U.S. Department of Interior

Geological Survey

Preliminary Map of Limonitic Hydrothermal Alteration for Portions of the Needles 1° x 2° Quadrangle, Arizona and California

by

Gary L. Raines

U.S. Geological Survey, Denver, Colorado 80225

Open-File Report 83-421

1983

This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

Introduction

Portions of the Needles quadrangle have been designated by the Bureau of Land Management as potential wilderness areas and are being evaluated by a multidisciplinary team to determine the mineral-resource potential. As a part of this study Landsat images are being used to map the generalized distribution of limonitic materials as a guide to hydrothermal alteration which, in turn, acts as a guide to mineralized systems. The term limonite, defined by Blanchard (1968) as a general term for hydrous iron oxides, is here modified to include any material with the unique spectral reflectance prpoerties of the ferric oxide minerals such as hematite and goethite, as defined by Hunt (1980).

The map shows areas of limonitic hydrothermal alteration but does not show hydrothermally altered areas lacking limonitic materials. Table 1 lists, for each hydrothermally altered area detected, the type of alteration and the anomalous trace-element geochemical suite found in that area.

Methods

The methods used for identification are based on the Landsat color-ratio composite technique of Rowan and others (1974). Color-ratio-composite images of the Landsat data, produced by digital image processing (Raines and others, 1978), are interpreted by inspection and by application of the Munsell-classification procedure of Raines (1977). Landsat scenes E280417212, E287517115, and E287617173 were used. The Munsell-classification procedure allows for simple classification of specific colors in a Landsat color image, such as the characteristic green color of limonitic areas in the color-ratio-composite image used here. A thematic map of limonitic areas is produced by this procedure. Combining this thematic data with the visual inspection of the color-ratio composite results in a thorough and accurate mapping of the limonitic areas at the Landsat resolution of 79 m.

These limonitic areas are evaluated in the field to determine if the limonite is associated with hydrothermally altered rocks. Pyrite and (or) hematite are commonly associated with hydrothermal alteration, and these minerals weather to produce limonite. Common sources of limonite unrelated to hydrothermal alteration include iron-rich, rock-forming minerals and disseminated limonite in sedimentary, volcanic or metamorphic rocks. All areas defined as limonitic in and near the proposed wilderness areas were visited in a rapid reconnaissance manner and selectively sampled to determine the following: (1) if the limonite was associated with hydrothermal alteration, (2) where present, the assemblage of alteration minerals, and (3) the assemblage of trace elements associated with the alteration. Rock mineralogy and texture, limited thin section studies, and identification of critical alteration minerals by spectral reflectance techniques (Hunt and Ashley, 1979) were used to determine the types of hydrothermal alteration. Selected mineralized rock samples, gossans, jasperoids, limonite coatings, and/or rocks containing visible sulfides were analyzed by a semi-quantitative emission spectrographic method (Grimes and Marranzino, 1968) and by a modified wet chemical method for antimony, arsenic bismuth, cadmium, gold, mercury, and zinc (Viets, 1978; Viets, J. G., oral communication, 1982) to define the trace-element assemblages associated with the observed alteration and mineralization. The anomalous geochemical values are selected somewhat arbitrarily, but based on consideration of the data in Rose, Hawkes, and Webb (1979) and from discussion with several U.S. Geological Survey associates in order to define what is an anomalous value. Because only one to six rock samples were analyzed from each limonitic area, anomalous elements are only indicative of mineralization. More detailed geochemical surveys covering all the study areas are being made to more fully define the mineralization. Table 1 lists the proposed wilderness areas studied to date, limonitic areas in and near the proposed wilderness areas, and elements determined to be anomalous from the samples taken in the limonitic areas. These anomalous elements are indicative of suites of trace elements associated with the mineralization.

Unevaluated Limonitic Areas

Limonitic areas with no associated symbols, are mapped areas delineated from analyses of the Landsat data that have not been evaluated in the field.

Unaltered Limonitic Rocks

Limonite-stained rocks unrelated to hydrothermal alteration are observed in the quadrangle, and the distribution is included on this map to document all of the areas studied. Neither the minerals characteristic of hydrothermal alteration nor anomalous trace elements were found during examination of these areas in the field and subsequent analysis of limonitic rock samples.

Limonitic Altered Rocks

The terminology used to describe the types of hydrothermal alteration generally follows the usage of Meyer and Hemley (1967) and is summarized in Table 2. The criteria used relies heavily on critical minerals that are diagnostic of certain types of alteration, and on rock texture. As mentioned above, only limonitic alteration types are considered.

The terms solfataric and iron metasomatism, as defined in Table 2, were found to be useful to describe mineralized rock that is at least incipiently altered. The solfataric altered areas are generally associated with manganese deposits in young volcanic rocks, and seem to result from warm ground water and/or hot spring activity probably related to late stages of volcanic activity. The term iron metasomatism is used with reservation to describe rocks with limonitic and occassionally pyritic coatings along horizontal joints in a 2-mica granite. These coatings have anomalous trace elements (Table 1, SH1), may represent residual fluids from the formation of the granites, and are considered indicative of the potential for mineralization in the area.

References

Blanchard, Roland, 1968, Interpretation of leach outcrops: Nevada Bureau Mines Bull. 66, p. 7.

Gary, Margaret, McAfee, Robert, Jr., and Wolf, C. L., (eds.), 1972, Glossary of geology: American Geological Institute, Washington, D. C., 805 p.

Goldschmidt, V. M., 1922, On the metasomatic processes in silicate rocks: Economic Geology, v. 17, p. 105-123.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Hemley, J. J., and Jones, W. R., 1964, Chemical aspects of hydrothermal alteration with emphasis on hydrogen metasomation: Economic Geology, v. 59, p. 538-569.

Hunt, G. R., 1980, Electromagnetic radiation: The communication link in remote sensing, in Siegal, B. S., and Gillespie, A. R., Remote sensing in geology: John Wiley and Sons, New York, p. 5-45.

Hunt, G. R., and Ashley, R. P., 1979, Spectra of altered rocks in the visible and near infrared: Economic Geology, v. 74, p. 1613-1629.

Lindgren, Waldemar, 1928, Mineral Deposits (3rd ed.): McGraw-Hill Book Co., Inc., New York, p. 85.

Mason, Brian, 1966, Principles of Geochemistry (3rd ed.): John Wiley & Sons, Inc., New York, p. 276-278.

Meyer, Charles, and Hemley, J. J., 1967, Wall rock alteration in Barnes, H. L., Geochemistry of hydrothermal ore deposits: Holt, Rinehart and Winston, Inc., New York, p. 166-235.

Raines, G. L., Offield, T. W., and Santos, E. S., 1978, Remote-sensing and subsurface definition of facies and structure related to uranium deposits, Powder River Basin, Wyoming: Economic Geology, v. 73, p. 1706-1708.

Raines, G. L., 1977, Digital color analysis of color-ratio composite Landsat scenes. Proceedings of Eleventh International Symposium on Remote Sensing of Environment, p. 1463-1472.

Rose, A. W., Hawkes, H. E., and Webb, J. S., 1979, Geochemistry in mineral exploration (2d ed.): Academic Press, New York p. 549-581.

Rowan, L. C., Wetlaufer, P. H., Goetz, A. F. H., Billingsley, F. C., and Stewart, T. H., 1974, Discrimination of rock types and detection of hydrothermally altered areas in south-central Nevada by the use of computer enhanced ERTS images: U.S. Geological Survey Professional Paper 883, 35 p.

Viets, J. G., 1978, Determination of silver, bismuth, cadmium, copper, lead, and zinc in geologic materials by atomic absorption spectrometry with tricaprylyl methyl ammonium chloride: Analytic chemistry, v. 50, p. 1097-1101.

Table 1: List of proposed wilderness areas studied to date, hydrothermally altered areas in and near the proposed wilderness areas, the type of alteration, and the anomalous trace-element geochemical suite associated with each hydrothermally altered areas. The anomalous geochemical values are selected somewhat arbitrarily, but based on consideration of the data in Rose, Hawkes, and Webb (1979) and from discussion with several U.S. Geological Survey associates in order to define what is an anomalous value. For those areas with both wet chemical and spectrographic analyses available, the wet chemical analyses are considered more appropriate than the spectrographic analyses; so the wet chemical analyses are the determining values in these cases. The star (*) in front of any area name indicates that no indications of previous mining or exploration activity were observed in this area. The identification, CDCA310 for example, is the identification number for the California Desert Conservation Area.

Definitiion of Anomalous Geochemical Values

Wet Chemical Analyses, Anomalous Values in Parts Per Million

As $\geq$ 30, Au $\geq$ 0.05, Bi $\geq$ 5, Cd $\geq$ 1, Hg $\geq$ .1, Sb $\geq$ 4, Zn $\geq$ 100

Semiquantitative Spectrographic Analyses, Anomalous Values in Parts Per Million

Ag $\geq$ 0.5, As $\geq$ 200, B $\geq$ 100, Ba $\geq$ 2000, Bi $\geq$ 10, Cu $\geq$ 100, Mn $\geq$ 2000, Mo $\geq$ 10, Pb $\geq$ 70, Sb $\geq$ 100, Sn $\geq$ 50, W $\geq$ 50 Zn $\geq$ 100

	Area Number	Alteration type	Anomalous Trace-element Geochemical Suite
		Chemehuevi Mountains (CDCA 310)	
	CH 1	Argillic/Solfataric	B, Hg
*	CH 2	Argillic/Solfataric	Ag, Ba, Hg, Mo, Pb, Zn
*	CH 3	Unaltered	Ba
	CH 4	Propylitic	Ag, Au, Ba, Cd, Cu, Zn,
*	CH 5	Propylitic	Ag
*	CH 6	Propylitic	Ag
*	CH 7	Advanced Argillic	Ag, Pb
*	CH 8	Propylitic	Ba
		Crossman Peak (Mohave Mountains; Spectrographic Analysis Only; CDCA 5-7B)	
	CP 7	Propylitic	Ag, As, Au, Cu, Mo, Pb, W, Zn
	CP 8	Argillic	Ag, Cu, Mn, Pb, W, Zn
	CP 9	Argillic	Ag, Bi, Cu, Pb,
	CP 10	Propylitic	Cu, Mn, Pb, Zn
	CP 11	Propylitic	Ag, As, Au, Ba, Bi, Cu, Mn, Mo, W, Zn
	CP 12	Sulfataric	Ag, As, Ba, Cu, Mn, Mo, Pb, Sb, W, Zn
		Sheephole Cadiz (Spectrographic Analysis Only; CDCA 305)	
*	SH 1	Iron Metasomatism	Ag, Ba, As, Pb
	SH 2	Propylitic	Cu, Pb
*	SH 3	Iron Metasomatism	Pb
	SH 4	Argillic	Ag, B, Ba, Bi, Cu, Mo, Pb, Zn, W
		Turtle Mountains (CDCA 307)	
	TM 1	Propylitic	Ag, Au, As, Bi, Cu, Hg, Mo, Sn, W, Zn
	TM 2	Propylitic	Au, Ag, Cd, Cu, Mn, Pb, Zn,
*	TM 3	Argillic	Ag, Ba
	TM 4	Argillic	Ag, Mo, Pb
	TM 5	Argillic/Propylitic	Ag, Au, Bi, Mo, Pb, W,
		Whipple Mountains (Spectographic Analysis Only; CDCA 312)	
	WM 1	Solfataric	Ag, As, Ba, Cu, Mn, Mo, Pb, W, Zn
	WM 3	Solfataric/Argillic	Mn, Pb
	WM 4	Argillic	Ag, Cu, Mo, W, Zn
	WM 5	Argillic	Ag, Bi, Cu, Mn, Mo, Pb, Zn,
	WM 6	Solfataric/Propylitic	Ag, As, Ba, Cd, Cu, Mn, Mo, Pb, Zn
	WM 7	Propylitic	Ag, As, Ba, Bi, Cu, Mn, Mo, Pb, W, Zn
	WM 8	Propylitic	Ag, B, Ba, Cd, Cu, Mn, Mo, Pb, W, Zn

Table 2: Definition of limonitic hydrothermal alteration types, ordered from weak to intense types of alteration. The definitions here summarize critical aspects of these terms; the reader is referred to the references for a complete discussion of the terms.

Alteration type	Symbol	Definition and References
Solfataric	S	An incipient alteration associated with late stages of volcanic activity characterized by emissions of sulfurous gases and other gases and vapors with associated hot spring activity. Critical minerals are opal, chalcedony, silceous sinter, limonite, hydroxides of manganese, barite, siderite, and pyrite (Lindgren, 1928; Gary and others, 1972).
Iron Metasomatism	FeM	An incipient alteration indicative of the past presence of interstitial, chemically active pore fluids or gases contained within the rock body or introduced from external sources. Critical minerals are limonite or local pyrite coatings with anomalous trace elements (Goldschmidt, 1922; Mason, 1966; Gary and others, 1972) .
Propylitic	P	Weak or incipient alteration characterized by replacement of mafic minerals by the formation of chlorite, albite, epidote, carbonate, quartz and minor allophane, sericite, montmorillonite, leucoxene, and pyrite (Meyer and Hemley, 1967).
Argillic	A	An intermediate alteration characterized by the destruction of mafic minerals and feldspars. Critical secondary minerals are montmorillonite, kaolinite, sericite, biotite, pyrite, and quartz (Hemley and Jones, 1964; Meyer and Hemley, 1967).
Advanced Argillic	AA	An advanced alteration characterized by the complete destruction of mafic minerals and feldspars. Critical minerals are kaolinite, dickite, pyrite, hematite, alunite, jarosite, rutile, leucoxene, tourmaline, topaz, and amorphous clays (Hemley and Jones, 1964; Meyer and Hemley, 1967).

Explanation

Anomalous limonitic areas interpreted from a Landsat color ratio composite image. The solid line represents a well defined boundary. The dotted line represents a arbitrary boundary separating an area that is the source of the limonite, generally bedrock, from transported alluvial limonite. The horizontally ruled area is an included nonlimonitic area. The symbol N is representative of the symbols designating the general source of the limonitic materials. If N is not present then the area has not been evaluated in the field. The symbol MX is the number of an area referred to in Table 1.

Symbols

Unaltered Limonitic Areas

E	Eolian Sands
V	Volcanic Rocks
VC	Volcanoclasitc Rocks
AL	Alluvium

Limonitic Hydrothermally Altered Areas

S	Solfataric
FeM	Iron Metasomatism
P	Propylitic
A	Argillic
AA	Advanced Argillic

NOTES:

1. When reconnaissance examination suggests that significant portions of an area might have more than one type of pervasive alteration, a two part symbol is used, Z/W. Z is the most pervasive type of alteration, and W is a significant but lesser type.

2. The mountain ranges without any limonitic areas have not been studied as of June, 1982.