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REMOTE SENSING OF GEOLOGIC MINERAL OCCURRENCES
FOR THE COLORADO MINERAL BELT USING LANDSAT DATA

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INVESTIGATORS:

Robert H. Carpenter
David W. Trexler

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16. Abstract The object of this program was to determine the value of LANDSAT imagery as a practical and productive tool for mineral exploration along the Colorado Mineral Belt. An attempt was made to identify all large, active and/or abandoned mining districts on the imagery which initially were discovered by surface manifestations. A number of strong photolinements, circular features and color anomalies were identified. Some of these form a part of the structural and igneous-volcanic framework in which mineral deposits occur. No specific mineral deposits such as veins or porphyries were identified. Promising linear and concentric features were field checked at several locations. Some proved to be fault zones and calderas; others were strictly topographic features related to stream or glacial entrenchment. The Silverton Caldera region and the Idaho Springs-Central City district were chosen and studied as "case histories" to evaluate the application of LANDSAT imagery to mineral exploration. Evidence of specific mineralization related to ore deposits in these two areas were observed only on low level photography.					
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INTRODUCTION

A contract was signed between the National Aeronautical and Space Administration and the University of Utah on March 31, 1975, under which the University agreed to evaluate the application of LANDSAT imagery to mineral exploration in the Nevada-Utah Mineral Belt and the Colorado Mineral Belt. The Colorado School of Mines subsequently was granted a sub-contract to assume the responsibility of the Colorado Mineral Belt investigations. These studies were started July 1, 1975.

The specific objective of this study was to establish methods and criteria for using LANDSAT multi-spectral scanner imagery as a practical and productive tool for mineral exploration along the Colorado Mineral Belt.

The Colorado Mineral Belt includes a northeast-southwest zone of major Precambrian and Tertiary shearing and intrusive activity. It extends from the Jamestown mineral district on the northeast to the Rico district on the southwest, a distance of approximately 300 miles. It ranges from 20 to 50 miles in width and includes most of the mining districts of the State (see fig. 1).

The first step in the program was a detailed literature search to establish a comprehensive bibliography of the Mineral Belt. References by mineral districts and by counties are given in Appendix A. This was accompanied by a study of LANDSAT multi-spectral scanner imagery, the scale of which is 1/1,000,000. No U-2 photography was available. Low level black and white photos of the Silverton Caldera area and the Idaho Springs-Central City district also were evaluated in conjunction with "case history" studies of these two areas.

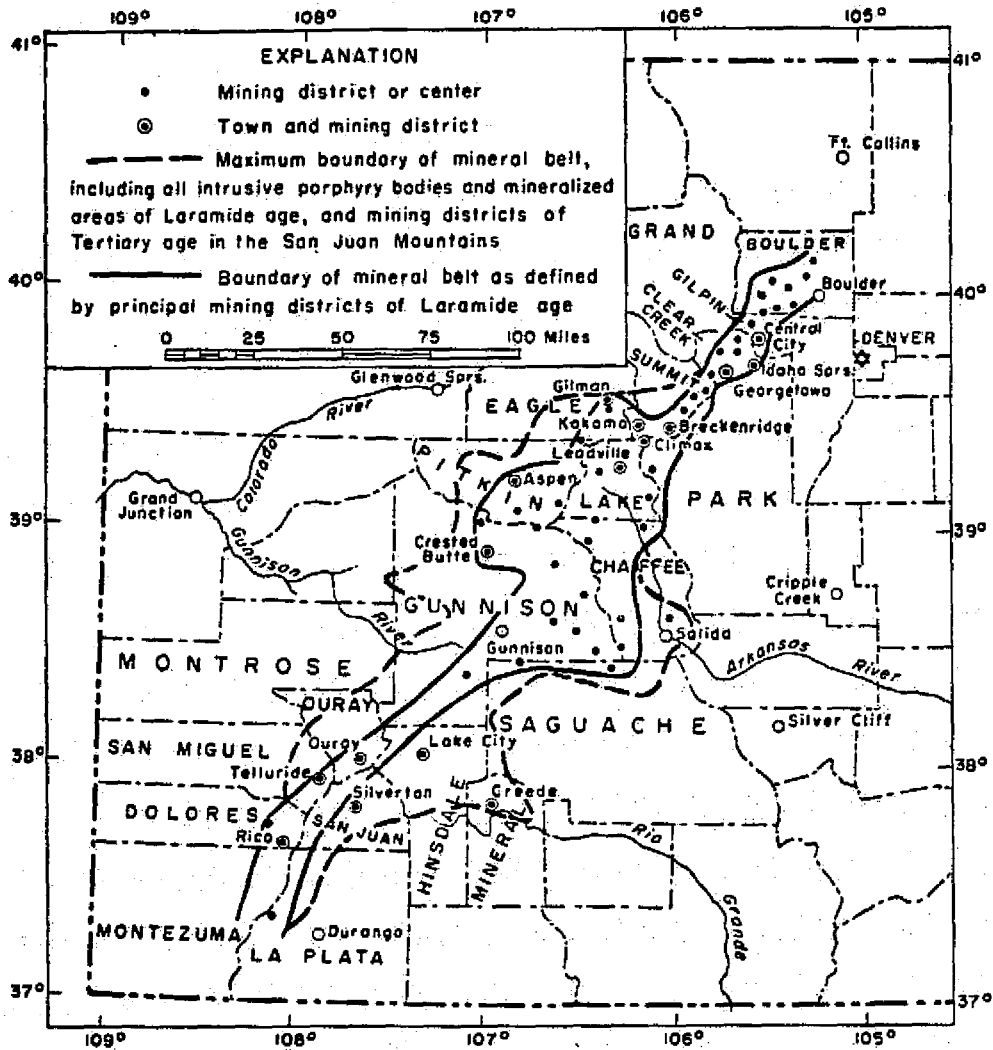


Figure 2. Shape and extent of the Colorado mineral belt

DESCRIPTION OF THE COLORADO MINERAL BELT

Introduction

The Colorado Mineral Belt is a tectonic zone which formed initially in Precambrian time and which was rejuvenated during the Laramide orogeny. Most all of the major metallic mineral deposits of Colorado occur within this zone. It extends diagonally across the State from Jamestown on the northeast to Rico on the southwest, a distance of over 300 miles. The width of the Belt varies from 20 to 50 miles (figs. 1 and 2).

Geologic Backdrop

Precambrian metamorphic rocks and granites constitute the country rocks in the northeast, central and locally in the southwest where the belt crosses the deeply eroded portion of the Front Range, the Sawatch Range and the San Juan uplift. Mesozoic sedimentary rocks occur in the Middle Park region between the Front and Sawatch Ranges, whereas Paleozoic and Mesozoic sediments with a thick cover of Tertiary volcanics predominate in the San Juan uplift (fig. 2).

Laramide and mid-Tertiary igneous activity consisting of dikes, sills, stocks and batholiths of intermediate to acidic composition occur along the Colorado Mineral Belt, reflecting mobilization of deeply buried crustal rocks in the root zone of the Belt.

In the central and northern part of the Mineral Belt tectonism is reflected by (a) a strong northeast arcuate trend in the Precambrian metamorphics and granites which probably formed when the crust was thin and somewhat mobile, by (b) northwest-trending faults including breccia reefs; they are parallel to the northwest-trending portions of the individual mountain arcs,

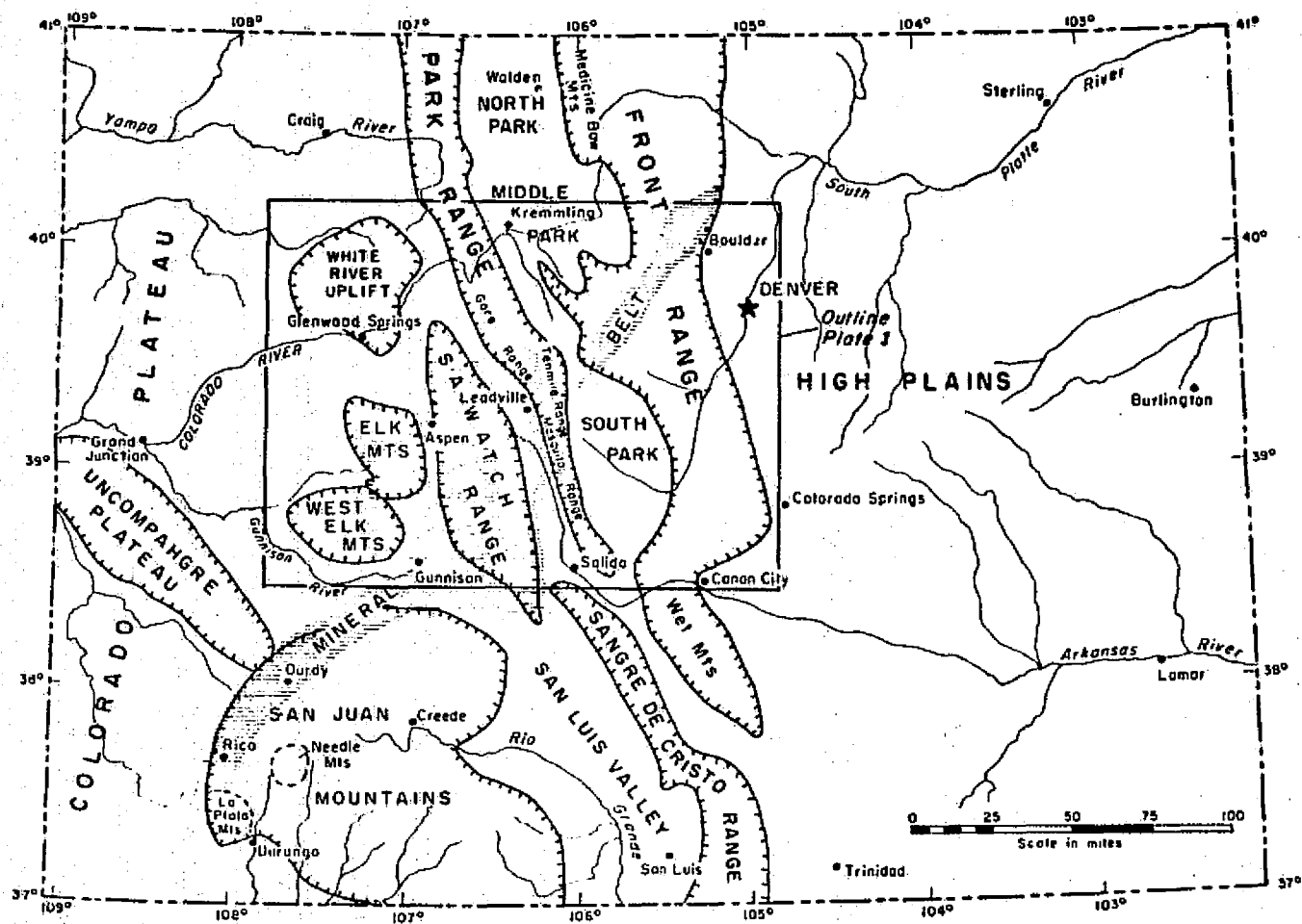


Figure 1. Location of principal mountain ranges and mineral belt in Colorado

by (c) north-northeast trending faults; these faults are essentially parallel to the Precambrian foliation trends, and by (d) east-northeast faults; they developed in the arcuate junctions where major foliation direction reversed trend very rapidly (Plate 4). These fault systems are believed to have developed as thrusts or high angle reverse faults in the Precambrian and were reactivated during the Laramide and Tertiary in part as strike slip faults resulting from east-west directed stresses (Plate 4). Low angle, northerly-trending thrust faults were active along the flanks of the Front Range and Sawatch Range as these arches developed during the early Tertiary.

In the southwestern part of the Mineral Belt deep-seated shearing related to failure within and along the flanks of the northwest-southeast trending Uncompahgre positive structural block appears to have been responsible for the mobilization of the crust and the subsequent expulsion of large volumes of intermediate to acidic volcanics and the emplacement of numerous underlying batholiths and stocks in the volcanic field. Failure over the crest of a number of the intrusives has resulted in the caldera features of this extensive volcanic pile which occupies approximately 25,000 km². There is a strong relationship in space and time during the Laramide and Tertiary between tectonic fabric along the Mineral Belt and igneous activity and mineralization. Deep rooted channelways are believed to have developed at the corners of wedge-shaped blocks in the northern part of the Mineral Belt (Plate 4). Molybdenum porphyry intrusions such as the Urad-Henderson are located at sharp changes in trend in the foliation of the Precambrian rocks and with associated faulting (Plate 4). Mineralization in the San Juan volcanic field is clearly associated with late stage failure within and between the caldera centers (Plate 3).

7

Two periods of mineralization are evident along the Colorado Mineral Belt: (a) precious and base metal vein and replacement deposits of Laramide age occur in the central and northeastern part of the Belt, (b) mid-Tertiary molybdenum porphyry deposits occur in the mid-portion of the Belt. The precious and base metal vein and breccia pipe mineralization in the San Juans also is mid-Tertiary in age.

LINEAR STUDY

Because the location of mineral occurrences along the entire length of the Colorado Mineral Belt is well documented an attempt was made by Dr. Trexler to relate visible linears to mineral deposits.

Procedure

Topolinears were plotted on LANDSAT transparencies using a Bausch & Lomb zoom stereoscope. Both LANDSAT 1 and 2 images of each scene which contained any part of the area of interest were annotated. Table I lists the frames used in this study. The photolinears were transferred from all images to photographic enlargements (1:500,000 approximate) with a transfer scope and from the enlargements to AMS 2⁰ topographic maps. A composite overlay was made at 1:250,000 scale. This is shown in reduced form on Plate 1 (scale 1:500,000 approximate). The locations of mineral occurrences were then plotted on the overlay (Plate 2). These locations were taken from USGS Prof. Paper 138, Plate I.








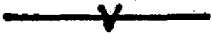


Interpretation of Linears

With the exception of ring structures associated with the caldera of the San Juan Mountains, no apparent relation could be seen between the toplinears and mineral deposits.

The geologic significance of photolinears was studied using all available geologic maps in order to detect any relation between linears and mineral occurrences. Figure 3 is an explanation of symbols used on maps for identified toplinears.

Only 48, or about 0.05%, of the linears were identified from the Geologic Map of Colorado (scale 1:500,000). As would be expected, a much

Fig. 3. Expansion of symbols used on Plates 1 & 2, Fig. 4 - 11

	Faults and shear zones
	Joint control
	Dip control
	Foliation control
	Lithologic contact
	Dike or vein system
	Ring fracture of cauldера
	Edge of volcanic flow
	Glaciated valley
	Unidentified topolinear

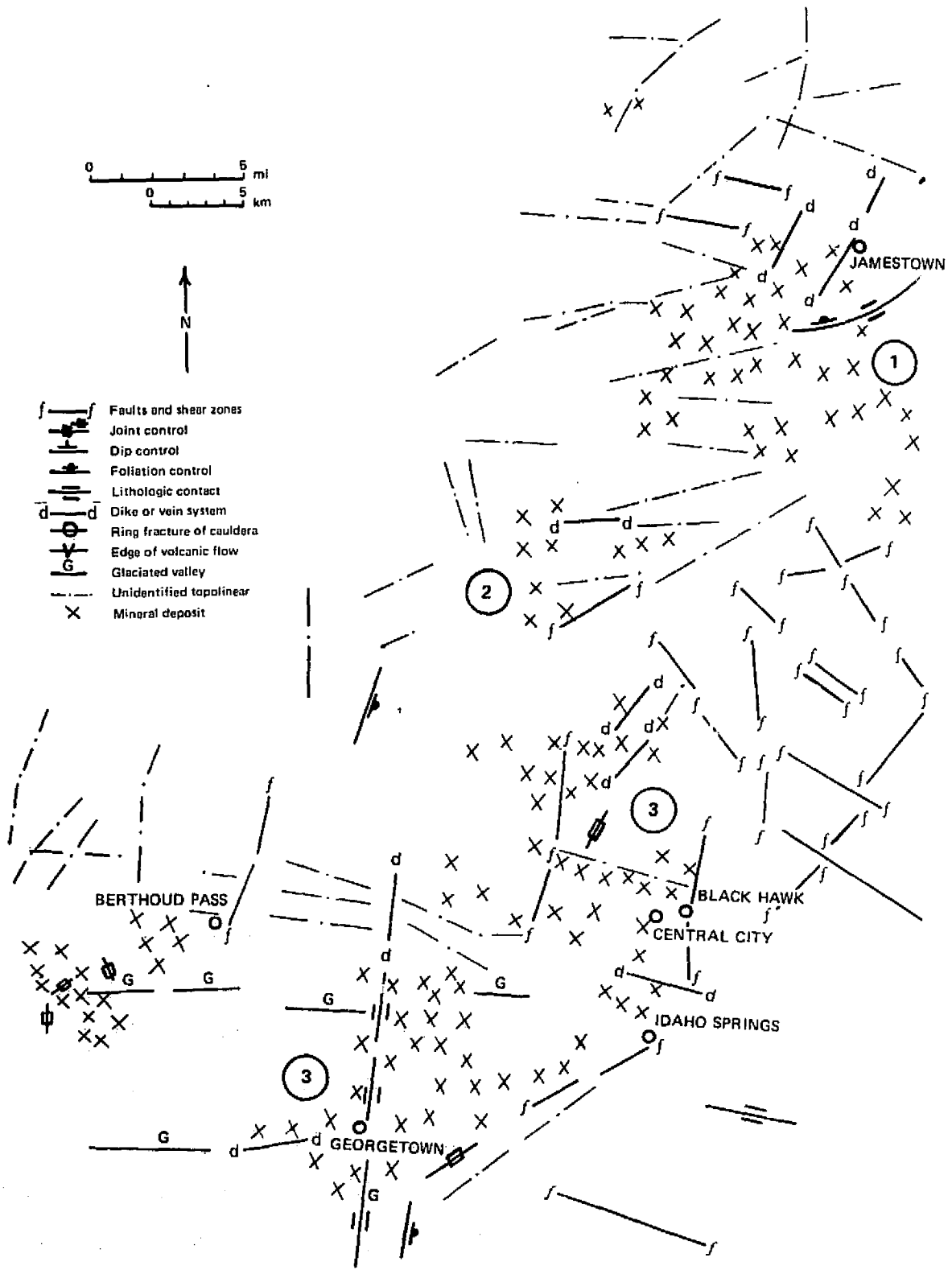


Figure 4. — Mining districts: (1) Jamestown-Gold Hill, (2) Caribou-Nederland, (3) Black Hawk-Central City-Idaho Springs — Georgetown.

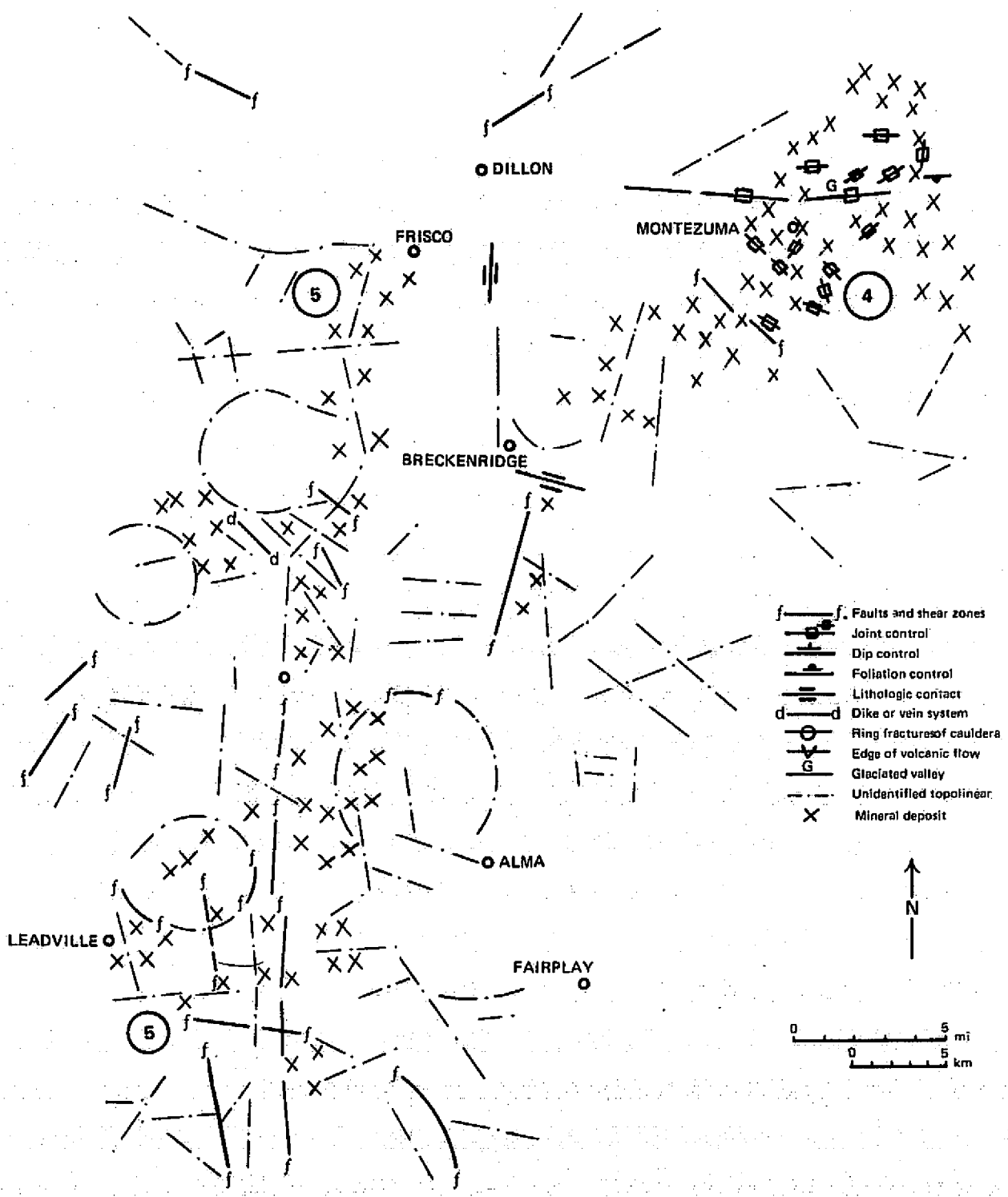


Figure 5. — Mining districts: (4) Montezuma-Breckenridge, (5) Kokomo-Climax-Leadville.

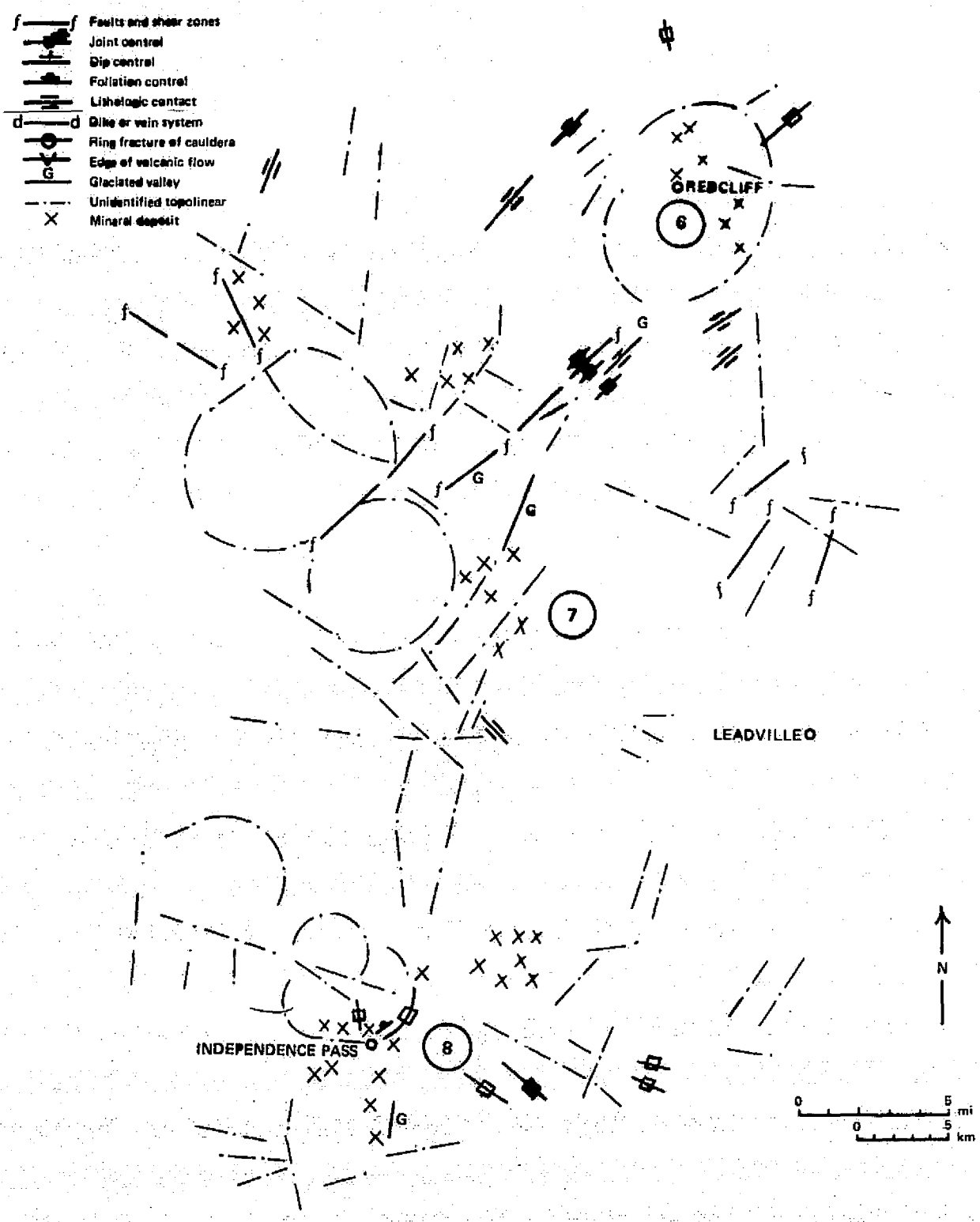


Figure 6. — Mining districts: (6) Battle Mountain (Red Cliff-Gilman), (7) Homestake, (8) Independence.

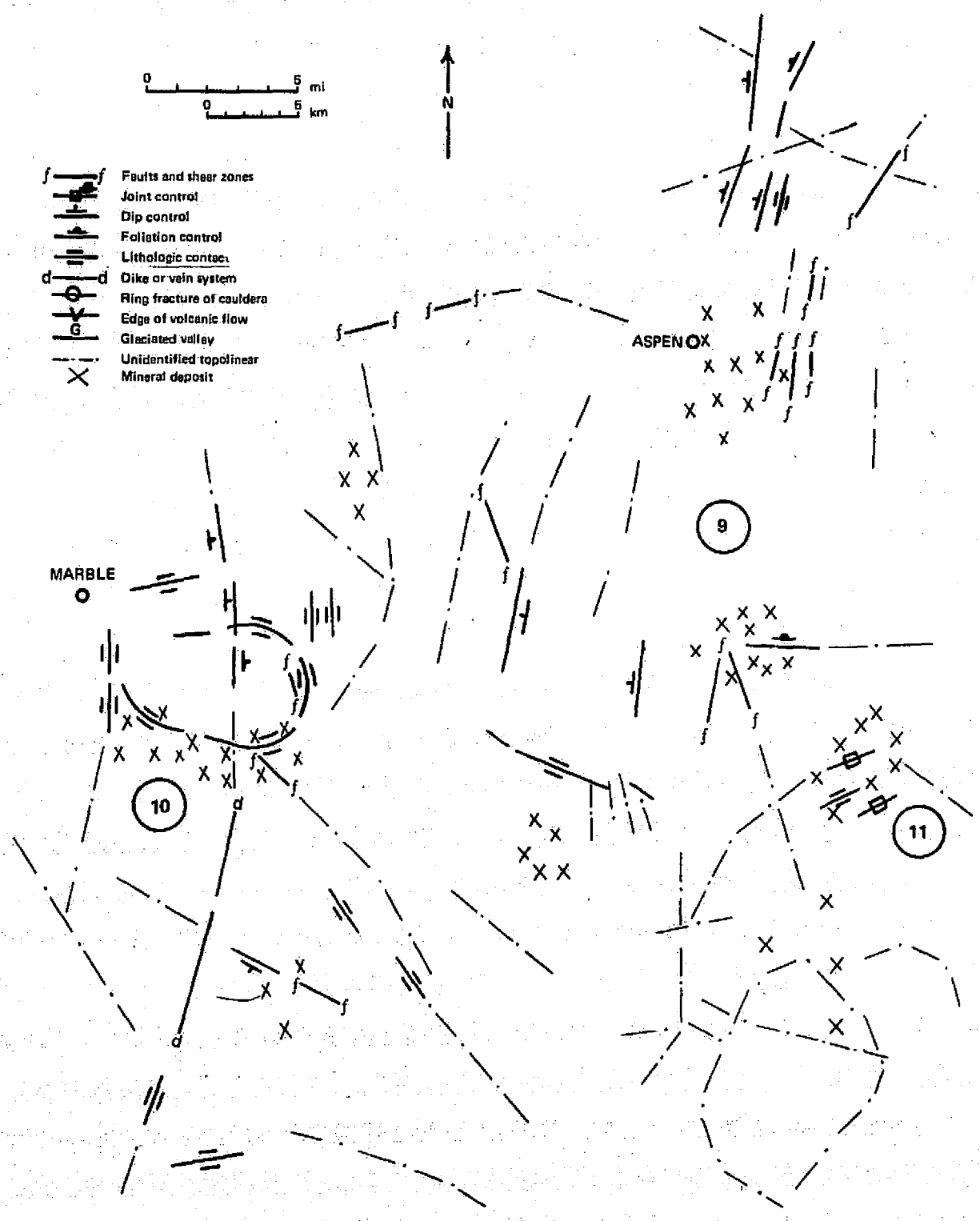


Figure 7. — Mining districts: (9) Aspen-Ashcroft-Snowmass, (10) Marble, (11) Taylor River.

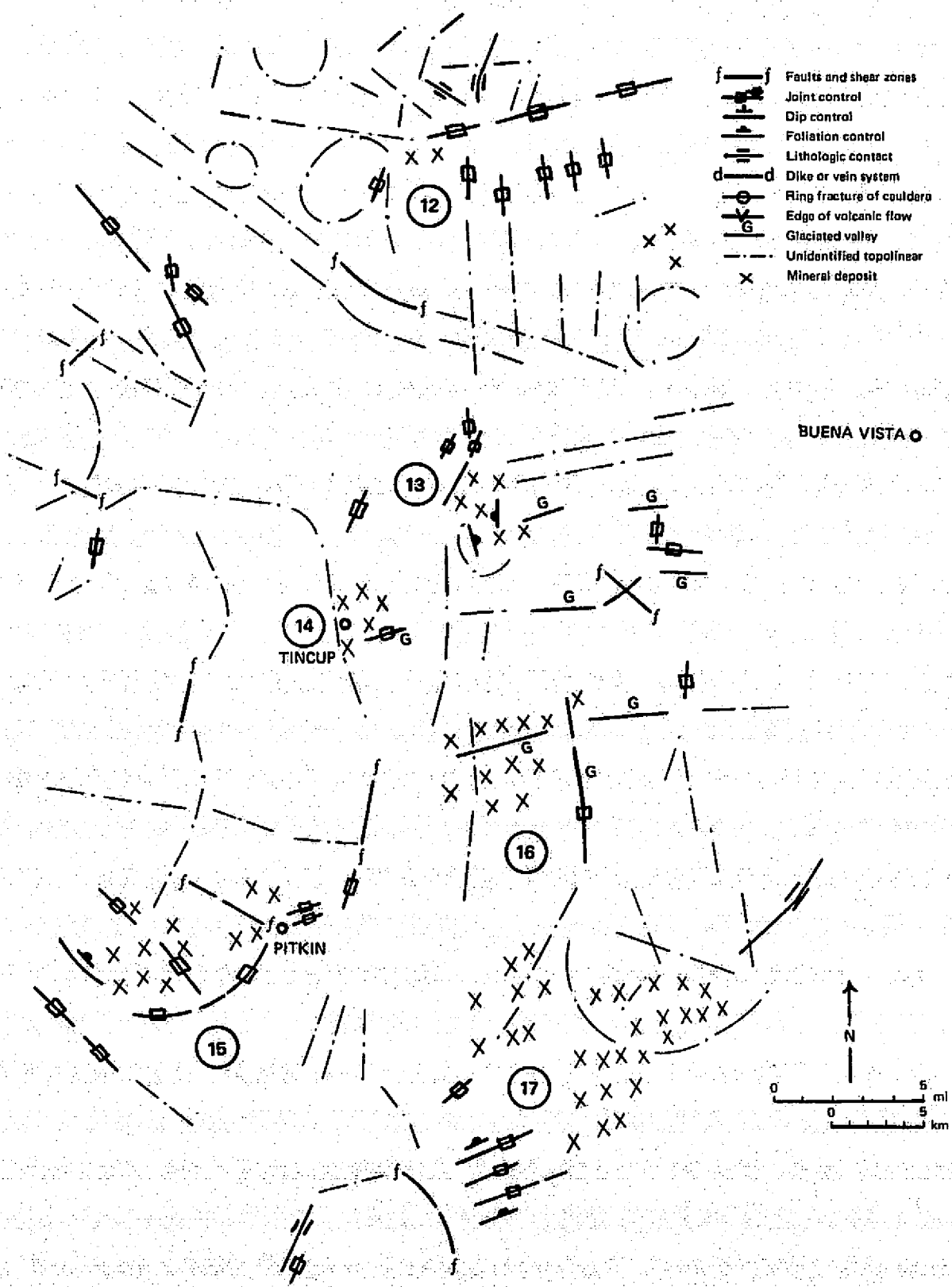


Figure 8. — Mining districts: (12) Winfield, (13) Cottonwood, (14) Tincup, (15) Pitkin-Ohio City, (16) St. Elmo-Chalk Creek, (17) Garfield-Monarch.

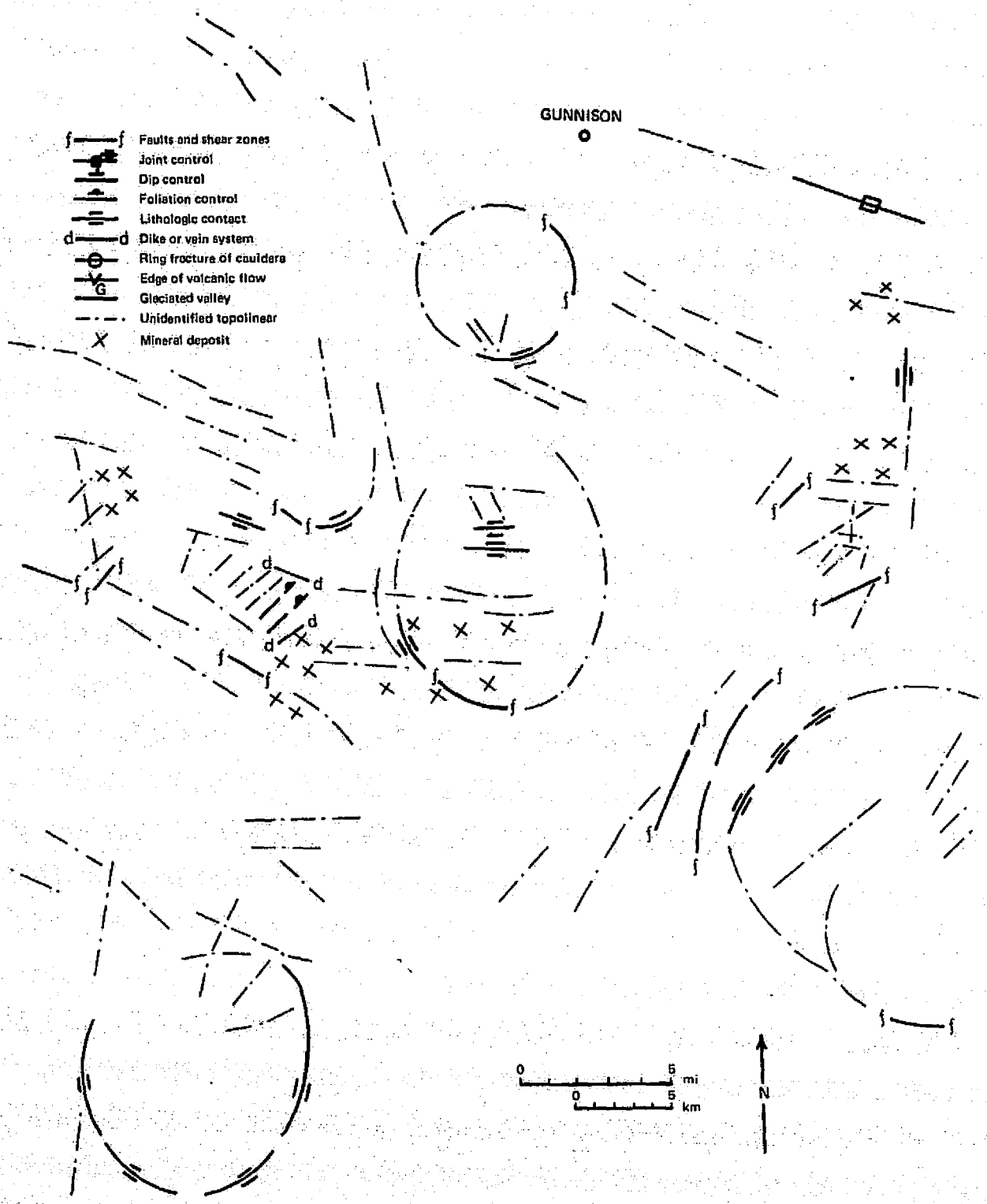
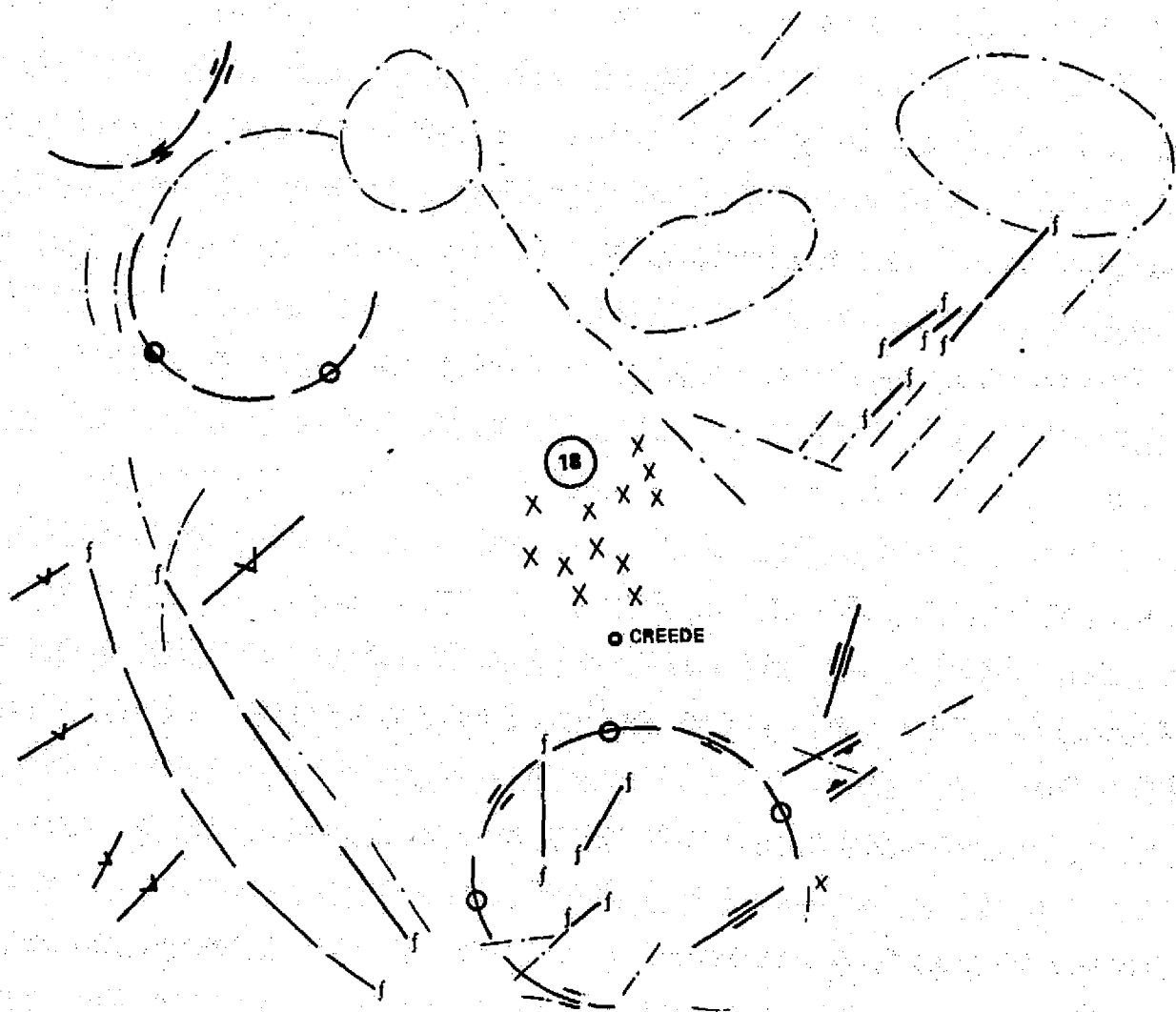


Figure 9. — Area south of Gunnison.



- f f Faults and shear zones
- ⊥ Joint control
- △ Dip control
- ▴ Foliation control
- Lithologic contact
- d d Dike or vein system
- Ring fracture of cauldron
- g Edge of volcanic flow
- G Glaciated valley
- - - Unidentified topolinear
- X Mineral deposit

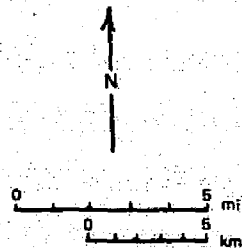


Figure 10. — Mining district: (18) Creede.

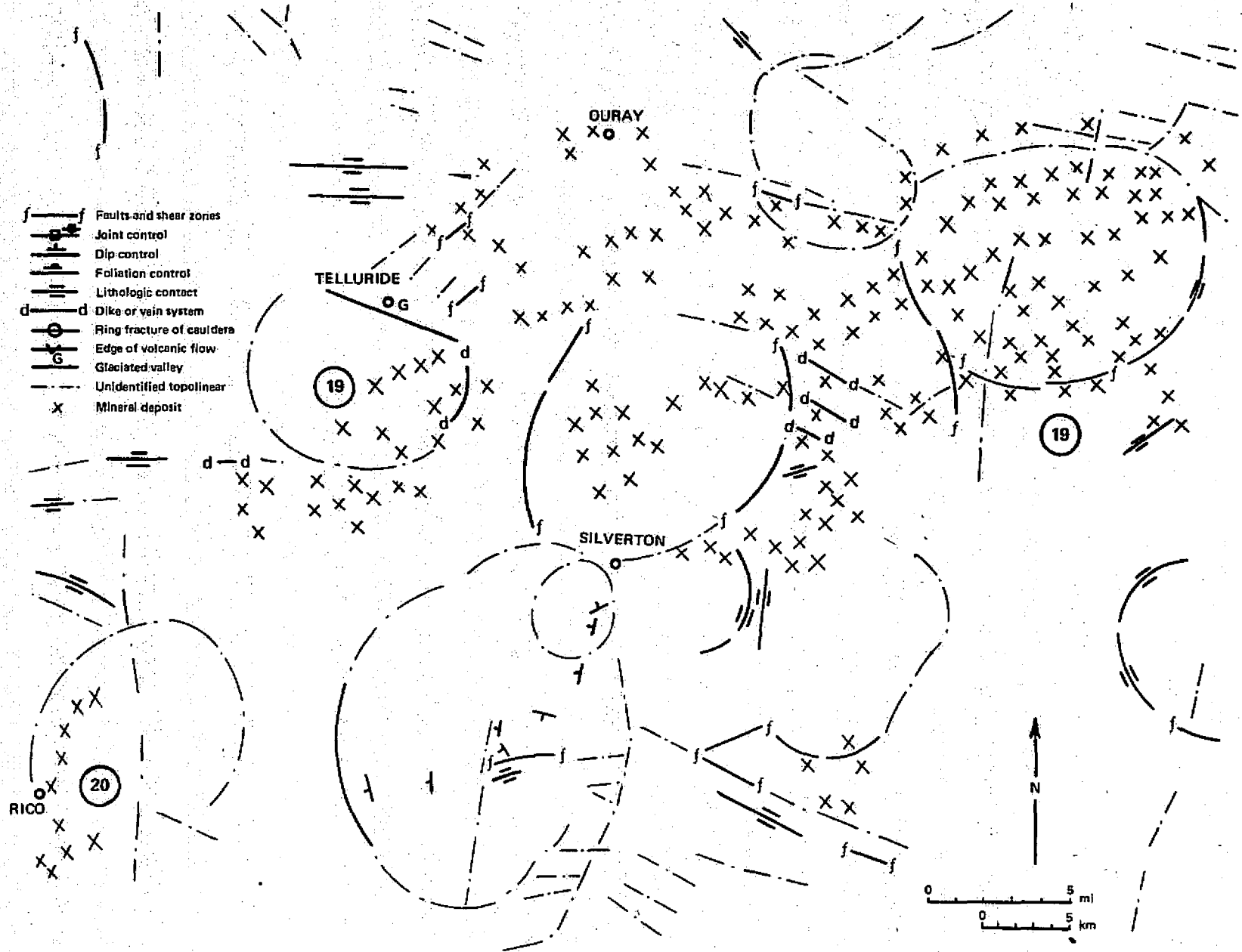


Figure 11. — Mining districts: (19) Lake City-Ouray-Silverton-Telluride, (20) Rico.

higher percentage of linears were identified from larger scaled maps. As for example about 50% of the linears within the coverage of USGS 1:24,000 quadrangle geologic maps could be identified (Table III).

Because large-scale geologic map coverage is limited, field checking was conducted in a number of areas of mineral occurrence in order to identify as many linears as possible and to see if these linears had any direct relation to mineral deposits. Figures 4 to 11 are large scale maps (1:250,000) of the mineral districts with both identified and unidentified linears shown. A brief discussion follows.

Figure 4 of the northern end of the mineral belt shows a high percentage of identified linears. Most of these are north-northeast and northwest Precambrian fractures. Northeast to east early Tertiary fractures were also identified. The northeast and east vein system at Central City and Idaho Springs (Fig. 14) were not detected, nor were the early Tertiary igneous stocks. Also the vein system could not be detected on 1:60,000 airphotos.

Figure 5; the mineralization at the Montezuma district (4) is associated with an early Tertiary stock which could not be detected. The east-west linear coincides with a known fault and parallels a strong set of east-west joints. The Kokomo, Climax, and Leadville districts (5) are along the trend of the Mosquito fault. The numerous sills, dikes, and stocks, which could not be detected, control the localization of ore minerals in Upper Paleozoic sediments.

Figure 6; the mineralization at Red Cliff and Gilman (6) is associated with sills and dikes in Paleozoic sediments (Fig. 13). A northeast joint trend was identified. Mineralization in the Homestake area (7) is associated with a northeast trending set of strong shear zones and parallel joints

(Fig. 13). These were also identified. A shear zone associated with mineralization at Independence Pass (8) was not identified.

Figure 7; a few north trending faults were the only linears annotated in the vicinity of Aspen and Ashcroft (9). The Treasure Mountain uplift (Early Tertiary) near Marble (10) was annotated as a conspicuous curvilinear. Mineralization along the upper Taylor River (11) seems to be related to a conspicuous northeast trending set of joints.

Figure 8; mineralization at Winfield (12), Cottonwood Pass (13), and St. Elmo (16) is associated with conspicuous north to north-northeast sets of joints. At Pitkin and Ohio City (15) joint sets and a fault were identified with northwest and northeast trends. On the southwest side of the Garfield and Monarch districts (17) the dominant trend of foliation and jointing is northeast.

Figure 9; the northern part of this area is an old erosional surface cut in Precambrian rocks on which can be detected numerous joint sets except on some stream divides where low dipping Mesozoic sediments and Tertiary volcanics cap the older rocks. The curvilinear in the southeast corner is the Cochetopa caldera. The other curvilinears may also represent older ring structures associated with caldera.

Figure 10; the curvilinear south of the town of Creede is the Creede caldera. Mineralization, however, is to the north at (18) where no topolinears were noted.

Figure 11; two of the annotated curvilinears are known caldera structures. These are the Silverton caldera (central) and the Lake City caldera (northeast corner). Mineralization is dominantly along northeast and northwest veins with some east-west veins south of Telluride (Fig. 12). These vein systems were not detected.

Conclusions

The only detectable linears that can have a bearing on ore deposits and can be detected on LANDSAT imagery are those structural features which are capable of geomorphic expression such as faults, joints, and some contacts. Surficial features produced by volcanism and glacial erosion and deposition were also visible. Vein systems in general are not reflected in the topography because of their relative strong resistance.

THE SILVERTON CALDERA - A CASE HISTORY

Introduction

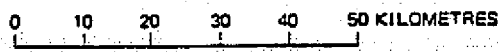
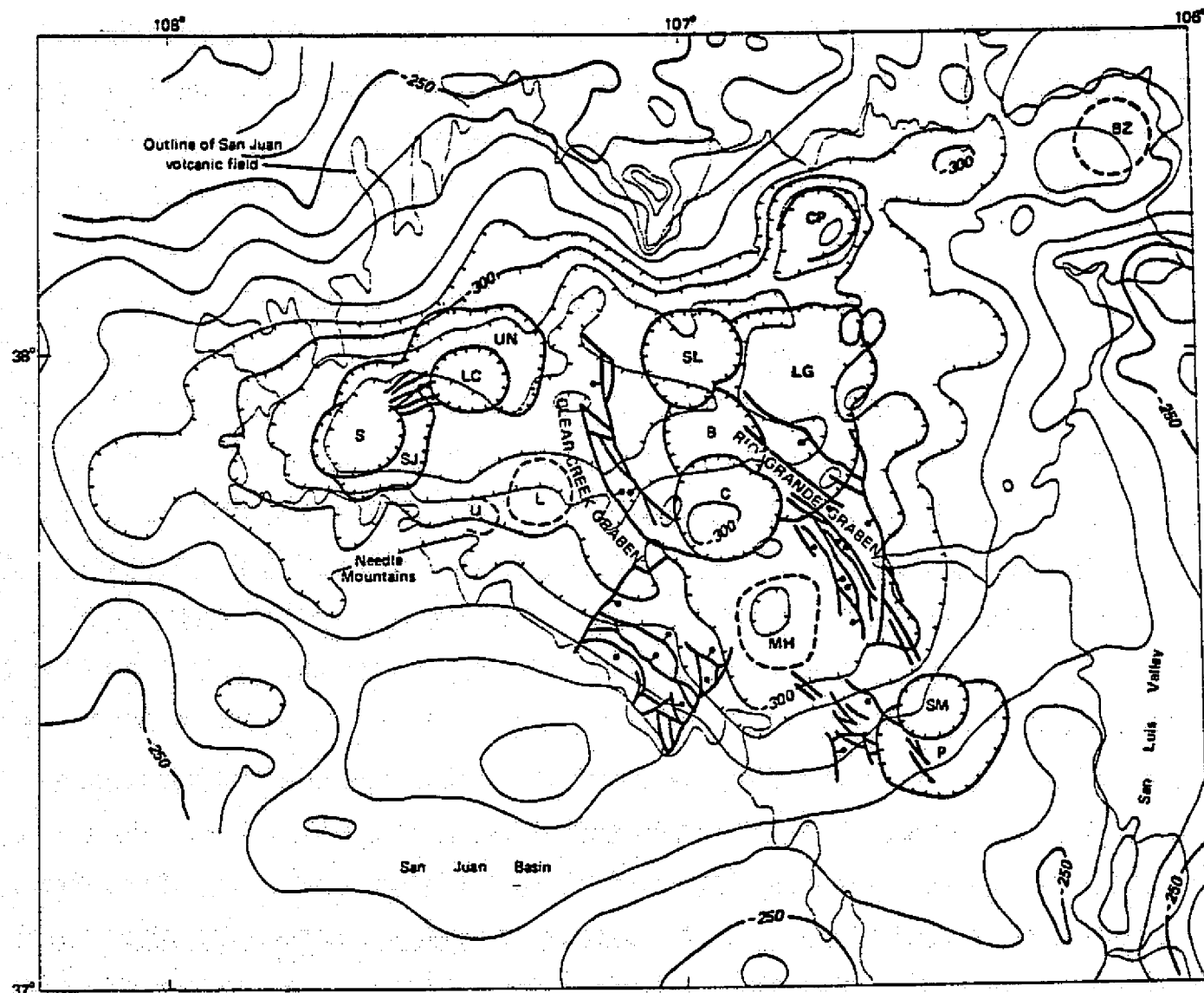
The San Juan Mountains which include the Silverton caldera, are located in the southwestern part of the Colorado Mineral Belt. They constitute a great, composite volcanic field covering an area 100 miles by 150 miles in which 18 calderas are known or are postulated (fig. 12). The volcanic rocks of this field consist of early stratovolcanos overlain by ash flow eruptions and pyroclastics. Calderas were superimposed as individual magmas moved upward toward the surface from an underlying regional batholith. This intrusive is identified by a sharp gravity low. The formation of the San Juan volcanic field extended in time from 35 m.y. to 20 m.y., but most of the volcanism occurred prior to 26 m.y.

Volcanic Sequence

A thickness of more than a mile of volcanic rocks rest on a basement of Precambrian, Paleozoic and Mesozoic rocks. These volcanics consist of lava flows, breccias, tuff-breccias, tuffs and welded ash-flow tuffs which average rhyo-dacite - quartz latite in composition, but range from andesitic basalt to rhyolite. There are many feeder dikes and sills and irregularly shaped porphyry intrusives within the volcanic pile.

Structural Fabric of the Region

The dominant structural pattern of the San Juan Mountains includes circular caldera centers and inter-connecting graben. These are indicated on intermediate level photography of 1/80,000 scale. In addition, both radial and concentric faulting form a strong structural fabric within and outward from each caldera center.



EXPLANATION

- Fault—Bar and ball on downthrown side
- Caldera
- Buried or inferred caldera

-300- Bouguer gravity contours—Machures point toward closed gravity lows. Contour interval 10 milligals. Gravity data from Plouff and Pakiser (1972, fig. 3)

CALDERAS (In order of increasing age)

- LC Lake City
- C Creede
- CP Cochetopa Park
- SL San Luis
- B Bachelor
- LG La Garita
- MH Mount Hope
- S Silverton
- SJ San Juan
- UN Uncompahgre
- L Lost Lake
- U Ute Creek
- SM Summitville
- P Platoro
- Bz Bonanza



LOCATION OF SAN JUAN VOLCANIC FIELD

FIGURE 1.—Calderas in the San Juan volcanic field (patterned) in relation to Bouguer gravity field.

Silverton Caldera

The Silverton caldera, located on the western side of the San Juan volcanic field, serves as one of two case histories for this study. It is about 10 miles in diameter and is situated within the western half of the San Juan volcanic depression which is about 15 miles wide and 30 miles long (Plate 3). The volcanic and basement rocks of this caldera are broken by systems of radial and concentric fractures, and the rocks within and adjacent to the caldera are broken, tilted and irregularly faulted. This widespread rock failure developed access for hydrothermal solutions which permeated the fault systems to cause profound rock alteration and selective mineralization in the area.

Widespread propylitic rock alteration occurred throughout the Silverton caldera region during the late stages of volcanism as a result of fluids and gases moving outward from the underlying magma chamber and mixing with meteoric waters. The near surface rocks were altered to chlorite, calcite and clays, whereas deeper epidote, albite, and chlorite are the predominant alteration minerals. As a consequence, the rocks of the Silverton caldera region have been well bleached to white, tan and light gray with superimposed iron oxide staining in specific mineralized centers to brown, yellow, orange and red. The latter are readily identifiable on low level color photography.

Strong, late alteration by sulfur enriched fluids also developed around the periphery of the Silverton caldera, along local faulted blocks and related pipe-like bodies of breccia and intrusive rocks. This type of alteration also has been effective near some of the channelways through which these sulfur-enriched fluids passed. The adjacent rocks have been strongly leached or silicified and kaolinized and permeated with both sulphates and sulfides. They are well bleached and subsequently stained by surface oxida-

tion of pyrite. This sulfotatic alteration usually is restricted in nature and can be identified, in some instances, on low level photography.

Mineralization in the Silverton caldera area is of two types: (a) vein systems and (b) chimney or breccia pipe deposits. The former occur in extensive systems of open fissures and along major faults and splits. The latter are found in solfateric centers along the margins of the Silverton caldera. The ore occurs as shoots within the veins and as a matrix of the breccias within the chimneys. Some of the major veins can be identified on low and intermediate photographs.

Application of Imagery

The overall features of the Silverton caldera are identifiable on LANDSAT imagery. Semi-detailed caldera features and associated fault systems are evident on intermediate level photography. Individual faults are apparent on low level photography, some of which are known to be mineralized, but mineralization itself and hydrothermal alteration halos related to mineralization are not recognizable.

IDAHO SPRINGS - CENTRAL CITY AREA

Introduction

The Idaho Springs-Central City area in the northern part of the Colorado Mineral Belt is the second case history selected for this project. This area lies about 30 miles west of Denver along the southern edge of the Mineral Belt on the east slope of the Front Range. It has yielded an estimated 170 million dollars worth of gold, silver, base metals, and uranium since 1859.

Geologic Summary








Precambrian crystalline rocks, constituting the core of the Front Range are the host rocks of the Idaho Springs-Central City area. They consist of an interlayered and generally conformable succession of gneissic, granitic and pegmatitic suites derived initially from a sedimentary sequence. Nine different types of porphyritic intrusive rocks of Early Tertiary age cut across the Precambrian rocks including leucocratic granodiorite porphyry, quartz monzonite porphyry, and bostonite porphyries.

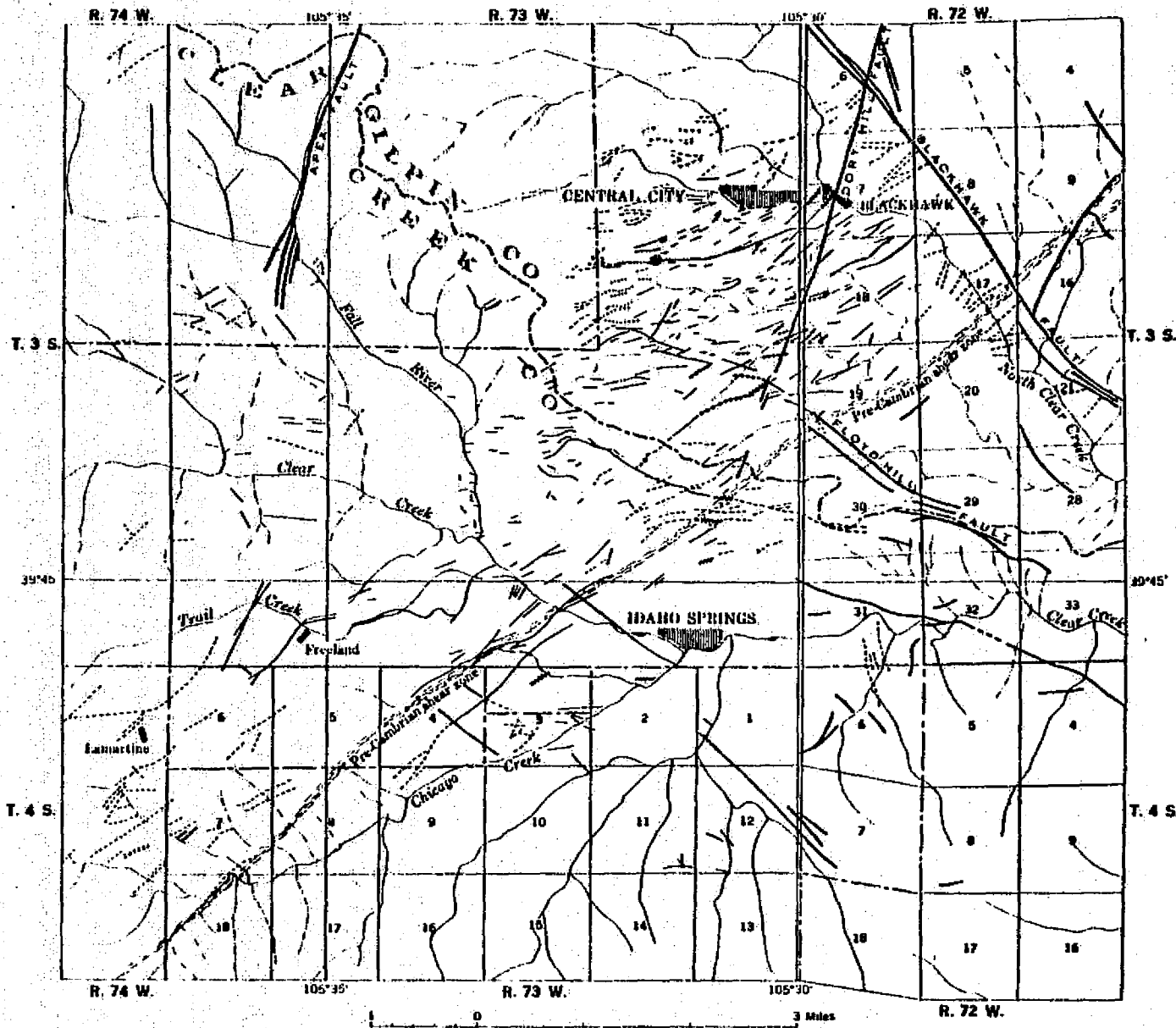
The gneissic rocks were folded during Precambrian time to develop broad north-northeast trending major folds which form the fundamental fabric of the area. They plunge gently to the northeast and southwest. Some contain siliceous breccias. A late Precambrian deformation formed northwest and north-northeast faults. Locally they form a closely spaced network particularly in the Central City district. Near the end of the Early Eocene igneous activity a third system of faults developed. Three main trends predominate: northeast, east-northeast, and east (fig. 13).

The ore base metal deposits of the area consist of veins and stockworks resulting from filling of open spaces along faults and highly fractured zones.

Fig. 13

EXPLANATION

-  Gold telluride veins
-  Silver-lead veins
-  Pyritic gold veins
-  Energetic-fluorite veins
-  Pitchblende veins
-  Strong fault
(Chiefly belonging to the
brevia reef period of faulting)
-  Pre-Cambrian shear zone



REPRODUCTION OF THE ORIGINAL PLAN AS MADE

MAP, SHOWING THE ZONAL ARRANGEMENT OF THE ORES OF THE CENTRAL CITY—IDAHO SPRINGS MINING DISTRICT

The veins range from 1 to 3 feet in width and vary from well defined, single fissures to complex, mineralized fractured zones. An extensively shattered, pipe-like body in the Central City district consisting of closely spaced, mineralized fractures, has been mined for its high gold content. This stockwork appears to have been formed by explosive activity.

Hydrothermal alteration adjacent to the veins is strong, but restricted to approximately the width of the vein on either side of the structure. Sericitization lies in an inner zone whereas propylitization has developed in an outer zone and grades outward into fresh rock. The hydrothermal fluids responsible for both the alteration of the wall rocks and the mineralization of the veins are believed to have been generated from an underlying magma body. Shallow intrusives, faulting, alteration and mineralization appear to be hood zone phenomena above the proposed magma body.

Application of Photography (Remote Sensing Technology)

Neither intermediate nor low level photography are effective in locating new veins or stockworks in the Idaho Springs-Central City area because of lack of surface expression and heavy vegetation and overburden.

CONCLUSIONS

1. LANDSAT imagery can cover large areas quickly and inexpensively, and there are some surface features in any given region that are general indicators of possible mineralization.

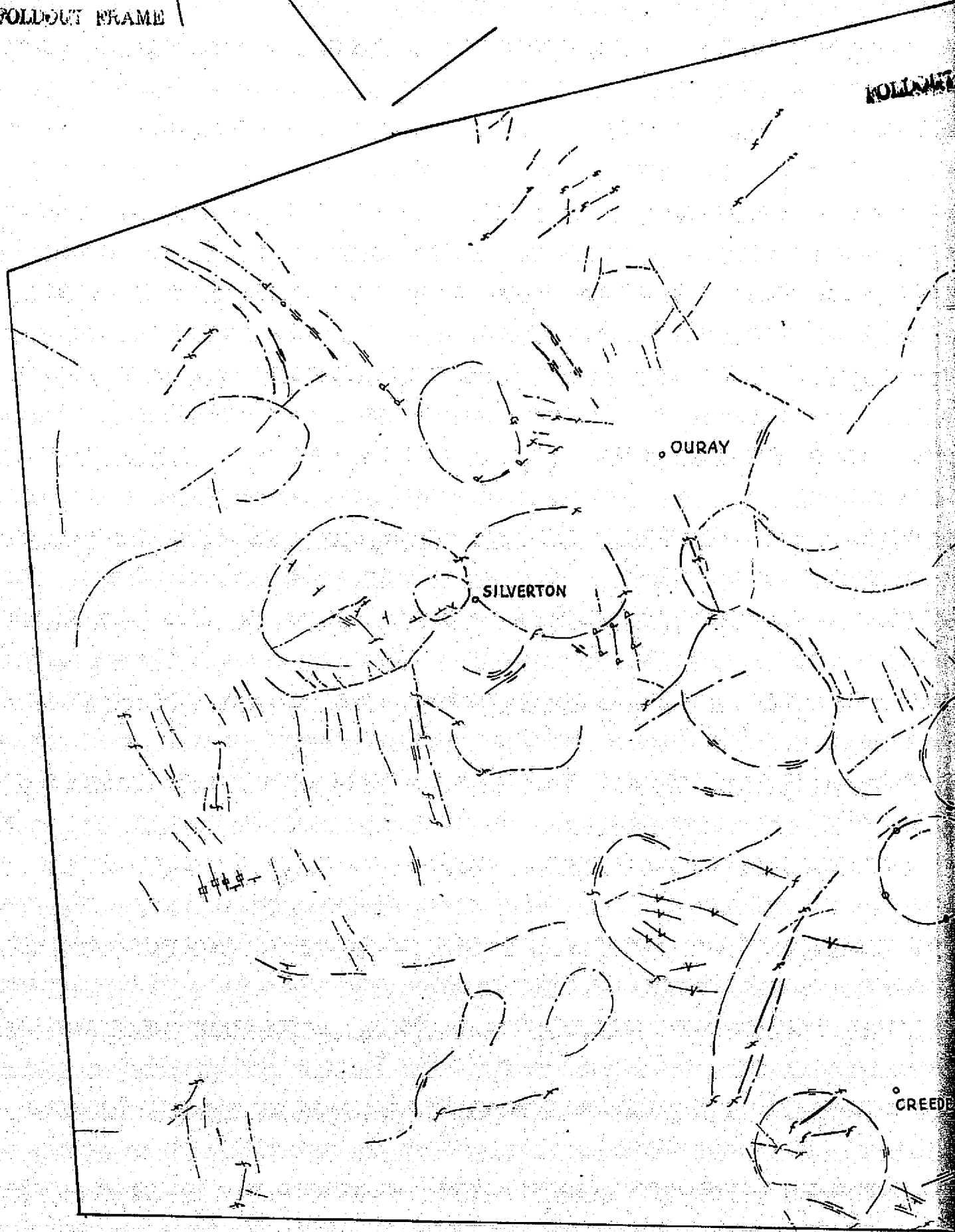
2. Lineament analysis of the less known geologic portions of the Colorado Mineral Belt on LANDSAT, intermediate and low level photography in conjunction with remote sensing techniques and ground geologic mapping may point to additional mineral target areas.

3. Orbital photography by itself is not considered adequate to fulfill exploration needs. It is useful in reducing the size of an exploration area, but like other remote sensing techniques, it is an applicable tool only when used in conjunction with detailed field work.

4. Linear structures are extractable from LANDSAT imagery.

5. Areas where orbital photography would be most useful in the search for mineral deposits include desert mountains or snow-free alpine mountains.

6. Areas extensively covered by soil, vegetation, clouds, or snow, no matter how favorable, are incapable of being evaluated.



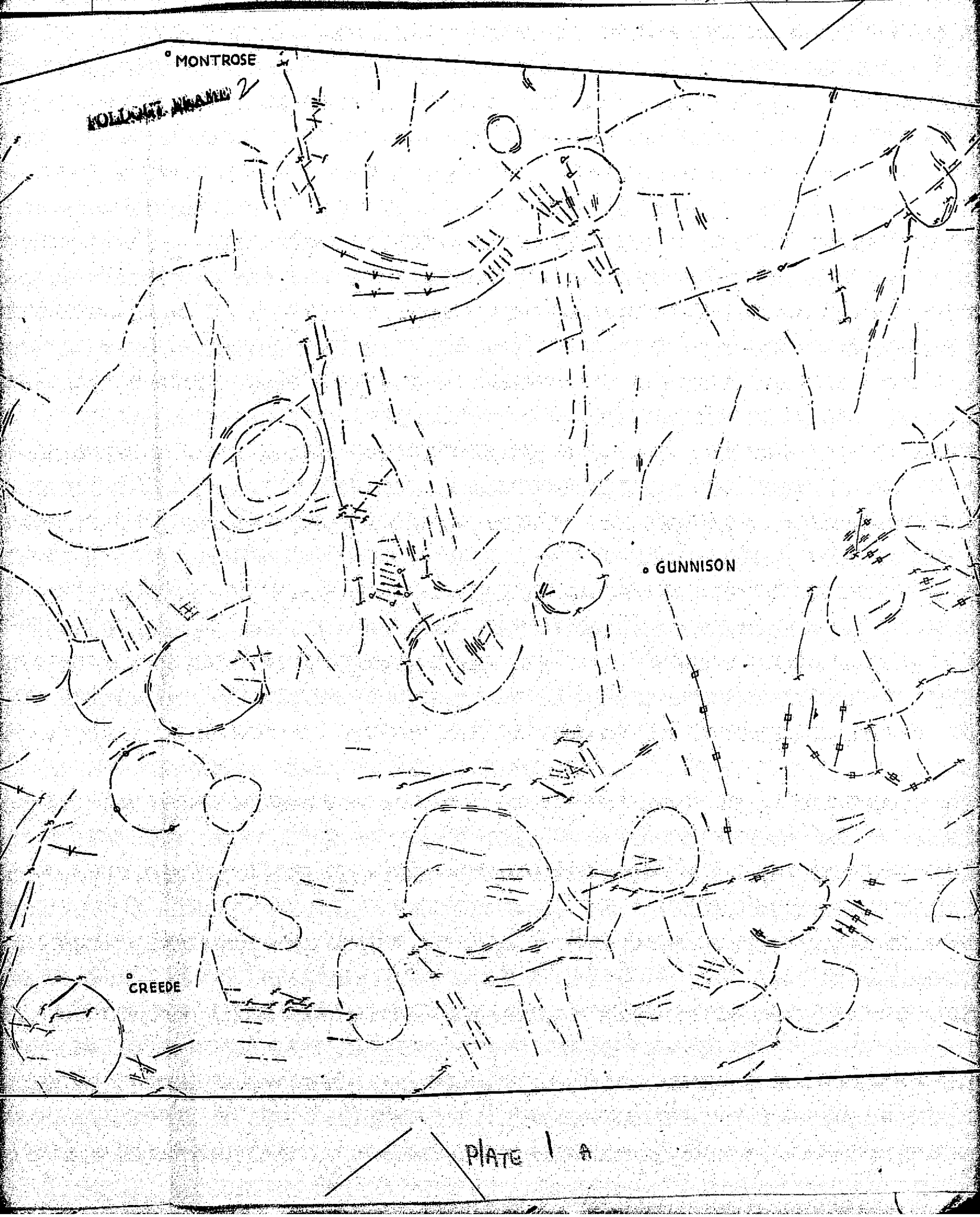
° MONTROSE

FOLIAGE PLANT 2

° GUNNISON

° CREEDE

PLATE 1 A



FOLDOUT FRAME 3

UNNISON

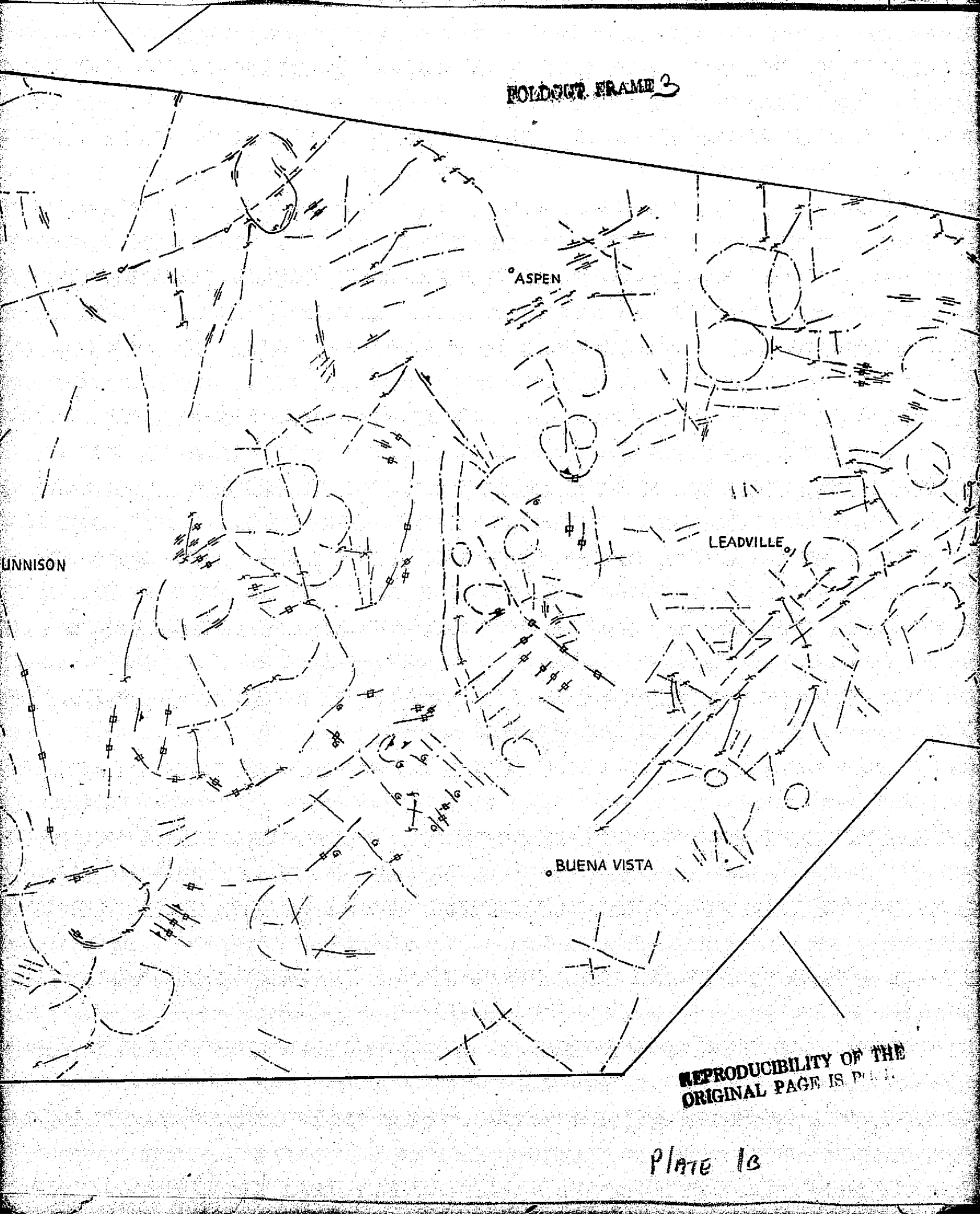
ASPEN

LEADVILLE

BUENA VISTA

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PLATE 13



FOLDDOUT FRAME 4

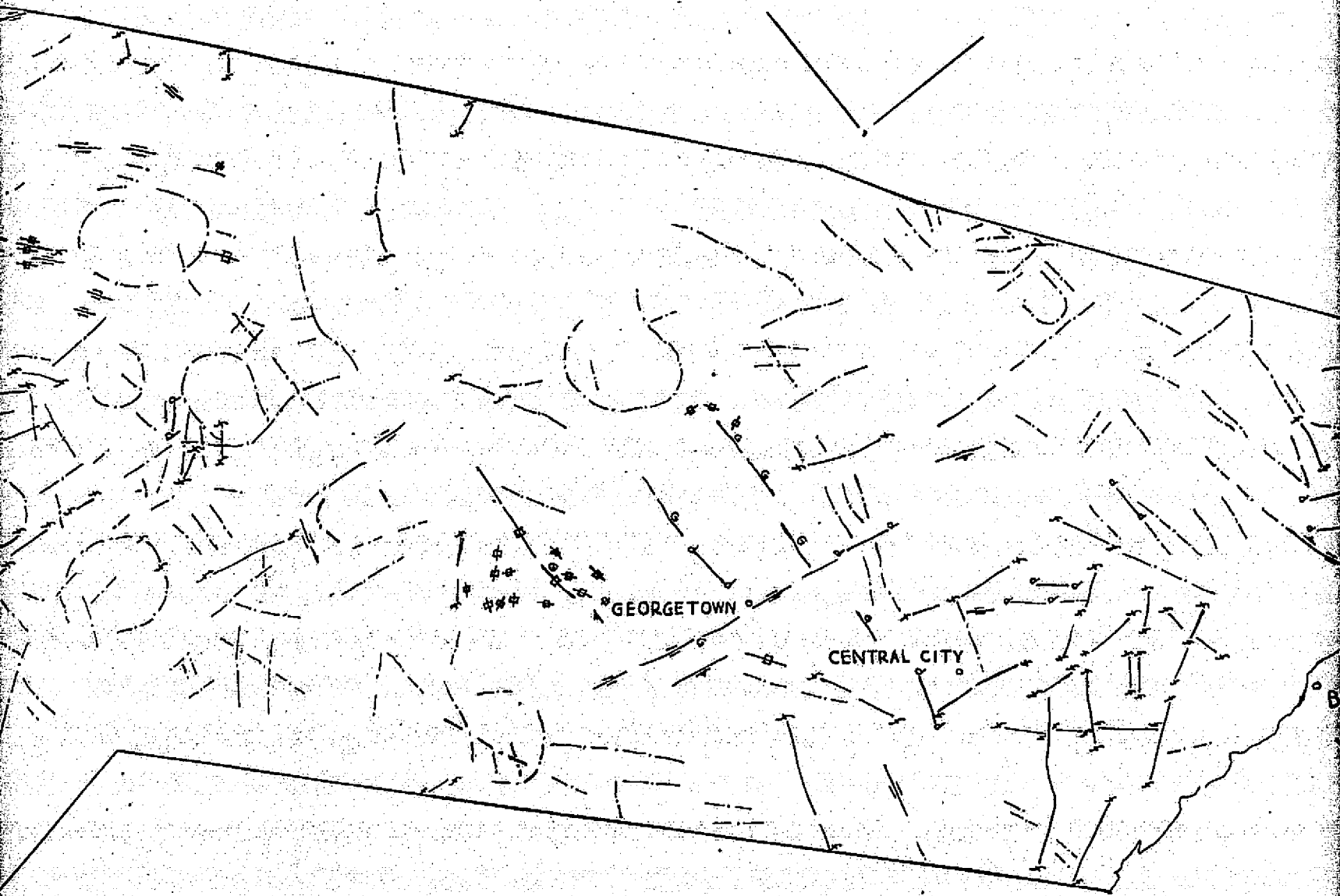


PLATE 1

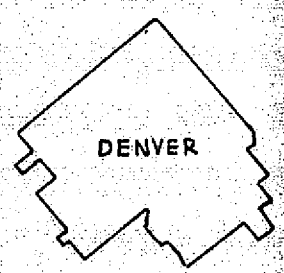
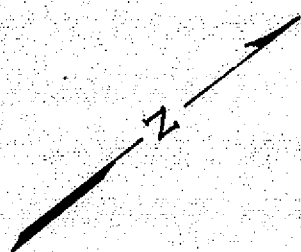
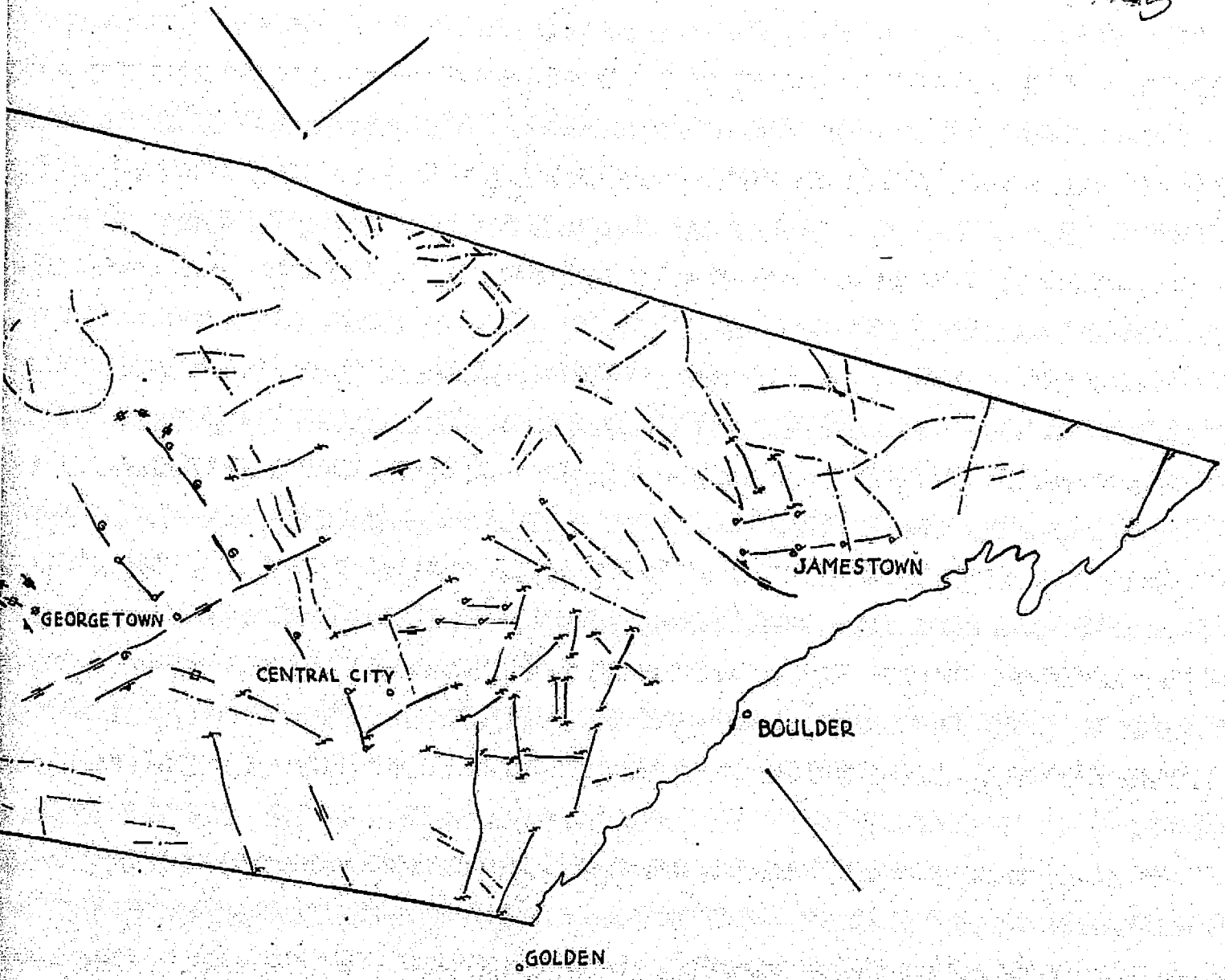


PLATE 1C

TOP OF THE
S P...

FOLDOUT FRAME 4

FOLDOUT FRAME 5



15 MILES
24 METERS

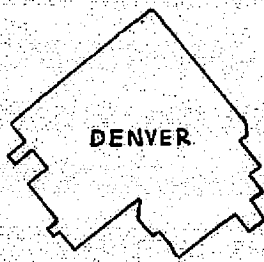


PLATE 1C

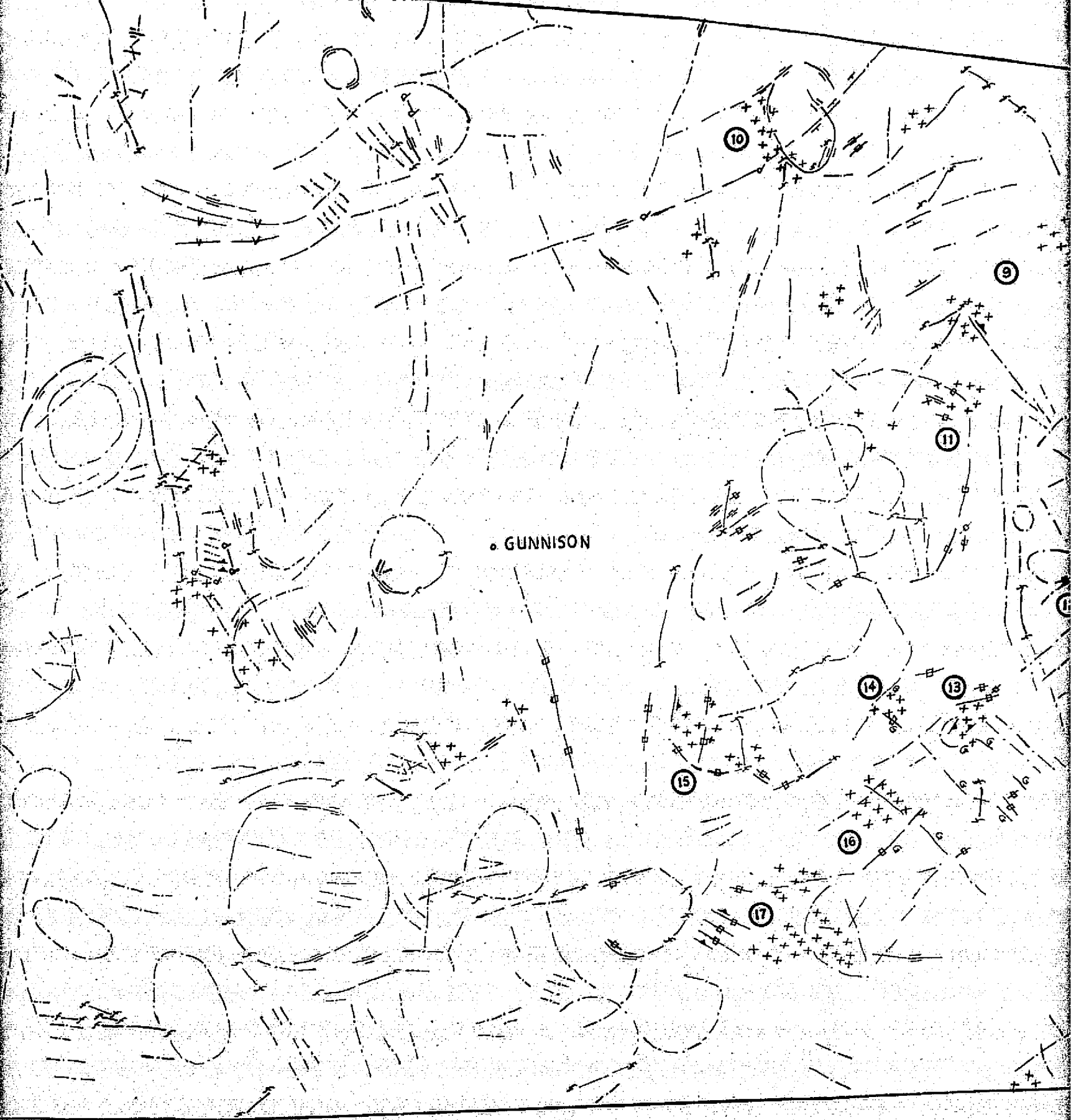
FOLDS OUT FRAME

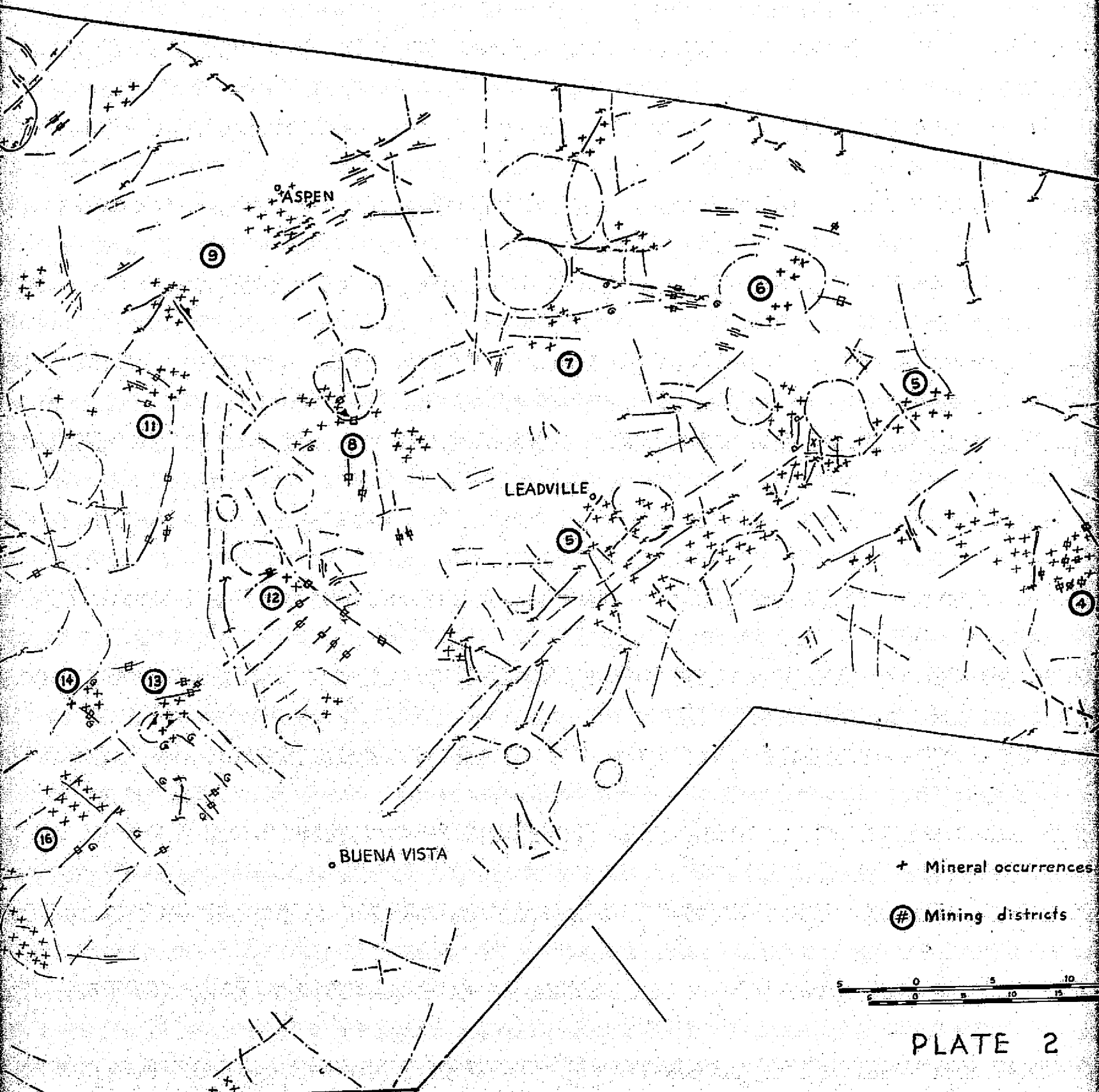
MON



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PLATE 2





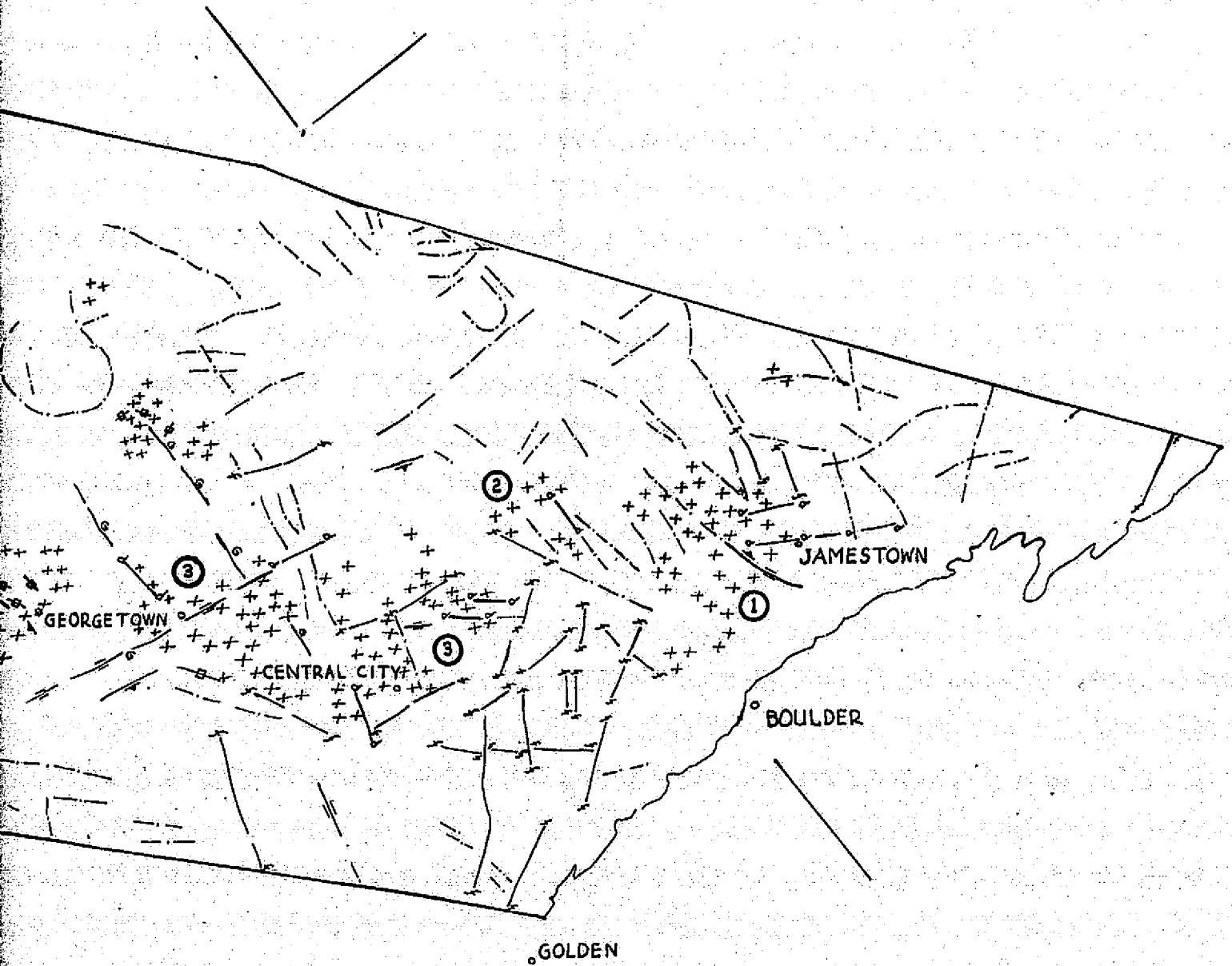
+ Mineral occurrences

Mining districts



PLATE 2

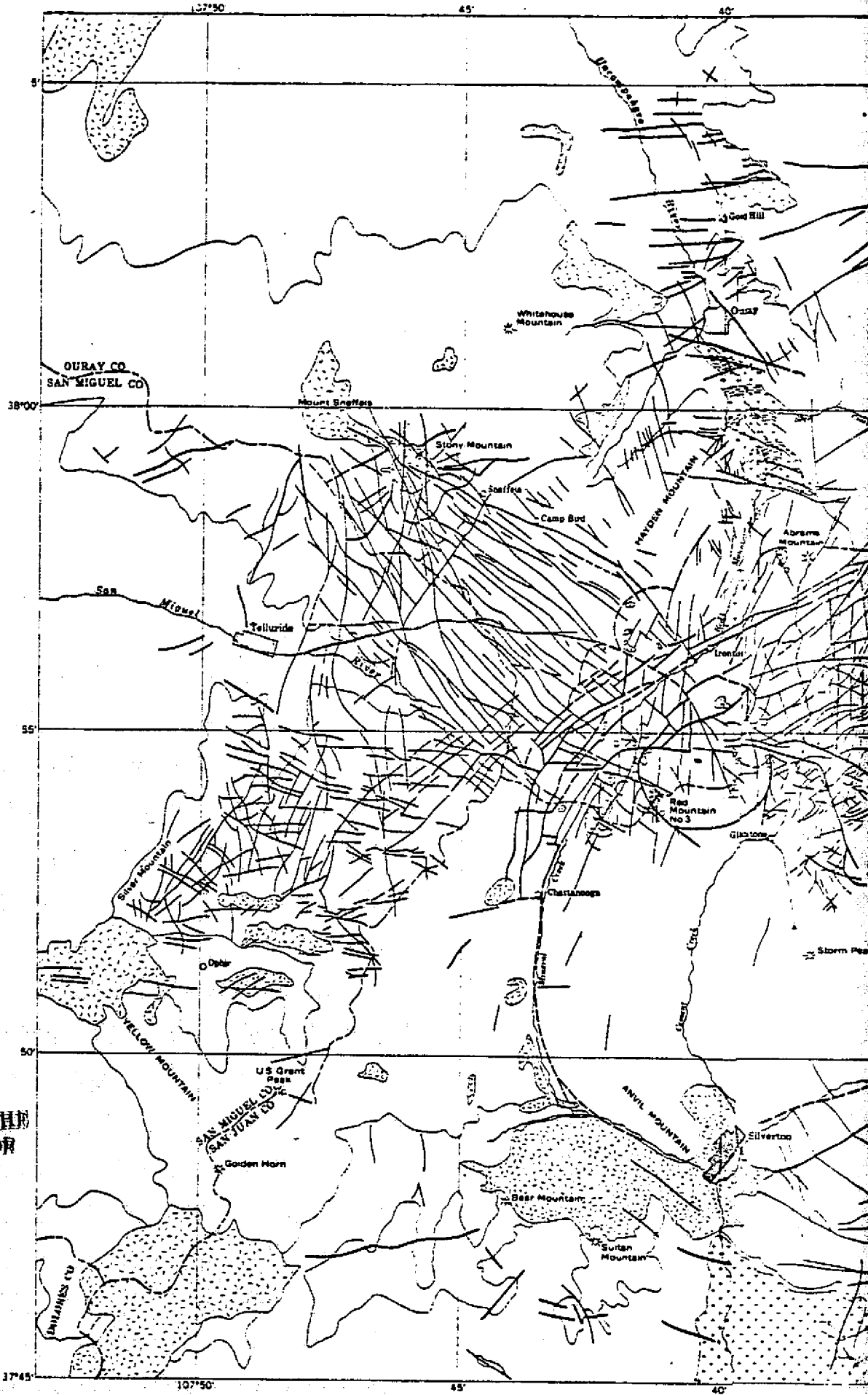
PLATE 2B



15 MILES
24 KILOMETERS



FOEDGAT FRAME



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PLATE 3

GEOLOGIC MAP SHOWING STRUCTURE OF PART OF THE SILVERTON C... IN OURA Y, SAN JUAN, SAN MIGUEL, AND HINSDALE COUN...

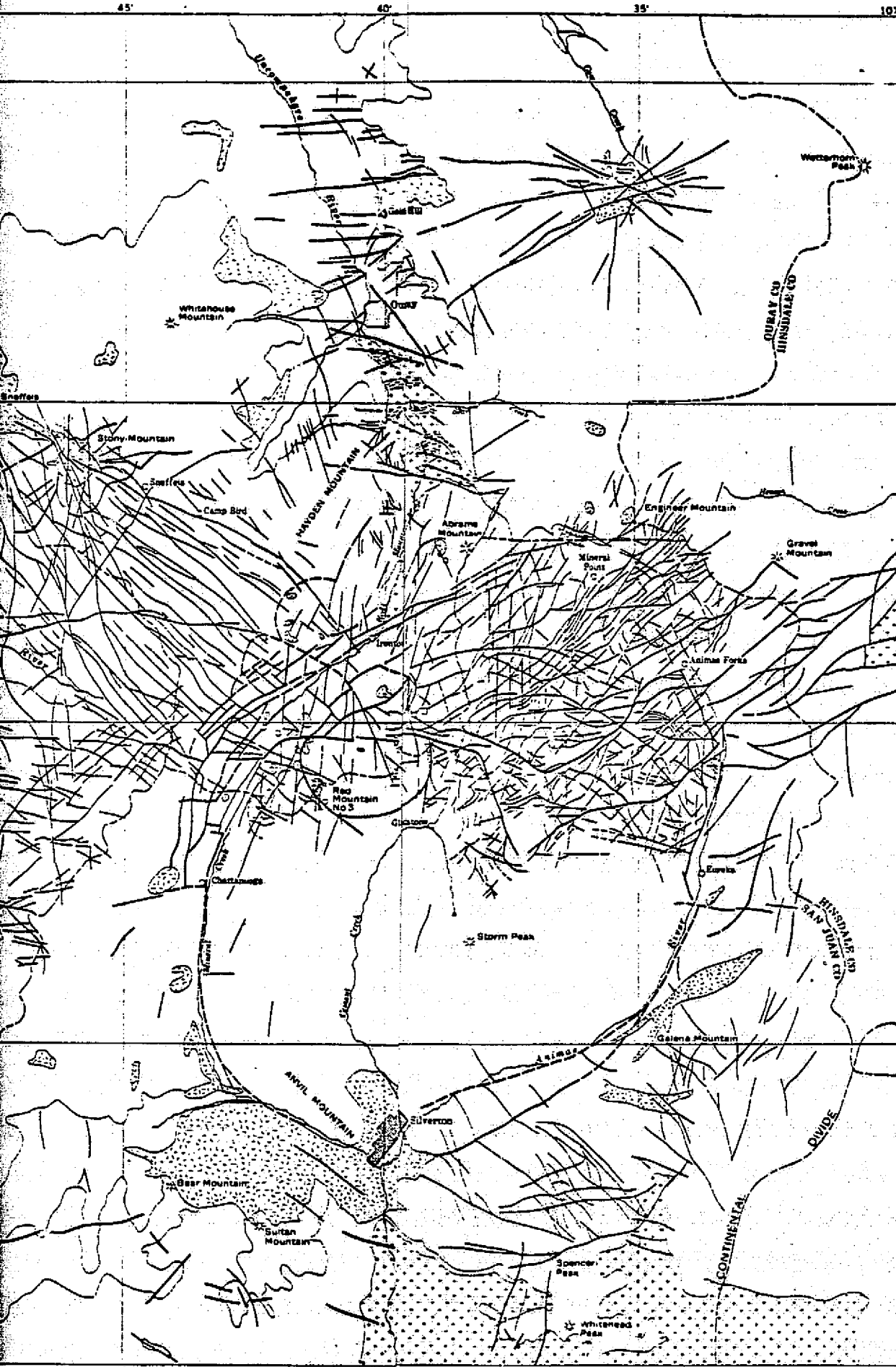
45°

40°






35°

107°30'

FOLDOUT FRAME 2



EXPLANATION

-  Upper Tertiary intrusive rocks
Not including dikes shown by lines
-  Tertiary volcanic formations
Including Tertiary Conglomerate
where present at base
-  Upper Cretaceous and lower
Tertiary intrusive rocks
-  Paleozoic and Mesozoic
sedimentary rocks undifferentiated
-  Precambrian rocks
Including sedimentary, metamorphic,
and intrusive rocks; a slate
- Contact
- Principal fissures, dikes, veins, and
minor faults
- Major faults
Dashed where approximately located
Include mineralized faults

From: U.S.G.S. P.P. 535
(Plate 1)

Geology by W. S. Burbank and R. G. Luedke
1945-47, 1950-53

STRUCTURE OF PART OF THE SILVERTON CAULDRON AND AREAS NEARBY
SAN JUAN, SAN MIGUEL, AND HINSDALE COUNTIES, COLORADO

PLATE 2a

TRAMP

EXPLANATION

IGNEOUS AND METAMORPHIC ROCKS

- Volcanic rocks
 - Stocks
 - Dikes and sills
 - Laramide intrusive rocks
 - Localities or groups of sills rocks
 - Granitic rocks
 - Metamorphic rocks
- Lines indicate general trend of foliation; star pattern indicates trend not known*

SEDIMENTARY ROCKS

- Sedimentary rocks and surficial deposits
- TQs, Tertiary and Quaternary rocks;
- PM, Paleozoic and Mesozoic rocks

Contact

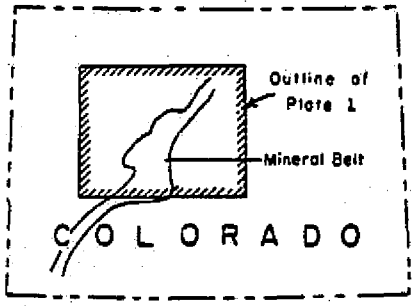
- High-angle fault
 - Dashed where inferred
 - Thrust fault
 - Dashed where inferred; barbs point toward upper plate
 - Shear zone
- Number refers to locality discussed in text

1:500,000

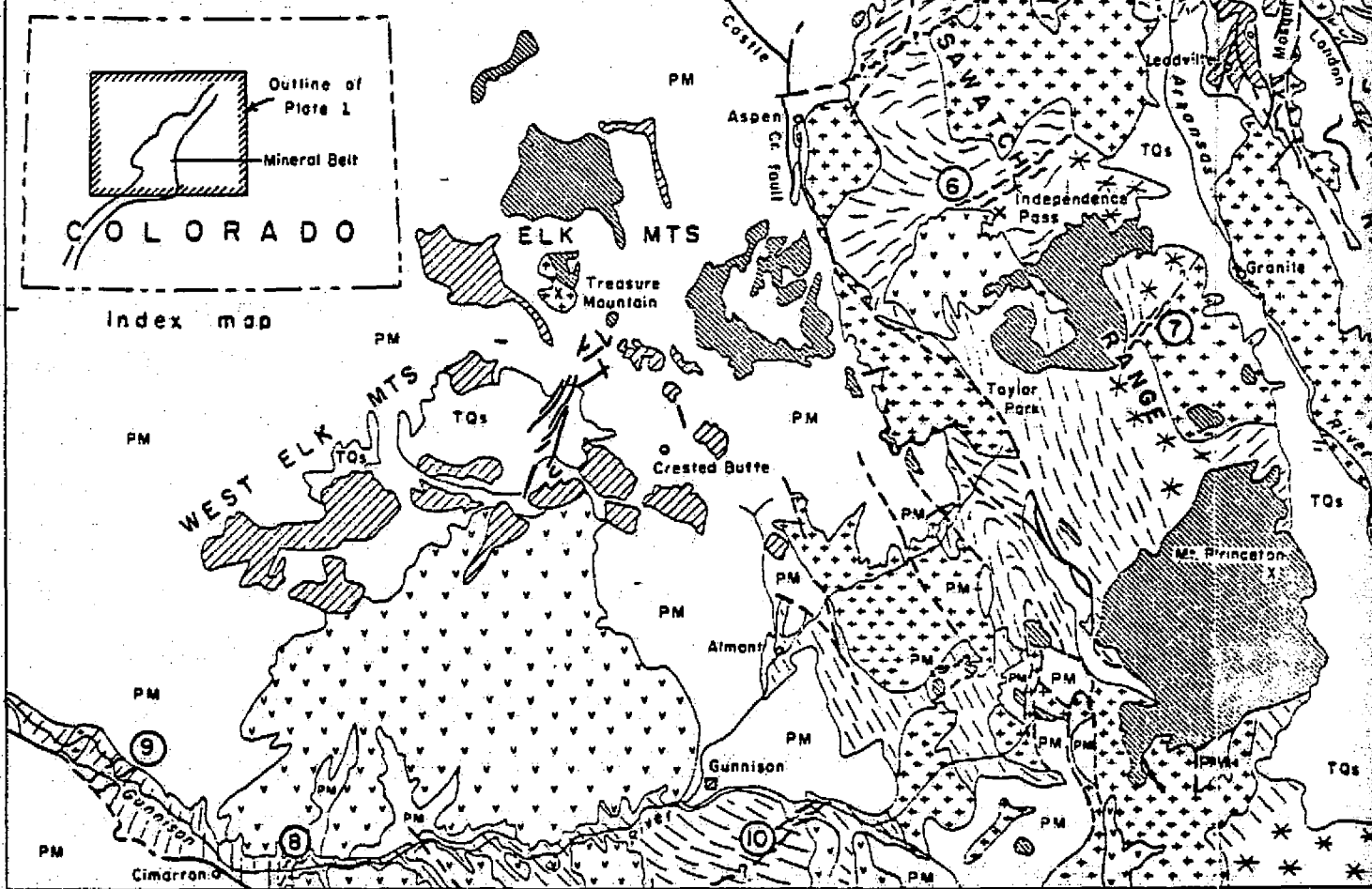
10 0 10 20 30 MILES

CRETACEOUS AND TERTIARY
PRECAMBRIAN AND TERTIARY
CAMBRIAN TO QUATERNARY

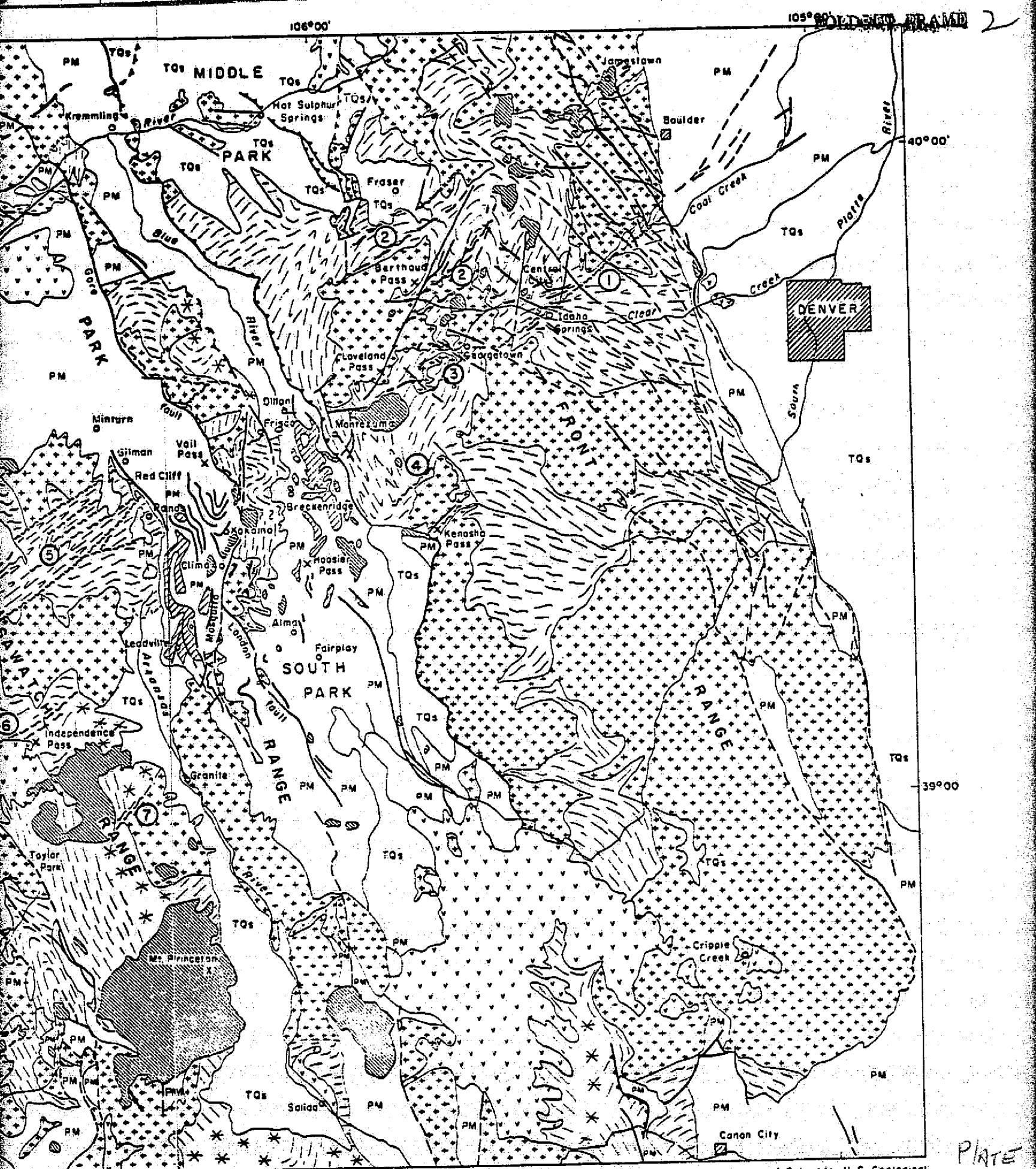
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Index map



GEOLOGIC SKETCH MAP OF CENTRAL COLORADO



GEOLOGIC SKETCH MAP OF CENTRAL COLORADO

Based on geologic map of Colorado, U.S. Geological Survey, 1935, and Lovering and Goddard (1950, Pl. 1); revised by Ogden Twesto and P.K. Sims, 1960. Includes published data from sources listed under "References" and unpublished data received.

PLATE 4 A

APPENDIX A

Table I. LANDSAT Imagery Used

Northern Front Range area

LANDSAT - 1
 1172-17135
 1190-17140
 1550-17100
 LANDSAT - 2
 2186-17015
 2168-17022

Aspen-Gunnison area

LANDSAT - 1
 1551-17161
 1515-17171
 1407-17190
 1461-17174
 1299-17203
 LANDSAT - 2
 2259-17070

Southern Front Range area

LANDSAT - 1
 1172-17141
 1190-17143
 1153-17143
 LANDSAT - 2
 2186-17022
 2276-17011

San Juan Mountains area

LANDSAT - 1
 1551-17163
 1191-17204
 1461-17181
 1425-17190
 1299-17205
 LANDSAT - 2
 2259-17073

San Luis Valley area

LANDSAT - 1
 1550-17105
 1172-17144
 LANDSAT - 2
 2276-17013
 2186-17024

Grand Junction area

LANDSAT - 1
 1516-17225
 1156-17260
 1462-17233
 LANDSAT - 2
 2260-17124

North Park area

LANDSAT - 1
 1515-17165
 1551-17154
 1191-17195
 1461-17172
 1299-17200
 LANDSAT - 2
 2187-17074

Table II. Key to Mining Districts

- (1) Jamestown-Gold Hill
- (2) Caribou-Nederland
- (3) Black Hawk-Central City-Idaho Springs-Georgetown
- (4) Montezuma-Breckenridge
- (5) Kokomo-Climax-Leadville
- (6) Battle Mountain (Red Cliff, Gilman)
- (7) Homestake
- (8) Independence
- (9) Aspen-Ashcroft-Snowmass
- (10) Marble
- (11) Taylor River
- (12) Winfield
- (13) Cottonwood
- (14) Tincup
- (15) Pitkin-Ohio City
- (16) St. Elmo-Chalk Creek
- (17) Garfield-Monarch
- (18) Creede
- (19) Lake City-Ouray-Silverton-Telluride
- (20) Rico

Table III. Geologic maps used in the identification
of toplinears

USGS GQ Series

152 Ouray
267 Central City
291 Ironton
443 Berthoud Pass
504 Telluride
512 Marble
536 Dolores Peak
578 Oh-Be-Joyful
631 Bristol Head
788 Maroon Bells
797 Rico
833 Nederland
853 Snowmass Mountain
863 Hayden Peak
932 Highland Peak
933 Aspen
978 Tungsten
1004 Ruedi
1011 Wetterhorn
1052 Spar City
1053 Creede
1177 Rudolph Hill
1178 Powderhorn
1248 Black Hawk
1277 Ward
1287 Houston Gulch

USGS MF Series

176 Gray Head
760 Leadville
761 Montrose

USGS I Series

764 Durango

APPENDIX B

SELECTED REFERENCES ON COLORADO'S MINERALIZED BELT

TABLE OF CONTENTS

PART I -- Selected References on Colorado Mineral Resources

PART II -- Selected References by County

Boulder

Chaffee

Clear Creek

Delta

Dolores

Douglas

Eagle

Fremont

Garfield

Gilpin

Grand

Gunnison

Hinsdale

Jackson

Jefferson

Lake

La Plata

Larimer

Mineral

Montrose

Ouray

Park

Pitkin

Routt

Saguache

San Juan

San Miguel

Summit

Teller

PART III -- Selected References by Mineral District

Alma

Aspen

Blue River

Bonanza

Breckenridge

Brush Creek

Calumet

Caribou

Cebolla

Central City

Central Jameston

Climax

Cochetopa

Creede

Cripple Creek

Crystal Mountain

Empire

Eureka

Freeland-Lamertine

Georgetown

Gold Brick

Gold Hill

Gilman

Horse Shoe

Idledale

Irwin

Kokomo

Lake Como

La Plata

Lawson-Dumont

Leadville

Magnolia

Marshall Pass

Mineral Point

Monarch

Montezuma

**PART III — Selected References by Mineral District
- Continued -**

North Gate

Ouray

Placerville

Platoro-Summitville

Poughkeepsie

Powderhorn

Quartz Creek

Red Cliff

Red Mountain

Rico

Silverton

Slick Rock

Sneffels

Summitville

Tarryall

Telluride

Ten Mile

Tin Cup

Tomichi

Tungsten

Twin Lakes

Uncompahgre

Uravan

Ward

Weston Pass

White Pine

PART I

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SELECTED REFERENCES ON COLORADO MINERAL RESOURCES

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SELECTED REFERENCES ON BOULDER COUNTY MINERAL RESOURCES

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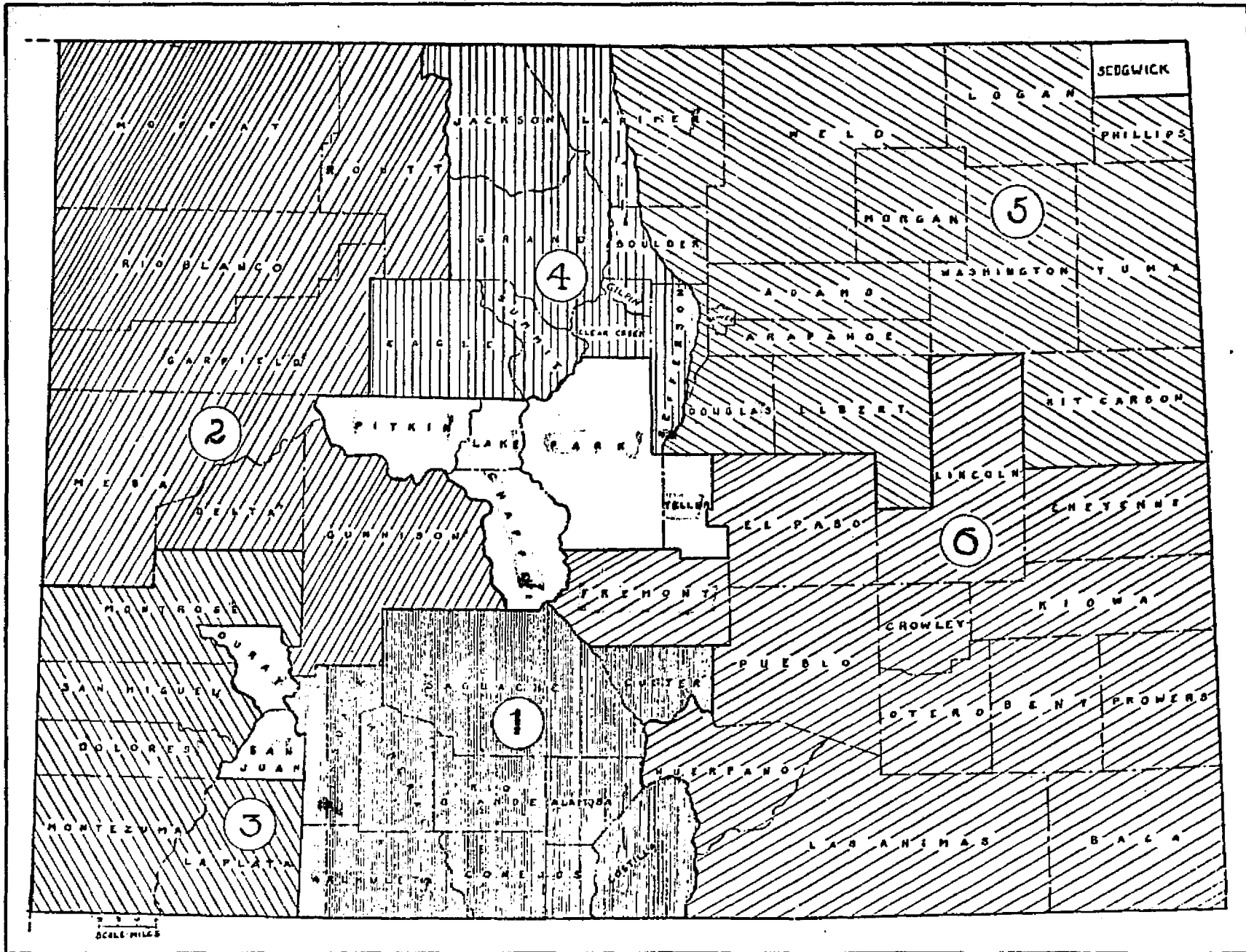
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