in Proceedings of the NASA Earth Resources Survey Symposium, Vol 1B - Houston, Texas, 1975
NASA TM X-58168

GL02804

G-28

UNIVERSITY OF UTAH
RESEARCH INSTITUTE
EARTH SCIENCE LAB.

MINERAL TARGET AREAS IN NEVADA FROM GEOLOGICAL ANALYSIS OF LANDSAT-1 IMAGERY

Monem Abdel-Gawad and Linda Tubbesing
Rockwell International Science Center
Thousand Oaks, California 91360

ABSTRACT

Geological analysis of LANDSAT-1 Scene MSS 1053-17540 suggests that certain known mineral districts in east-central Nevada frequently occur near faults or at faults or lineament intersections and areas of complex deformation and flexures. Seventeen (17) areas of analogous characteristics were identified as favorable targets for mineral exploration. During reconnaissance field trips we visited eleven areas. In three areas we found evidence of mining and/or prospecting not known before the field trips. In four areas we observed favorable structural and alteration features which call for more detailed field studies. In one of the four areas limonitic iron oxide samples were found in the regolith of a brecciated dolomite ridge. This area contains quartz veins, granitic and volcanic rocks and lies near the intersection of two linear fault structures identified in the LANDSAT-1 imagery. Semiquantitative spectroscopic analysis of selected portions of the samples showed abnormal contents of arsenic, molybdenum, copper, lead, zinc, and silver. These limonitic samples found were not <u>in situ</u> and further field studies are required to assess their source and significance.

PREFACE

Over the past four years, the Rockwell International Science Center has been pursuing research on the applications of space photography in the discipline of geology. In addition to the Rockwell International supported effort, the Science Center has been under contract to NASA Goddard Space Flight Center (LANDSAT-1 Contract #NAS5-21767) and Johnson Space Center (Skylab Contract #NAS2-7523) to perform investigations related to the identification and interpretation of regional geological structures from space imagery and to attempt to correlate known mineral deposits with these observed geological structures.(Abdel-Gawad and Tubbesing, 1974, 1975a, 1975b). As part of the Rockwell funded application of this technology, the Science Center has carried out an IR&D project for establishing the feasibility of utilizing space imagery to locate favorable target areas for future mineral exploration. The space imagery used in this study were taken by the NASA Resources Technology Satellite LANDSAT-1. This report presents a summary of the results of the IR&D project.

INTRODUCTION

One of the objectives of our research project funded by Rockwell International Science Center (CFY 1974) was to investigate the application of space imagery for identifying targets for mineral exploration and to carry out field studies in order to check our observations in the field. This special report describes significant results obtained from analysis of LANDSAT-1 Scene No. 1053-17540 over east-central Nevada.

BACKGROUND

Research on the utilization of space imagery as a tool for mineral exploration is based on the assumption that sites of hydrothermal mineral concentrations may have characteristics which can either be directly observed in the imagery or more likely to be indirectly derived from a combination of geological indicators. The assumption is generally valid because mineral deposits do not occur at random and are often associated with ore guides. Although each mineral district has some unique characteristics, occurrences in a given metallogenic province often have in common distinctive similarities in their modes of occurrence such as a favorable host rock, type of structural control, the mineral assemblage and alteration features. Global factors, which control the distribution and type of metallogenic provinces, are caused by deep seated tectonic and magmatic processes within the earth's crust and are reflected in an intimate relation between metallogenic and petrographic provinces. On a regional scale, many geologists have presented persuasive arguments that clusters of mineral deposits tend to occur at the intersections of tectonic belts. An example is the porphyry copper districts in southern Arizona which lie at the intersection of Jerome and Texas tectonic belts. Individual lineaments and their intersections have also been noted to control the location of mineral districts and even an individual large mine. On the local scale of an individual mine detailed geological studies have frequently revealed that ore bodies are structurally controlled. In cases, the ore body may occur along a specific structure such as a shear zone, a fault, a breccia pipe, etc.

If these structures could be identified, satellite imagery could be utilized in mineral exploration. It has become very well known that linear structures such as faults, fractures and shear zones are among the most prominent features observed in satellite imagery and are the easiest to map. It is also true that some "lineaments" recognized by researchers are subtle and are not recognized by all. Subjectivity of interpretation no doubt complicates lineament analysis of imagery and detracts from the basic validity of this potentially useful approach.

Area of Investigation

One area selected for this study is in the Basin and Range province in east-central Nevada. The space imagery used is LANDSAT-1 Scene No. 1053-17540 (Fig. 1).

Selection of this particular scene for detailed study was based upon several geological factors:

1. From regional stratigraphic considerations, the area lies mainly in the eastern Nevada province which is underlain largely by Precambrian metamorphic and sedimentary rocks and particularly by Paleozoic carbonate rocks in contradistinction to the western province characterized by Paleozoic and Mesozoic clastic rocks (Nolan 1943, 1962). The significance of this distinction is that the carbonate strata particularly the dolomites of Cambrian age have been known to be favorable host rocks for emplacement of mineral deposits where intruded by the Laramide granitic stocks.

2. Most of this area lies east of the leading edge of the Roberts Mountain thrust which brought the western clastic Paleozoic section on top of the carbonate section (Fig. 2). Farther west, within the domain of this major thrust many mineral deposits probably occur concealed beneath the upper clastic plate; several major mineral districts occur in erosional windows where the carbonate section is uncovered.

3. Although large areas have not been geologically mapped in detail, many Laramide granitic intrusives are known to occur.

4. Besides the carbonates as favorable host rocks, Tertiary acidic volcanic tuffs and rhyolites which are known to be good host rocks for precious metals are widespread and are exposed in many places from beneath the generally barren volcanic flows.

5. The area lies within the eastern Nevada metallogenic province characterized by major lead and zinc deposits with associated gold and silver. The western province is known for gold and silver, tungsten, antimony, mercury and iron. Two northwest-trending mineral belts or

metallogenic lineaments cross the area: Ely, Battle Mountain-Eureka. The Lovelock-Austin and Fallon-Manhattan belts may also project southeastward (Figs. 2 and 3).

6. The scene includes three major mining districts: Eureka, Mount Hamilton, and Ruth: major producers of silver, gold, lead, zinc, copper and molybdenum. In addition, many smaller mining districts and individual mines are present.

Analysis of the structural pattern in relation to those known occurrences was made in order to gain some insights which may help us identify structurally analogous areas.

Approach

The basic approach in conducting this investigation was to: 1) analyze the structural pattern inferred from the imagery in relation to known mineral districts and relevant geological data, and 2) apply this analysis in identifying favorable sites for detailed mineral exploration in the field. In order to attain our objectives we performed the following tasks:

1. Assembled and plotted on overlays relevant data from the literature. These included: a) Basic geographic and geomorphologic data. b) The locations of known mineral districts classified by type and relative size of production, as well as many individual mines. c) Major structural elements, lineaments or mineral belts published in the literature. d) Basic geological information on the distribution of major time-stratigraphic or rock units.

2. Identified and mapped significant structures which include: a) Linears such as inferred faults, shear zones or fractures. b) Structural trends showing bends, flexures, oroclines, discontinuities.

3. Analyzed all pertinent data in relation to the distribution of known mineral districts.

4. Identified candidate targets for exploration on the basis of a) Location within the structural pattern such as intersections, flexures, re-entrants and areas of complex deformation. b) Areas showing color and textured characteristics similar to those observed in known mining districts.

5. Identified priorities for field checking mainly on the basis of easy access from major transportation routes and probable presence of favorable host rocks.

6. Carried out reconnaissance field observations for obtaining ground truth data.

PROGRESS

The area selected for this investigation covered approximately 26,000 km^2 in the Basin and Range province of east-central Nevada (Fig. 1).

In order to apply the concept that analogous metallogenic districts often show similarities in their structural settings, we plotted known mineral districts on imagery overlays showing the elements produced and their relative size of production. Figure 4 shows the known mineral districts and occurrences in relation to geological structures inferred from LANDSAT-1 imagery. Figures 2 and 3 show the axes or trends of major mineral belts which cross or project into the area taken from Roberts (1964). The leading edge of the Roberts Mountain thrust was also approximately located. The mineral belts suggested by Roberts are: Ely, Battle Mountain-Eureka, Lovelock-Austin and Fallon-Manhattan, all trending northwest and Pioche which trends east-west.

The LANDSAT-1 image was analyzed to identify and map significant structural linears, fault zones, fracture lines and major flexures or structural bends. Figures 4 and 5 show the structural pattern corresponding to Fig. 1.

Some of our linears appear to coincide with or are parallel to Ely, Battle Mountain-Eureka and Pioche mineral belts. The structural expressions of Lovelock-Austin, and Fallon-Manhattan mineral belts are either vague or absent. However, we noted that many mineral deposits tend to occur along faults or linears and particularly at their intersections (Fig. 4). Examples of these are the Eureka mining district which was a major producer of silver, gold, lead, zinc and copper. This district lies at the intersection of north and northwest and northeast trending fault systems and a structural flexure. The Ruth district, which is a major producer of copper, silver, gold, molybdenum, lead and zinc, lies at a structural flexure where north and northwest trending fault zones converge. Mount Hamilton district is known mainly for silver and gold production together with tungsten, molybdenum and copper. This district appears to be controlled by north and northwest fault systems.

From observations on the structural control of known mining areas, as well as color, tonal and textural characteristics which reflect rock properties, we have identified a number of target areas judged to be favorable for exploration.

Study of the target areas on geological maps resulted in the selection of 17 high priority targets for ground truth field investigation. The high priority target areas (Fig. 5) were selected mainly on the basis of the presence of rocks of geochemical composition favorable for mineralization. Examples of these are Paleozoic dolomites, limestones and Tertiary rhyolitic intrusives, flows and tuffs.

SUMMARY OF FIELD OBSERVATIONS

During reconnaissance field trips we visited 11 sites. In ten sites we were able to identify the structural and lithologic features observed in the imagery. Table 1 lists a summary of the most pertinent field observations. Sites 17, 18, and 19 were found to have mining areas not known to us before the field trips. Sites 4, 23, 25, and 32 show favorable structural and alteration features which call for more detailed field studies.

AREA OF LIMONITIC IRON OXIDE

Area No. 4 lies in the Hot Creek Range, Morey Peak Quadrangle, Nye County, Nevada. Since available topographic maps show that section corners have not been established in much of that quadrangle, the precise location within section corners has not yet been established.

Table 1. Summary of Field Observations

Site	Location	Field Structures	Country Rocks	Evidence of Mineralization
1	Monitor Range	NW trending fault	Volcanic tuffs	Limonitic alteration, placer magnetite
2	Monitor Range	ENE fractures	Tertiary volcanics	None
4	Hot Creek Range	N-S and NE fault intersection	Dolomite, granite quartz veins, volcanic rocks	Gossan samples found in float
17	Horse Range, Elson Creek Area	NW topographic linears	Tertiary volcanics	Hematitic alteration old mining areas
18	Horse Range, White Pine Range	NE fracture zone	Tuffs, volcanic flows	Alteration, prospecting pits
19	Horse Range, Currant Summit	Extremely deformed rocks	White tuffs, Paleozoic rocks	Prospecting pits, mining in vicinity
22	Schell Creek Range	Subtle, uncertain	Paleozoic rocks	None
23	Schell Creek Range	Highly deformed	Quartzites, dolomite basalt	Secondary copper minerals in basalt
24	South Egan Range, Shingle Pass	NE anticline	Intrusive granites, dolomite, quartz veins	None visible
25	Schell Creek Range	NE fracture zone	Tertiary volcanics	Widespread rock alteration
32	Quinn Canyon Range	NW, NE faults	Volcanic tuffs	Alteration, pyrite in green tuffs

During reconnaissance field work within target area No. 4 (Fig. 5), chunks of limonitic iron oxide samples were found in the regolith of a dolomite ridge. The area lies at the intersection of a northeast-trending fault zone with a north-trending regional fault zone which aligns with the Eureka mining district. The latter zone is approximately parallel to the leading edge of the Roberts Mountain thrust. The country rock consists of dolomite, a favorable host rock for sulfide mineralization, cut by quartz veins and intrusive granite (Fig. 6). We have not located any of this limonitic material in situ and further detailed field work and geophysical measurements are needed to establish the source of the float and its economic significance.

Table 2, columns 2, 3, and 4 show semiquantitative emission spectroscopic analyses of limonitic material scraped from three distinctively different color regions in the samples. A large number of semiquantitative x-ray fluorescence analyses done in our scanning electron microscope showed that in addition to the major elements, potassium at about the one percent level and arsenic at less than one percent were generally distributed through these samples. On a scale varying from centimeters to micrometers no significant localization of important elements could be found.

Gray dolomite samples collected from the regolith and a brecciated outcrop are veined with calcite. Spectroscopic analysis of white, fluorescent encrustations shows trace amounts of lead, copper, and silver, Table 2, column 5.

Table 2. Semiquantitative Analysis* of Samples Found in Hot Creek Range, Nevada

	Red	Yellow-Orange	Black	White	Best, Red
Fe-	55.%	56.%	65.%	0.57%	35.%
Si-	5.4	5.5	2.3	2.1	4.0
Al-	1.3	1.1	0.36	0.50	4.4
As-	0.74	0.76	0.69	-	17.
Ca-	3.5	1.7	0.33	29.	2.6
B-	0.016	ND<0.003------------------		TR<0.005	0.22
Sb-	-	ND<0.05-------------------		-	0.95
Mg-	0.22	0.49	0.22	6.1	0.40
Mn-	0.042	0.20	0.14	0.013	0.12
Pb-	0.091	TR<0.02-------------------		0.016	0.63
Mo-	0.082	0.086	0.034	-	0.28
V-	0.0051	0.0063	0.0034	-	0.0090
Cu-	0.017	0.027	0.023	0.00041	0.18
Ag-	0.0010	TR<0.0002-----------------		TR<0.002	0.0045
Zn-	0.064	0.26	0.073	-	0.86
Ti-	0.085	0.027	0.0096	0.027	0.049
Ni-	0.0026	0.0038	0.0016	TR<0.002	0.017
K-	-	ND<0.50-------------------		-	TR<0.50
Cr-	TR<0.0005	0.0058	TR<0.002	0.00075	TR<0.002
Other Elements		nil	nil		nil

*Pacific Spectrochemical Laboratory, Inc., Los Angeles, California

Our first spectroscopic analysis of red limonitic material showed concentrations of arsenic, antimony, lead, and zinc much higher than a subsequent analysis of similar but not identical material taken for verification. These initial results are listed in Table 2, column 6. Flakes from all identifiable red areas in the remaining samples have been examined in the scanning electron microscope. No region with arsenic, lead, or zinc concentrations approaching those in column 6 could be found. Therefore, it is certain that even if the high analysis is correct, it probably represents a small fraction of the material in the samples.

Examination of polished sections indicate the presence of goethite, lepidocrocite and secondary banded hematite. Available evidence seems consistent with the possibility that these samples are a gossan derived from the weathering of a massive sulfide vein, although other possible modes of origin certainly cannot be ruled out without additional work.

SUMMARY AND CONCLUSIONS

Geologic and structural analysis of a LANDSAT-1 scene in east-central Nevada in relation to known mineral districts resulted in the selection of 17 target areas for mineral exploration. During reconnaissance field observations three areas were found to show evidence of mining and prospecting not known before these areas were visited. Four areas showed structural as well as alteration features which appear to be favorable for detailed geological and geophysical exploration. In one area in the Hot Creek Range we found limonitic iron oxide samples in the regolith of a dolomite ridge containing abnormal contents of several economic elements. These limonitic samples found were not *in situ*, and further field exploration is needed to assess their source and significance.

REFERENCES

Abdel-Gawad, M. and L. Tubbesing, 1975a, Analysis of Tectonic Features in U.S. Southwest from Skylab Photographs: Final Report SC5007.16FR Rockwell International Science Center, Thousand Oaks, CA, prepared for NASA Johnson Space Center, Houston, TX, 94 p.

Abdel-Gawad, M. and L. Tubbesing, 1975b, Identification and Interpretation of Tectonic Features from Landsat-1 Imagery - Southwestern North America and The Red Sea Area : Landsat-1 Investigation Final Report SC543.16FR Rockwell International Science Center, Thousand Oaks, CA, prepared for NASA Goddard Space Flight Center, Greenbelt, MD, 118 p.

Abdel-Gawad, M. and L. Tubbesing, 1974, Transverse Shear for Southwestern North America - A Tectonic Analysis: Fist International Conf. on the New Basement Tectonics, June 3-7, 1974, Salt Lake City, UT Geological Assoc., (in press).

Nolan, T. B., 1943, The Basin and Range Province in Utah, Nevada and California; U.S. Geol. Survey Prof. Paper 197-D, p. 141-196.

Nolan, T. B., 1962, The Eureka Mining District, Nevada; U.S. Geol. Survey Prof. Paper 406, p. 78.

Roberts, R. J., 1964, Economic Geology in Mineral and Water Resources of Nevada; Nevada Bureau of Mines Bull. 65, p. 39-45.

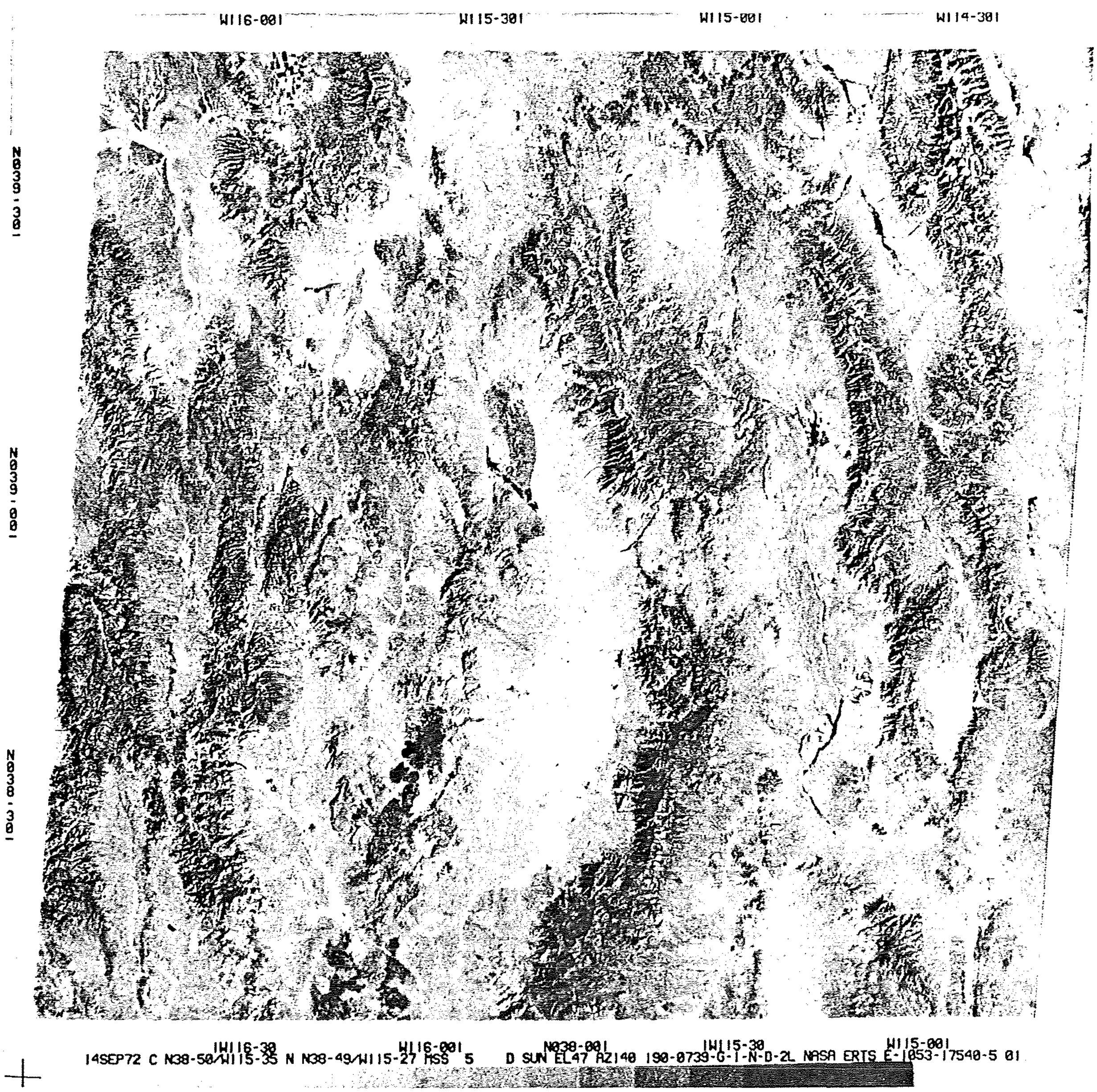


Figure 1 - LANDSAT-1 Scene MSS 1053-17540, Band 5

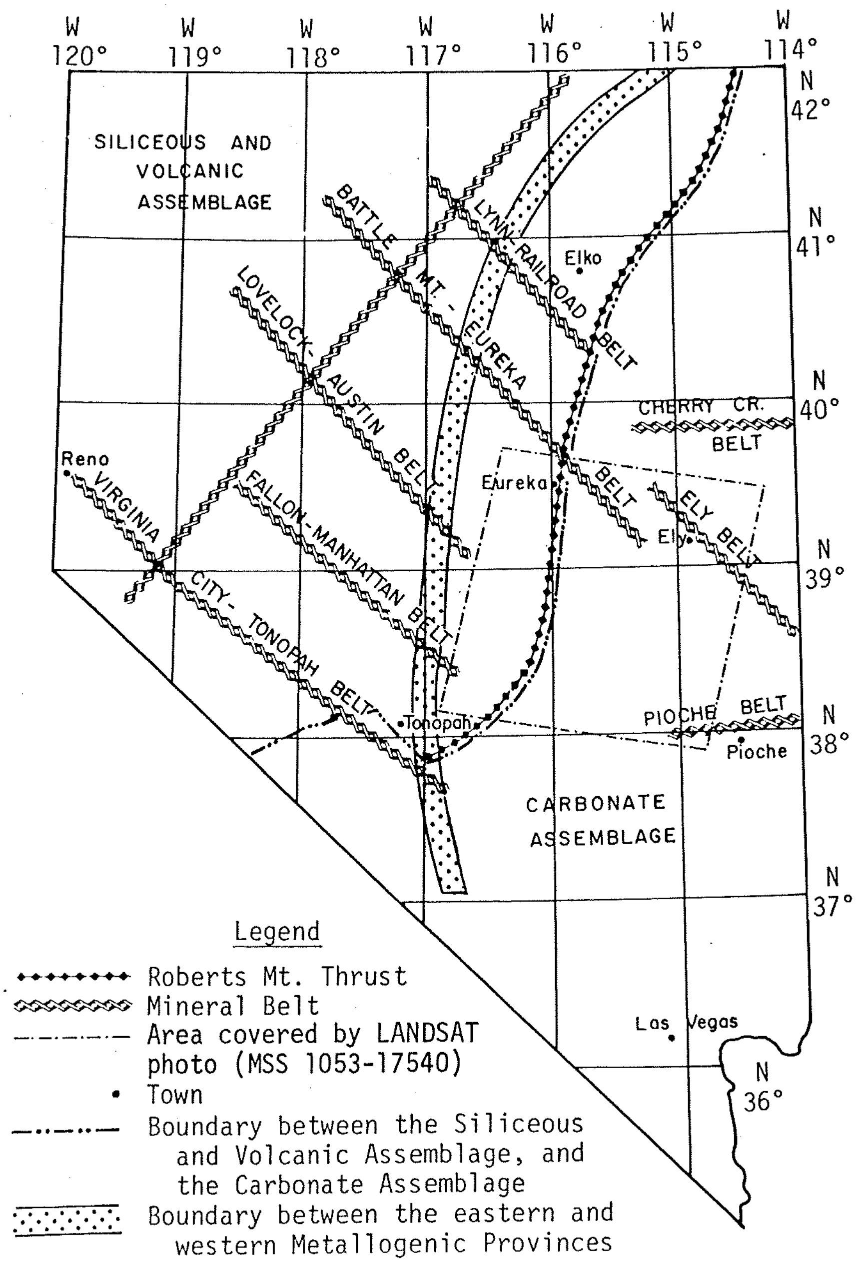


Figure 2 - Mineral Belts of Nevada (After: R. J. Roberts, 1964)

MSS 1053-17540

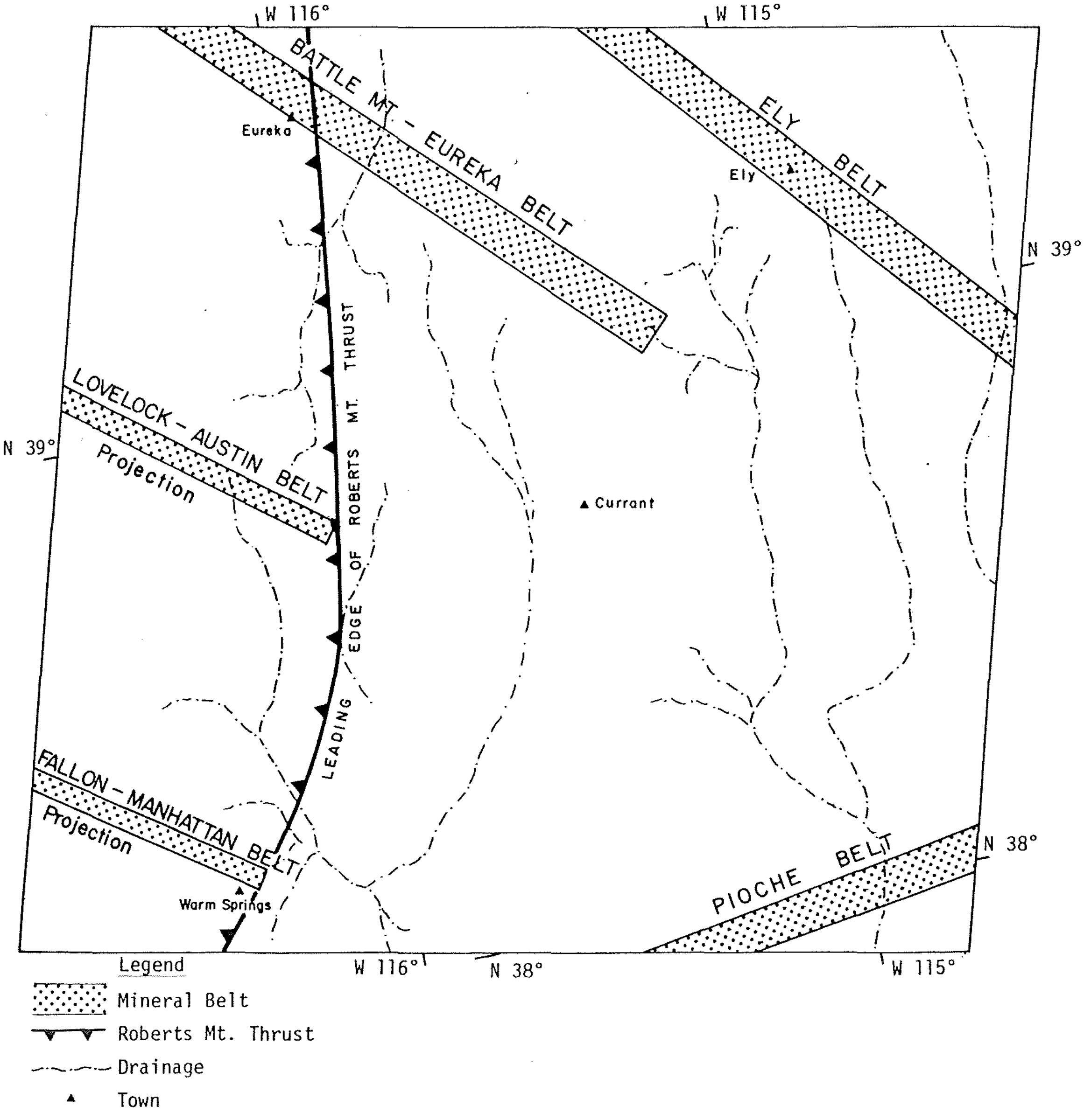
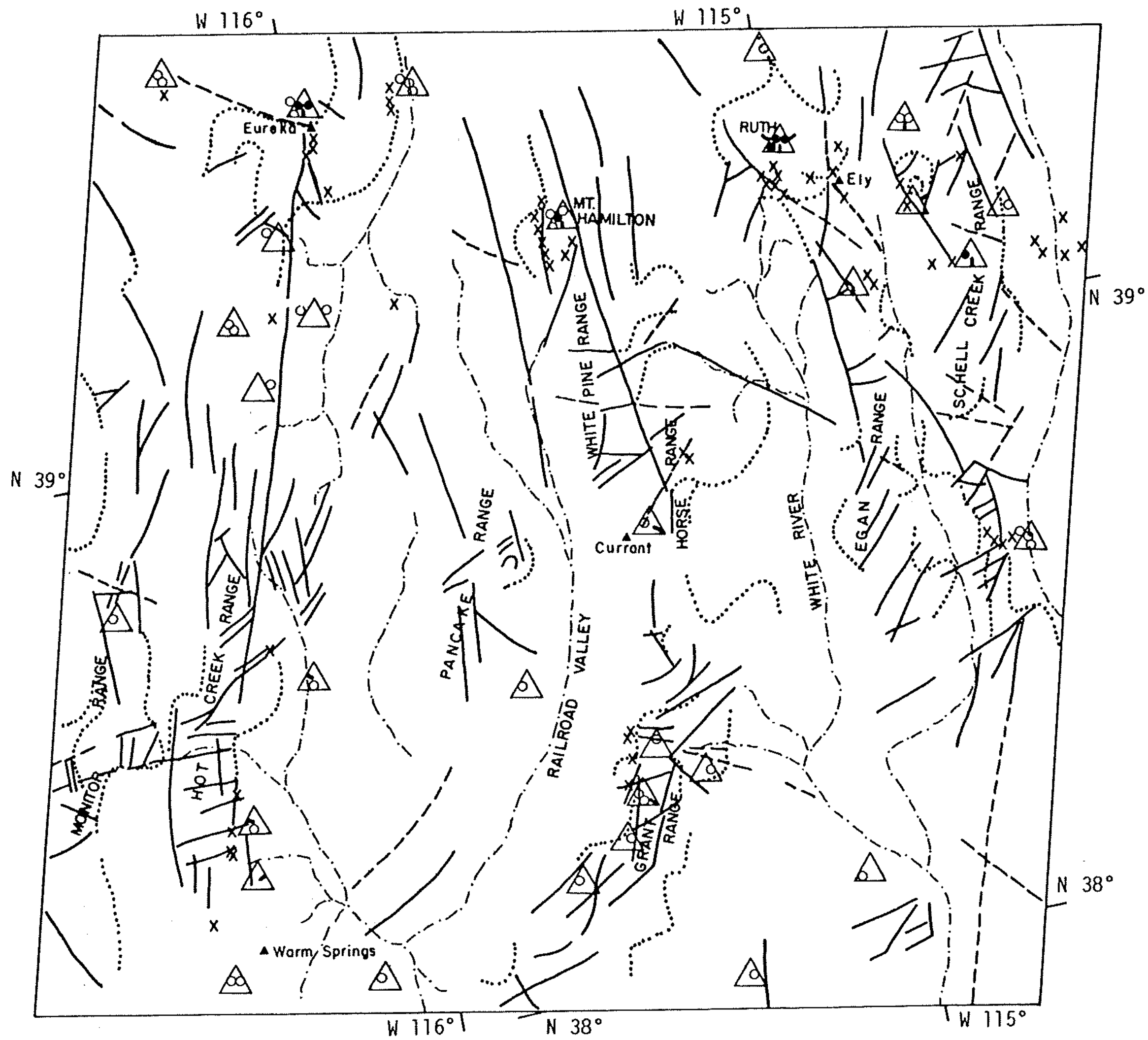


Figure 3 - Mineral Belts Projected on LANDSAT-1 Scene MSS 1053-17540



Legend

- Drainage
- Town
- Linear trends of faults, shear zones, fractures (dashed where ill defined or uncertain)
- Structural trends showing bends and oroclinal flextures
- Mine location
- Ore production areas

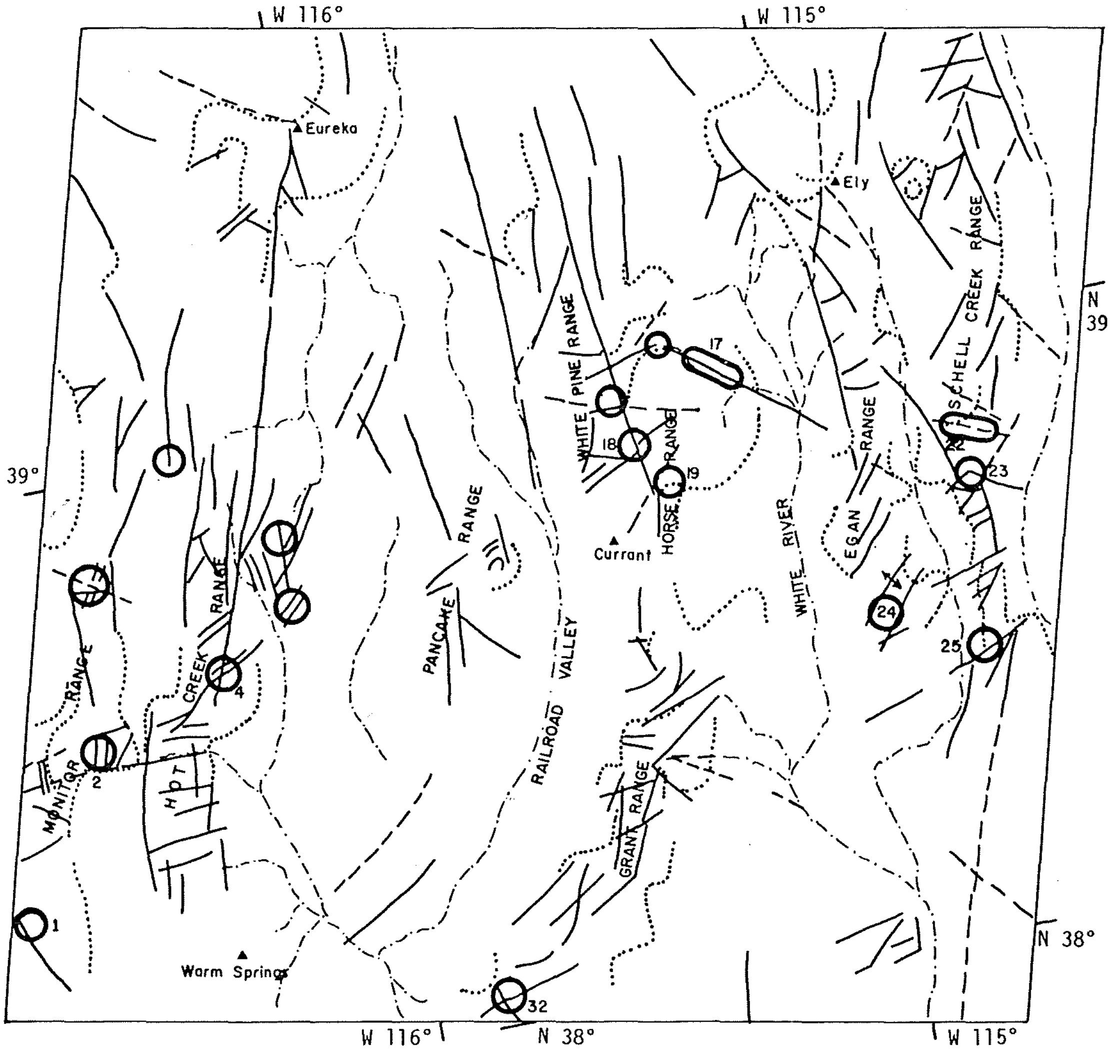
Ag, Au, PbZn, Cu, W, U, Mo, Mn

Large production area

Medium production area

Small production area

Figure 4 - Structures Inferred from LANDSAT-1 Imagery and Mineral Districts



Legend

Drainage
Town
Linear trends of faults, shear zones, fractures (dashed where ill defined or uncertain)
Structural trends showing bends and oroclinal flextures
High priority target areas

Figure 5 - High Priority Targets Identified on LANDSAT-1 Imagery Scene MSS 1053-17540

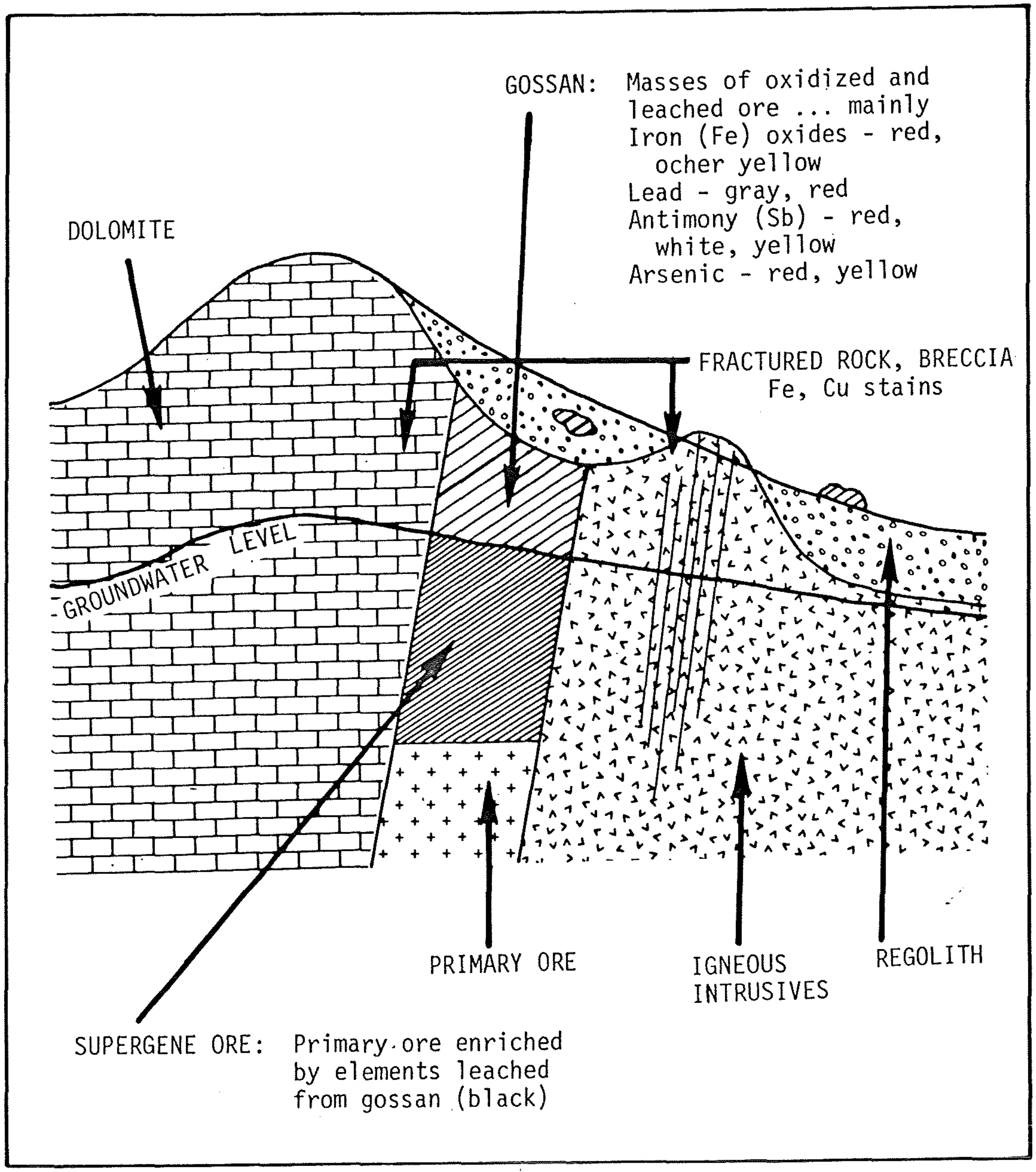


Figure 6 - Hypothetical Cross-Section of Vein Type Deposit.