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Revised.

THE UNIVERSITY OF UTAH

COLLEGE OF MINES
AND MINERAL INDUSTRIES

DEPARTMENT OF GEOLOGY
AND GEOPHYSICS
717 MINERAL SCIENCE BUILDING

May 28, 1976

(E76-10417) REMOTE SENSING IN MINERAL EXPLORATION FROM LANDSAT IMAGERY Quarterly Report, Jan. - Mar. 1976 (Utah Univ.) 30 p HC $4.00 CSCL 08I

N76-27633

Unclas
G3/43 00417

TO: Mr. James Broderick
Technical Officer, Code 902
NASA
Goddard Space Flight Center
Greenbelt Road
Greenbelt, Maryland 20771

FROM: L. H. Lattman
Geophysics and Geology Department
College of Mines
University of Utah
Salt Lake City, Utah 84112

SUBJECT: Quarterly Report IV,
January, February, March, 1976

RE: Contract No. NAS 5-20955

22840

Original photography may be purchased from:
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

TITLE: REMOTE SENSING IN MINERAL EXPLORATION FROM LANDSAT IMAGERY

A. PROBLEMS

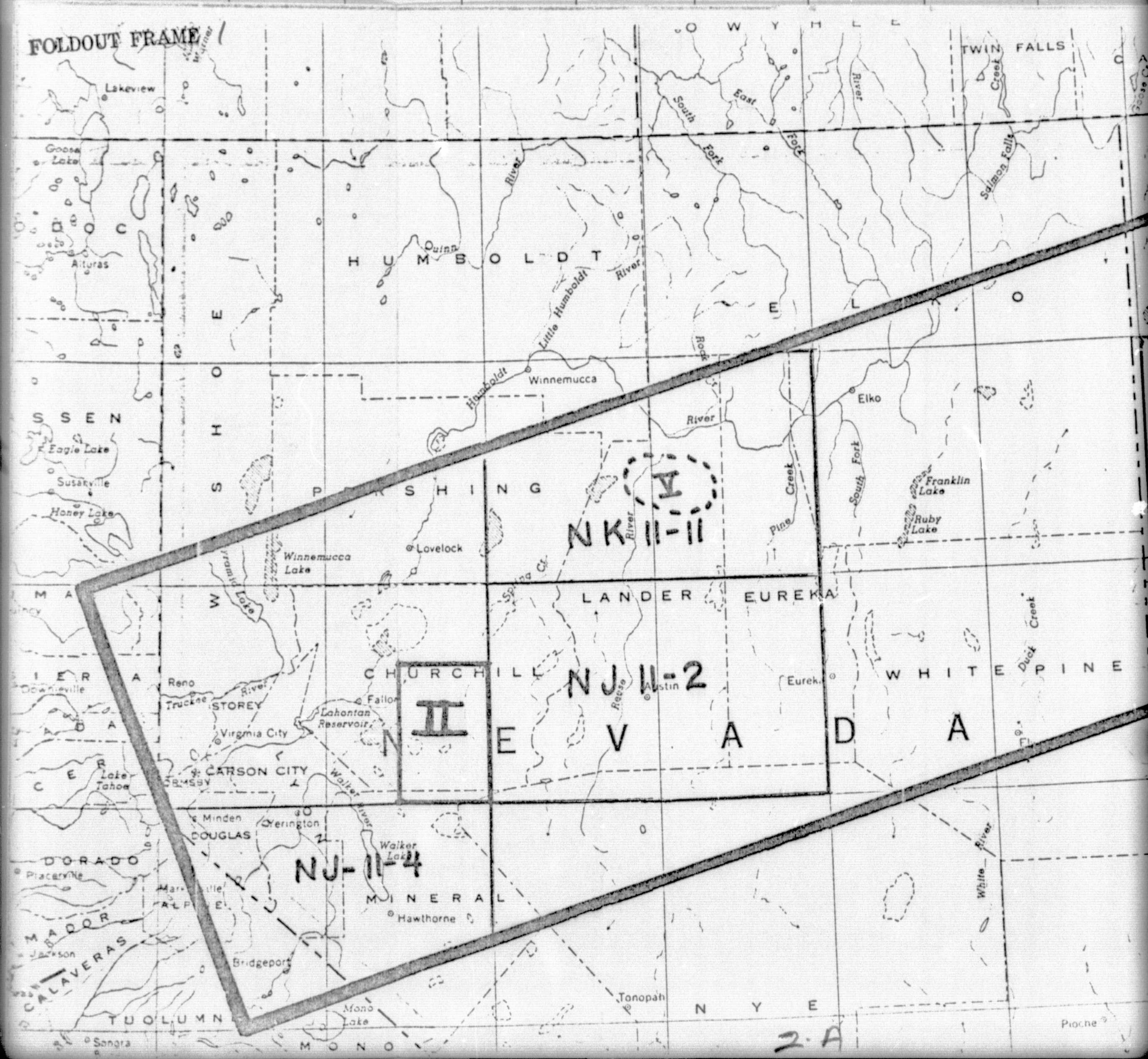
Due to snow cover, no overflight imagery has been received for comparison with existing imagery.

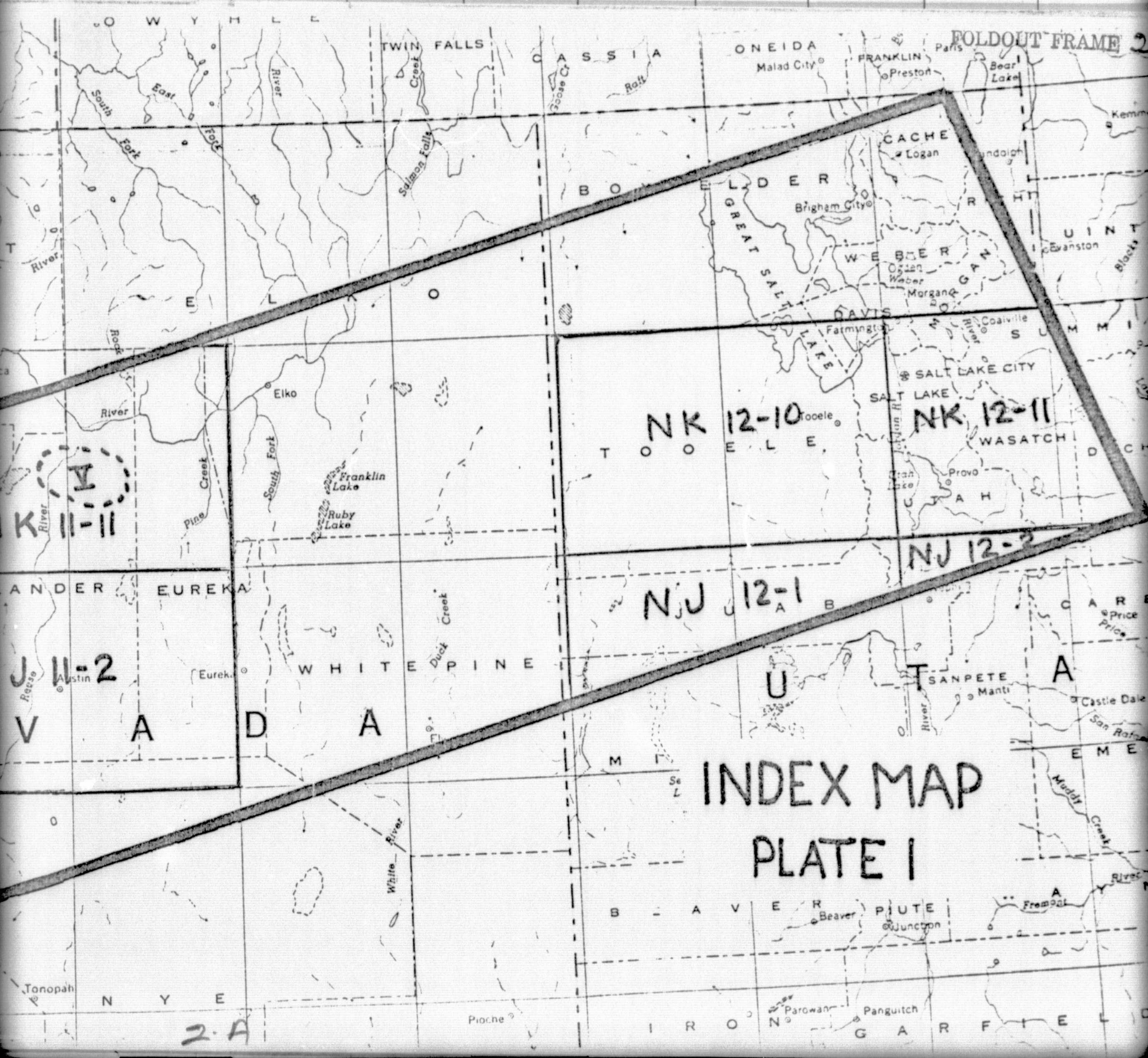
B. ACCOMPLISHMENTS

INDEX

List of Illustrations

FOLDOUT FRAME 1




FOLDOUT FRAME 2
OWYHEE
TWIN FALLS
CASSIA
ONEIDA
Malad City
FRANKLIN
Preston
Paris
Bear Lake
Kemm
South Fork
East Fork
River
Creek
Salmon Falls
Goose Cr.
Raft
CACHE
Logan
BOX ELDER
Brigham City
GREAT SALT LAKE
WEBER
Ogden
Weber
Morgan
MORGAN
DAVIS
Farmington
Coalville
SUMMIT
UINT
Evanston
SALT LAKE CITY
SALT LAKE
ELKO
Elko
River
Rock
NK 12-10
NK 12-11
Tooele
TOOELE
WASATCH
Provo
Utah Lake
UTAH
Franklin Lake
Ruby Lake
South Fork
Pine Creek
K 11-11
V
NJ 12-2
NJ 12-1
LANDER
EUREKA
JUAB
CARBON
Price
Duck Creek
J 11-2
Austin
Reese
Eureka
WHITE PINE
UTAH
SANPETE
Manti
Castle Dale
San Rafael
NEVADA
EMERY
MILLARD
INDEX MAP
PLATE I
Muddy Creek
White River
River
BEAVER
Beaver
PIUTE
Junction
Fremont
Tonopah
NYE
Pioche
Parowan
Panguitch
IRON
GARFIELD
2-A

B. ACCOMPLISHMENTS

I Lineament Study

Relationships between mining districts in the Utah-Nevada study area and lineaments located on LANDSAT imagery have been studied in the following projects:

a. Criteria for selection of lineaments on 1:250,000 scale LANDSAT mosaic.

The following criteria have been used for the selection of several hundred lineaments having a total length of 7400 km:

1) Each is greater than 5 km in length
2) Each has at least 50% topographic expression by length
3) Each must cross range crests to insure its not being a single consequent drainage line
4) Each must be obvious to at least two independent operators

The lineaments have been plotted on U.S. Army Topographic Command maps (AMS sheets), then traced on transparent mylar overlays to eliminate distracting background.

b. Identification of lineaments.

Several lineaments have been compared with geologic maps of the same scale as the imagery (Geologic Map of Utah, Stokes, 1963, scale 1:250,000) to see if lineaments have geologic as well as topographic manifestation. Lineaments on the AMS NK-12-10 (Tooele) sheet were chosen as a test case because of their ready accessibility for field checking. About one-half of the total lineament length is on or closely parallel (within 1 km) to mapped faults or geologic contacts.

c. Control of mining districts by lineaments:

1) Mines in the study area have been plotted on mylar overlays to locate and delineate mining districts. Data is taken from USGS Commodity Resources Information Bank (CRIB) forms compiled earlier in the preliminary literature search; from mining district maps compiled by Mardirosian (1974) and from Utah and Nevada state and county maps.

2) To test the concept that mines are controlled by lineaments or lineament intersections, direct comparison was made of mines and lineaments. The number of mines on, within 1 km of, and between 1 and 5 km of lineaments have been counted. Of a total of 666 mines plotted in the Utah-Nevada study area, 37 fell on lineaments, 80 were within 1 km, and 200 between 1 and 5 km. Seven lineaments contain 2 or more mines and 20 have 2 or more within 1 km. Seven of a total of 165 lineament intersections are on or within 1 km of a mine.

From these preliminary data, the qualitative conclusion is that there is no apparent control of lineaments on mine locations. No further work on this study is planned at this time.

3) To test the concept that mines are controlled by a particular azimuthal range of lineaments, the plotted lineaments were grouped into azimuthal ranges (15° classes). Of the 80 mines falling within 1 km of the lineaments, the distribution is as follows:

from	N 52-1/2° to 67-1/2° W	- 9 mines
	N 37-1/2° to 52-1/2° W	- 9 mines
	N 22-1/2° to 37-1/2° W	- 16 mines
	N 7-1/2° to 22-1/2° W	- 13 mines
	N 7-1/2° W to 7-1/2° E	- 5 mines
	N 7-1/2° E to 22-1/2° E	- 6 mines
	N 22-1/2° E to 37-1/2° E	- 6 mines
	N 37-1/2° E to 52-1/2° E	- 16 mines

There does not appear from these data to be any significant relationship between mines and lineament direction. No further work on this project is planned at this time.

4) To find if more mines are located on lineaments than on mapped faults, the total length of all mapped faults within the Utah portion of the study area was measured from the Geologic Map of Utah, (Stokes, 1963). (This area was subdivided by AMS sheets, as listed below.) The mines falling on and within 1 km of the faults were counted. These figures were compared with the total length of lineaments in the same area and the number of mines within 1 km of the lineaments:

AMS SHEET	km of lineaments per mine	km of mapped faults per mine
NK-12-10 Tooele	150	35
NJ-12-1 Delta	33	176
NJ-12-2 Price	27	35
NK-12-11 Salt Lake	147	28

The mines do not show any consistent preference for lineaments. No further work is planned at this time.

5) To find if several mines along a single lineament show any evidence of having a common source of mineralization, the metal content of mines on those lineaments having several mines on or within 1 km of the lineament were compared. It was found that several mines falling on a single lineament had completely different suites of metals. A lineament therefore does not appear to be a conduit to a single common source of mineralization. No further work is planned at this time.

6) A study was made to determine if lineaments bound areas having markedly different degrees of mineralization (density of mines).

For a preliminary sample, the area covered by the NJ-11-4 Walker Lake AMS sheet (see Plate 1) was selected. This area has a high density of mines and available geologic data.

All lineaments trending within 10° of north were plotted. This orientation was chosen because it is a dominant structural trend in this area, parallel to the Sierra Nevada front. The selection of these lineaments differed from the initial lineament study in that:

(1) minimum length was 2 km

(2) all natural linear features were traced, whether identified as topographic in origin or unidentified tonal contrasts. These are distinguished on the map by solid and broken lines, respectively.

These lineaments divide the area into sections from 1 to 30 km wide. Some mining districts (clusters of up to 30 mines) fall between two adjacent lineaments. They are sharply delineated from areas without mines on either side. These sections are within mountain ranges and have exposed outcrop areas to either side of the mineralized sections; that is, the boundaries between mineralized and non-mineralized sections are not range fronts.

The north-south extent of any particular mining district averages about 5 km. Several mining districts may be aligned in a north-south direction between two lineaments, with a total length of about 25 km.

Similar tests were made with lineaments ranging within 10° of East. This orientation was selected to parallel several strong E-W topographic trends across the area under study. The E-W trending lineaments tend to separate mining districts aligned in a north south strip but distinguished by different metals. This relationship shows up particularly well in the Pine Nut Range, the Garfield Hills and Pilot Mountain.

This study suggests the possibility that:

(1) lineaments bound tectonic blocks and bring together blocks having different tectonic and igneous histories

(2) some of these blocks may be elevated, bringing mineralized rock to the surface.

Further work is being done on these relationships. The working maps are large transparent overlays and are not included in this report.

7) Local areas free of lineaments were noticed when the north trending and east trending lineament overlays were superimposed. After basin areas were excluded, 17 areas were delineated on the Walker Lake AMS sheet. All of these lineament-free bedrock areas are greater than 25 km^2; their minimum width is 4 km, and their maximum area about 100 km^2. These areas were compared with the imagery and with geologic maps.

Of the 17 lineament free areas, 7 contain intrusive rocks, 10 principally volcanic rocks. Nine of these areas contain mining districts. Five are apparently related to the intrusives, and 4 to the volcanics or sediments. Only one of the lineament-free areas is dominantly sedimentary rocks. Sediments, where present, appear to be highly fractured.

The tonal contrast within the lineament-free areas is strong. The north and east trending lineaments may not have been mappable in these areas for one or more of the following reasons:

(1) They may not be present

(2) They may be overprinted and hence obliterated by NE and NW trending lineaments, which are present in the area as short (less than 5 km) segments.

The relationship between igneous rocks and lineament-free areas is being further checked.

II Special Study Areas

a. Park City District, Utah

Further work on this project has been postponed until snow cover melts and field work can be started. Field checking is planned for features visible on various types of imagery but not shown on available geologic maps.

b. East Tintic District, Utah

Imagery studies of hydrothermal alteration in the East Tintic Mountains has not been pursued this quarter, while waiting for additional photographic data from EROS Data Center.

c. Wonder-Eagleville Area, Nevada (see II pl. 1)

A linear trend consisting of light tonal and topographic features has been recognized on Landsat scene E-1397 18051 (see fig. 1)

Approx. length:		60 km
Azimuth	:	N25E
Location	:	W118°00' to W118°15' N39°00' to N39°30' Northern Mineral and southern Churchill Countines, Nevada

Coincident to the above mentioned trend are five mining areas (fig. 2). When these five mining areas are connected by a straight line, the line has the same azimuth as the tonal and topographic alignments visible on the LANDSAT image (figs. 1 and 2).

Converging lines of evidence from literature documentation suggest that this trend mayhave significance in future mineral exploration in this portion of Churchill and Mineral counties.

These lines of evidence are:

(1) Coincidence of location and orientation (azimuth) of 5 mining areas (see fig. 2) along this alignment, suggesting a continuous trend of mineralization.

(2) A fault zone extending from near Slate Mountain, through Fairview Peak, past Chalk Mountain to Wonder. This fault zone is recognized by geologic mapping in the field (see fig. 3).

(3) Recent fault activity (fig. 4) and clustering of earthquake epicenters along the trend (fig. 5).

(4) Alignment and elongation of intrusive bodies along the trend (see fig. 3).

The above information suggests that there may be additional undiscovered ore deposits along this apparent LANDSAT trend. However, it must be understood that the LANDSAT data may not be suitable for detailed investigation of this trend, as recognition of the trend is all that was expected from the synoptic view of LANDSAT. Additional exploration involving higher resolution imagery, geophysical methods and a drilling program would be required. The latter two methods, of course, are not an integral part of this NASA project. A further study is presently underway, however, to determine if this trend, recognized first on LANDSAT imagery, will maintain its integrity or or become diffuse when viewed with higher resolution and more detailed photography.

A small portion of the LANDSAT trend has been analyzed by density slice methods to delineate and quantify levels on the imagery. A printout was prepared (fig. 6) showing the distribution of lightest tone in the southern location of the LANDSAT trend (see also rectangular outline on fig. 1). The density slice method does not of course, identify the surface geologic features present, but does show that grey levels can be accurately mapped at a substantially larger scale than the original imagery permits. Geologic maps indicate that the light areas are zones of Tertiary dacite flows, very similar in chemical composition to the intrusive bodies in contact with ore bodies at Wonder and Fairview districts.

d. Battle Mountain-Eureka mining district trend

The northern end of this trend was considered in part V of this report. A study of the possible expression of this alignment of mining districts on the LANDSAT imagery will be carried out.

e. Battle Mountain-Wonder-Eagleville

Information derived from examination of LANDSAT scenes E-1792-17491 and E-1755-17554 coupled with literature studies indicate a northeastern alignment of acidic intrusions, basaltic cones, and seismic events with the Bernice, Jersey and Battle Mountain mining districts. A southerly extension of the alignment appears to intersect the Wonder-Eagleville trend at a sufficiently small angle to suggest that both alignments may in fact be related. On the premise that this direction may represent a line of crustal weakness a study is now in progress which uses this direction as a template to relate mining districts, intrusive centers, seismic events and surface expression of faults.

f. Yerington

No work was initiated in this study area during the quarter.

III Mining District Recognition

a. Frequency charts have been made to show production in millions of dollars, principal metal occurrence, host rock, hydrothermal alteration, control of ore emplacement and composition of intrusives associated with the 246 mining districts found in the Utah-Nevada study area. (see figs. 7, 8, 9, 10 and 11).

b. A list of approximately 100 descriptive features visible on LANDSAT imagery has been compiled, based on the detailed study of eight mining districts and two non-mineralized districts on LANDSAT transparencies. The mining districts have an average area of about 50 km^2. This list includes cultural, linear, tonal, and textural features present within a specified area and to facilitate statistical comparisons.

A systematic study of a larger population of mining districts is planned to see if any combination of these recognition features can distinguish mining districts from non-mineralized areas.

IV Relationships of intrusives to mining districts

The spatial relationships of mining districts to known intrusive outcrops has been under investigation during this quarter. From literature sources (Nevada Bur. of Mines maps #30 and #24) a bar histogram (fig. 12) has been constructed showing the number of mining districts within a specified distance from the nearest intrusive body. It is understood that the nearest intrusive body may or may not have influenced mineralization in a district; nevertheless, the histogram shows conclusively that there is a preponderance of mining districts in the 0 to 2 kilometer distance class. Further, 229 of the 325 districts are within 10 kilometers of the nearest outcrop of intrusive.

The areas of individual intrusives were measured and compiled, along with other mining district location data (see summary table below).

NEVADA, North of 37° latitude:

Total area of Nevada north of 37° lat.	:	254,119 km^2
Total area of igneous intrusive outcrop	:	8,420 km^2
Total number of metal mining districts	:	325
Total number of districts on intrusives	:	60
Total number within 2 km of intrusives	:	90
Total number on + within 2 km of intrusives	:	150

Intrusive outcrop represents approximately 3% of the area of Nevada under consideration. If a 2 km radius around each intrusive is studied, 46% of the mining districts fall in about 12% of the area under consideration. This regional approach suggests that almost half of the deposits are located on or within 2 km of intrusive bodies, although the converse is not necessarily true. A further conclusion is that a potential mineral reconnaissance program would locate almost 50% of the mining districts by concentrating efforts in only 12% of the area under consideration.

If the intrusive-ore body relationship is to have significant merit, a reconnaissance mineral exploration program which utilizes LANDSAT imagery must be able to consistently recognize intrusive outcrops from the imagery. A test site with mineral vegetation was chosen to compare known intrusives with their expression on LANDSAT imagery. Preliminary results indicate that intrusives in the study area tend to be distinguished by a conspicuous light tonal appearance. Other parameters currently under investigation include drainage, slope form, topographic expression and other geomorphic features. These parameters will be quantified and assessed as to their discriminating potential. These criteria will then be applied to other localities in the Nevada-Utah test site.

V Valley-Stream lineament analysis by length and azimuth in mineralized and non-mineralized areas

Introduction

As one phase in our study of possible applications of LANDSAT imagery in the recognition of mineralized areas, valley-stream orientations of various length classes were compared in mineralized and non-mineralized areas.

It was proposed that those stream courses or valleys whose length and azimuth could be reliably measured at the scale of LANDSAT imagery might serve to delineate regional fracture and/or fault traces. Further, a prefered azimuth might be related to mineralized areas.

The study area which lies in north central Lander County, Nevada, (see V on Plate 1) is underlain by folded and faulted euogeosynclinal siliceous strata and includes several mining districts. The area is also the northwestern terminus of an apparent trend of mineral districts which extends between Battle Mountain and Eureka.

Method

Imagery on bands 5 and 7 from Landsat scene E-1072-17592 was examined on a Bausch and Lomb model ZT-4 transfer scope. The magnification was adjusted to conform to the 1:250,000 scale of the AMS sheets NK 11-11 (Winnemucca) and NJ 11-2 (Millett). The scale and rectification adjustments provided by the ZT-4 permitted the various linear cultural elements, e.g. roads, railroads, as well as much of the topographic features to be placed in register with the maps.

Linear valley-stream segments within the study area were traced on to a mylar transparent overlay. The minimum segment length chosen was 1.6 km, the longest segment was approximately 25 km. After an interval of about 3 weeks the imagery was reregistered to the map and a new tracing of the stream and valley segments was made. The two tracings were compared for the operator's repeatability in tracing the length and azimuths. Very little change was noted in the direction of azimuth; .. segment lengths varied up to 1 km in about 10% of the measurements for the two trials.

Areas of known mineralization were then outlined on the tracing. Because of the scale it was considered necessary to include all the mineralized areas in the tally in order to have sufficient measurements to constitute a reliable sample.

Stream lengths were grouped into classes of 1.6-3.2 (1-2 mi); 3.2-6.4 (2-4 mi) and greater than 6.4 (4 mi) kilometers with azimuth intervals of 30°. Because of the considerable variation in the number of segments in each class the data for the statistical test were grouped then chosen by a random number method. Working maps for this portion of the project are not included in this report due to size.

Results

A Chi-square test was applied to each length category in order to determine if azimuths were significantly different in mineralized and non-mineralized areas. It was determined that within the 1.6-3.2 km and greater than 6.4 km length groups there was no significant difference at a=0.05 in azimuths in either the mineralized or non-mineralized areas. There was, however, a significant difference at a=0.05 in azimuths of the 3.2-6.4 km group when the mineralized and non-mineralized areas were compared.

Discussion

Due to the difference of the sample size in the mineralized and non-mineralized areas and in view of the stratigraphic and structural complexity within the areas, we are uncertain if the differences reported are entirely related to mineralization. These preliminary results suggest that additional efforts should be concentrated in the 3.2-6.4 km class and in an area of less variable lithology. Such an area in west central Utah covered by AMS sheets NJ 12-1 (Delta) and NK 12-10 (Tooele) is under study. Although this region is structurally complex, a substantial portion of the section is composed of carbonates.

C. SIGNIFICANT RESULTS

See under parts I through V above

D. PUBLICATIONS

None

E. RECOMMENDATIONS

Request additional funds in the amount of $1,472.00 in EDC LANDSAT account #G22840, to complete data on order.

F. FUNDS EXPENDED

Total expenditures to 5/1/76	$ 68,439.00

G. DATA USE

Value of LANDSAT data allowed	$ 9,300.00
Value of LANDSAT data ordered to 3/31/76	$ 10,761.00
Value of data received to 3/31/76	$ 9,289.00

This fourth quarter report for the period January through March is herewith submitted. Attached is the quarterly report for the same period from the Colorado School of Mines.

Respectfully submitted,

L. H. Lattman, Principle Investigator

M. P. Nackowski, Co-Principle Investigator

T. A. Belchak, research assistant

C. E. Cronenwett, research assistant

Ms. M. R. Smith, research assistant

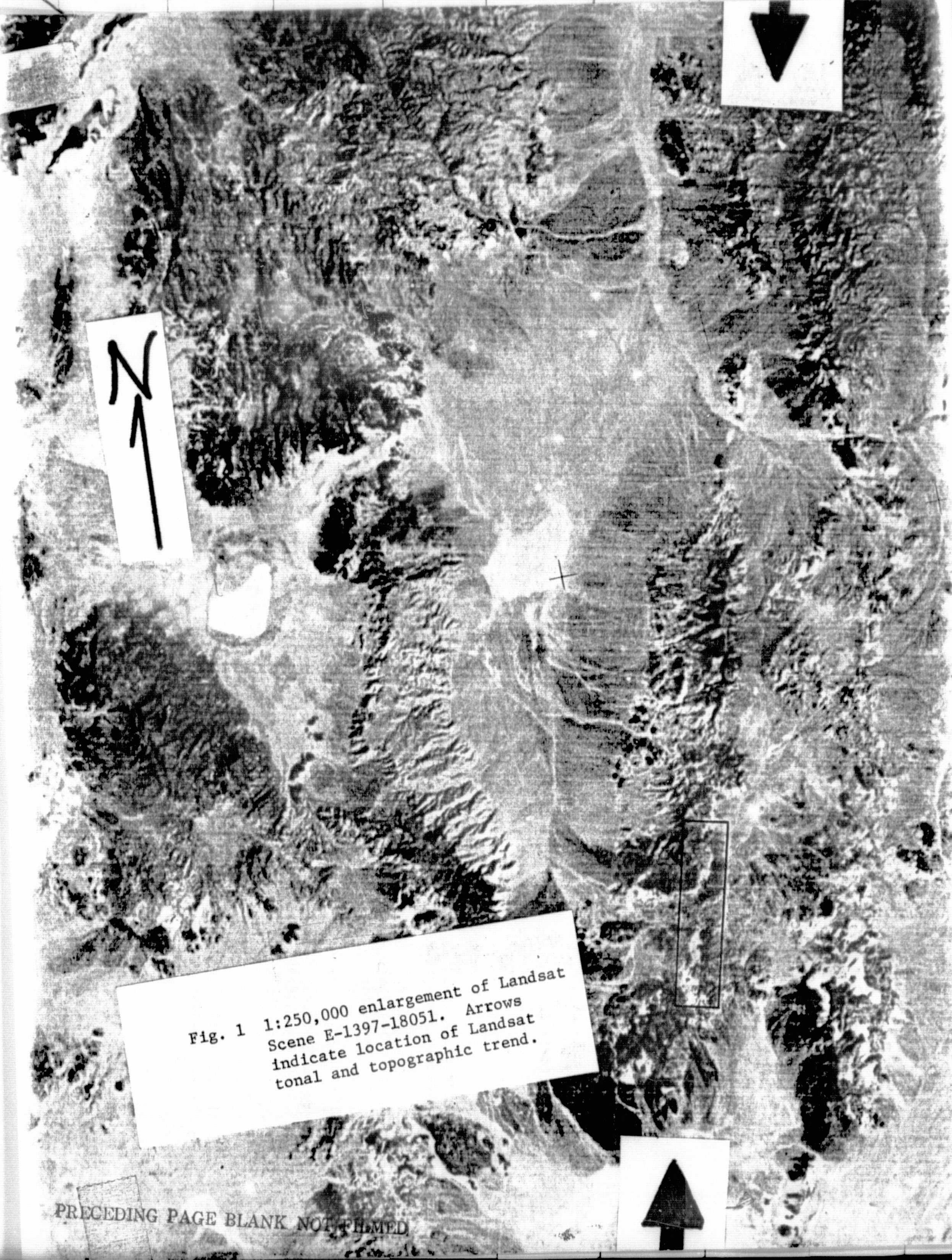


Fig. 1 1:250,000 enlargement of Landsat Scene E-1397-18051. Arrows indicate location of Landsat tonal and topographic trend.

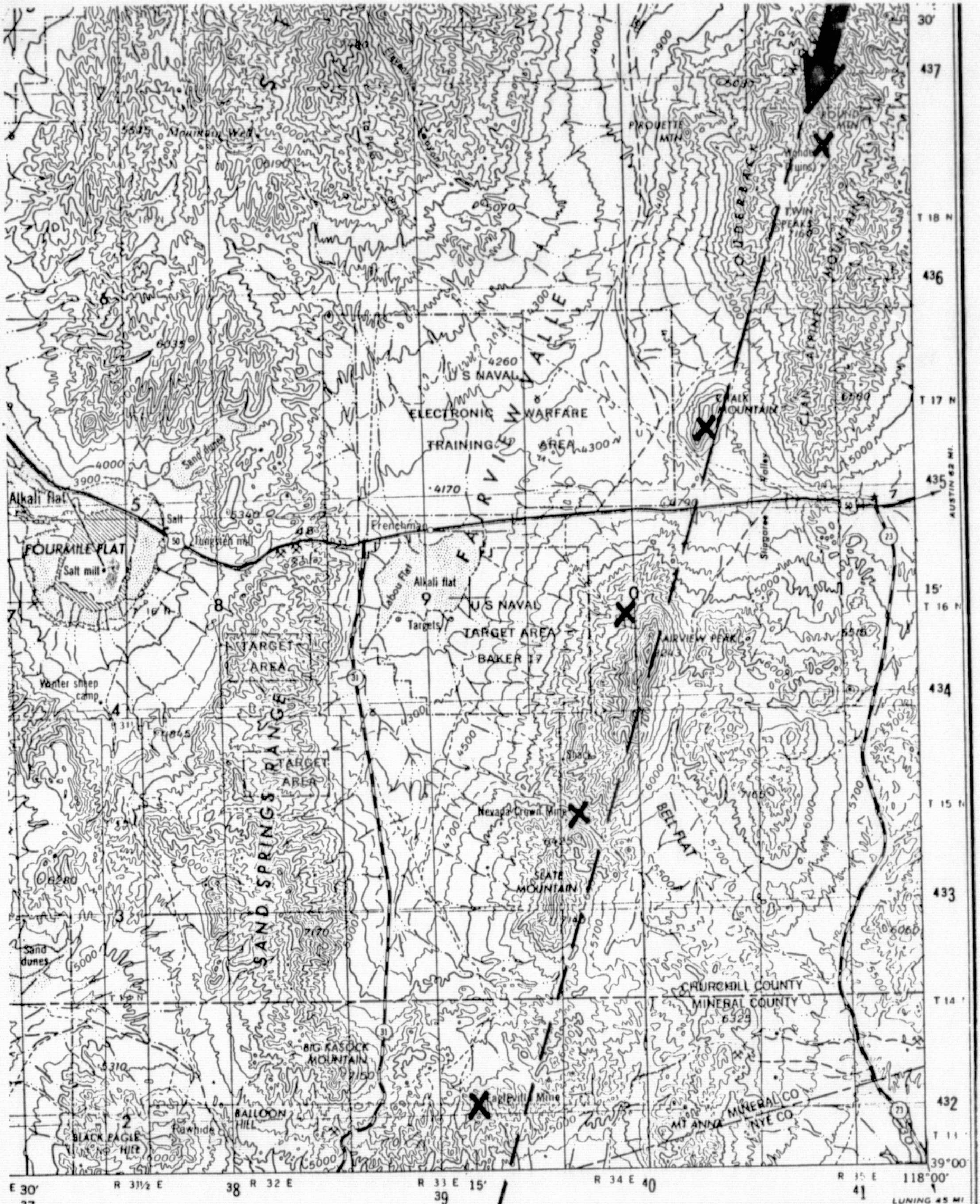


Fig. 2 Southeastern portion of Army Map Service NJ 11-1 Reno AMS topo sheet showing location of 5 mining areas (crosses) and Landsat trend (arrow and dashed line).

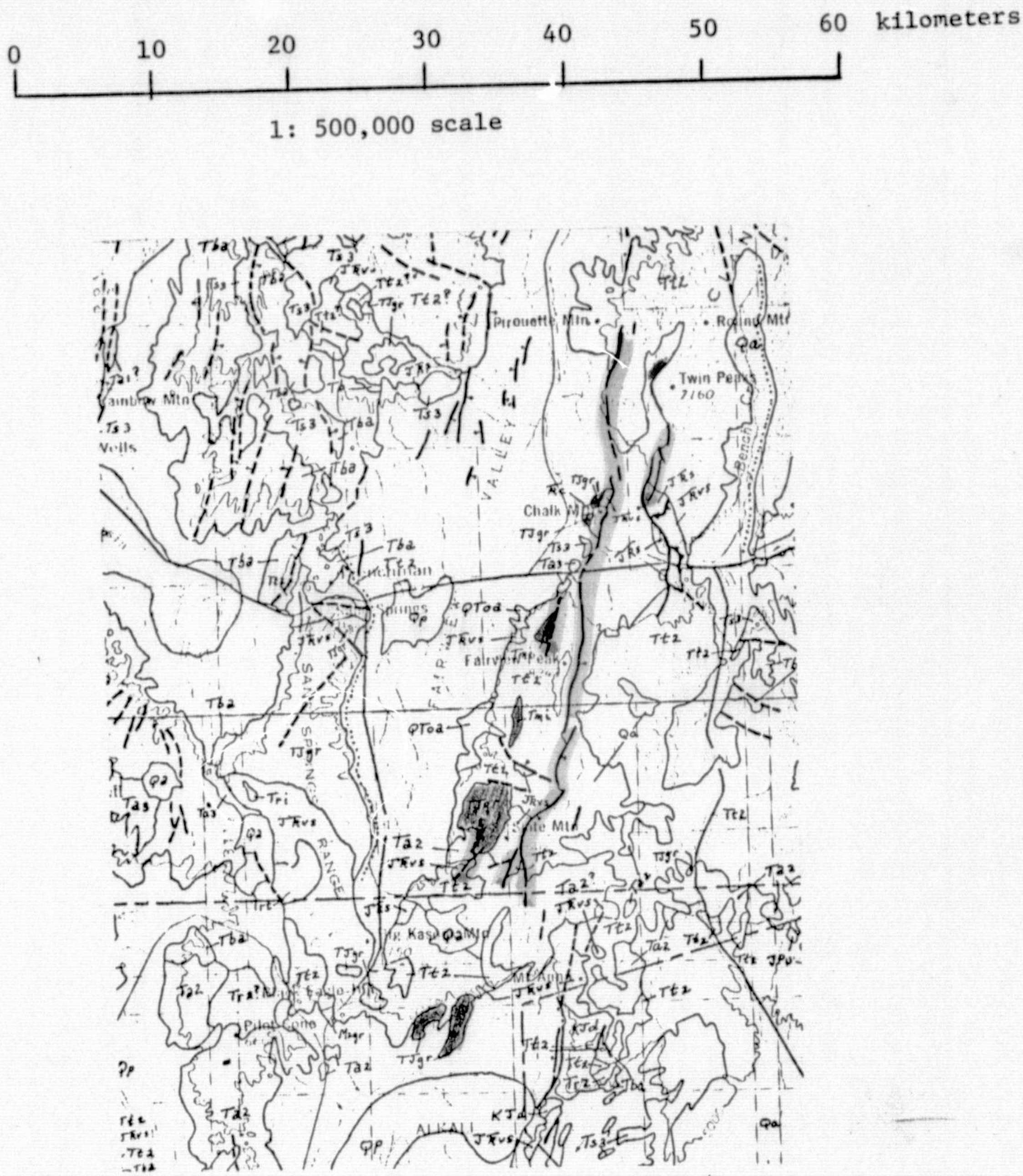


Fig. 3 Portion of Preliminary Geologic Map of Nevada (Stewart and Carlson, 1974) showing NNE alignment of intrusive bodies (red) and faults (blue) along Wonder-Eagleville mining trend, Mineral and Churchill counties, Nevada.

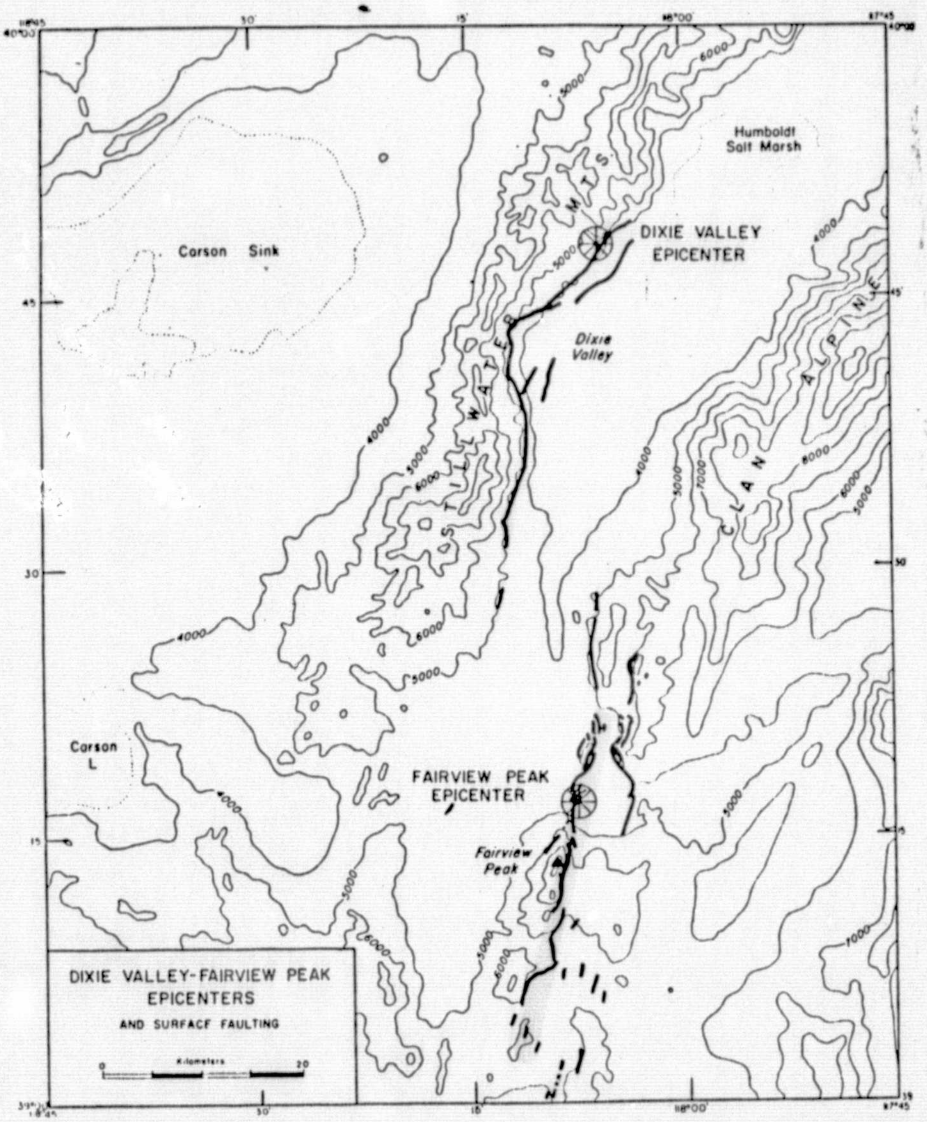


Fig. 4 Fault scarps of the 1954 Dixie Valley and Fairview Peak earthquakes, and coincidence with Landsat trend (in yellow).

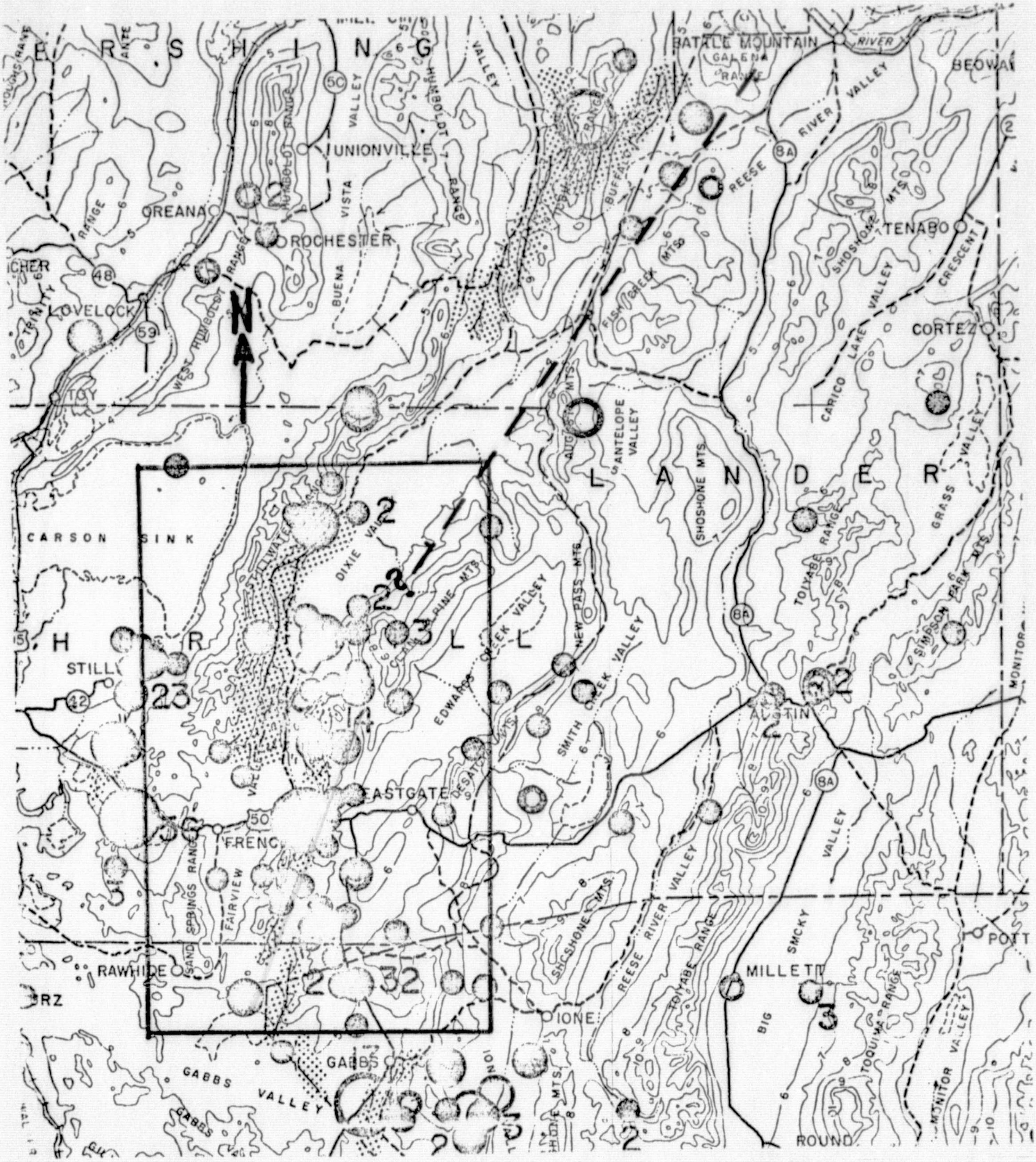


Fig. 5 Portion of Earthquake Epicenter Map of Nevada (NBM map #29) showing high concentration of epicenters in SE Churchill Co. of Wonder-Eagleville trend. Black line indicates possible Battle Mountain extension.

0 10 20 30 40 50 100 kilometers

1:1,000,000 scale

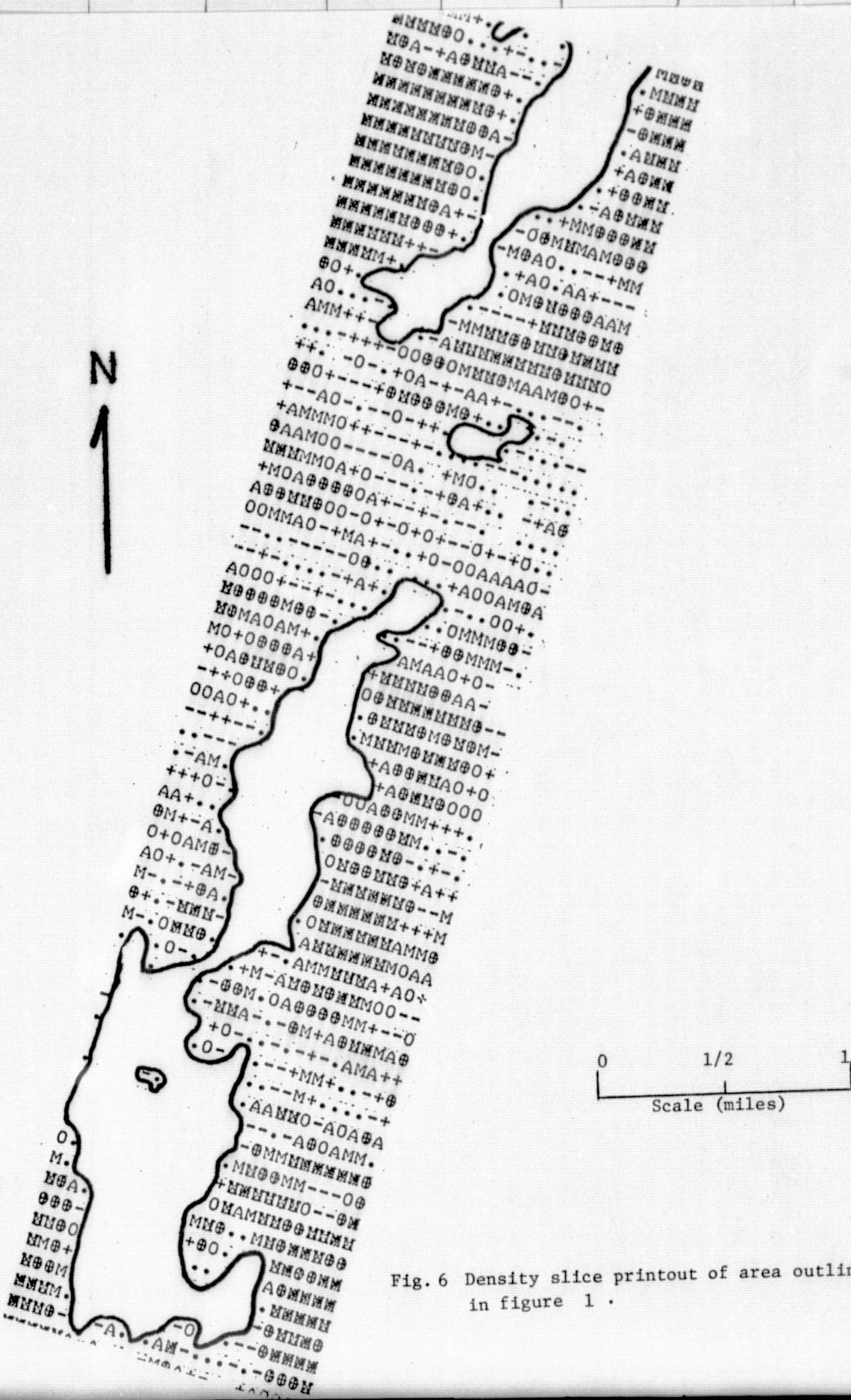
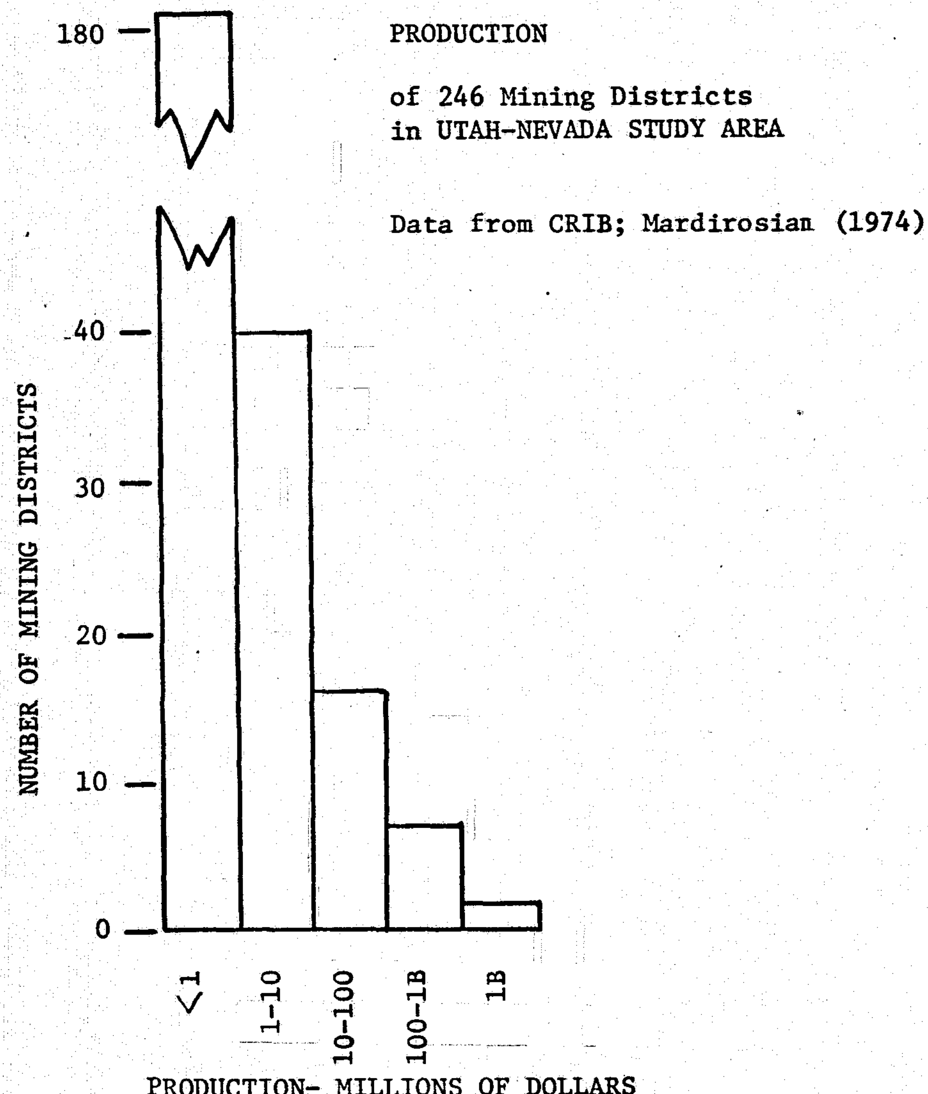


Fig. 6 Density slice printout of area outlined in figure 1.



PRODUCTION
of 246 Mining Districts
in UTAH-NEVADA STUDY AREA
Data from CRIB; Mardirosian (1974)
180
40
30
20
10
0
NUMBER OF MINING DISTRICTS
<1
1-10
10-100
100-1B
1B
PRODUCTION- MILLIONS OF DOLLARS

Figure 7

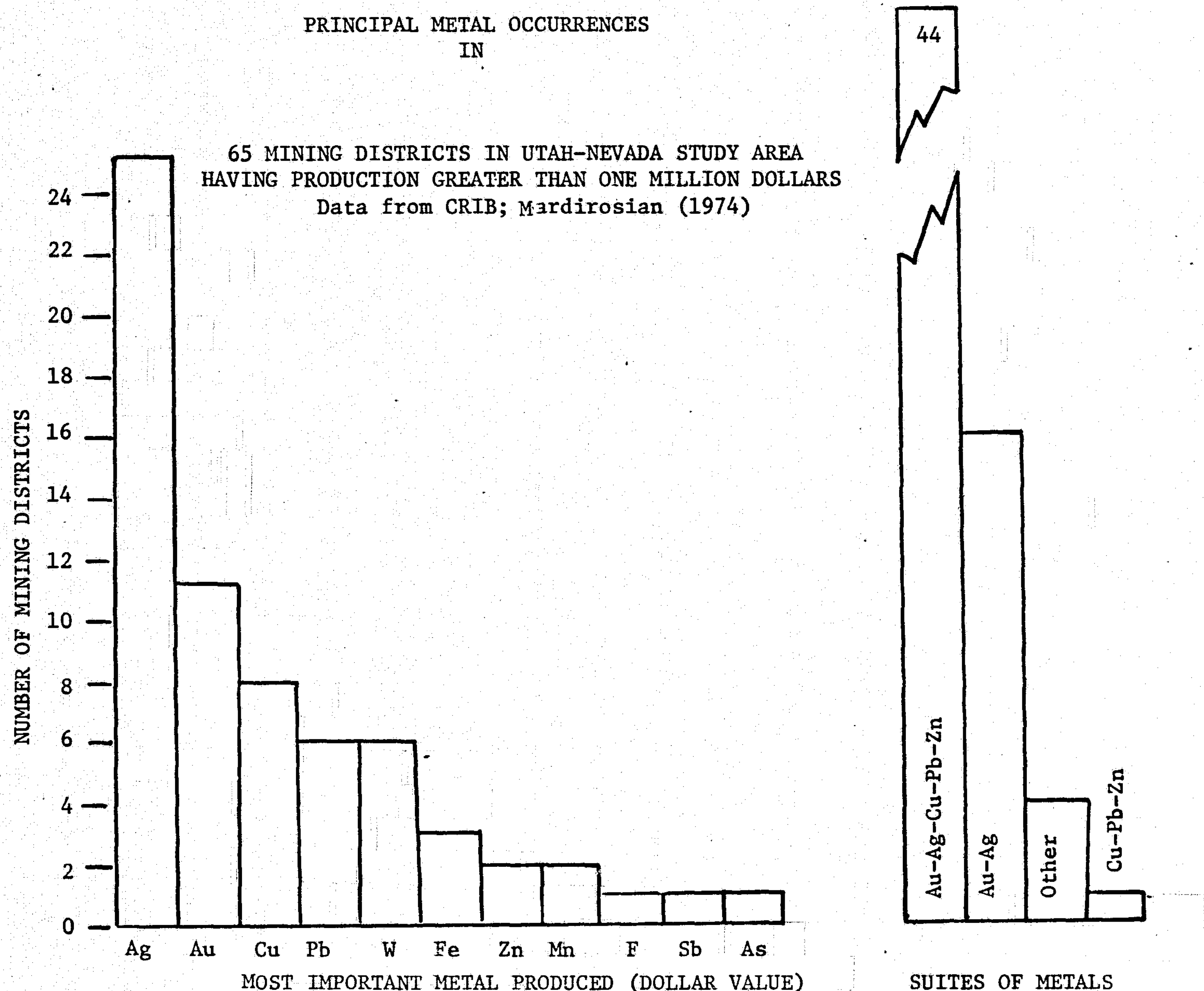

PRINCIPAL METAL OCCURRENCES
IN
65 MINING DISTRICTS IN UTAH-NEVADA STUDY AREA
HAVING PRODUCTION GREATER THAN ONE MILLION DOLLARS
Data from CRIB; Mardirosian (1974)
NUMBER OF MINING DISTRICTS
0
2
4
6
8
10
12
14
16
18
20
22
24
44
Ag
Au
Cu
Pb
W
Fe
Zn
Mn
F
Sb
As
MOST IMPORTANT METAL PRODUCED (DOLLAR VALUE)
Au-Ag-Cu-Pb-Zn
Au-Ag
Other
Cu-Pb-Zn
SUITES OF METALS

Figure 8

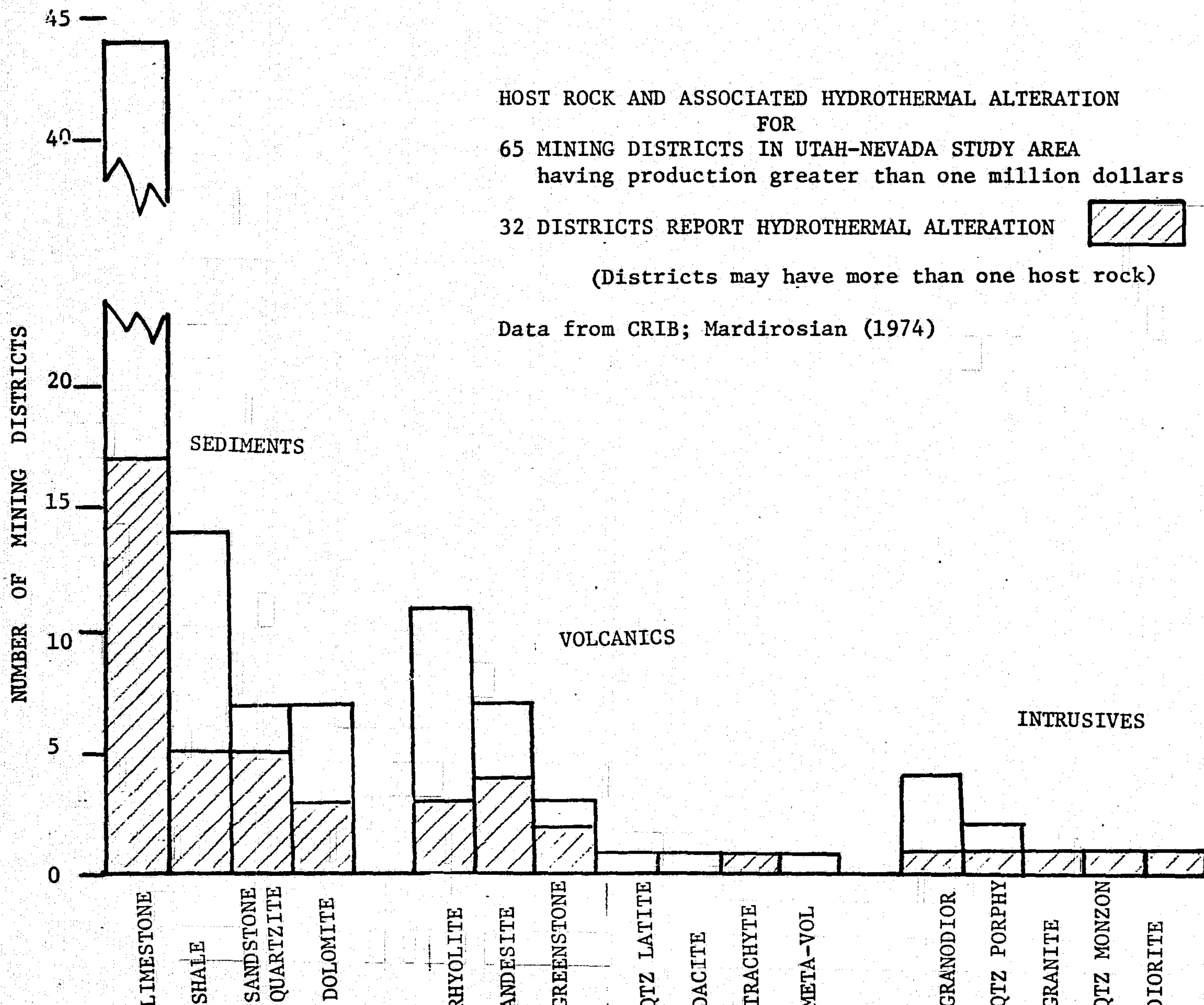

HOST ROCK AND ASSOCIATED HYDROTHERMAL ALTERATION
FOR
65 MINING DISTRICTS IN UTAH-NEVADA STUDY AREA
having production greater than one million dollars
32 DISTRICTS REPORT HYDROTHERMAL ALTERATION
(Districts may have more than one host rock)
Data from CRIB; Mardirosian (1974)
NUMBER OF MINING DISTRICTS
45
40
20
15
10
5
0
SEDIMENTS
VOLCANICS
INTRUSIVES
LIMESTONE
SHALE
SANDSTONE QUARTZITE
DOLOMITE
RHYOLITE
ANDESITE
GREENSTONE
QTZ LATITE
DACITE
TRACHYTE
META-VOL
GRANODIOR
QTZ PORPHY
GRANITE
QTZ MONZON
DIORITE

Figure 9

CONTROL OF ORE EMPLACEMENT

IN

65 MINING DISTRICTS IN UTAH-NEVADA STUDY AREA
HAVING PRODUCTION GREATER THAN ONE MILLION DOLLARS

Data from CRIB; Mardirosian (1974)

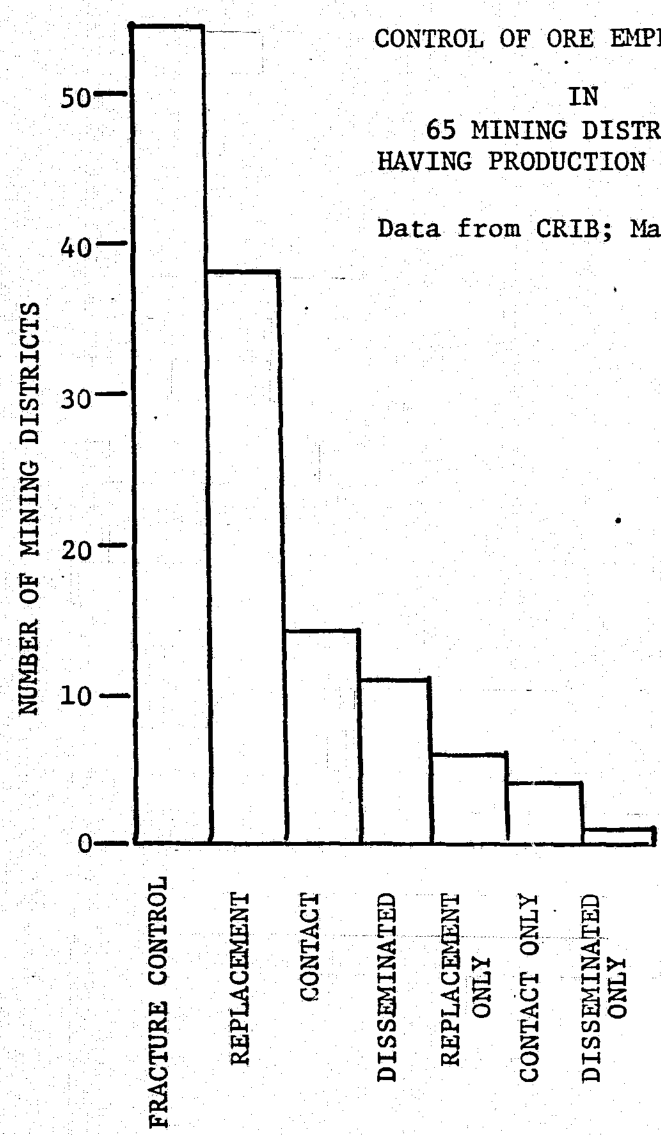
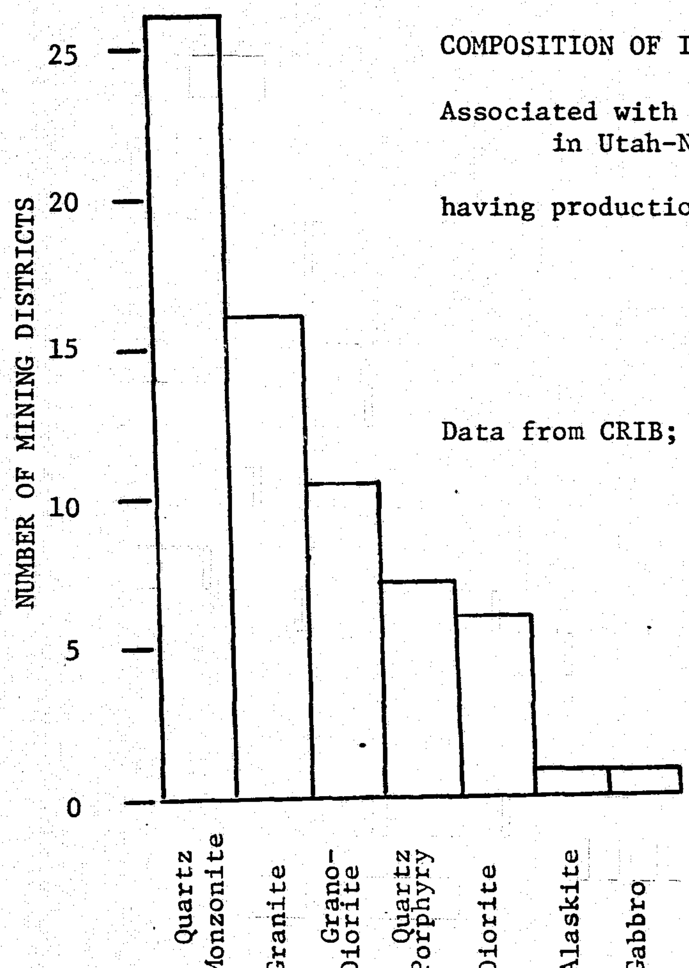


Figure 10



COMPOSITION OF INTRUSIVES

Associated with 49 Of 65 Mining Districts
in Utah-Nevada Study Area

having production greater than one million dollars

Data from CRIB; Mardirosian (1974)

Figure 11

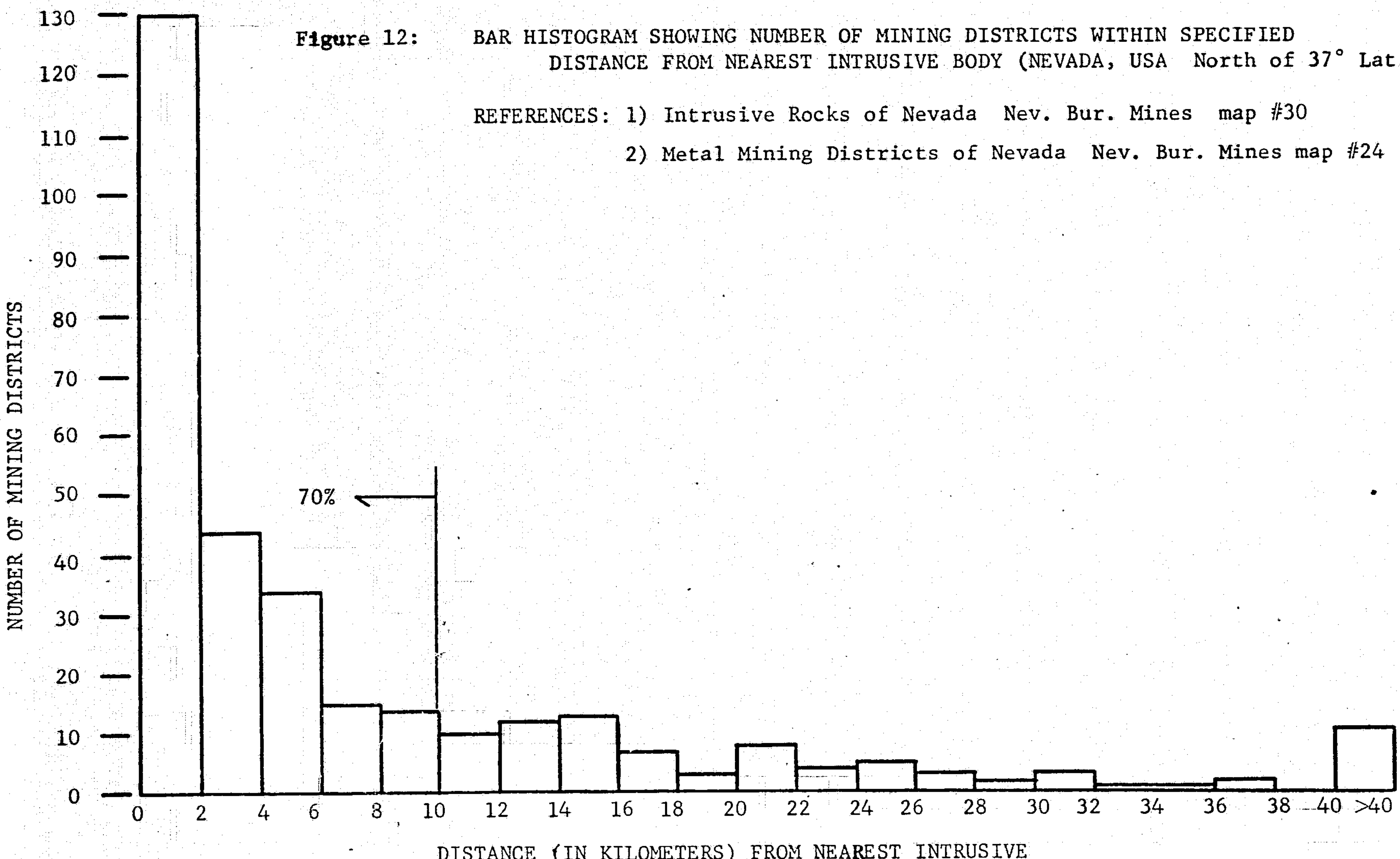


Figure 12: BAR HISTOGRAM SHOWING NUMBER OF MINING DISTRICTS WITHIN SPECIFIED DISTANCE FROM NEAREST INTRUSIVE BODY (NEVADA, USA North of 37° Lat.)

REFERENCES: 1) Intrusive Rocks of Nevada Nev. Bur. Mines map #30

2) Metal Mining Districts of Nevada Nev. Bur. Mines map #24