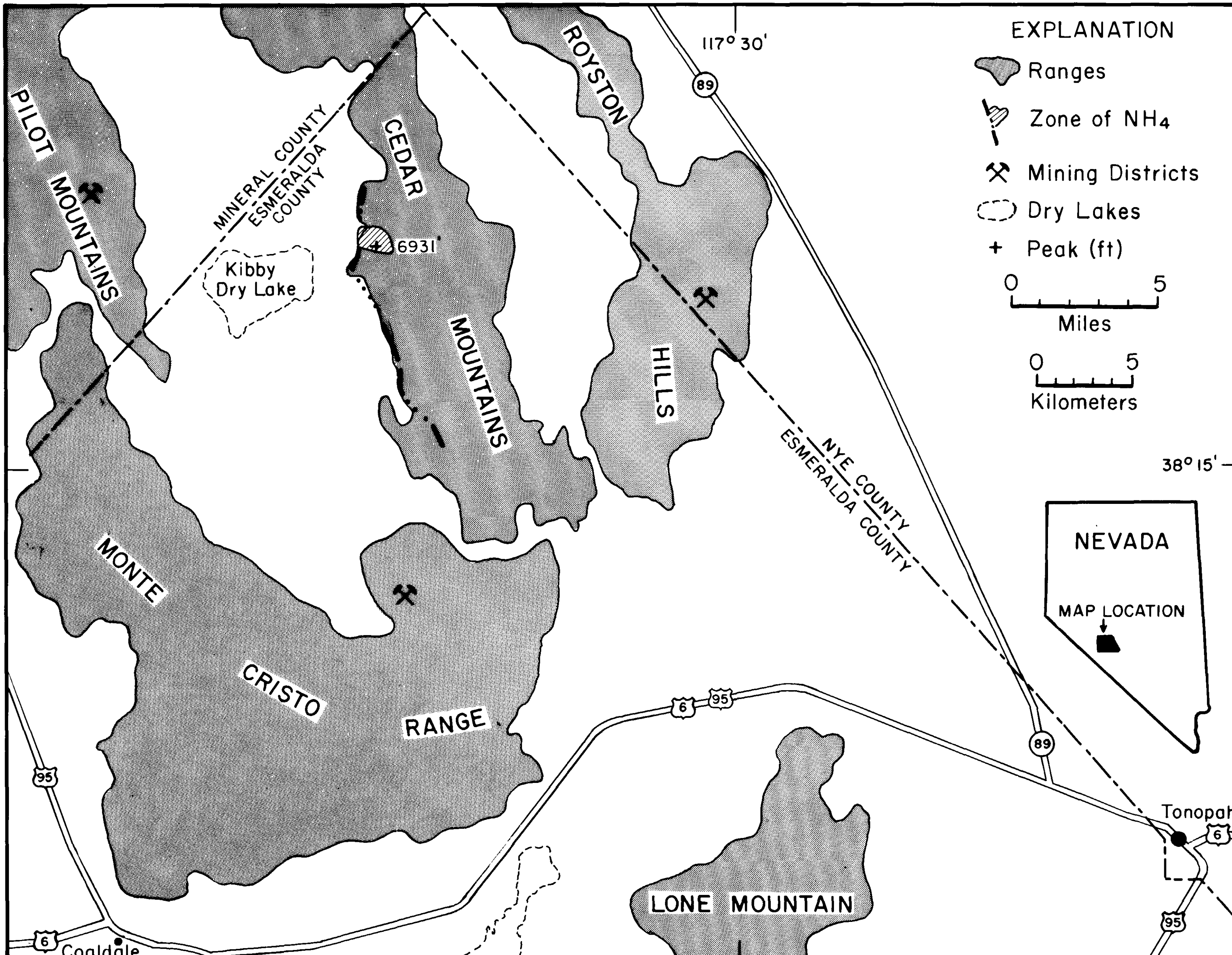
EXPLANATION
Ranges
Zone of NH_4
Mining Districts
Dry Lakes
+ Peak (ft)
0 5
Miles
0 5
Kilometers
117° 30'
38° 15'
PILOT MOUNTAINS
MINERAL COUNTY
ESMERALDA COUNTY
Kibby Dry Lake
CEDAR MOUNTAINS
6931'
ROYSTON HILLS
NYE COUNTY
ESMERALDA COUNTY
MONTE CRISTO RANGE
LONE MOUNTAIN
NEVADA
MAP LOCATION
Tonopah
Coaldale
6
95
89

Figure 1

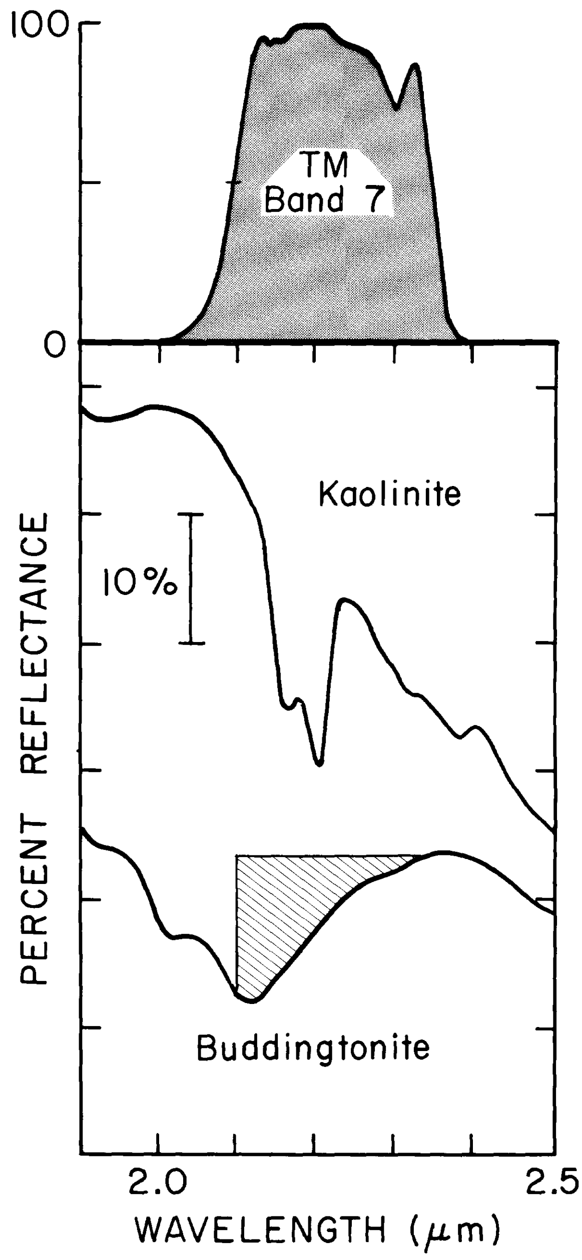
100
0
TM
Band 7
Kaolinite
10%
PERCENT REFLECTANCE
Buddingtonite
2.0
2.5
WAVELENGTH (μm)

Figure 2