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TECTONIC ANALYSIS

THE BONANZA MINING DISTRICT,

SAGUACHE COUNTY, COLORADO

By

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MILLERS FALLS
EZERASE
COTTON CONTENT

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April 16, 1961

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TECTONIC ANALYSIS

THE BONANZA MINING DISTRICT

SAGUACHE COUNTY, COLORADO

Introduction:

The following tectonic analysis of the Bonanza District, Colorado, is based upon the idea of Professor Edward Wisser that an analysis of the sucession of structural events prior to and during the critical period of metallization can be used to predict which of the many structures visible in a mining district were open at the time of metallization. An analysis of this sort is of primary importance in the intelligent planning of exploration openings for the discovery of new ore. The major data for this study have come from U.S. Geological Survey Professional Paper 169 by W. S. Burbank (1932).

Geographic Setting:

The Bonanza District is located at the southern end of the Sawatch Mountains and within the far eastern extreme of the San Juan Volcanic province. The district occupies a high, extremely rugged part of the head waters of the San Luis Valley of South Central Colorado (figure 1). Bonanza is 15 to 20 miles southeast of the Monarch and Gold Brick Districts and 100 miles northeast of Silverton.

The Bonanza District has produced (to 1929) $7.6 million worth of an epithermal Ag-Ce-Pb-Zn ore from a thick sequence of Tertiary volcanics and intrusions which were completely fractured and faulted soon after deposition during the Miocene.

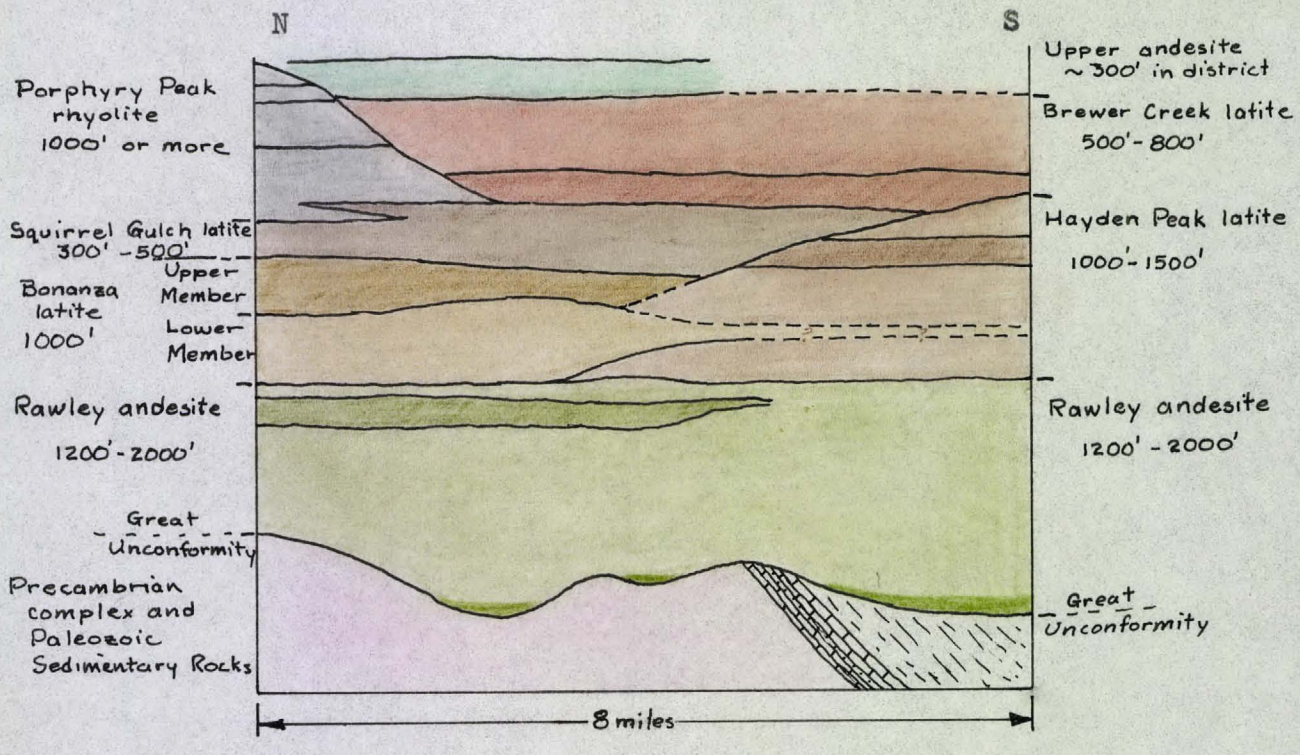


Figure 2. North-South Columnar Section of the Tertiary Lavas of the Bonanza District.

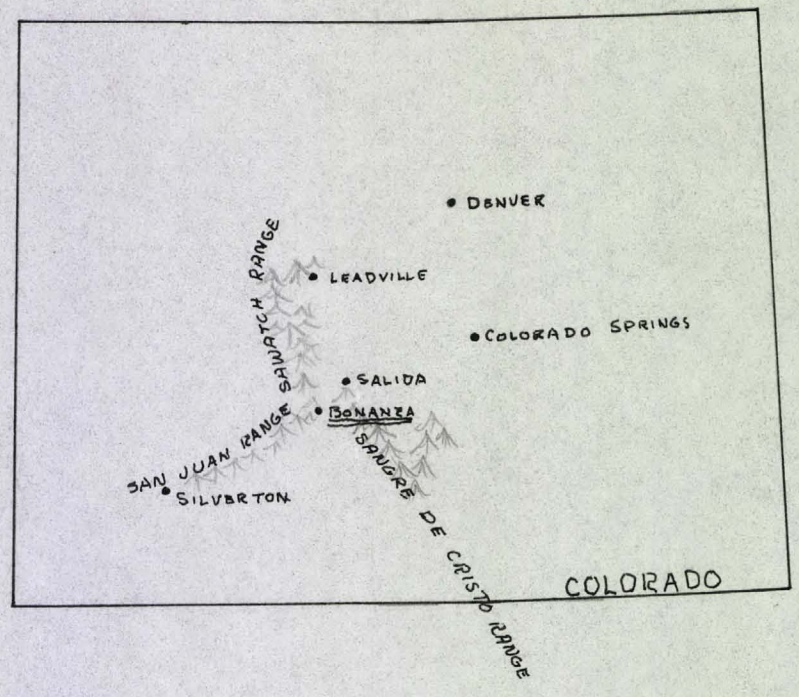


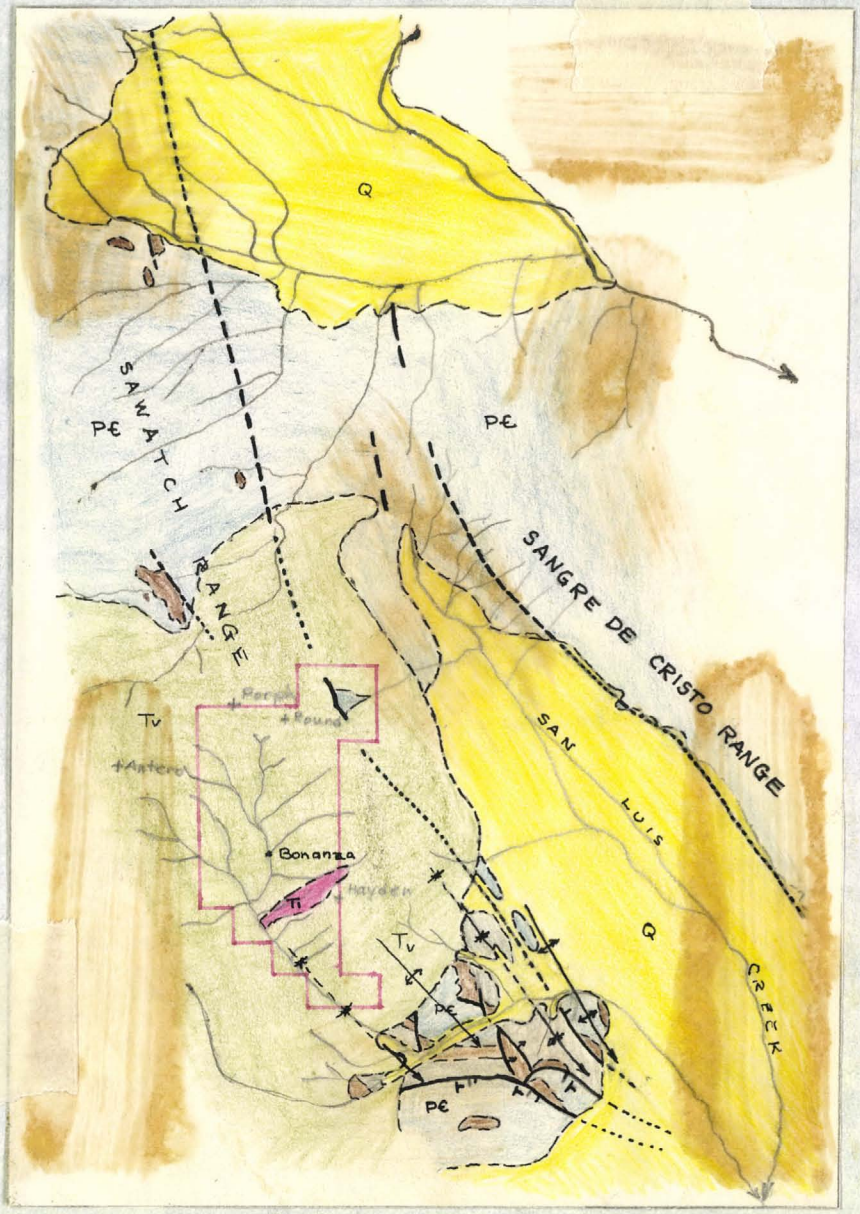
Figure 1. Outline map of Colorado showing the location of Bonanza.

Geologic Setting:

Figure two is a north-south columnar section of the rocks found in the Bonanza district. The complex of tertiary lavas is underlain by the Precambrian basement in most of the district, but it is perhaps underlain by Paleozoic sediments, including several limestones, in the southern part of the district.

The Precambrian rocks of the area are schists and gneisses which Burbank (1932) tenitatively correlates with the Idaho Springs formation of the Colorado Front Range. These schists and gneisses have, in the Bonanza area, been extensively intruded by granites, also of Precambrian age. Burbank (1932) does not note the structure present in these rocks.

The Paleozoic rocks are exposed in Kerber Creek Valley, a mile south of the district and also two miles north of the district (Plate I). The stratigraphic section is typical of central Colorado and includes several lower Paleozoic limestone and dolostone horizons which are considered favorable replacements horizons in the surrounding mining districts. These limestones and dolostones are capped by the Pennsylvanian red-bed-shale series of the central and southern Rocky Mountains. These These Paleozoic sediments were compressed into a series of NNW trending folds, and steep dipping thrusts during the early laramide. Much erosion took place before the Rawley Andesite, the first of the lavas, flowed over the surface. South gently plunging synclines are all that are left of the Paleozoic rocks. The volcanico, which began to flow in late Oligocene, entirely covered the 200 to 500 feet of relief developed upon the Precambrian and Palozoic rocks. Most of the flows were viscous and



Scale 1" = 6 miles

plunging syncline

fault

Legend

Q = Quaternary Alluvium

T = Tertiary Intrusive

Tv = Tertiary Volcanics

Paleozoic Sediments

P€ = Precambrian metamorphics and Intrusives

Plate I Generalized Geologic map of Bonanza and Surrounding Area. Saguache County, Colorado.

MILLERS FALLS
EZERASE
COTTON CONTENT

they flowed from many different vents. This resulted in much interfingering and in a very complex, discontinuous section with very few marker horizons. The earliest flow is andesite, and is followed by a number of different latites and rhyolite. The last flow is again andesite and is tenitatively correlated with any certainty even over very short distances. Fortunately the only relatively continuous horizon in the district, the top of the Rawley Andesite, is also intimately associated with the ore deposits (figure 3).

The volcanics have been intruded by five types of intrusives, but some of these intrusives are probably contemporaneous with some of the volcanics. All of the intrusives are apparently pre-ore. As can be seen from Plate IV the fracture pattern in existance at the time of intrusion was much less complex than that in the district at present. Burbank states that their are many more dikes present than he could represent at a scale of 1:12,000. The order of intrusion is that listed on Plate IV.

Burbank (1932) recognized three main types of hydrothermal alteration which preceeded ore-deposition: (1) Silicification, (2) Sericitization, and (3) Propylitization. He notes in the text five types of silicification that have varying relations to the ore, but on his map he represents them all with one symbol (Plate V). The oldest alteration most closely associated with the ore is sericitization. All veins have a certain amount of associated sericite, but the sericite appears in many fissures that do not contain known ore. The most intense propylitization appears to represent an early stage of sericitication and generally grades into sericite in the direction of the fissure.

Ore Deposits:

The ore deposits of the northern part of the district have been calssified by Newhouse (1942, p. 30) as complex epithermal Ag-base metal ores, which because of fine grain size, caused the mettalurgist no end of troubles. Table I lists the amount of metal and value recovered from 503,572 tons of ore from this part of the district between the years 1905 and 1929. The amount of zinc recovered does not reflect the zinc content of the ore as most of the zinc was lost in the smelting. Present value was computed from the metal market listings in Engineering and Mining Journal for February 1961.

TABLE I, Metal recovered from 503,572 tons of ore treated from 1905-1929, Bonanza, Colorado

METAL	AMOUNT	VALUE WHEN MINED	VALUE AT PRESENT
Gold	6,512.08 oz.	$ 134,617	$ 227,923
Silver	3,544,749 oz.	2,260,093	3,207,998
Copper	12,361,638 lb.	1,861,745	3,581,875
Lead	27,048,753 lb.	1,752,362	2,975,363
Zinc	2,578,610 lb.	191,343	296,540
Total		$ 6,200,160	$10,292,700

In the southern part of the district the ores are high in manganese and low in sulfides. These ores have not been as extensively developed as the ores further north so that less is known of them. They were apparently only economic in the oxidized porttions of the veins. These ores contained some silver, in part as pyrargyrite, and were mined very early for this metal.

In the whole district the major ore bodies are found in the upper part of the Rawley andesite. Figure (3), taken from Burbank (1932, p. 62) illustrates this relation as well as the relation of the ores to the present topography. This relationship to topography is fairly typical of epithermal deposits and probably indicates little erosion since deposition of the ores.

The ores are found over a range of 3500 feet topographically, but only over a range of about 1500 feet stratigraphically.

The ores of the northern part of the district change gradually with increasing depth from a high lead-zinc ore at the surface to a high copper-silver ore in depth, but all metals are present at all depths. The principle sulfide minerals present are pyrite, sphalerite, galena, silver bearing tennantite and chalcopyrite with some enargite, bornite, stromeyerite and chalcocite. The gangue minerals are mainly quartz barite, manganiferous calcite, and rhodonite.

Tectonic Analysis

Before the detailed tectonic analysis of the Bonanza District is presented it will be helpful to consider the laramide and cenozoic tectonic hostory of this part of Colorado. The discussion will be based upon a paper by Gabelman (1952) on the structure and origin of the Northern Sangre de Cresto Range.

The Laramide began with a vertical rise of the whole of central Colorado out of late Cretaceous seas. Along with or immediately following

vertical uplift the area was subjected to a west-directed compression which produced the major anticlinal mountains of central Colorado, including the Sawatch anticlinorium. The synclinal, inter-mountain, basins at this time received sediments of Denver age. West directed compression continued through the Paleocene and into lower Eocene and produced north-north-west trending folds (in the southern Sawatch), and east dipping reverse faults. The synclinal remnents of these folds and the reverse faults are exposed in lower Kerber Creek. The major part of the reverse faulting occurred in very early Eocene. During Huerfano time, compression was directed eastward and northeastward and produced a southwest dipping thrust in lower Kerber Creek which brings Precambrian granite up over the Paleozoic sediments. To the east in Huerfano Park the thrust is contemoraneous with the deposition of the lower part of the Huerfano formation which it in part displaces. Following the uplift of the northern Sangre de Cristo Mountains in late Eocene, the oligocene was a period of erosion. Oligocene erosion produced a surface of at least 500 feet of relief as measured in the lower Kerber Creek Valley by Burbank (1932). All post precambrian rocks were removed from the area by this erosion with the exception of the isolated remnents of Paleozoic rocks present in synclines.

In upper Oligocene the down faulting of the San Luis Valley began and it continued at least through the end of the Pleistocene. This appears to have been a basin and range type of block faulting with a contemporaneous size of the Northern Sangre de Cristo to the east and a lesser rise of the Sawatch Range to the west. Through out the Miocene,

contemporaneous with the down faulting of the San Luis Valley, the San Juan lavas were poured out and in part filled the western part of the San Luis Valley with flows and detritus.

The whole of the central Rocky Mountain Region was uplifted during Plio-Pleistocene.

The above sequence of events is illustrated by Plate II and represents a tectonic frame work in which the tectonic events at Bonanza must fit.

Throughout the critical period of Bonanza history the San Luis Valley to the east was moving downward along a steeply dipping, northwest trending normal fault along its eastern boundary; but this zone of down-drop along its western side is not so well defined. This western zone trends northwest through the northeastern part of the Bonanza district (Plate I) and seems to have consisted of a combination of movement along pre-existing northwest fractures in the basement and a slight bending of the lavas along this trend as a hinge line. Further south the Sawatch arch plunges beneath a widened San Luis Valley. Insufficient mapping to the south makes it very difficult to discuss the structure.

The first datable structures in the Bonanza district are N55°E tension fractures which are reflected in the drainage (Plate III). This system of fractures may be related to the plunge of the Sawatch arch or to the widening of the San Luis Valley to the south, data are insufficient to explain it at present. This system contains the earliest intrusives of the district, a single dike of mica andesite which is much dissected by most of the later systems of fracturing,

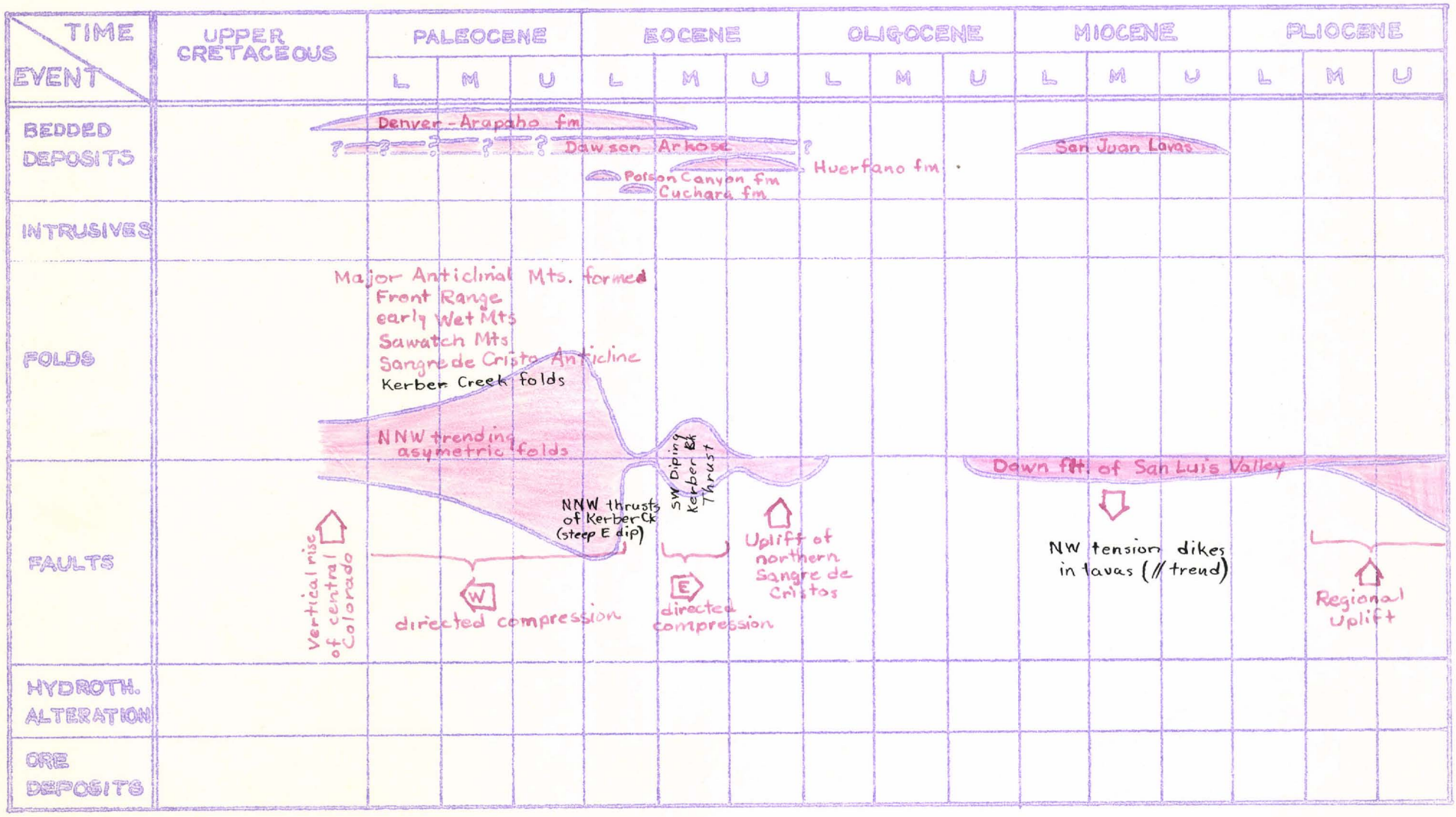


PLATE II, Time-table of Laramide and later events affecting the Bonanza District, Colorado.

Data from Gabelman (1952)

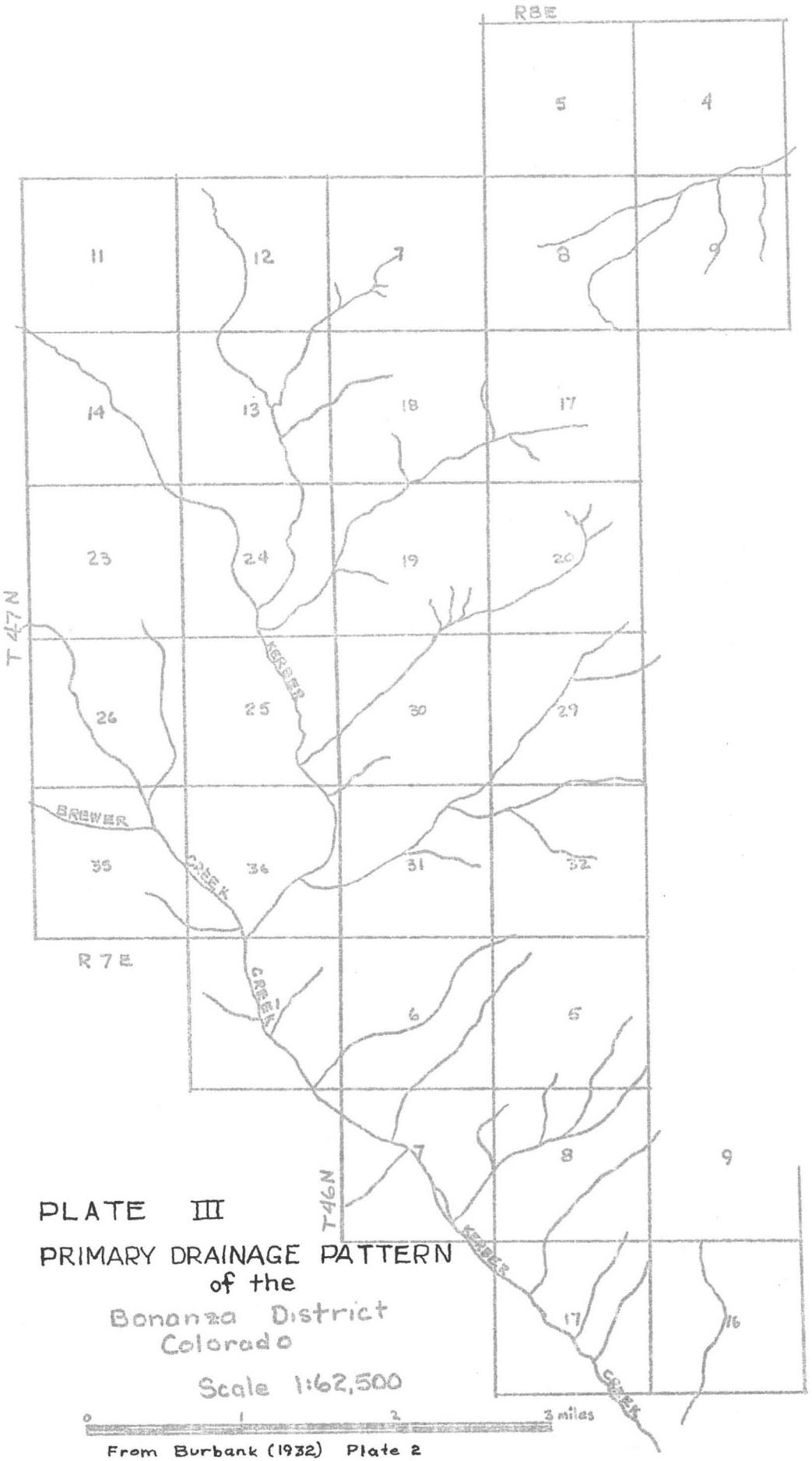


PLATE III

PRIMARY DRAINAGE PATTERN
of the
Bonanza District
Colorado

Scale 1:62,500

From Burbank (1932) Plate 2

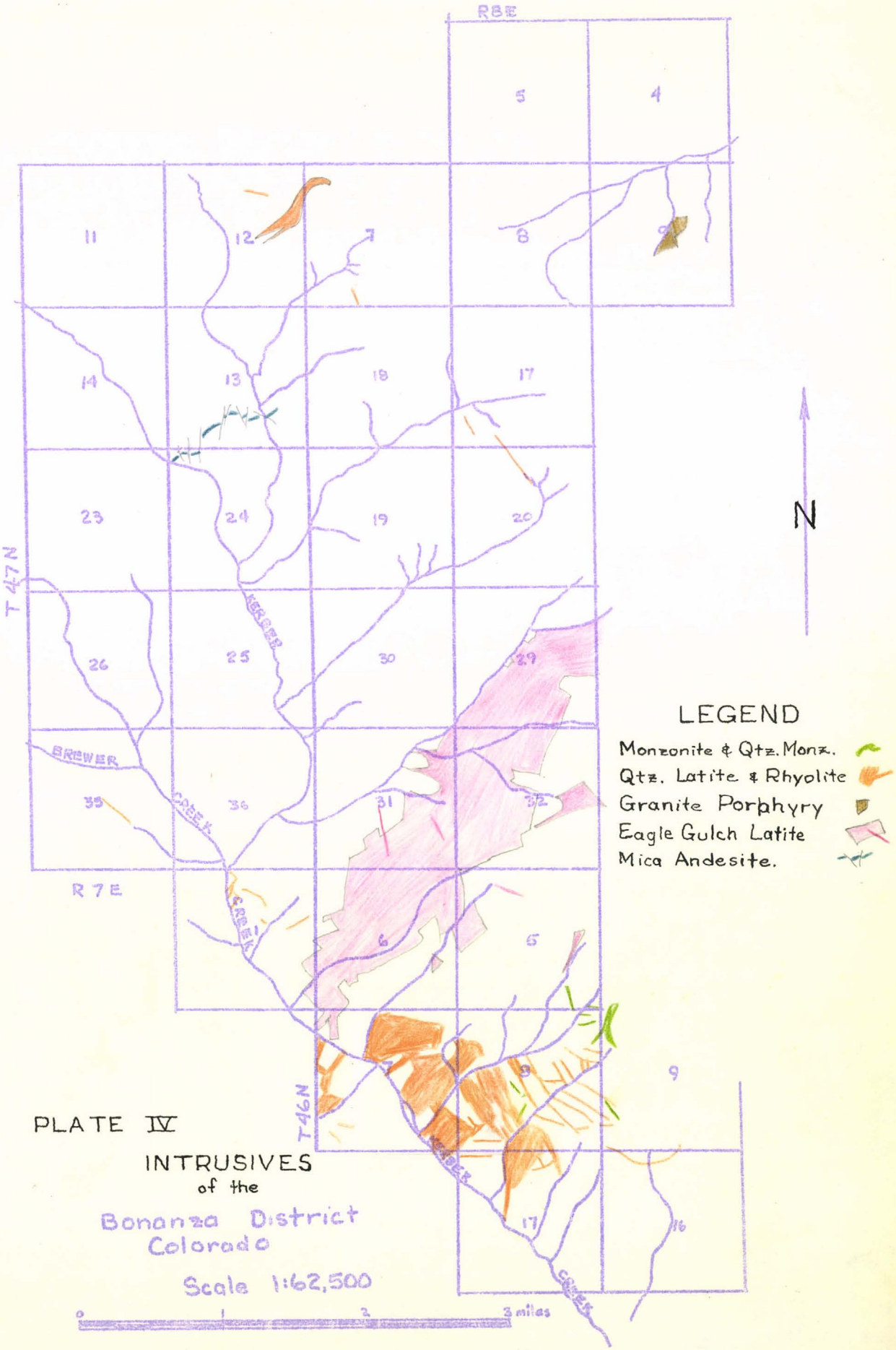


PLATE IV

INTRUSIVES
of the
Bonanza District
Colorado

Scale 1:62,500

and the Eagle Gulch Latite stock. According to Burbank (1932) cross-cutting field relations show the Eagle Gulch Latite to be earlier than the Quartz latite and rhyolite dikes. These quartz latite and rhyolite dikes are closely associated with N35°W trending tension fractures. The northwest trending fractures are shown to be later than the Eagle Gulch Latite since that body contains dike filled fractures of the northwest system. Since the quartz latite and rhyolite dikes are contained in both of the above systems but not in any of the later systems its time with respect to structure is well fixed. The fissures of both of these two systems are extensive and both are reflected in the primary drainage as well as in the dike systems. They have greatly affected all later fracturing and where at all possible later fracturing has utilized the lines weakness already developed. This fact has served to complicate the later fracture patterns.

Following the intrusion of the quartz latite and rhyolite a slight dome was formed. The center of this dome was just east of the center of the east side of the mapped area and it produced a complex area of radial and concentric faults superimposed upon the earlier systems of fissures in the Bonanza district. The concentric fractures are antithetic faults, that is, faulting was produced by the rotation of the fault blocks as they toppled away from the center of uplift, thus their movement is in opposition to that of the uplift (Wisser, 1960, p. 56). Burgank (1932) as Emmons and Garrey (1910) before he concluded that such a structure could only be produced by simultaneous faulting and tilting. Emmons and Garrey were studying the Bullfrog district in Nevada where

a similar structure, not as greatly complicated by earlier structure, is found. Burbank attributes the almost chaotic fault block system at Bonaza to later collapse of the dome but the present author doesn't feel that any such mechanism is necessary since Burbank's cross-sections show the dome as it would be expected to appear with antithetic faulting. Burbank attributes the dome to a large intrusive at a depth of which the intrusives mentioned above are a part but it has been shown by the present author that these intrusives are pre-doming. It is felt by the present author that an intrusion into ground as well prepared by fracturing as the rocks of the Bonanza area appear to have been, would surely have left some evidence in the form of dikes. The domal structure can be explained most readily by assuming local impedance of some sort to the down faulting of the San Luis Valley to the east. If the fault in the Precambrain basement met a local resistance in the area to the east of Bonanaza but not to the north or south the effect at the hinge line in the lavas would be a dome of just the sort that is present at Bonanza. This would also explain the apparent ceasation in the development of the northwest fracture system even though the down faulting of the San Luis Valley continued. Such a structure is illustrated by Wisser (1960, p. 59 from Thom, 1923) for anticlives in Montana.

The fracture patterns associated with hydrothermal alteration (Plate V) indicate that silification preceeded sericitization and represents an early relatively simple stage of the doming. The sericitization appears to have come in at the maximum development of the dome. The ore deposits (Plate VI) of the southern part of the district are systematically related to doming and followed the sericitization very closely.

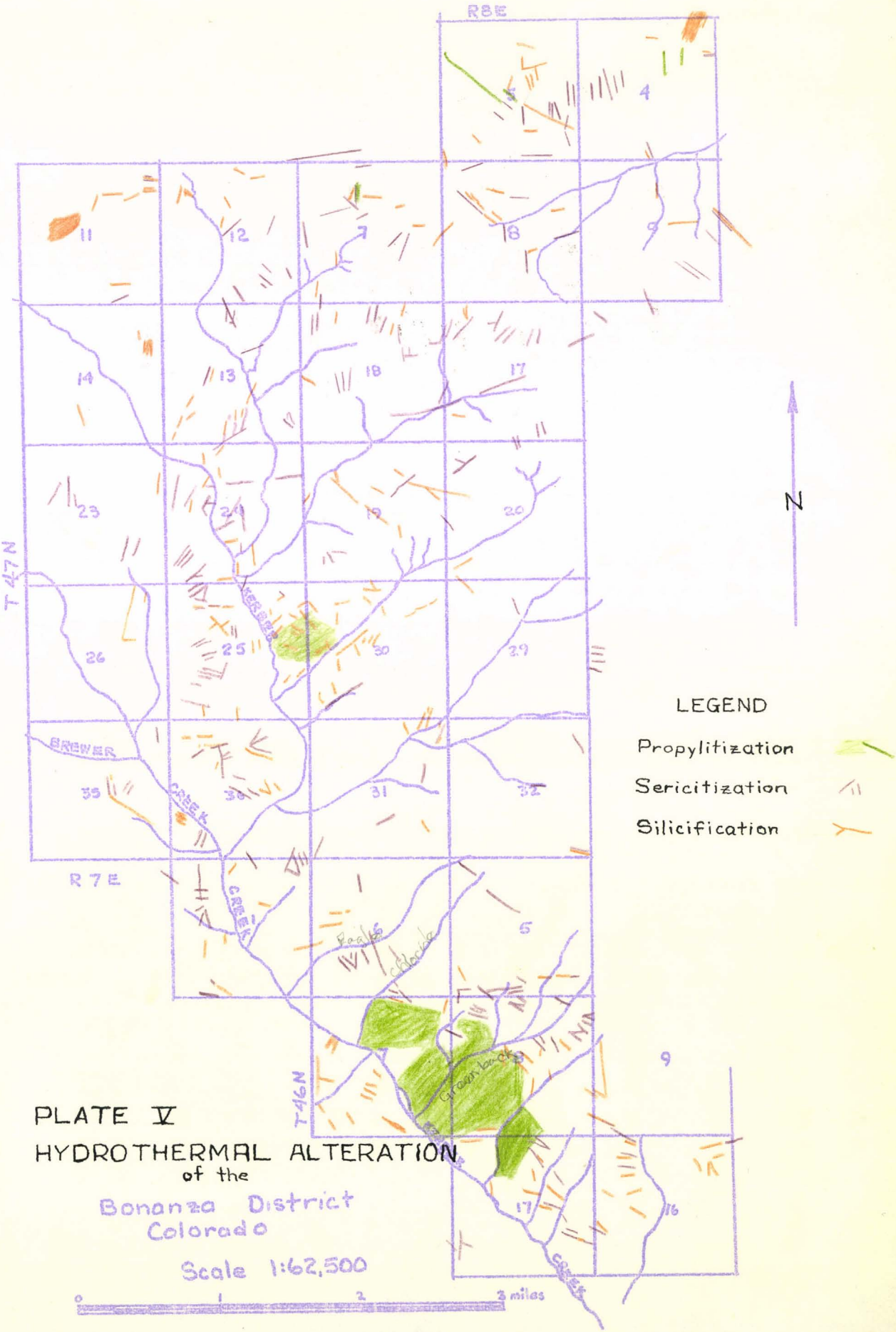


PLATE V
HYDROTHERMAL ALTERATION
of the
Bonanza District
Colorado
Scale 1:62,500

The distribution of the later and more complex ores of the northern part of the district, however, indicates that the positive phase of doming has passed and that the openings which were made available were due to relatively minor and unsystematic gravitational adjustments.

The complete sequence of tectonic vents for the Bananza district is summarized on Plate VII.

Suggestions for Prospecting:

In the northern part of the district the ore deposits cannot be systematically related to any one system of fractures, but they can be related to the present topography and to the upper part of the Rawley andesite. Further prospecting of this horizon near the present surface in areas of strong hydrothermal alteration will undoubtable reveal some new ore bodies, but it is doubtful if the return from the ore found by systematic exploration in this area would justify the high exploration expense at the present state of the metal market.

The ore bodies of the southern part of the district are too low grade to justify exploration even though they could probably be found relatively inexpensively. Further, large scale exploration in this area could only be justified on the basis of replacement of ore bodies in the underlying Paleozoic rocks. The Kerber Creek syndine can realistically be projected under this southern part of the district and belief in the following quotation from Hewett and Fleicher (1960) might give good cause for drilling.

> "Even though there seems to be a persistant tendency for Mn minerals; rhodochrosite, rhodonite, and alabandite to be deposited in a zone that surrounds a central core in which cu-bearing sulfides predominate no attempt is made here to offer an hypothesis that might explain these zonal relations".

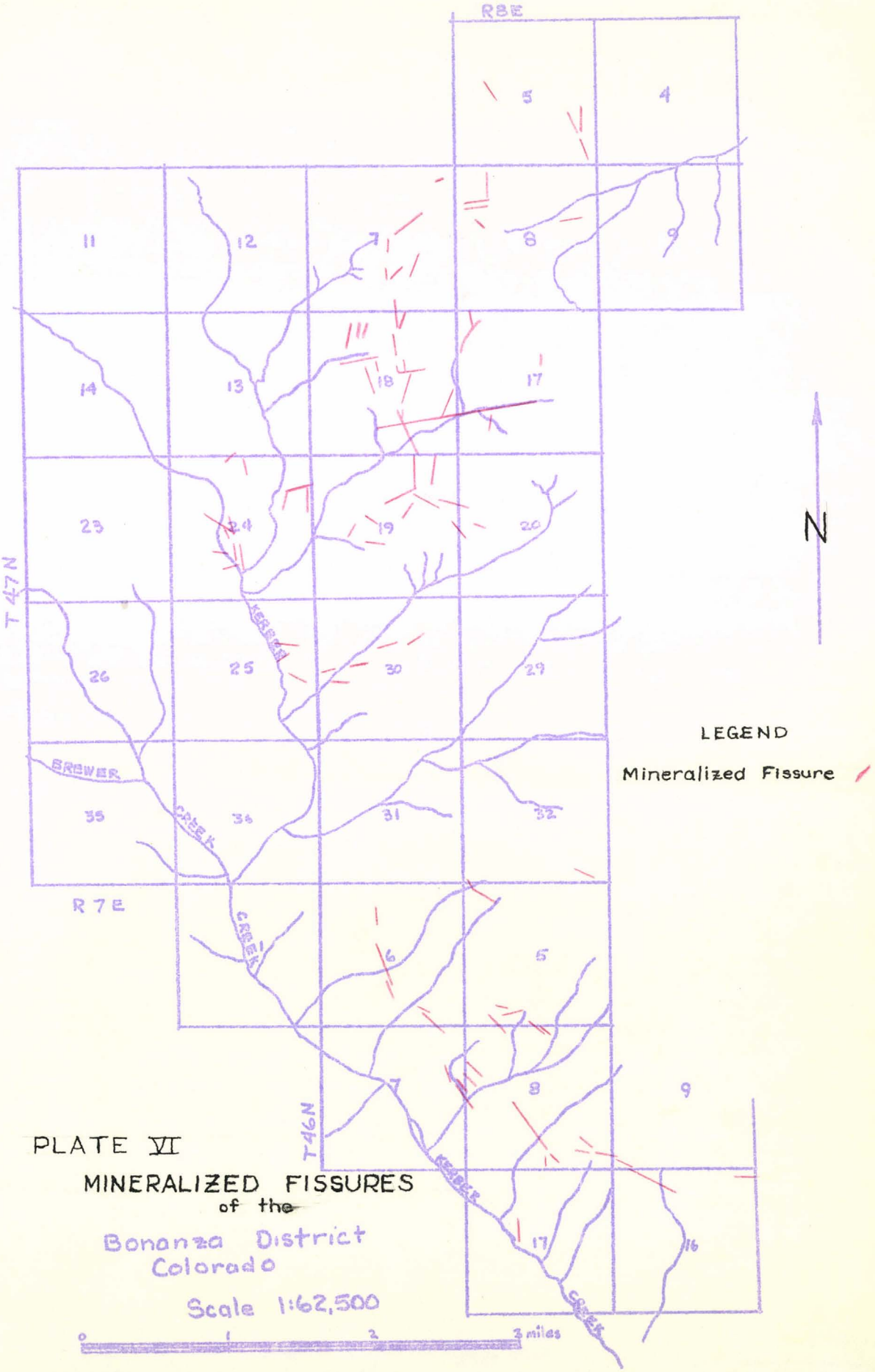


PLATE VI

MINERALIZED FISSURES of the Bonanza District Colorado

Scale 1:62,500

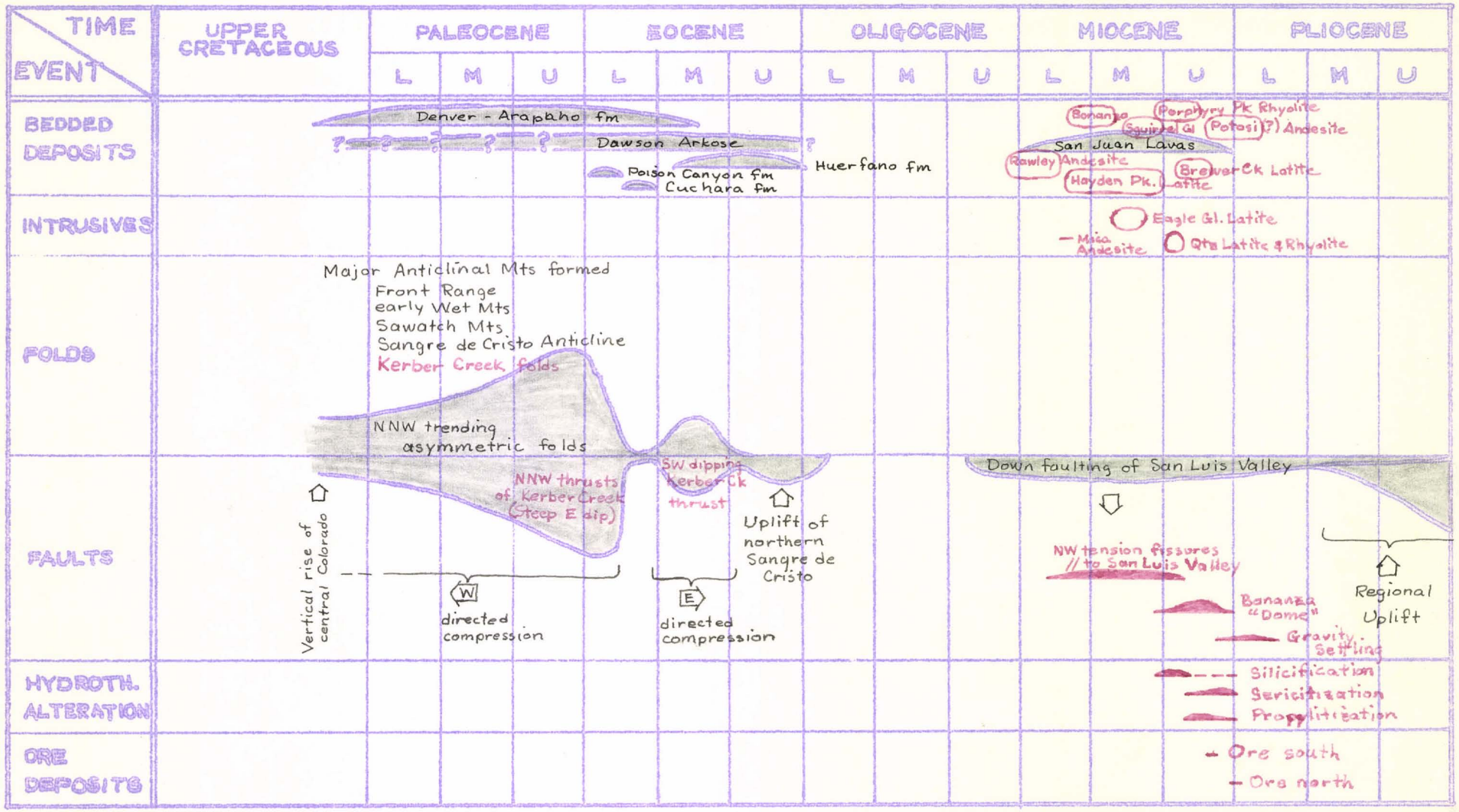


PLATE VII, Time-table of Laramide and later events affecting the Bonanza District, Colorado.

Bear Creek Mining Company apparently drilled on this basis (Cook, 1961) but pulled off after drilling three holes 1800 - 2000 feet deep without passing through the lavas. The present author would place a hole at the mouth of Greenback Gulch and drill NE at 10 - 20° from vertical. Geologic projections are difficult in an area which has so much relief both at present and on the pre lava surface, but at least a 3000 foot hole would seem warrented.

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0 1m 2m 3m 4m 5m 6m 7m 8m 9m 10m

Section

1" = 30m

100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800 2900 3000

EDWARD WISSER
MINING GEOLOGIST
533 CALL BUILDING
SAN FRANCISCO

TELEPHONE GARFIELD 4676

Bonanza, Colo.

Two classes of veins:(1)quartz-high sulphide,with Pb,Zn,Cu and Ag. (2) quartz-rhodochrosite-fluorite,low sulphide. (1) north of Bonanza,(2) S of Bonanza. Local criteria.

86 First class. Variations with depth. Rawley ,1200' vertical development. Increase in copper, decrease in lead going down. Small sporadic bodies of massive galena below 600' level show irregular nature of the main body of lead ore as it fingers out in depth. Only one period of mineralization.

88 Classification of Veins According to Nature of the Vein Fractures.

1.Fault fissures. Cocomongo and Paragon faults.
2. Joints in walls of faults. Vertical fissure veins,Cocomongo mine.
3. Fissures of uncertain origin less directly related to large faults.

Structural Criteria for Ore.

94 1.Changes in strike or dip or both,aided by relative faulting motion of the walls. Steep dip favorable;flat dip won't keep fracture open.

Flat faults characterized by small lenticular oreshoots separated by barren. Barren faults usually N.G.,but on the other hand,steep HW branches may serve.

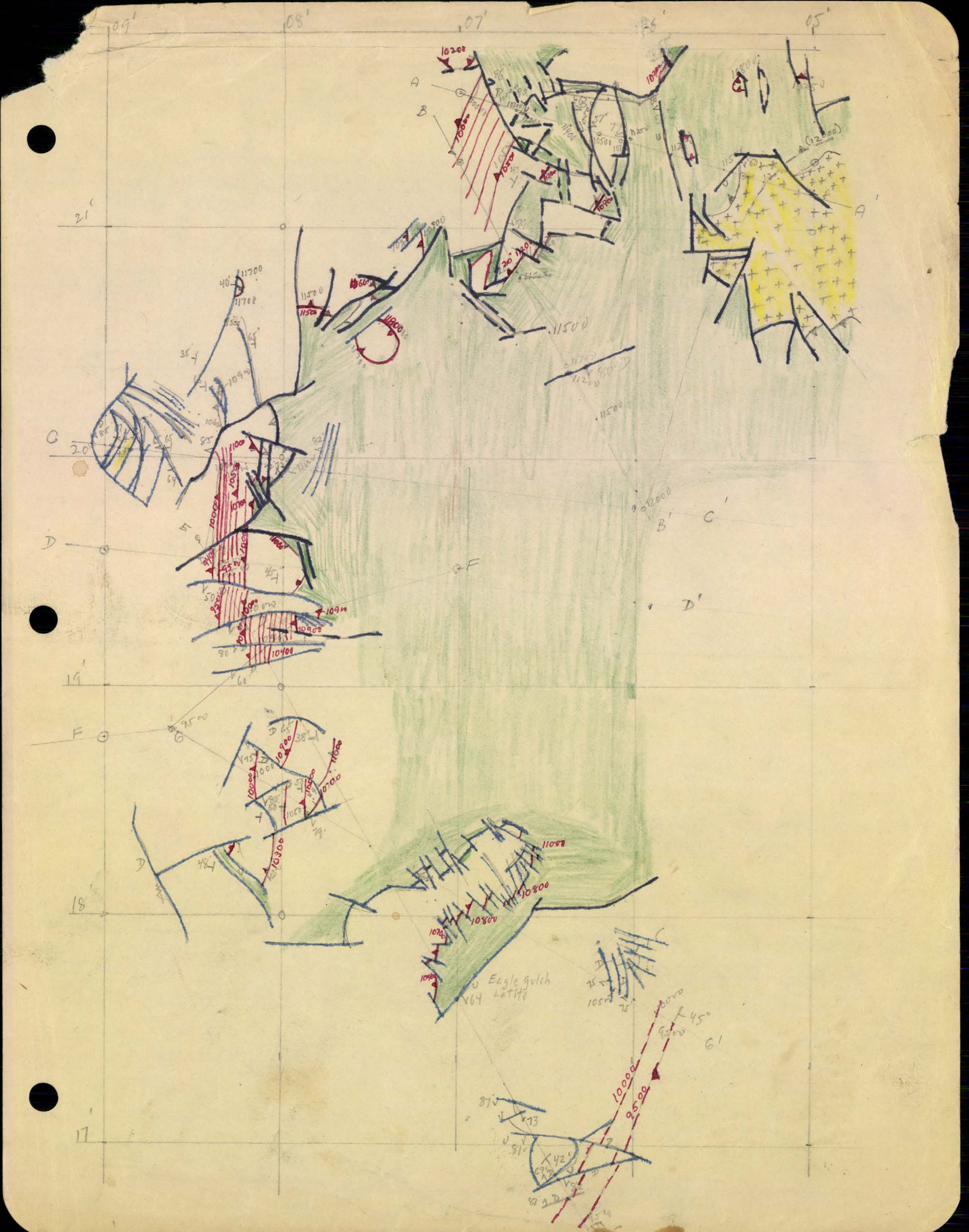
95 2. Cross faults have favired formation of SMALL oreshoots at intersections. Cross breaks tight,gouge,weakly mineralized. Intermineral.

3. Feather joint and other HW branches. Characteristically gouge-free.

97 South of Rawley Gulch,practically all important orebodies lie in the N-S fissures,but near the strongest zones of east-west faulting. The east-west faults have usually been mineralized,but are mostly too gouge-choked to favor oreshoots.N-S fissures successively reopened during the period of faulting activity on the east-west faults.

4. Intrusion of dikes between fissure walls may help to hold the walls apart after solidification of the dike.Since some dikes terminate upward while the fissure persists,the dikes may have controlled the movement of the mineralizing solutions.

5. Rubble-filled fissures. Little or no gouge an essential.



09'
08'
07'
05'
21'
20'
19'
18'
17'
A
B
C
D
E
F
A'
B'
C'
D'
G
Eagle gulch
Latite
10200
10300
10400
10500
10600
10700
10800
10900
11000
11500
11700
12000
9500
45°

also. Tendency toward radial fracturing, ditto dikes.

Structure.- (Tertiary Volcanics). p.42:" The structural history of the region in which the Bonanza district lies is closely tied up with the history of igneous intrusion and mineralization. The main elements that have produced the present structure of the district consist of the arching and tilting of the formations, the igneous intrusions, and the faulting. It appears reasonably clear that these elements are all closely related and were part of a single cycle of deformation. The occurrence of areas of complex faulting and fissuring accompanied by mineralization has been commonly recognized in volcanic regions, and the causes of these processes have been variously correlated with the upthrusting force of bodies of molten rock beneath the surface, or gravtitational adjustment attending the transfer of lava from one position to another within the crust, or the extrusion of lava to the surface ....

p.43:"The cycle of deformation in the Bonanza district is believed to have been initiated by the intrusion of a large body of molten lava within the crust, probably at a depth of several thousand feet. The crust was consequently bulged upward, blocks of it were tilted in different directions, and these movements were accompanied by further injections and uprising of the lava. Eventually the rising lava broke through to the surface and may have in part escaped laterally from the underlying reservoir. The consequent loss of its pressure appears to have caused the bulged mantle of rocks to sink back, and because of their lack of solid support they were intensely broek and fissured. The lava beneath entered many of the openings thus formed, and these small intrusives are now exposed by erosion, but the main intrusive body is still concealed beneath the surface."..."Some faulting and readjustments of the rocks continued throughout and after the period of ore formation."

p.46:

GEOLOGY AND ORE DEPOSITS OF THE BONANZA MINING DISTRICT, COLO.

W.S.Burbank, USGS PP 169 (1932).

Rock Formations.- Basement: pre-C metamorphics and Paleo seds, the former exposed only in 3 small areas within the district, the latter several miles SE of mineralized part of district. xxxx

Cover: Tertiary effusives rest unconformably on all older rocks. Flows, tuffs, breccias., in part of local origin, in part from outside centers.

Oldest to youngest.

Rawley andesite, 1200 -2000 ft. thick flows and breccia beds. Augite andesite to latite. Flow thickness 10' to 100 ft. plus. Main ore formation.

Bonanza Latite: 1000 ft. Lower latite, upper rhyolite. Next to Rawley andesite, chief ore formation; like Rawley andesite, fractures well. Prominent flow structure, but usually mainly at top and base of the flows, center more massive. Where a bed is tilted 50° plus, these closely spaced partingsrtend tend to interferre with the formation of simple fractures and fissures, unless the fissure plane is at oblique angle to the beds. Faults parallel to the partings form tight shear zones (Sombrerete). Several mineralized fault fissures cut the latite obliquely to the strike, 40°-90°. Upper rhyolite member is soft, cleavable, NG for simple fissuring.

Squirrel Gulch Latite. 300-500 ft. Outside area of mineralization.

Porphyry Peak rhyolite. 1000 ft. plus. NW part of district only.

Intrusive Latite: Eagle gulch latite. Major intrusion.

Tertiary granite: at contact between pre-C granite and Rawley ande. granitoid texture.

Dikes: diorite, QM./Occupy fault fissures. One fissures has a monz. and a latite dike. Rhyolite, latite. All dikes in district pre-mineral. Rhy, latite porphyritic, marked flow banding, bend around feldspars or rock inclusions; parallel contacts even tho latter change direction abruptly. p.34: "Some of these dikes are mere narrow stringers and discontinuous sheets from a few inches to a foot or so in width, which have been forced into irregular openings in the fissures, presumably by faulting movement in the walls during intrusion. Such narrow bodies...show a very pronounced fluidal structure. In the larger dikes the flow structure may be lacking except along their contacts." Dikes all intruded presumably xxxxx shortly after or duting the faulting."The presence of the smal dikelike stringers of intrusive latite along some fissures suggests that intrusion occurred in part during faulting, as the stringers appear to have been too narrow and viscous to have entered such openings in quiescent rocks by their own pressure, particularly as they undoubtedly came from molten bodies at great depth."

Greenback Gulch neck. S part of mapped area. Mases and ramifying rhy great andesite blocks (CR), altered breccia. Volcanic neck. HT alteration plus. Dikes vert. Mineraliz. channel as well as volcanic. Monz., lat. bodies

MINING 111B. 3A-8. CONCLUSION.

1. Time is lacking to go on with these environments, although the epithermal class furnish perhaps the most interesting settings, on account of their comparatively recent age, relative lack of extensive post-ore erosion, fact that metallization orogeny is usually superimposed on all earlier ones except in some cases basin range faulting. Dependence on fracture, open spaces whereas with deeper types depth complications enter. Fracture better understood than flow.

A word or two only on one or two more districts.

W.S. Burbank: Geol. & OD's of Bonanza M.D. Colo. USGS PP 169, '32

Bonanza, Colo.: In far E portion of San Juan volcanic field. Probably Oligocene, latite, rhy., andesite. ~~Sum of maxima over 8400'.~~ About 4000'. Big unconformity between Paleo and extrusves-uplift in early Tertiary. No extensive unconformities between volcanic formations. Latter intruded by monzonite to GP; many minor intrusions of QL and rhy., esp. dikes. Volcanic plateau or pile built up; rather gentle doming, broad, but very complex in detail. Supposed intrusion with laccolithic top under the dome. Beatiful series of antithetic faults. p.55, USGS PP 169, 1932, W.S. Burbank: ""One conclusion reached-namely, that a considerable part of the tilting and faulting were produced simultaneously--would seem to be an inherent part of any explantion of the structure. Simultaneous faulting and tilting have been previously suggested by Emmons and Garrey (Bull. 467, 1910, 81-89) for the structure in the Bullfrog district of Nevada where the tilting of the lavas and certain features of the faulting appear similar to those at Bonanza.... The zones of most intense mineralization appear to coincide roughly with zones of simple tension, which existed along the border between areas of highly tilted and gently tilted fault blocks".

Most of veins, as at Creede, in fault fissures; fissures locally choked by gouge; irregularities in the fault walls cause alternation of open and tight places, a pinching and swelling. Flatter veins have vertic-

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al feather joints, narrow but productive. Usually in connection with gou gy flat master faults, barren. Gouge indicates stress, movement. Feather joints are mineralized rubble-filled fissures,typically gouge-free.

Main veins show successive reopenings. Lead-silver veins,with ZnS pyrite, ZnS, PbS,ccpy.,bornite etc.,Ag-tennan ite,stromeyerite. Gangue qtz.,the bulk of which preceded the PbS.Also in gangue, Mn-cal., rhodochrosite, barite.

Steep dip of vein-fractures favorable;this goes with uplift,steep dips parallel to thrusting force.

Burbanks has a new idea: intrusion of dikes between fissure walls may help to hold walld apart after dike solidifies/ Some dikes end upward while fissure persists:such an opening mahev served as an ore solution channel.

Productive veins all mineralized rubble-filled fissures. Little or no gouge is an ore gyide.