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REGIONAL STUDY OF PORTIONS OF THE
SILVERTON AND TELLURIDE QUADRANGLES,
COLORADO.

W.E.Bush
Mining 198
22 January 1948

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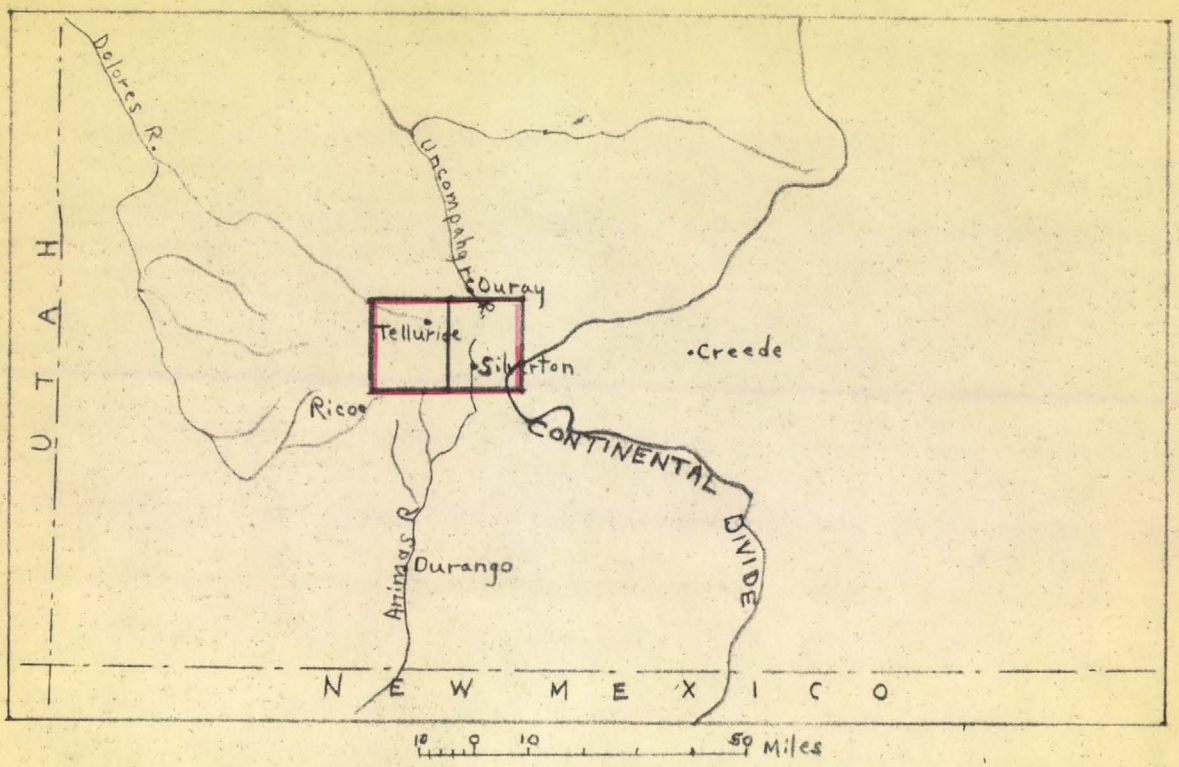


PLATE I-LOCATION MAP OF THE SILVERTON AND TELLURIDE QUADRANGLES, COLORADO

INTRODUCTION

The area described in this paper is in the San Juan Mountains of southwestern Colorado and comprises parts of the Silverton and Telluride quadrangles, an area of approximately 270 square miles.

The paper is based on a review of available literature, converaations with and personal notes of several authorities acquainted with the area, and includes personal observations and interpretations of the writer. This regional study has been undertaken primarily in an attempt to relate the structures in which ore deposited and localized to regional geologic history and structure, but some of the other interesting features of the region are also briefly mentioned. The paper itself is divided into sections: the first presents a brief description of the area, which is based entirely on the literature; the second includes interpretations, theories, and discussions, some phases of which are certainly open to question.

In compiling the data for this rather brief paper from the extensive literature available, much detail has been necessarily omitted; for this detail or clarification of any of the descriptive material presented, the reader is respectfully referred to the bibliography which follows the text.

As W.S. Burbank has pointed out, some confusion, disagreement, and perhaps inaccuracies are to be found in the literature. Some portions of the area have received

little or no attention. The results of work currently in progress in the Silverton area will certainly clarify the situation and will perhaps greatly modify the interpretations, theories, and discussions presented here in section two.

The numbers in parentheses, following names of various authorities referred to in the text, designate the particular reference as listed in the bibliography.

I

PHYSICAL CONDITIONS

The San Juan Mountains, extending 90 miles E-W and 70 miles N-S, are a well-defined group of high, rugged mountains, almost entirely surrounded by lowlands or plateaus. Included in this group are at least 13 mountains with altitudes of more than 14,000 feet, and more than a score of others whose altitudes are close to 14,000 feet. Most of the latter are in the general vicinity of Silverton, which is near the center of the range.

In the vicinity of Silverton, the stream canyons are of the order of 4,000 feet deep. Glcial cirques and other erosional evidence of intensive glaciation are quite markedly present. The contour of most canyons exhibits a pronounced shoulder about halfway up the canyon wall, pointing to a history of recent erosion, uplift, glaciation, and erosion.

Exposures on the canyon walls are good. Rock glaciers, talus slopes, torrential fans, landslides, etc, of considerable magnitude completely mask large portions of the area, and have resulted in some confusion on the part of workers in the area.

Vegetation is dependent on the degree of slope of any given area and the extent of the soil cover; it ranges from abundant to non-existent.

This area is drained by the systems of the Uncompahgre River to the north, the Dolores River to the west, and the Animas River to the south, all immediately west of the Continental Divide. The drainage pattern of these consequent streams is generally radial, with its center in the vicinity of Silverton.

Precipitation is heavy on the slopes of the mountains. Most of the roads are snowbound from October to May, and from July through September daily rainstorms are the rule. This is a definite limiting factor placed on prospecting and geologic field work as well as on ore shipments in some parts of the area.

GEOLOGIC FORMATIONS

BEDDED ROCKS

	AGE	NAME	THICKNESS (feet)	CHARACTER
Quaternary	Pleistocene and Recent		?	Alluvium, talus, landslides, rock streams, mud flows, and glacial deposits.
Tertiary	Miocene	Potosi Volcanic Series	1000	White dense rhyolite; alteration widespread.
	Miocene	Quartz-biotite latite	200-400	Complex of "tuffs", flows, and breccias.
Silverton Volcanic Series	(Miocene	Henson Tuff	?	Sandy green, buff, brown, and purple tuff which is well stratified and locally cross-bedded.
	(Miocene	Pyroxene Andesite	500-800	Dense felsitic to porphyritic andesite or latite.
	(Miocene	Burns Latite	500-1000	Rhyolite and latite tuffs, flows, and breccias; includes welded vitreous tuffs, pyroclastic breccias, and banded fluidal rhyolite flows. Banded latite. Amygdaloidal gray andesite grading into coarse tuff. Dense porphyritic andesite flows.
	(Miocene	Eureka Rhyolite	0-2000	Greenish rhyolite and latite flows, flow breccias, and possible welded tuffs.
	(Miocene	Picayune Volcanic Group	300-1300	Latite and rhyolite flows and breccias. Andesite flows and breccias

	AGE	NAME	THICKNESS (feet)	CHARACTER
Tertiary cont'd	Miocene(?)	San Juan Tuff	1800-3000	Tuff-breccias composed of andesitic and latitic fragments, mostly in angular and chaotic aggregates. Base often contains fragments similar to those in Telluride Conglomerate. Silverton flows interfinger with it.
	Oligocene (?)	Telluride Conglomerate	0-300	Conglomerate, coarse arkosic sandstone, and talus accumulations of quartzite, schist, and granite fragments.
Mesozoic	Jurassic	Morrison Formation	500-700	Alternations of sandstone with red and green shales.
	Jurassic	Wanakah Formation	85-125	Marl, sandstone, and limestone.
	Jurassic	Entrada Formation	45-80	White to yellowish even-bedded sandstone.
	Triassic	Dolores Formation	40-300	Pink sandstone, shale, and lime-pebble conglomerate.
Paleozoic	Permian	Cutler Formation	2000-2400	Sandstone, grit, shale, and conglomerate beds.
	Pennsylvanian	Hermosa Formation	1400-1600	Arkosic sandstones, shales, and limestones; fossiliferous.
	Carboniferous	Molas Formation	40-60	Sandstone, shales, and marly beds.
	Mississippian	Leadville Limestone	180-230	Coarse clastic limestone with interbedded sands and shales; fossiliferous.
	Upper Devonian	Ouray Limestone	65-75	Dolomite and dolomitic limestone.
	Upper Devonian	Elbert Formation	35-50	Dolomitic limestones with interbedded sandstones and shales.
?	Pre-Cambrian	Uncompahgre Formation	5000-8000	Quartzite and slate. Slaty members locally contain schists.

INTRUSIVE ROCKS

The intrusive rocks in the area include clastic dikes, intrusive rhyolite, quartz latite porphyry, intrusive latite, intrusive andesite, gabbro-diorite, and quartz monzonite porphyry. They are quite widespread and no attempt will be made to generally describe them further.

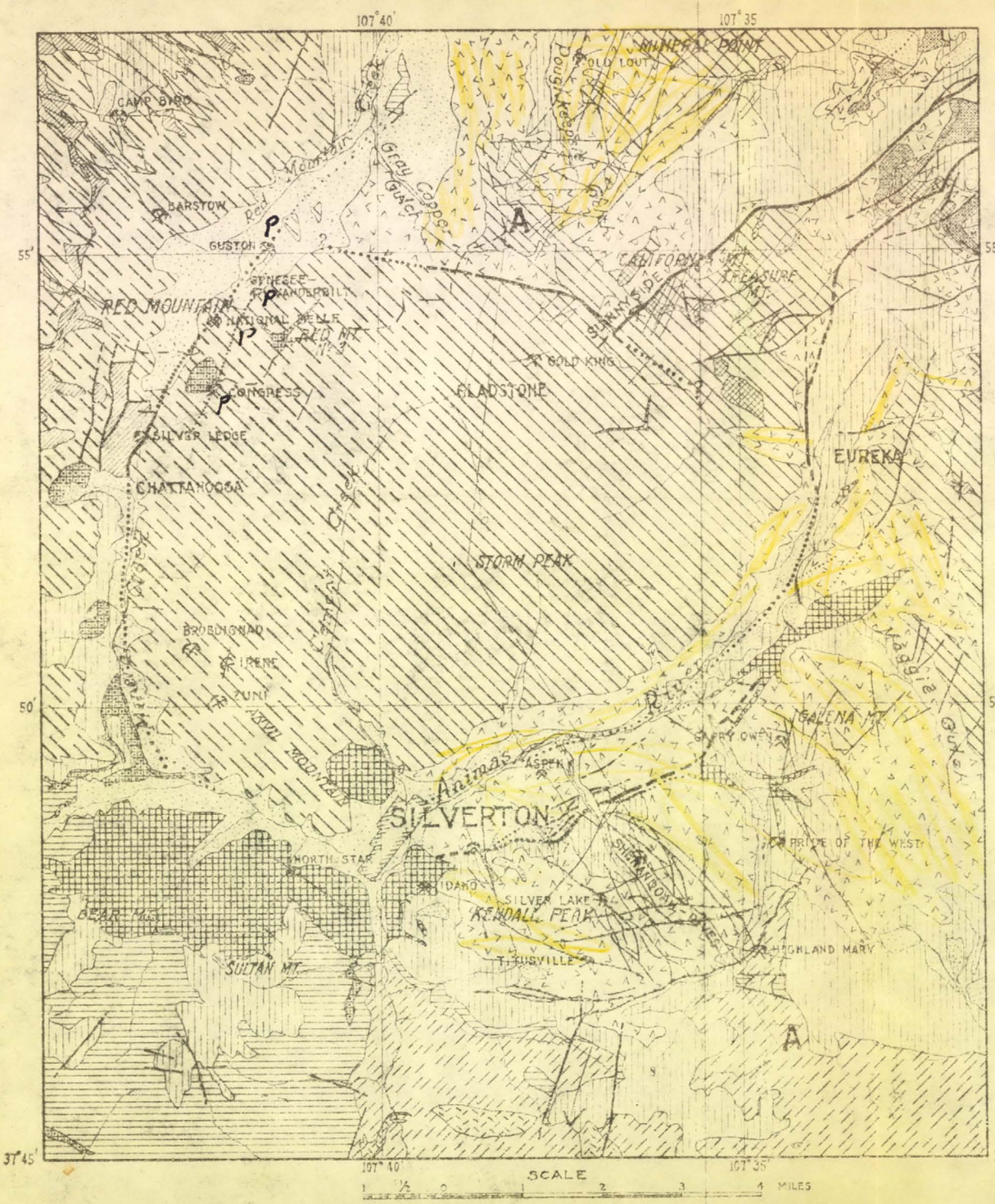
The following pages on the regional geological structure, fissuring, and mineralization are from:

"Vein Systems of the Arrastre Basin,etc", by W.S.Burbank, Proc. Colo. Sci. Soc., vol 13, No. 5.

PLATE III

GEOLOGY OF A PORTION OF THE SILVERTON QUADRANGLE, COLO.

ADAPTED FROM ECONOMIC GEOLOGY SHEET, U.S.G.S. FOLIO 120, WITH CHANGES AND ADDITIONS BY W.S. BURBANK.



LEGEND

Quaternary

- Alluvium, Glacial deposits, and landslides

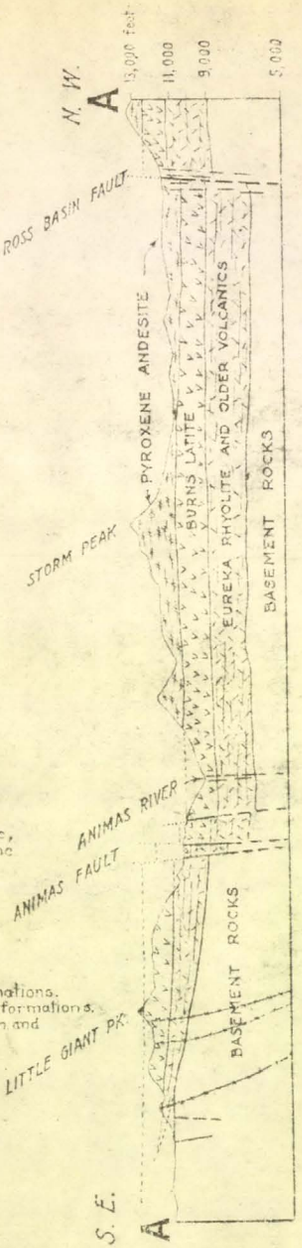
Tertiary

- Quartz Monzonite
- Intrusive porphyries
- Intrusive rhyolite
- Intrusive andesite
- Potosi volcanic series
- Pyroxene andesite
- Burns latite
- Silverton volcanic series.
- Telluride conglomerate, San Juan tuff, Picayune volcanic group, and Eureka rhyolite

Archean Algonkian Paleozoic

- Rico and Cutler formations. Molas and Hermosa formations. Leadville ls. Elbert fm. and Ouray ls. Ignacio quartzite.
- Granite
- Schist and gneiss

- Faults
- Veins, fissures and dykes (marked by crosses)



REGIONAL STRUCTURE

The bow-shaped fault zone of the Animas Valley region has been shown to form the southeast margin of a great down-faulted block, and by considering this faulting in relation to regional structure in the Silverton quadrangle it appears that this sunken block includes a large mass of roughly triangular outline, which extends from Mineral Creek on the west to the Animas Valley and northwestward and northward to the Red Mountain district and the vicinity of Treasure Mountain. This sunken mass or volcanic sink has a width from the Animas fault to Red Mountain of about 8 miles, and a length from the Bear Mountain stock to Treasure Mountain of about 10 miles.

The displacement of the Animas faults near Eureka amounts to about 1,000 or 1,500 feet, and their strike has turned to N. 15° E. Near Eureka Mountain the displacement on the north-south fault that crosses the mouth of Eureka Gulch is taken up by a prominent series of northeasterly faults that form a zone about 2 miles in width. The general effect of this system is to fault down a wedge-shaped block that narrows northeastward between the Cinnamon and Rainbow faults to a width of less than a mile. The structure of this fault zone farther east, in the Lake City quadrangle, is complicated by relatively high masses of pre-Cambrian granite, but this structure is evidently foreign to the sunken block of the Silverton quadrangle and has merely complicated local

faulting where the two structures adjoin. This sunken wedge of the Treasure Mountain area therefore forms a northeasterly projection of the main sunken block, and is bounded on the northwest by the great Cinnamon fault and its southwest extension that pass into the fault and fissure systems of the Sunnyside mine, at the head of Eureka Gulch. Cross and Howe have presented evidence to show that the northwestward striking Ross Basin fault is part of this fault system and takes up the greater part of the throw of the Sunnyside system. The Ross Basin fault drops the pyroxene andesite downward to the south at least 1,000 feet, as the base of the andesite is faulted below the level of Eureka Gulch and Cement Creek. It is not improbable, however, that the throw may exceed this figure considerably. If the base of the andesite maintains the uniform level shown in the surrounding country the displacement would be nearer 1,500 to 2,000 feet. The Ross Basin fault has been traced to the head of Gray Copper Gulch with apparently undiminished throw, but westward toward Red Mountain the extreme alteration of the volcanic rocks made recognition of different formations so difficult that in the Silverton folio they were not differentiated and the fault line was not indicated. There can be little doubt, however, that the fault extends westward to the Red Mountain Valley, where the displacement is taken up by a series of northeasterly faults.

The faults systems of Cement Creek and the Red Mountain Valley describe a bow-shaped curve like those

of the Animas Valley but are convex to the west and limit the entire western margin of the sunken block. The most striking evidence of the intensity and nature of faulting along this zone is shown by large blocks of the Potosi volcanic series (flows of latitic and rhyolitic composition succeeding the Silverton volcanic series) which have been down-faulted below the level of Mineral Creek above Chattanooga. The Silver Ledge mine is situated on the eastern fault bounding the sunken rhyolite bodies, and as the 400-foot level of this mine is in Potosi rhyolite it is evident from the normal position of the rhyolite on adjoining ridges that the displacement of this block must have exceeded 2,300 feet. This displacement does not, however, represent the net effect of the fault zone but merely the adjustment of fault blocks within the marginal zone. The net displacement must be somewhat less than the displacement of the rhyolite block, as otherwise rhyolite instead of pyroxene andesite would be exposed east of the fault; but changes in thickness of the different volcanic formations and uncertainty as to how deep the rhyolite extends below the level of the mine workings make the extent of this displacement likewise indeterminate.

An approximation of the net displacement south of this position along Mineral Creek may be obtained from the fact that the San Juan tuff is not exposed on the east side of the valley but on the west side extends 800

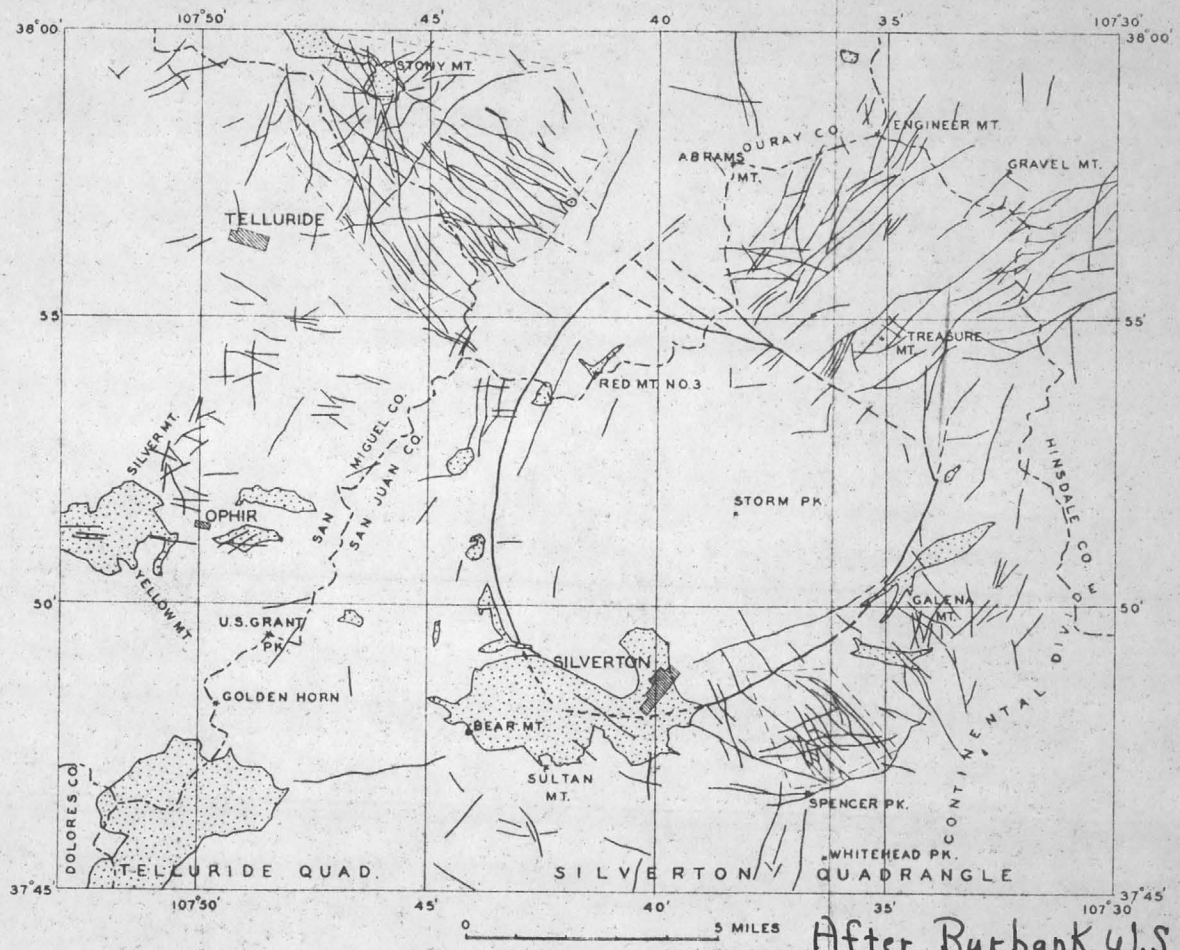
to 1,500 feet above the valley floor. As the lavas on the east side are chiefly pyroxene andesites, representing the upper part of the Silverton series, the displacement must exceed 1,500 feet and probably is not less than 2,000 feet. The difficulty of obtaining an exact measurement of displacement along Mineral Creek is due partly to the fact that the Silverton lavas thin markedly toward the west and partly to the fact that intense alteration along the fault zone prevented the mapping of individual members of the series. However, when allowance is made for changes in thickness of the formations, it seems likely that the net displacement ranges from 2,000 to 2,500 feet near the Bear Mountain stock to 1,000 feet or less near the head of Mineral Creek. Cross and Howe have called attention to evidence indicating the northeastward extension of the Mineral Creek fault zone through the Red Mountain zone of ore deposits to the head of Ironton Park. The chimney-like ore bodies of the National Belle, Yankee Girl, Robinson, Guston, and Paymaster mines are all alined along an altered fault zone of north-northeast trend, and about half a mile east of this zone another line of chimney deposits extends through the St. Paul, Congress, Hudson, and Genesee-Vanderbilt mines. The localization of chimney deposits along these fault-lines is believed to have been controlled in part by cross fissures of east-west and northwest trend, such as those that limit the ends of the downthrown blocks of rhyolite. Thus the entire margin

of the area bounded by the Animas Valley above Silverton, Mineral Creek, the Red Mountain Valley, Ross Basin, and the Treasure Mountain region is marked by steep faults whose displacements indicate relative subsidence of the central block ranging from 1,000 feet or less to about 2,500 feet.

Another line of monzonite or granite porphyry intrusions extends up Mineral Creek toward Red Mountain and several dikes and two larger stocks of an intrusive rock, termed quartz syenite porphyry by Cross, occur in the Red Mountain district. They are much more alkalic than the normal monzonitic rocks farther south along Mineral Creek. Between Red Mountain and Ross Basin no intrusive rocks occur along the fault zone, or if any are present the bodies are too small to have been shown on the Silverton folio map. Near Treasure mountain are numerous dikes and sheets of intrusive rhyolite of felsitic texture, many of which are displaced by fault systems of this area, but some larger dikelike bodies are alined parallel to the faults, suggesting that these intrusives were partly localized by fissuring but that the major fault displacement took place after intrusion. Except for 4 miles between Ross Basin and Red Mountain, the border of the down-faulted block is thus characterized by a marginal zone of intrusive bodies.

Outward from the east, south, and west sides of this sunken block there is a marked decrease in thickness of the Silverton series; the most abrupt change in the

formations occurs near the edge of the down-faulted block. It is therefore possible that at least these sides of the structure were localized by the distribution of the Silverton series, but as yet no faults of Silverton age have been recognized or differentiated from those of post-Silverton age. In the central part of the Silverton quadrangle there is 3,000 feet of the pyroxene andesite flows, and if we add to this the mormal thickness of Burns latite and Eureka rhyolite, nearby, the total thickness of the series here must have reached 4,000 to 5,000 feet, whereas the maximum thickness of the series on the west and south of the area close to the marginal faults rarely exceeds 1,500 to 2,000 feet and decreases rapidly to a few hundred feet not many miles distant. A part of this difference is accounted for by the erosion that followed the Silverton epoch and preceded the eruption of the Potosi series, but the preservation of the series in the down-faulted blocks shows that a broad depression occupied the central part of the Silverton quadrangle and that it was filled with eruptive debris of the Silverton epoch. Though not essential to the structure this evidence suggests that down warping of the area caused by theextra heavy load of volcanic debris may have weakened the crust during the Silverton epoch; but the sunken block as it now exists retains the approximate margins of this earlier basin only along the south and west sides.



After Burbank, W.S.

PLATE IV. Pattern of the fracture systems and principal cross-cutting intrusive bodies in the Silverton quadrangle and eastern part of the Telluride quadrangle. Two areas which have been mapped on a scale of 1 in 1,000 feet are outlined by light dashed lines.

FISSURING AND MINERALIZATION

A map showing important fissure veins in the Silverton quadrangle indicates that most of them do not parallel the marginal faults of the sunken block but are distributed radially, somewhat like the spokes of a wheel about the hub. Many complex factors are involved in the production of this radial fissuring, and our present knowledge of details in different parts of the quadrangle does not permit analysis of these factors for each sector of the region. It is known, however, that the great zone of northeasterly fissuring and faulting in the Treasure Mountain region and the zone of northwesterly fissuring on the mountain ridges west of the Red Mountain Valley are in part related to a regional structural pattern that involves adjoining centers of igneous and dynamic activity. Perhaps when all the facts are known it may be found that the subsiding block of the Silverton quadrangle is but one of many conjunctive elements of the structural pattern in the western San Juan region and that these seemingly independent centers are closely related both in time and origin. The description of the structural features about the sunken block is made without implying that they were all developed by forces originating solely within the Silverton center.

South of the sunken block a marginal zone of fissure veins 3 to 4 miles in width extends from the Bear and

Sultan Mountain stock eastward through Galena Mountain to and beyond Maggie Bulch. Most of these veins strike northwest to north and belong to that group disposed radially about the sunken block, but a lesser number strike east to northeast, more or less parallel or oblique to the marginal faults. The ores are chiefly the base-metal sulphides, from which the most valuable recovered metals have been lead, silver, and gold. There is a rough zonal distribution of the different kinds of ore suggesting that the igneous intrusions and the Animas fault were the principal agents controlling sources and trunk channels by which the mineralizing solutions were fed into the open fissures in which ore bodies were deposited. The most heavily mineralized and most massive base-metal veins are those of the Arrastre Basin and Silver Lake mines and the veins of Cunningham Gulch, which lie about in the center of the mineralized province south of the Animas fault. There are, however, sufficient exceptions to an idealized zonal arrangement to indicate that structure has been locally more influential than the commonly accepted temperature zones in controlling distribution of the different ores. Furthermore, it is apparent that the largest exposed body of quartz monzonite west of Silverton does mot lie above the source from which ore solutions emanated, but rather that this body and the several smaller bodies are only shallow manifestations of more deeply buried bodies of molten rock that were rising along the

marginal faults and that remained partly molten long after the solidification and fracturing of intrusive rocks now exposed.

On the north and northeast sides of the foundered block there are one or more areas that appear to be independent of the one south and east of Silverton, but with the possible exception of certain local ores the mineralogic characteristics suggest that there was a common magmatic source or at least that the magmas underlying this portion of the crust had certain common characteristics. This border zone includes the veins of the Treasure Mountain area, the Sunnyside group and those near Poughkeepsie Gulch and Mineral Point. The radially disposed veins of this group strike from N. 20° E. to N. 60° E., and the veins parallel and diagonal to the marginal faults strike from N. 50° W. to west. Here, as in the Animas Valley, the radially disposed fissures form the larger group numerically, but all systems of fissures are mineralized. The most productive veins now are those of California Mountain~~s~~ and Sunnyside Basin, which form part of the fault system limiting the down-faulted block of the Treasure Mountain area. Past production has also been made from many veins of Poughkeepsie Gulch and Mineral Point, of which the Old Lout was the most profitable. The vein systems of the Sunnyside mine are part of the great northeast and northwest fault systems that border the sunken block, and local variations in strike and dip of the fault

fissures and intersections of these systems and other north-south faults have been dominant factors in localizing mineralization. Hulin has further shown that movements on these faults are largely pre-mineral, but that later movements during mineralization have been important factors in reopening fissures and localizing ore shoots. Still later reopenings have resulted in dilution of ore by large bodies of relatively barren rhodonite. Movements on the fissure and fault systems of Arrastre Basin have likewise exerted important control on the formation of ore shoots, but the Sunnyside fissure systems differ somewhat from those of Arrastre Basin in that they lie close to and within the zone of marginal faults of the sunken block. The effect of faults paralleling the margins of the down-faulted blocks was a dominant factor in the Sunnyside area. In those parts of the Arrastre Basin area that are more distant from the marginal faults vertical and horizontal movements on radial fault systems were more effective than movements on other systems, which were relatively more inactive at increasing distances from the edge of the sunken block.

The western area of mineralization may be conveniently divided for purposesof description into two parts. One lies chiefly along the marginal faults and within marginal areas of the sunken block, and the other comprises the radially fissured zones outside the sunken block, occupying western edge of the Silverton quadrangle

and the eastern part of the Telluride quadrangle.

The first of these subdivisions extends from Ironton Park southward along the entire western border of the sunken block embracing the area bounded by Gray Copper, Cement, and Mineral Creeks, and contains certain unique features. However, the northern part of this area is characterized by mineralogic and structural features indicating its relationship to the northeasterly veins of Poughkeepsie Gulch and thus the probable merging of these areas. The distinguishing feature of the area is the occurrence of stocklike ore bodies that are localized in part along the marginal faults of the sunken block, such as those of the Red Mountain mines, noted for their exceptionally rich silver ores. Nearly the entire western border of the sunken block over a width of several miles is broken by innumerable fissures that provided channels for the escape of volcanic vapors and solutions, which altered the Silverton volcanic rocks to an unusual degree. This alteration has resulted from emanations earlier than those that deposited the valuable ore minerals, and because of its widespread nature it offers little clue to the most favorably mineralized zones.

The localization of ore bodies in the western area is dependent in large part upon structural features produced by marginal and radial faulting and fissuring, but in addition the fissuring and therefore the shape and

location of ore shoots have been modified by the action of the volcanic emanations that preceded the deposition of ore. The important effect of these pre-ore volcanic emanations become apparent from the nature of the Red Mountain ore bodies. These ore bodies have been variously called "stocks," masses," or "chimney deposits," but Ransome says regarding their shape, "It is evident from the descriptions given of the Red Mountain stocks that the term "chimney" applied to them is somewhat misleading. They are not simple vertical pipes of ore extending from the surface to indefinite depths but are separate bodies of irregular, lenticular, or spindle-shaped form, often completely enclosed by country rock, but linked with neighboring stocks by fissures which are often small and which carry little or no ore."

The origin of the spaces filled with ore, as suggested by Emmons and Ransome, is probably due in part to complex intersecting fissure systems that were at one time channels through which the earlier volcanic emanations escaped. The more productive ore bodies in the Red Mountain district are grouped along lines of fracturing in a belt less than a mile wide and about 4 miles long, bearing about N.20°E.

The mineralization of other areas near the west edge of the down-faulted block was similar in some respects to that of the Red Mountain district, but at other places simple fissuring and fissure intersections have

been more dominant factors in localizing ore shoots. The mines of Anvil Mountain, north and northwest of Silverton, are within similarly altered rocks, but the ore shoots of the Zuni and other mines depart somewhat from the extreme stocklike forms of Red Mountain. Furthermore, ore bodies near Gladstone, at the head of Cement Creek, partake of the nature of ordinary fissure deposits, and some, such as the Gold King, contain important shoots of gold ore.

The region comprising the radially fissured sedimentary and volcanic rocks west of the sunken block is by far the largest of the mineralized areas surroundings that block. The extreme northeastern portion, between Red Mountain, Telluride, and Sneffels, has been the most productive region of the San Juan Mountains and includes such veins as the Camp Bird, Liberty Bell, Smuggler Union, Tomboy, Virginius, and others, all of which have been mined to unusual length and depth. This series of dikes, fissures, and veins forms another radial group, bearing from N.40° W. to N.70° W., the main zone of which is 2 to 3 miles in width and has an average course of N.45° W. The zone has a length of about 6 miles along the strike, from the edge of the down-faulted block near Red Mountain to the Stony Mountain-Mount Sneffels stock. This outlying stokc of gabbro-diorite forms a center of igneous activity seemingly independent of the intrusives of the Silverton center, but andestic dikes radiate

from it much as they do from the Silverton center. Those extending southeastward can be followed continuously from Stony Mountain to the ridges adjacent to the Red Mountain Valley and appear to indicate intrusion simultaneous with the central activity of the Silverton region. The strength and continuity of the fissures throughout this distance also suggest that this outlying igneous center had an important control upon the connecting structural features. The veins nearest to the sunken block of the Silverton quadrangle consist chiefly of base-metal ores in a gangue of quartz, with some rhodonite and rhodochrosite. Nearly all the veins show many stages of reopening of the fissures, with deposition of several distinctive types of vein filling. The principal gold-producing vein of this group, the Camp Bird, contains base-metal ore, followed in order by mixed carbonate vein filling; fluorite; gold in quartz, adularia, and carbonates; late barren quartz; and calcite. This vein strikes about N.80° W., diagonally across the N.45° W. veins, most of which were not affected by the rich gold mineralization characteristic of the Camp Bird shoots. The Barstow vein, however, on the mountain slopes adjacent to the Red Mountain Valley, belongs to the N.45° W. group and has been productive of both gold and silver from base-metal ore. The Tomboy vein, likewise in this group, was a large producer of free gold ore. Veins

farther northwest, such as the Virginius, Montana, and Smuggler, contain chiefly mixed lead-silver or gold ores, and those most distant, such as the Liberty Bell, are of very low sulphide content and commonly produced silver in excess of gold. The complexity of the veins tends to mask any marked zonal belts of ore deposition, excepting at the southeast end of the belt where the heavy base-metal ores are clearly developed to their strongest degree. The Liberty Bell constitutes at least one individual vein in which the base-metal content of the ore definitely increased toward the east. The Stony Mountain stock, like the large stock near Silverton, appears to have played but little part in the distribution of metals, as the veins of this region contain chiefly silver ores with a late stage of finely divided sulphides and a little free gold in quartz, more like the distant facies of ore deposition in the southern area of the Silverton Quadrangle. Thus the conditions in this area likewise suggest that the sources of the ore-depositing solutions were chiefly very deep reservoirs of crystallizing magma, probably concentrated mainly nearer the marginal faults of the sunken block, but extending toward the outlying satellitic bodies.

Much less is known about the fissure systems and distribution of different facies of mineralization in the region west of Mineral Creek and south of this northwesterly group of veins. In the districts just south of

Telluride, on Silver Mountain and adjacent ridges, the veins show unmistakable mineralogic affinities to the veins just described, but the dominant direction of fissuring in the canyons south of Telluride is more nearly due east. The dominant directions of fissuring in the Telluride quadrangle are indicated by a few veins, the strikes of which were recorded by Purington on the Telluride folio map. Purington enumerates three systems in the eastern part of the quadrangle-namely N.87°W., N.53°-63°E., and N.25°-51°W. He states that the east-west and northeast systems are best developed in the central and southeastern portions of the quadrangle, and that the northwesterly veins are best exemplified in the northeastern portion, which has just been described. The dominant east-west system in the Ophir Valley region continues 8 miles or more west of Ophir to the intrusive centers of the Mount Wilson group, holding this strike with remarkable consistency. South of this on the ridge north of Ice Lake Basin and terminating in W.S. Grant Peak, to the north, zones of mineralization have a northeasterly direction.

Throughout this region the sedimentary rocks underlying the volcanic formations are a much more important factor in structure and ore deposition, and not far west of Ophir they become the dominant surface rocks. Because of lacked of detailed data on different phases of mineralization it does not seem advisable to attempt a review of the veins and ores of this region.

Purington's conclusions regarding the origin of this fissuring in the eastern part of the Telluride quadgangle, however, are significant. He states.

"It has been siad that the fissuring is of dynamic origin; also that the joints penetrate all rocks and consequently are later than any in the district. It cannot from present evidence be asserted, however, that certain of the fissures may not be earlier than the latest volcanic flows and diorite stocks. By far the major part are of recent origin. From all observed phenomena it seems probable that the fissuring was made by forces acting at time intervals not far removed from one another. Since the fissuring is later than all the rocks of the quadrangle, volcanic disturbances whose product is now visible cannot be cited to account for it, but it is entirely possible that later disturbances of volcanic nature, which did not result in surface flows of lava, have produced a straining to the point of rupture in the tract under consideration. It is thought, with great reason, that in the area directly east and northeast of the Telluride quadrangle there are centers and necks of volcanic eruption. Such evidence as has been collected in the present investigation points to those quarters as the source from which presure came."

The following pages on the regional geologic history of the San Juan Mtns are taken from:

"Physiography and Quaternary Geology of the San Juan Mountains, Colorado", by W.W.Atwood and K.F.Mather, USGS Prof Paper No 166.

HISTORY

The earliest rocks of which there is any record in the San Juan region are the crystalline schists and gneisses that form the walls of the canyon of the Animas River in the Engineer Mountain, Needle Mountains, and Silverton quadrangles.

These schists and gneisses are intruded by the Twilight granite, a large batholith now exposed in the West Needle Mountains, which culminate in Twilight Peak. These extensive intrusions of granitic magmas were probably accompanied by mountain building and were certainly followed by a long period of erosions, which must have been accompanied by deposition, but of the resulting rocks almost none now remain. The accumulation of sediments was accompanied or followed by the second great episode of igneous activity in this region. The injection of basic igneous magma and the accompanying metamorphism produced a complicated series of schists and greenstones to which the name Irving greenstone has been applied. Associated with these schists and greenstones are a few bands of quartzite, in part mashed and schistose, whose structural relations and origin are obscure. The crustal movements elevated the region sufficiently to permit its widespread degradation, and thus an episode of crustal movement, mountain building, and subsequent erosion brought to an end the second of the three pre-Cambrian epochs.

The detritus resulting from long-continued erosion

in the interval succeeding the metamorphism of the Irving greenstone supplied the materials for the next younger series of sediments. As erosion progressed, finer materials were deposited, and sedimentation continued without interruption for a very long period. The thick series of quartzites and schists thus formed is known as the Uncompahgre formation and is the most widely distributed of all the pre-Cambrian terranes.

The metamorphism of the Uncompahgre quartzites and schists was followed by the intrusion of many granitic batholiths with numerous dikes and apophyses. This igneous activity was accompanied or followed by great orogenic movements that deformed and uplifted the entire San Juan region. Thus was started a long period of erosion which marked thetransition from pre-Cambrian to Paleozoic time and ended the third of the pre-Cambrian epochs. Gradually the entire southwestern part of Colorado was reduced well toward base-level, and a peneplain of almost continental proportions was developed. In the beveling process each of the pre-Cambrian rocks was exposed in one place or another at the surfaceof the nearly level plain and in positions suggestive of the vicissitudes throughwhich it had passed.

Very little is known concerning the early Paleozoic history of the San Juan region. In all probability during much of Cambrian, Ordovician, and Silurian time it was part of a large land area. The extensive denudation that marks the transition from pre-Cambrian to Paleozoic time developed a surface of slight relief before the end

of the Cambrian period. The lower undulations of this surface were for a time covered by ocean waters.

The rocks next younger carry fossil fishes regarded as of Upper Devonian age and indicate that at this time there was a widespread submergence of the entire San Juan region. The strata of the Elbert formation, the earliest deposits then laid down, consist of impure limestone or limy sandstone and shale; these are overlain by the richly fossiliferous marine limestone that forms the basal part of the Ouray limestone.

The Mississippian epoch began at a time when the entire San Juan region was a shallow sea. After 300 or 400 feet of limestone had been deposited, most of the land rose a little above sea level, apparently without folding in this vicinity.

The beds of the Molas formation represent the beginning of a long period of marine sedimentationwhich continued through all of Pennsylvanian time and into Permian time. This change from marine to continental sedimentation, begun during the deposition of the Rico formation, was completed in Permian time, as the Cutler formation is almost entirely a continental accumulation.

The Cutler is the youngest of the known Paleozoic formations in the San Juan region. In the southwestern part of the region Upper Triassic beds rest upon the Cutler without an obvious stratigraphic break. North of Ouray, however, there is a striking unconformity which

indicates that during the transition from Paleozoic to Mesozoic time crustal movement flexed the Paleozoic strata and occasioned considerable erosion in a small part of the region.

The Mesozoic era in the San Juan region was a time of prolonged accumulation of sedimentary rocks. Strata aggregating approximately 9,000 feet in thickness were laid down over most, if not all, of the region.

The San Juan region at the beginning of the Mesozoic era may be pictured as an area of extremely slight relief, situated very close to sea level.

In the later part of the Triassic period, and possibly extending into the Jurassic period, the Dolores formation was deposited over all the western half of the San Juan region.

The accumulation of the Dolores sediments was terminated by an episode of crustal deformation, far greater than any previous crumpling of the earth's crust which had occurred in this locality since the beginning of Cambrian sedimentation. Apparently all of the San Juan region east of aline approximating rather closely the east border of the Ignacio, Needle Mountains, Silverton, and Montrose quadrangles was greatly elevated and compressed into a series of strongly developed folds, complicated here and there by faults.

The corrugated uplands of the eastern San Juan region, developed by this deformation, were immediately attacked by the rejuvenated streams of the disturbed

localities and by the later part of the Jurassic period were reduced approximately to base-level. Throughout this time the recently accumulated sediments in the western half of the San Juan region had remained practically unaffected either by deformation or by erosion. Hence when sedimentation was renewed throughout the region by the new strata were there deposited in nearly perfect conformity to the old. East of the above-mentioned line, however, where crustal deformation had been succeeded by profound erosion, they overlapped the quondam land mass; consequently its beds transgress the upturned edges of all Paleozoic formations and over large areas rest upon the pre-Cambrian complex itself.

When the Cretaceous marine sedimentation ceased the San Juan region was an almost plane area approximately at sea level. The upper 6,000 or 8,000 feet of the earth's crust in this entire region was formed of the recently accumulated beds. In the eastern half and possibly in the central part of the region this terran rested upon the peneplaned surface of the pre-Cambrian complex. In the western half of the region, however, the thick formations of Paleozoic and earliest Mesozoic age intervened. Only in the zone of transition between the east and west halves of the area were the older sedimentary rocks uptilted. From conditions such as these the modern San Juan Mountains were to be constructed during the Tertiary and Quaternary periods.

The first step in this constructive process was the regional uplift and domal deformation of the entire San Juan province. Gradually the eperogenic uplift changed to a more localized and intensified orographic movement. A huge dome, 70 or 80 miles in length from east to west and 30 to 40 miles in width from north to south, was arched. The apex of this dome must have been not far from the s-w corner of the Silverton quadrangle. This differential movement must have amounted to at least 10,000 feet, so that the summit of the dome would have been that much higher than the surrounding plain had not contemporaneous erosion partly neutralized the effects of deformation. In consequence of the movement the Paleozoic and Mesozoic strats, so far as now known, dip outward at angles approximating the slope of the flanks of the dome. Thus in the Ignacio quadrangle the regional dip is toward the south, in the Telluride and Rico quadrangles toward the west, in the Montrose quadrangle toward the north.

This first warping of the San Juan dome was the expression in this locality of the widespread orographic movements which in the Rocky Mountain region represent the Laramide revolution. Obvously erosion would begin as soon as there was any appreciable difference in altitude between the center of the San Juan region and its periphery. Streams rising near the summit of the dome would radiate toward its margins. At their heads these streams would form canyons, whose depth would be

determined by the amount of domal uplift. In their lower courses the same streams would tend to deposit the materials obtained from the canyons.

Early in this stage of crustal flexing and concomitant erosion there occurred the first of the repeated volcanic outbursts which characterize the Tertiary history of the San Juan region.

Singularly enough, the next recorded event in the history of the San Juan Mountains was a glacial episode, but between the volcanic outbursts and this glaciation there was a long interval, during which erosion must have gnawed deeply into the newborn San Juan dome. The entire sedimentary veneer, 6,000 to 10,000 feet in thickness, was in places stripped from the surface of the pre-Cambrian complex at and near the center of the dome. Inevitably this process involved the carving and sculpturing of mountains, characterized by lofty peaks and deep-etched canyons.

Erosion had succeeded, in the interval subsequent to that volcanic outburst, in laying bare considerable masses of intrusive porphyry, which presumably filled the conduits through which the molten magma had approached the surface. How much time was involved by all this denudation can not now be estimated. It would seem, however, that the conditions thus sketched were achieved before the end of Eocene time.

Then came a change in climatic conditions of such import that glaciers of no mean size formed among these mountains.

The glaciation of the early Tertiary San Juan Mountains seems to have been an incident in the midst of a long interval of erosion. Assisted by the ice the streams in these ancestral mountains succeeded after a time in reducing them to comparatively low altitudes. The western part of the region was reduced to a surface of slight relief, to which the name Telluride peneplain has been applied. Slight down-warping of portions of the peneplain in the area now occupied by the western summits of the San Juan Mountains and the neighboring. Mount Wilson group may have developed sharply defined basins of alluviation. The deposits laid down in these basins are of the bolson type, and form the Telluride conglomerate.

The long interval of gradation that produced the Telluride conglomerate was followed by a short episode of violent volcanic activity. From one or more vents near the center of the Uncompahgre quadrangle extensive lava flows and a considerable mass of volcanic debris were ejected. The eruptive rocks thus formed have been named the Lake Fork breccia. Shortly thereafter other volcanic vents became active at localities not now definitely known. From them a tremendous quantity of detritus was spread broadcast over the whole northwest quarter of the San Juan province, making up the formation that has generally been called the San Juan tuff, the vast bulk of which was transported only a short distance from its source.

Erosion during the interval that followed the accumulation of the San Juan tuff left great cliffs overlooking deep valleys at several localities in the Silverton, Montrose, and Uncompahgre quadrangles. At a few places the streams cut channels even below the level of the Telluride peneplain. But before they had made much headway in the task of removing the great mass of San Juan and Lake Fork debris volcanic outbursts were renewed in the eruptions that constructed the well-defined Silverton volcanic series. Great quantities of lava were poured out from numerous vents to fill the hollows in the surface of the land and spread in great sheets over the San Juan tuff. The eruptions were for the most part confined to the neighborhood of the Silverton, San Cristobal, and Uncompahgre quadrangles. Some of the many lava flows welled quietly out from long fissures, but part of the Silverton series was the result of explosive outburts, and in places volcanic cones were built.

The series itself consists of half a dozen formations representing successive eruptive stages, separated by short intervals of quiescence during which erosion held sway.

As the volcanic energy of the Silverton epoch abated, the ever-ready agents of erosion once more began to dominate. The Silverton volcanic plateau was extensively eroded. Then came another long epoch of extremely violent volcanic activity. The numerous formations that have been recognized as a product of this outburst are

grouped together into the Potosi volcanic series. The whole series is extremely complex and embraces many varieties of rocks, from water-laid pyroclastic deposits to vast lava flows. The variety of magmas represented was very great but is, of course, not of primary interest to the physiographer.

Between successive outbursts of lava or explosive eruptions of whatever sort, there were numerous short intervals of comparative quiet, during which ersion modified the topography in places to such an extent that the successive formations of the Potosi series display numerous unconformities and overlaps. In spite of this interference offered by the streams to the constructive work of the volcanic forces, the net result of the Potosi epoch was a huge volcanic plateau, which in places was several thousand feet in height. Into this plateau numerous bodies, large and small, of intrusive rocks, generally porphyritic, were injected at different times. In places laccolithic masses raised the plateau surface by a few hundred feet. Elseqhere great fissures were filled to become dikes, some of which are in systems radiating from a volcanic pipe.

The exact extent of the Potosi volcanic plateau is not known. Undoubtedly in places, especially near its former margins, its materials have been entirely removed by erosion. It is certain, however, that practically allof the area included within the Ouray,

Silverton, and Needle Mountains quadrangles and the entire San Juan Country farther east was buried by this volcanic pile, which overlapped the surrounding region, especially on the south and west, for many miles. There is good reason for believing that the accumulation of this great mass of ejecta upon the surface was accompanied by a compensating depression of its buried floor. The surface beneath the Tertiary volcanic rocks in the San Juan Mountains is at the present time a great saucer tipped downward toward the east.

From the volcanic plateau, which had been progressively constructed by the long series of Tertiary volcanic eruptions, there was carved a great mountain range. Inasmuch as the Potosi series is of Miocene age, it seems probable that this generation of mountains was developed during Pliocene time, but it will be safer to refer to them in a more general way as the late Tertiary San Juan Mountains.

It may have been at about this time that the great laccolithic intrusions which in the last analysis produced the Rico and La Plata Mountains, on the west and southwest flanks of the San Juan group, took place. Some time in the Pliocene epoch there was developed in the San Juan province a graded surface of low relief, which is now near the summit of the mountains. To this summit peneplain we have applied the name San Juan peneplain.

This surface was the inevitable product of the long interval of comparatively uninterrupted erosion. For the most part it was about as level a plain as could be cut by running water. Above it, however there stood many monadnocks which rose a few hundred feet, or even as much as 2,000 feet, above the general level.

The gradual process of stream erosion, coupled with the spreading of fine gravel overportions of the graded surface of the San Juan peneplain, was terminated by the renewal of crustal warping. The great San Juan dome was once more affected by stresses that warped the surface in much the same manner as the earlier domal movements. Vertical uplift near the center of the dome raised that portion of the land 2,000 or 3,000 feet above the peripheral zone, and at the same time the entire southwestern part of the United States seems to have undergone an uplift amounting to several thousand feet. In the absence of definite information it seems best to consider that this deformation of the San Juan peneplain marks the transition between Tertiary and Quaternary time. It was apparently accompanied by still another volcanic episode, the last of great significance in San Juan history. To the lavas and eruptive debris of this epoch the name Hinsdale volcanic series has been applied by Cross.

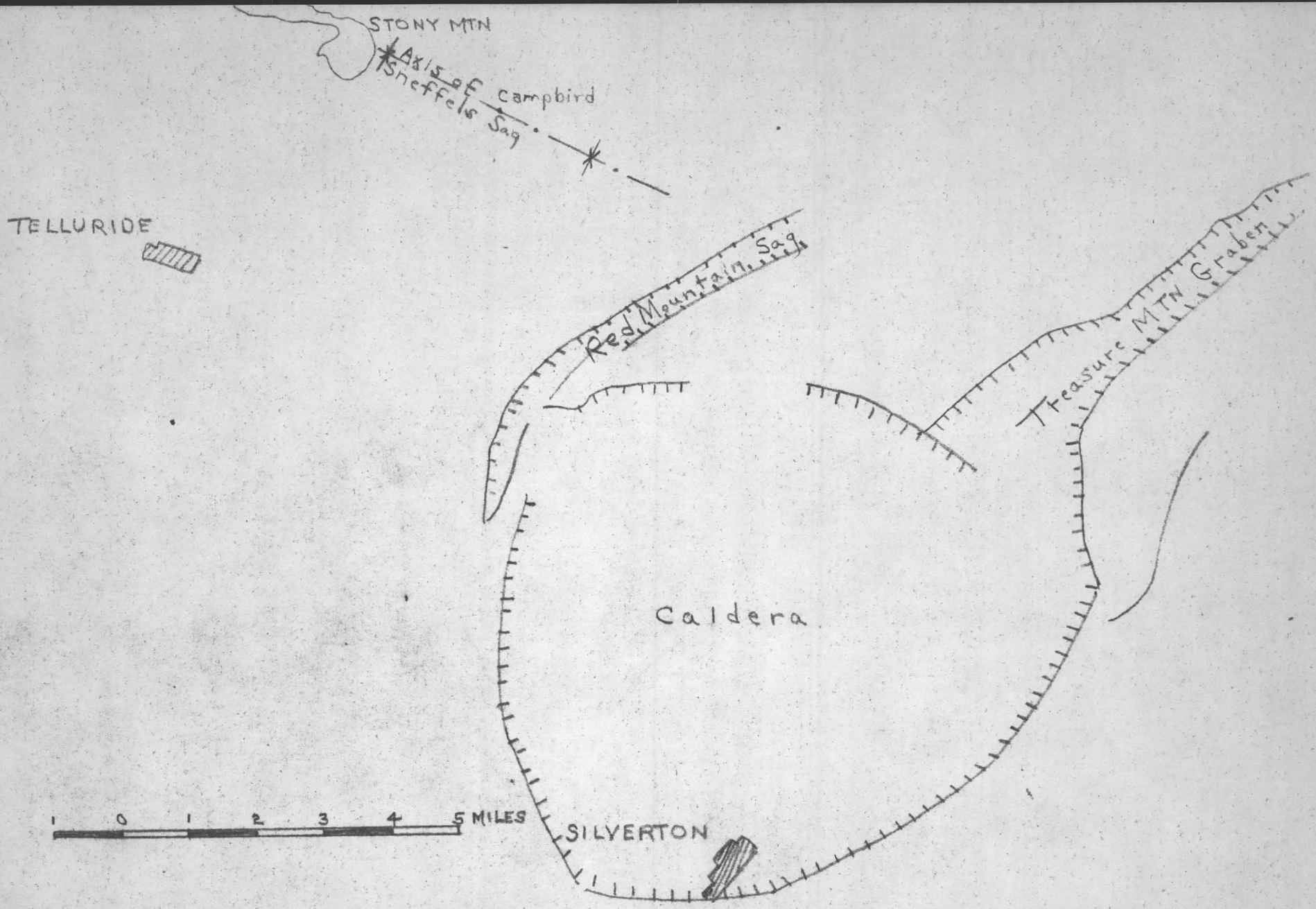


PLATE V REGIONAL GRABEN

W.E. Bush
15 Jan '48

SUMMARY OF ORIGIN OF REGIONAL GEOLOGIC STRUCTURE

The regional fracture pattern is primarily the result of uplift. This is evident from the fact that repeated reopenings over large vertical and horizontal distances took place in many veins distributed throughout the area. The general lack of shoots of occurrence indicates strong intra-mineral movements; repetitions of movements of lkie kind have occurred to make the different stages of mineralization coextensive in many fissures as in the Camp Bird vein. The banded character of the mineralization is indicative of open fissure filling, and the coextensive nature of the several stages of mineralization is indicative of dynamic ore control. These facts point to repeated uplift throughout the period of mineralization. In Arrastre Basin dikes striking N80°E and N45°W are described as being similar in appearance and mineralogical character.

The Treasure Mountain Graben perhaps indicates an elongation of the domal uplift to the northeast, accounting for the prominence of the fissuring in this direction. The influence of the Stony Mountain Center seems largely responsible for the concentration of fissuring in a northwesterly direction from the sunken block of the Silverton Center.

Five epochs of mineralization are to be noted in the San Juan Mountains. Of these, two (Pre-Cambrian veins and late eocene placers) have shown no production. Jurassic

sedimentary deposits and eocene veins have shown some production; but only the conditions related to the Middle to late tertiary mineralization are considered in this paper.

Burbank indicates that seismic methods may find applications here in aiding in the determination of geologic structure. Another future possibility might be the application and correlation of radioactivity logging or electrical logging in deep drill holes throughout the area.

II

ORIGIN OF THE REGIONAL STRUCTURE

There can be little doubt of the existence of the central sunken block in the Silverton area. The displacements along its marginal faults as determined by Burbank are of too great a magnitude to be ignored. Atwood and Mather (3) in accompanying geologic section A-A' show large erosional cliffs overhanging the Animas River but indicate no faults. Owing to the wide area covered by the work of Atwood and Mather and the abundant erosional debris and alteration in the Animas Valley, this phase of their work will be discounted. In the following paragraphs, the validity of the more detailed field work of Burbank will be assumed.

Burbank (1 pg174) points out the inaccuracies inherent in generalizations made concerning a region as large as this, but seems to feel that the remarkable symmetry and relations between various structural features offer reliable evidence that the regional structure resulted from "some comparatively simple and systematic failure of the crust". He points out further that "the forces producing this structure were probably generated by the upthrusting of igneous bodies and by gravitative adjustments that followed their upward surge."

The fissure systems of most parts of the region are known in a general way, and for several small parts of it

they are known in detail. A glance at the occompanying map (Plate IV) on which available data has been plotted will reveal a notable lack of fissures in several areas. It is agreed by all authorities that this lack is dde mainly to insufficient data. This is particularly true of the western border of the sunken block and the area west of the sunken block; the east and central parts of the central sunken area are not, however, strongly fissured.

. The effect of the structure of the underlying pre-cambrian and pre-tertiary rocks on the visible regional structure and fissure system has not received a great deal of attention. This is mainly because of insufficient knowledge of the structural details of these rocks. Burbank (1 Pg 156) has pointed out that further studies are necessary in this regard. V.C. Kelley (2 pg364) has shown that the Dunmore Vein is partly pre-tertiary in age. It would appear, from geologic section B-B', to have been positioned by a prominent fold in the pre-cambrian rocks. Kelley further points out that it has acted as a feeder channel for many of the shallower and later local veins in the volcanics. This may perhaps be indicative of a widespread but hitherto unrecognized, and as yet mainly concealed, regional condition.

Burbank (1 pg213) suggests the possible application of geophysical methods in supplementing geologic data. Further information could perhaps be gained from deeper mine workings and drill holes.

Burbank (1 pg175) goes on to say that inward projection

of the principal radial fracture systems results in their "focal concentration" near the center of the Silverton quadrangle, suggesting their origin in some common force. Dikes in many of the radial fissures are older than the faults resulting from subsidence of the central block, which offset them. Many of the dikes in the areas mapped in detail (southern and northwestern areas) are reported to occupy simple tensional fissures which show little or no faulting prior to the dike injections. Not all intrusions preceeded the subsidence of the central block, but a sufficient number of them did to indicate that the major structural pattern was in existence before subsidence.

The Formation of radial fractures distributed through such a large volume of the crust could hardly have been formed by subsidence of the central block alone without the stresses causing it producing marked crushing and shearing of the central block itself. As stated previously, only the western margin of the central block is strongly fissured. Wisser (4) in a talk before the S.F. Section AIME went further to state that "Collapse never forms radial fissures, as easily performed experiments show. Dollapse never produces any kind of fissure, for segments of the crust collapse to fill a void below." Elsewhere he noted that veins filling fractures formed by crustal collapse might be expected to fill openings caused by abrupt changes in strike or dip, but would hardly be expected to fill them over long distances. The ore body in the Tomboy vein was

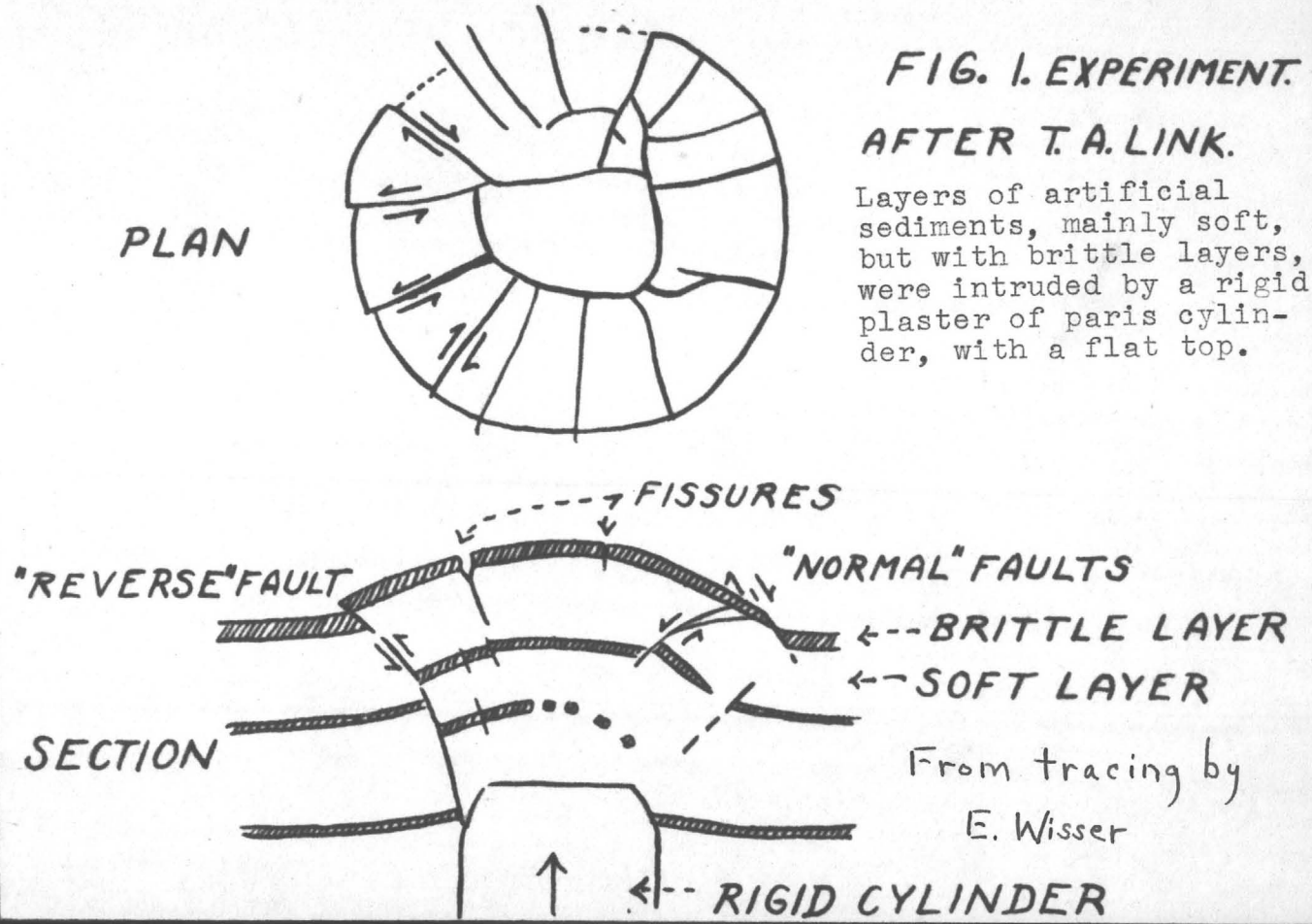
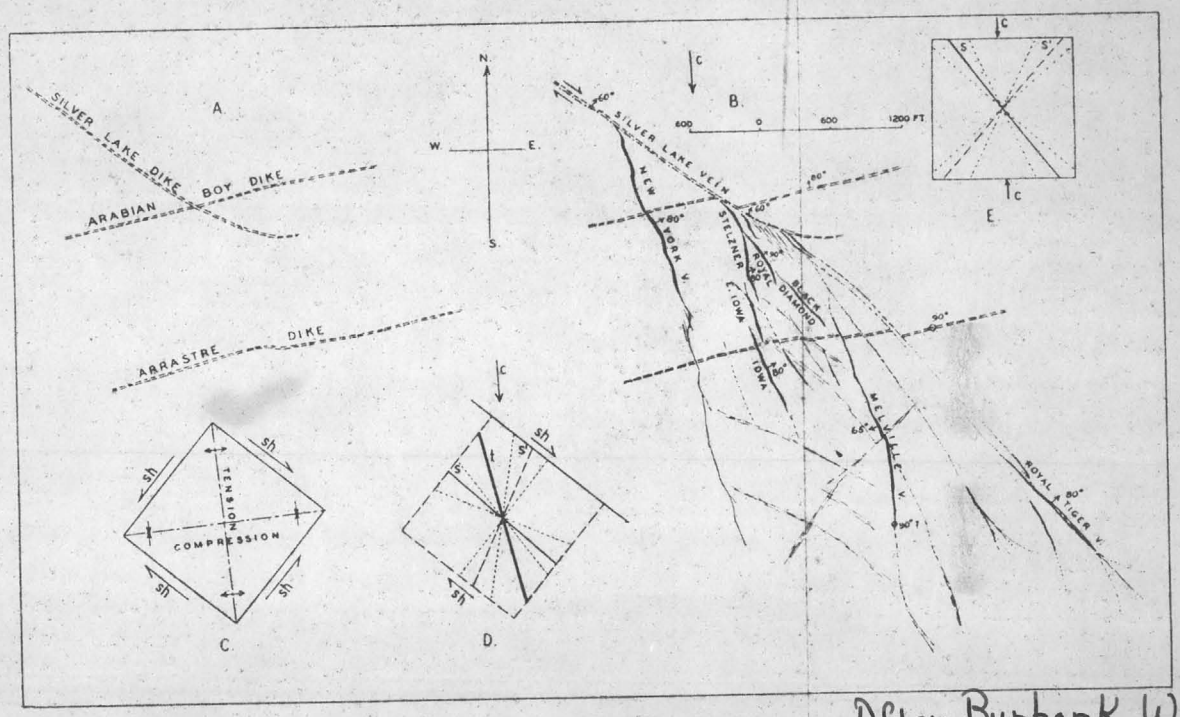


FIG. 1. EXPERIMENT.

AFTER T. A. LINK.

Layers of artificial sediments, mainly soft, but with brittle layers, were intruded by a rigid plaster of paris cylinder, with a flat top.

From tracing by E. Wisser



After Burbank, W.S.

Figure 2. Silver Lake vein system.

A. Relation of Silver Lake and other dikes before displacement.

B. Relation of Silver Lake vein system to displacement of the dikes.

C. Axes of tension and compression and direction of maximum shearing stress (sh) in a body subjected to pure shear.

D. Interpretation of stresses and resulting fractures near Silver Lake vein: c, regional compressive stress: sh, shearing stress: s,s', shear fractures: t, tension fracture.

E. Interpretation of regional stresses in hanging wall of Silver Lake dike: s,s', shear fractures; c, regional compression.

almost continuous for 2000 feet, that in the Camp Bird for 1200 feet. The long shoots were identical with the lode itself, disappearing only where the lode pinched.

The foregoing evidence seems to conclusively show that stresses resulting from subsidence of the central sunken block were not responsible for the formation of the earlier fractures. Burbank (1 pg176) concludes by saying "If the stresses were chiefly vertical, and the maximum force were applied near the center of the Silverton quadrangle, radial fissuring might readily result from tensional stresses developed by bulging of the earth's crust."

Fig 1, showing results of an experiment described by T.A. Link, illustrates the fracture pattern resulting from a simple uplift. Similarity between this experimental result and the Silverton quadrangle fracture system (Plate IV) is at once apparent. The similarity becomes more marked upon realization that many more concentric fractures and dikes undoubtedly exist than are shown on Plate III. Of those shown. Burbank (1 pg177) reports that one 4 1/2 miles NW of the margin of the central block has been traced for over 4 miles, dips SE (toward the central block) and shows clear evidence of at least 4 tensional openings, "each opening accompanied by forceful injection of igneous or clastic material before deposition of vein matter." He also reports that several in the SE area extend for 4 or 5 miles, dip to the north (toward the central block), and contain igneous dikes. Several wide fractures in the Ice

Lake Basin area west of Silverton (near the Golden Horn, plate IV) which approximately parallel the western margin of the sunken block are known to exist.

The similarity of the concentric dike pattern to the "Cone Sheets" of western Scotland (5 pg 24) has been mentioned by several authorities. Burbank (1 pg 177) while admitting a possible sumilar origin, notes that in Silverton the radial dikes are dominant while in western Scotland they are subordinate. As a possible explanation for this and in consideration of the large area of influence, he suggests a very deep seated source of the forces involved in the deformation and the great depth of the central igneous body involved. Another comparison drawn between western Scotland and Silverton is with regard to the annular distribution of the igneous intrusives about the central block. Burbank (1 pg 178-9) infers from the distribution of ore deposits and other evidences of hydrothermal activity with relation to the margin of the sunken block that "had erosion penetrated deeper in the Silverton quadrangle, igneous bodies that almost completely encircled the sunken block would have been exposed." It is noted, however, that the opposite dipping separate, independent, and subsequent" ring dike"fractures are not found related to the "cone sheet" fractures in the Silverton Area.

Burbank offers evidence based on a study in Arrastre Basin (see fig 2) of the modification and re-opening of earlier tension fractures by outward thrusting and shearing forces

set-up by subsidence of the central block.

Some of the concentric dikes are reported to limit or deflect the radial fractures. The greater concentrations of fissures are found on the sunken block or inward side of the outlying concentric dikes. From Fig 1, this would be expected of a simple uplift.

Moehlman (6) has indicated that the faults at the west side of the sunken block are clearly the result of tensional stresses. Under microscopic examination he found less than 10% pulverized rock in the shattered zones, indicating but little grinding action.

Several features ~~wprtjl~~ worthy of note are the previously mentioned presence of a graben extending NE from the sunken block in the vicinity of Treasure Mountain, and the NW trending "Sneffels Sag." The major Treasure Mountain graben is much more strongly developed (see Plate V) than the "Sneffels Sag" which trends about at right angles to it and which ~~the axis of maximum~~ parallels the axial line of the NW vein and dike swarm.

Figures 5 and 7 illustrate the formation of graben under the action of the vertical forces which produce domal or anticlinal structures, and figure 6 shows several field examples of this. Wisser offered the suggestion that the theory of the origin of the Rhine Uplift and Graben (7) (see fig 6) might find application here. This theory is essentially similar to the ideas of Burbank previously given with the important exception that subsidence would be a natural consequence of the uplift and independent of mag-

ma tranfer at depth. It here could include deep-seated vertical forces producing a slightly elongated dome trending SW-NE. The dome would fracture as shown by a combination of figures 1, 5, and 7. The subsidence of the central block and the Treasure Mountain Graben geing the natural consequence of the uplift and being closely related thereto in time. It must be remembered that the volcanics were poured or erupted into an eastward trending basin, thus giving them a slightly synclinal structure. The weight of the thick accumulation of volcanics doubtless aided in the subsidence of the central block after, but in conjunction with the doming. The history of the area as set forth by Atwood and Mather (3) shows several periods of doming all with their centers in or near the Silverton quadrangle. This undoubtedly developed crustal weakness which contributed to the localization of the late tertiary uplift in the Silverton area and perhaps provided the vents and fissures from which the pre-doming tertiary volcanics poured into the basin mentioned above.

The doming and resultant fissuring was accompanied by the intrusion of dikes; subsidence and intrusion of the annularly distributed igneous bodies about the sunken block were probably contemporaneous, with intrusion outlasting faulting in at least one area Bear Mountain southwest of Silverton); mineralization was mainly post-faulting, but with a few local exceptions. This timetable seems to fit the essentials of the situation as elsewhere given from Burbank'S descriptions.

Several portions of geologic sections by Kelley (2) are offered in support of the above proposed NE elongated the similarity between these sections and the example of the tilting of blocks due to uplift (Magdalena District, N.M.) shown in figure 9 is at once apparent upon comparison.

Reference to the areal map will reveal that the lines of these sections are NE of the NE limit of the central sunken block as described by Burbank, and that all of the sections indicate an uplift to the SE of the Poughkeepsie-Mineral Point Area. Kelley (2 pg 310) indicates that in this area the volcanics dip 10°-20° N to NW and that this dip was caused partly by an early doming uplift; "but with the formation of the NE striking fissures the tilting to the NW was accomplished by dropping of the NW edges of the elongate blocks with reference to their SE edges." This seems to be putting essentially the ideas as previously given into different words.

Certainly in spite of the generally radial pattern, the two most prominent of the radial directions of fissuring are, N45°W. Some factor or factors must have governed this concentration. The recognition of the Treasure Mountain Graben, the Mineral Point-Poughkeepsie structure, and a consideration the experimental data presented in figures 5, 6, and 7 indicate elongation of the doming to the NE, thus accounting for the prevalence and persistence of the fracturing in this direction. The overloading of the central

block by volcanics, plus the "dropped keystone" graben formation, taking advantage of concentric fractures formed during doming, probably account for its greater and more extensive subsidence.

The situation to the NW of the caldera or sunken block is more complex. The Stony Mountain Center toward which the N.W. trending fissures point would seem to have been influential in so directing them. Indeed according to Burbank (8 pg 159) the Stony Mountain stock, is the center of an independent series of dikes and fissures divided into: a) radial system, and b) "spiral" and cone-fracture systems, essentially similar to the radial, and "spiral"and cone-fracture systems of the sunken block or caldera. Many of the older fissures of the radial caldera system are filled by dikes as well as veins. Some of the dikes are curved in strike and join with or are common to the radial dike system of the Stony Mountain Center, but in part the radial systems are independent. The density of fissures between the Stony Mountain Center and the caldera is indicative of the existence of a probable set of localizing factors. Burbank (8 pg 213) indicates that in general the dikes of the southwest half of the swarm dip SW and those in the northeast half dip steeply northeast. He states that these occupy tension fissures related to a downwarping of the crust. "The conclusion is reached, therefore, that at least some of the radial dike systems of the caldera result from

downwarping rather that upbowing of the crust." He goes on to say that although differing slightly from his previous interpretations " it does not invalidate the general interpretation of structural disturbances around the caldera, except to the extent that differential forces acting on rock bodies near the caldera ~~except in the~~ might result from inwardly directed rather than outwardly directed pressures."

The veins here show ample evidence of repeated reopening and enlargment. Burbank (8 pg 215) gives the succession of events as follows: 1) "spiral" dikes or cone sheets; 2) curved dikes that join the Stony Mountain Stock to margin of the main caldera; (initial downwarping of the Sneffels axis) 3) straight radial dikes of the Stony Mountain center followed perhaps by straight dikes of the main center; 4) broadening of north-westerly axis of sagging; 5) Development of the Sneffels axis of sagging (mineralization began approximately at this time), the ore-bearing fissures resulted from subordinate stresses induced by this sagging. The formation of these fissures is illustrated in figure 12.

In the Red Mountain district the ring faults and subsidiary fissures of the ring system range in strike from N25°E to N65°E. Burbank (8 pg 158) reports that roughly paralleling the ring faults is another "sag or graben" along Red Mountain Valley. This sag is similar to that found in many places around the calders, and its appearance is sketched in figurell. It is a type of graben resulting

from downwarping (similar to the "Sneffels, Sag" described above) but differing from that near Treasure Mountain, which seems the result of a dropped keystone following uplift.

The possibility that the domal uplift and "surgence of magma" was localized by the intersection of two major "sets of regional fractures" has been pointed out by Burbank (1 pg 180), who goes on to say, however, that the structure of a much larger area of the surrounding country must be better known before this possibility can be critically examined.

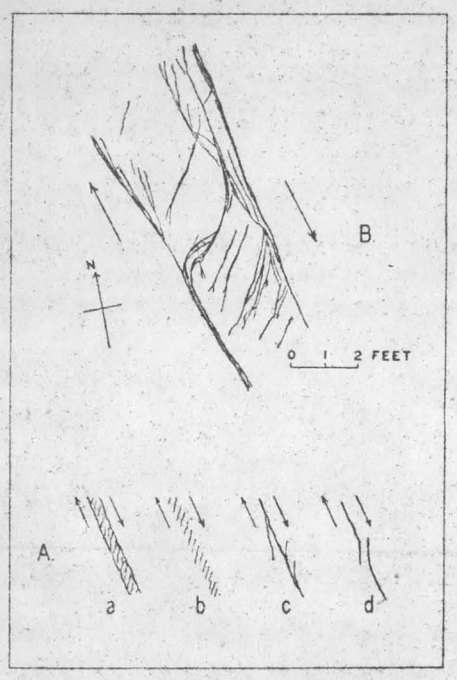


Figure 3. A. Types of surface cracks associated with the horizontal fault slip which caused the California earthquake of April 18, 1906. Arrows show direction of movement of underlying crust blocks. From G. K. Gilbert, Prof. Paper 153, p. 13. B. Characteristic cross-fracturing between shear planes observed in Dives Basin.

Both illustrations are plans.

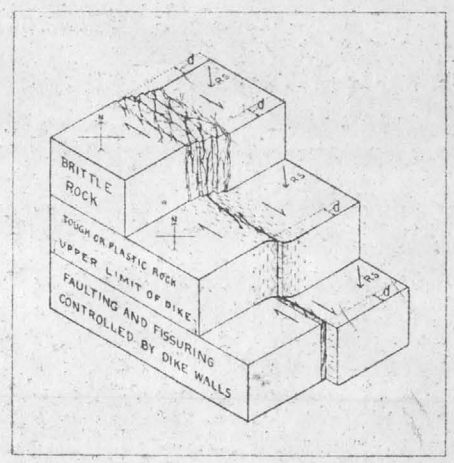


Figure 4. Diagrammatic illustration of change of character of fissuring under different geologic settings. RS, regional stress; d, relative displacement of walls in horizontal direction.

After Burbank, W.S.

THE RELATION BETWEEN WALL ROCK CONTROL AND STRUCTURE AND THE EFFECT OF WALL ROCK ON ORE DEPOSITION AND VEIN FORMATION

Examples fromx various parts of the area show a lack of agreement in the relative favorability of the varoous rocks with gegard to ore deposition and vein formation. Burbank (1 pg 232) admonishes against the common practise of projecting, as a basis of exploration, local determinations of the "most favorable altitude" of ore deposition, stating that it fails to take into account the critical physical-chemical factors involved. His remarks on this subject are quoted in part below. "The character of the initial fracturing in a rock mass is controlled not only by the physical properties of the particular mass, but also by its relative competence in the structural environment, by the localization of strains that cause final rupture, by the rate of application of the deforming forces, and many other factors. "In the Telluride and Sneffels districts, the San Juan Tuff is the most productive formation, the underlying sediments are intermediate, and the Potosi volcanics are unproductive, essentially." From the basic data of production in these districts one might conclude that quartz latites and rhyolites in general are unfavorable rocks for ore deposition; however, the prospector would be at loss in another district, for example, the Creede district, where silver-lead veins are found mainly in rocks of the Potosi volcanic series. Hence the chemical and physical properties of quartz latite and

rhyolite can hardly be the dominent control, even though under certain conditions they may constitute an unfavorable balance of control." The Creede veins are along strong faults, while those of Telluride and Sneffels display only faulting of a minor degree. "By comparison with the tuff neither the Potosi Volcanic series above it nor the sedimentary rocks beneath would be resilient enough to store equal energy in the form of strain. The conditions are comparable to those of a slab of resilient material embedded between layers of stiff mud, the whole being subjected to bending under its own weight. Very little energy would be stored in the mud, but that stored in the slab would be partly released when the stress exceeded the elastic limit and rupture occurred. The released energy would fissure materila in contact with the slab, but, away from the contact the forces would become dispersed in the plastic material. If the system were supported below, major faults could form only where some major plane of weakness in the supporting basement were activated at the time of rupture."

"At most times the rhyolite was protected from severe strains by the alternations of rocks between it and the basement. Until deformation had reached correspondingly more advanced stages of graben formation, as at Creede, the flows of the Potosi volcanic series could not have been fissured adequately to localize ore deposits."

"The results derivable from this theory of division

certainly accord with some well-known facts. Thus, if a tough mass is acted upon by a shearing tool, it is a matter of daily experience that the mass undergoes a single cut. For this case viscosity comes into play, and by the theory only one set of fissures will be developed, which means that only one fissure will intersect the mass. Again, if one attempts to cut a brittle substance like glass with a shearing engine, the mass, according to experience, shatters instead of simply dividing. In theory, as in practice, only masses capable of considerable deformation under the system of external stresses can be divided b y a single cut."

Figure 4 (1 pg 205) diagramatically shows the change in character of a rupture passing from one kind of rock to another. The changes would not be as abrupt as shown and in the block diagram a solely horizontal movement is depicted. According to theory the more brittle beds would rupture first, while the other rocks were still undergoing elastic or plastic deformation.

Kelley (2 pg 321-324) states that the influence of the wall rock in localizing ore shoots along a fissure may be expressed in three ways: "1) the pattern of its fissuring, 2) its permeability, and 3) its chemical reactivity to ore-forming solutions."

Figure 4, cited above, illustrates the first point; however the physical properties and character of fracturing are also related to depth. Identical rocks are less brittle at depth than near the surface. With regard to the second

point, Kelley infers that "on the whole, differences in permeability are more likely to affect the extent and character of wall-rock alteration than the position and extent of ore shoots within the fissure vein." Referring to the third point Mochlman (6 pg 392) points out that andesite is the most reactive and rhyolite the least reactive to the ore forming solutions. Kelley , however, says "The degree to which differences in chemical or mineralogical composition of these volcanic rocks are influential in localizing ore shoots is doubtful." Mochlman believes, on the other hand, that since some veins are largely replacements, the chemical action of wall rock is important. The pattern of its fissuring, with due regard to the influence of depth appears to be the most important effect of wall rockk on ore localization.

Numerous examples of "favorable and unfavorable" wall rocks appear in the literature and will not be repeated here except to note several contradictions emphasizing the dangers of "projection." In Arrastre Basin the Burns Latite is considered favorable and the Eureka Rhyolite unfavorable. However, in the Columbus Mine at Animas Forks and the Little Ida property in California Gulch, ore is found in the Eureka Rhyolite.

Speculation upon fracturing likely to occur within the pre-Cambrian and other basement rocks is scarcely warranted, as little is known about the reactions of these rocks to fissuring forces. It is evident, however, that they are sufficiently rigid and tough to transmit the fissuring energies much greater distances than the more easily deformable rhyolites and breccias. Ransome (16) has called attention to the fact that fissuring in the pre-Cambrian rocks tends to be simpler and narrower than in the shallower volcanic formations, but this comparison is evidently made with the more favorable kinds of volcanic rocks.

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VERTICAL RANGE OF ORE AND AREAL AND VERTICAL ZONING

With regard to depth of ore, Kelley (2 pg 326) in the Mineral Point, Poughkeepsie, and Upper Uncompahgre districts, concludes:" 1) No relation exists between the copper, lead, or zinc content of the ore shoots and altitude. 2) No relation exists between the silver or gold content and any of the base metals in the ore shoots. 3) No relation exists between the silver content and gold content in the ores." He goes on significantly "Since the aggregate vertical range of ore shoots already worked is over 4,000 feet, it is quite possible that exposed shoots, and high-altitude shoots especially, are quides or clues to underlying shoots even though not continuous or directly connected. A succession of shoots along one course of circulation seems to have been formed in certain other districts and a similar succession in these districts is worthy of consideration."

Burbank (9 pg 253 and 8 pg 156) indicates changes in grade of ore and the zoning of the minerals in depth is most pronounced along and near the margin of the down-faulted block, whereas in the intermediate and outer zones changes in depth are very much less conspicuous. Ore found in the chimney deposits of Red Mountain shows the most abrupt changes with depth from argentiferous galena near the surface to exceptionally high grade silver-copper ores at a depth of several hundred feet and to low-grade pyritic ore within a thousand feet. The gold-bearing quartz

adularia veins, as in the Camp Bird mine, on the inner edge of the intermediate zone also show definite impoverishment in depth, but not as abruptly as the Red Mountain deposits. In the outer parts of the intermediate zone high-grade gold shoots have been mined without appreciable impoverishment down ot the basement rocks beneath the volcanic formations.

At greater depth, structural changes involving the length and width of high-grade shoots rather than decreases in precious-metal content seem to be responsible for the most abrupt diminution in quantity and grade of ore. In general where the width of the ore shoot decreases the grade also falls, but there appear to be examples of strong fissures that continued in depth, though the grade of ore diminished, especially where the vein passed into the sedimentary beds. Lack of competency of the beds to support clean-cut wide fissures and consequent constriction of the solution channels in the fissured zone appears to account for these unfavorable veins.

Moehlman (6) indicates that the Camp Bird showed a change over a depth of 2300 feet from predominantly galena near the surface to sphalerite and pyrite at depth. The Virginius showed only coarser-grained sulfides and quartz at a depth of 1900 feet than at the surface. The Terrible over the same depth range changed from a heavy sulfide vein at the surface to a barren vein with scanty sulfides at depth.

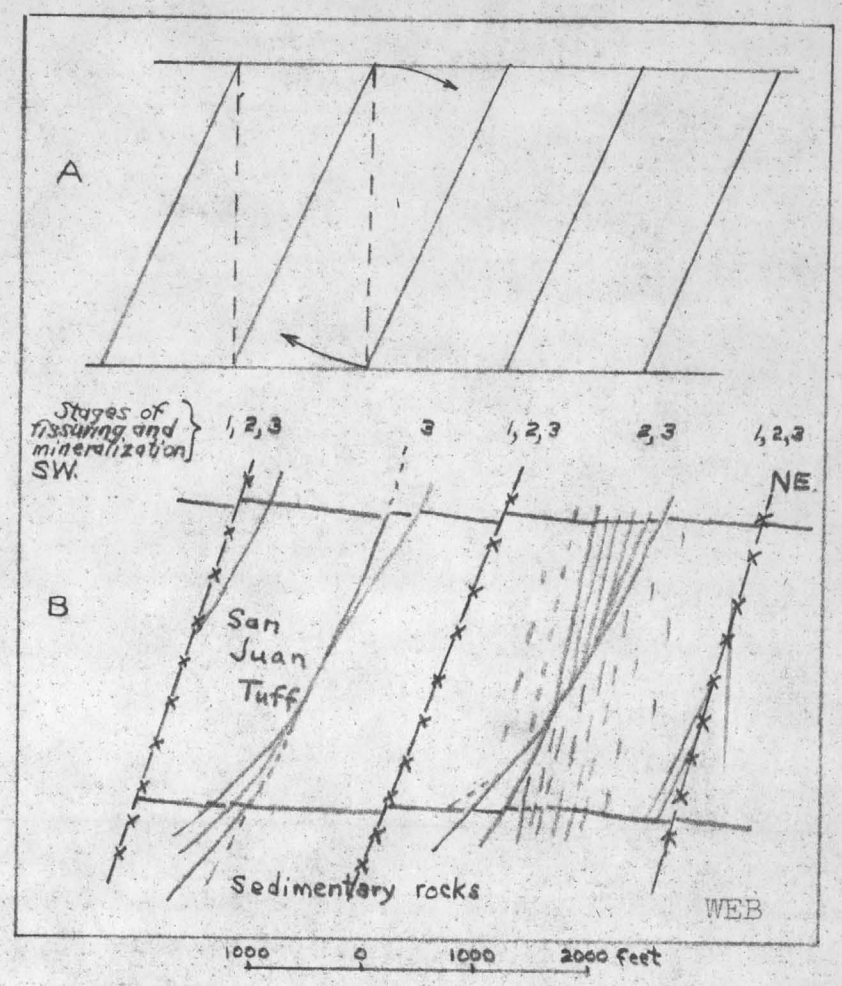
Hulin, in a report on the Sunnyside Mine, Eureka, Colorado, (1927) stated:"Base metal deposits of the Sunnyside type commonly pass from pre-dominating lead values in the upper parts to predominating zinc values in the lower. Silver and gold usually decrease with depth also. Sunnyside, developed thru a vertical range of 1750' (1926) shows no regular variation in the lead-zinc ratio thru this distance. However, with increasing depth there is a regular decrease in gold, silver and copper relative to the lead present. The copper decrease is surprising. The fact that the lead-zinc ratio shows no regular or persistent decrease suggests that there is still a considerable distance above the lower possible limit of deposition of lead ore. The possible vertical range of lead ore in central and SW Colorado is 3000'-12000' below the mineralization surface."

Areally Burbank (1 pg 164-173) and Moehlman (6) supply the following information. Just west of Red Mountain Creek, veins are richer in sulfides than they are farther to the northwest. Southwest of the Caldera, the NW trending fissures contain base metals, but argentiferous tetrahedrite also becomes important a mile south of the Caldera. The veins of the Sneffels and Telluride districts are much lower in base metals than those nearer the Caldera. Purington says there is an increase in gold and a decrease in silver from N to S in several of the main Telluride veins. The base metal content of the Liberty Bell increased to the east. The Cement Creek area is dominantly made up of base metal

ores containing silver with some high grade gold shoots.

The Areal zoning is reflected in the production records San Juan County with marginal veins produced half as much gold and silver, three times as much copper and zinc, and twice as much lead as the outlying San Miguel County veins near Telluride.

Previously mentioned, under another heading, was Burbank's theory, which finds considerable favor among other writers, that the magma underlying this area was very deep-seated. Moehlman, however, feels that the source of the mineralizing solutions must have been rather close to the surface to permit such pronounced areal zoning as is described above.



DIAGRAMATIC ILLUSTRATION OF THE THEORY OF SPACING OF FISSURES. A. MAXIMUM SPACING OF FISSURES UNDER ROTATIONAL STRAIN TO PERMIT RELIEF WITH LEAST EXPENDITURE OF ENERGY. B.DIAGRAMATIC RELATIONS OF FISSURING IN THE TELLURIDE DISTRICT. FISSURES WITH CROSSES ARE ALONG THE OLDEST FISSURES OCCURIED BY DIKES. OTHER LINES REPRESENT TENSION FISSURES WHICH WOULD BE OPENED DURING FOLLOWING STAGES OF ROTATION OF BLOCKS.

AFTER: W.S. BURBANK, "ORE DEPOSITION IN RED MOUNTAIN, SNEFFELS, AND TELLURIDE DISTRICTS, COLO." PROC. COLO. SCI. SOC. vol 14, No. 5.

fig 8

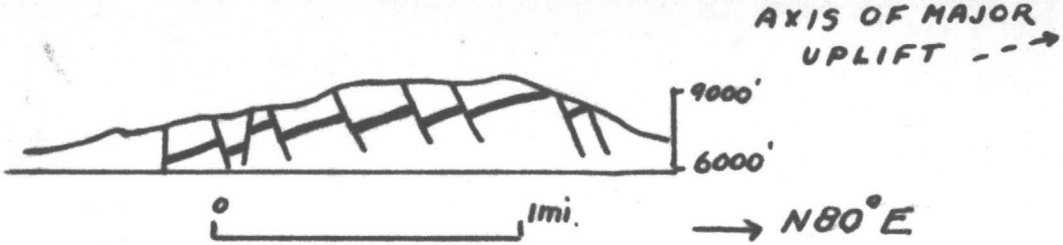
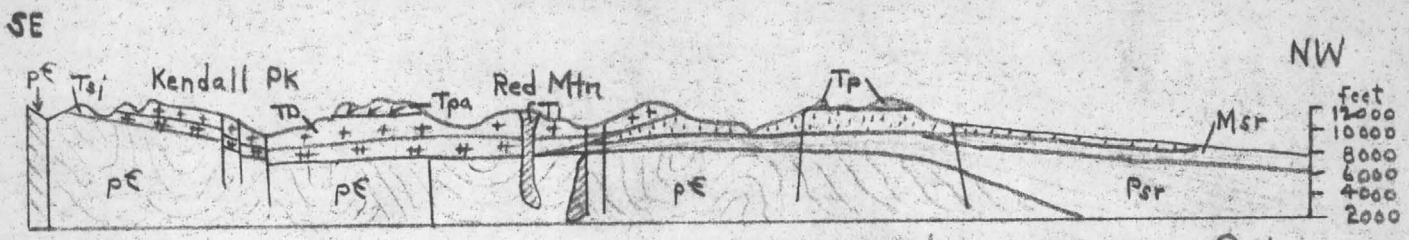


FIG. 9. SECTION THROUGH MAGDALENA DISTRICT, NEW MEXICO. (FROM: "ORE DEPOSITS OF N.M.")

from tracing by
E. Wisser



Line of section: N 20°W

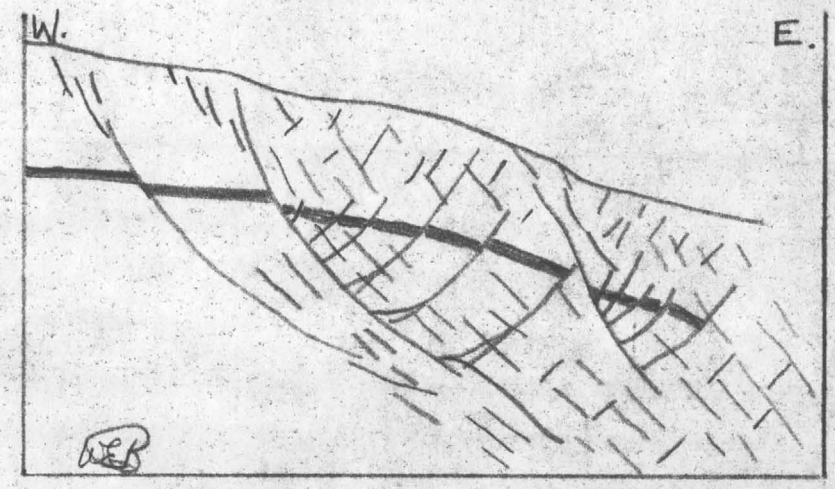
0 1 2 3 4 5 miles

W.E. Bush

W. San Juan Mtns., Colo.

after: W.S. Burbank, "Camps of the San Juan", E + M J., vol 136.

fig 10



Ideal fault and fracture systems formed on the flanks of the Red Mountain sag.

After: W. S. Burbank
Proc Colo Sci Soc, vol. 14, No. 5.

fig 11

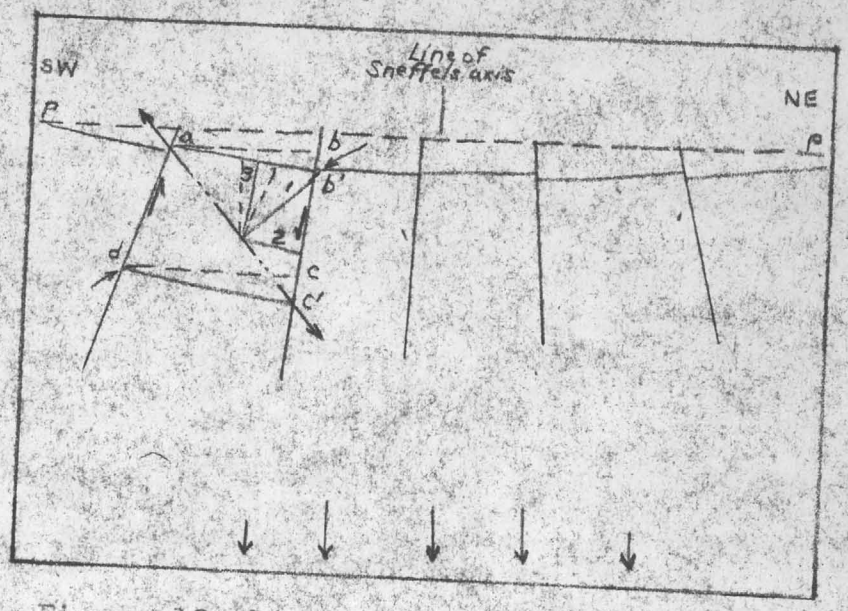


Figure 12- Diagrammatic section across Sneffels Sag After Burbank, W.S.

Tensional cross-fractures tend to develope in the deforming blocks in the approximate direction shown by the heavy line (1), and shear fractures as shown by the lighter lines (2) and (3).

Section A-A'
After Atwood and Mather

fig 13

THEORY OF SPACING OF FISSURES

Burbank (1 pg 207) in discussing the fissuring in Silver Lake Basin says in part: "Why diagonal fissuring under certain conditions produces favorable lodes and under other conditions less favorable lodes is apparently dependent on physical laws governing the spacing of fissures. Becker (18 pg 57-68) developed on a purely mathematical and physical basis a partial theory of the spacing of fissures, in which he showed that under ideal conditions the division of bodies by sets of fissures results in blocks whose faces are parallelograms. The ratio of the long and short sides of these faces and the inclination of the planes of fissuring to each other and to the faces of the slabs of rock being deformed are dependent on the physical properties of the material and the inclination of the applied pressure." "Where the principal planes of movement were closely spaced the diagonal fissuring is likewise closely spaced, and where the planes of movement were widely spaced, as near Silver Lake, the diagonal fissures are widely spaced and correspondingly increased in size, (see figure 2).

Concerning the formation of the late "tensional" productive fissures (see figure 8) in the Sneffels and Telluride districts, Burbank (8 pg 221-225) states: "The origin of the "flat" veins and associated steeper fractures according to the theory of rotational shearing involves certain limitations to the maximum spacing of the rotating blocks. As

shown by the vein systems of Arrastre Basin, if the sides of blocks stressed by rotational shear were widely spaced the cross fissures were likewise widely spaced, whereas if the blocks were narrow the cross-fractures were correspondingly closer spaced. As the blocks in the Arrastre Basin have rotated mainly about a vertical axis, their horizontal dimensions are evident, but, as those of the Telluride and Sneffels districts have rotated about a nearly horizontal axis, there is no exposed or obvious limitation to the vertical dimensions of the blocks or to the depths at which the tensional fractures may have formed.

According to Becker's partial theory of spacing (fig 8A), the blocks would be of such dimensions that they may rotate to afford relief of stress with the least expenditure of energy. This condition is ideally met, as shown by the figure, when their width is such that he blocks overlap with their corners in a vertical line. Each block may then rotate without extending the vertical dimensions of the space occupied. If the spacing of the inclined fissures is greater than this maximum, then the rotating blocks must lift the cover. If the cover were not very heavy this could actually happen, but it may be inferred that the cover was not actually lifted very much in the Telluride and Sneffels districts. The initial sheeting of the blocks noted above may represent a counter-deformation produced by a slight lifting of the cover, but in order to evaluate this possibility the dimensions of the rotating blocks must be more closely defined.

By reference to the cross sections of the districts it

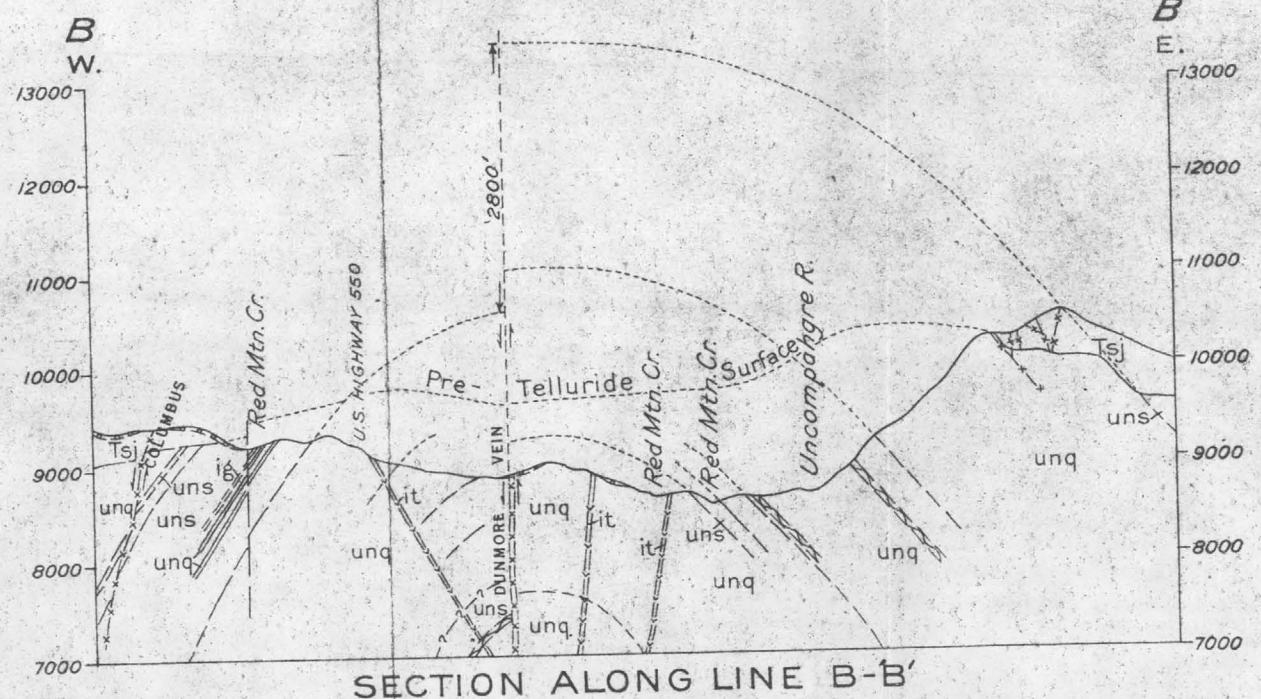
would seem unlikely that an entire block of the ~~xxxxxxxxx~~ shallower crust, some 8,000 feet in thickness to the base of the sedimentary rocks, could deform as a unit under rotational strains. Such a block is not a unit in its physical properties, but is divided into a number of parts by horizontal planes of stratification.

Among the weakest of the stratified layers are those which bound the massive or competent formations at their contacts with much weaker ones, as represented by the softer sedimentary rocks or the rhyolitic members of the volcanic formations. Knowledge of the general physical properties of the different rock formations leads to the inference that the San Juan tuff is by far the most massive, uniform, and competent of the volcanic rocks, excluding, however, the local thick bodies of massive latites in the Picayune group. The stratification of the tuff-breccia composing the San Juan tuff is too imperfectly formed and the clastic materials composing the rock sufficiently bonded so that slippage parallel to its own coarse layering becomes a negligible factor in the reaction of the formation as a whole to strains. This is bounded below by a comparatively thin layer of Telluride conglomerate, which in turn rests directly at many places upon soft shales and thin-bedded sandstones of the Mesozoic formations. The underlying beds of the Cutler and Hermosa formations are thus separated from the San Juan tuff by a relatively continuous and incompetent layer of beds ranging from several hundred to a thousand feet in thickness.

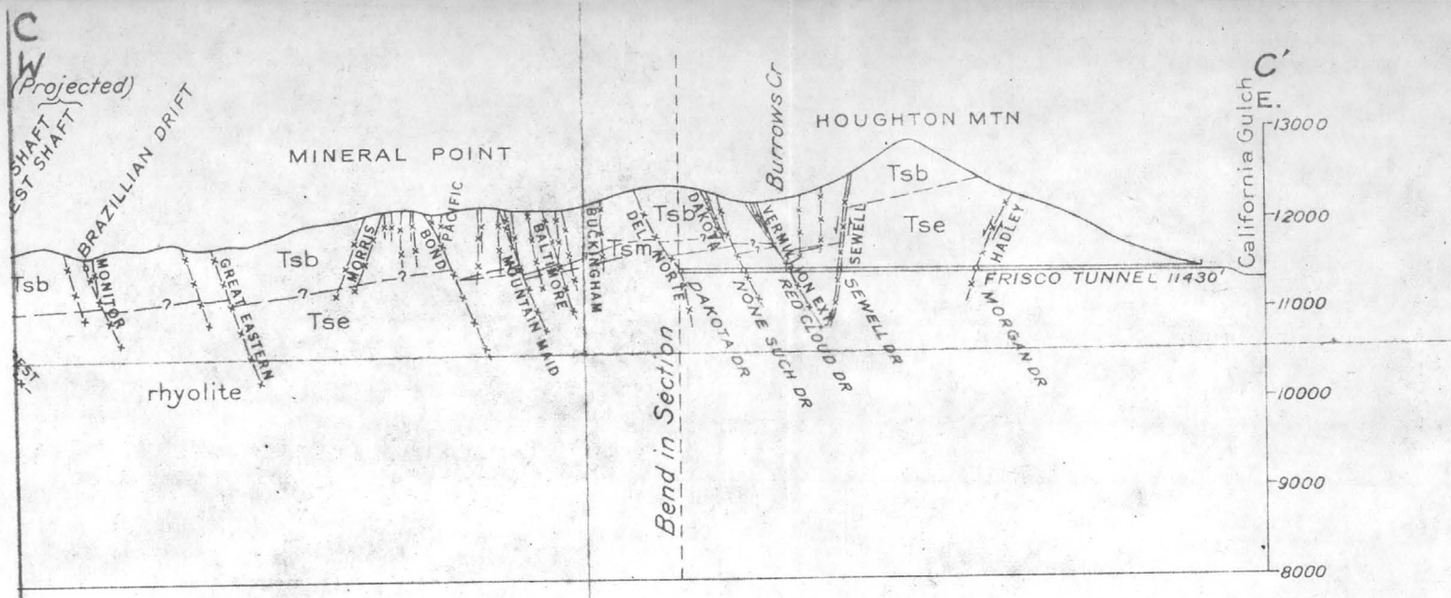
SECTION FROM: " GEOLOGY, ORE DEPOSITS, AND MINES OF THE MINERAL POINT, POUGHKEEPSIE, AND UPPER UNCOMPAHGRE DISTRICTS, OURAY, SAN JUAN, HINSDALE COUNTIES, COLORADO" by V.C. KELLEY
Proc. Colo. Sci. Soc., Vol 14, No. 7

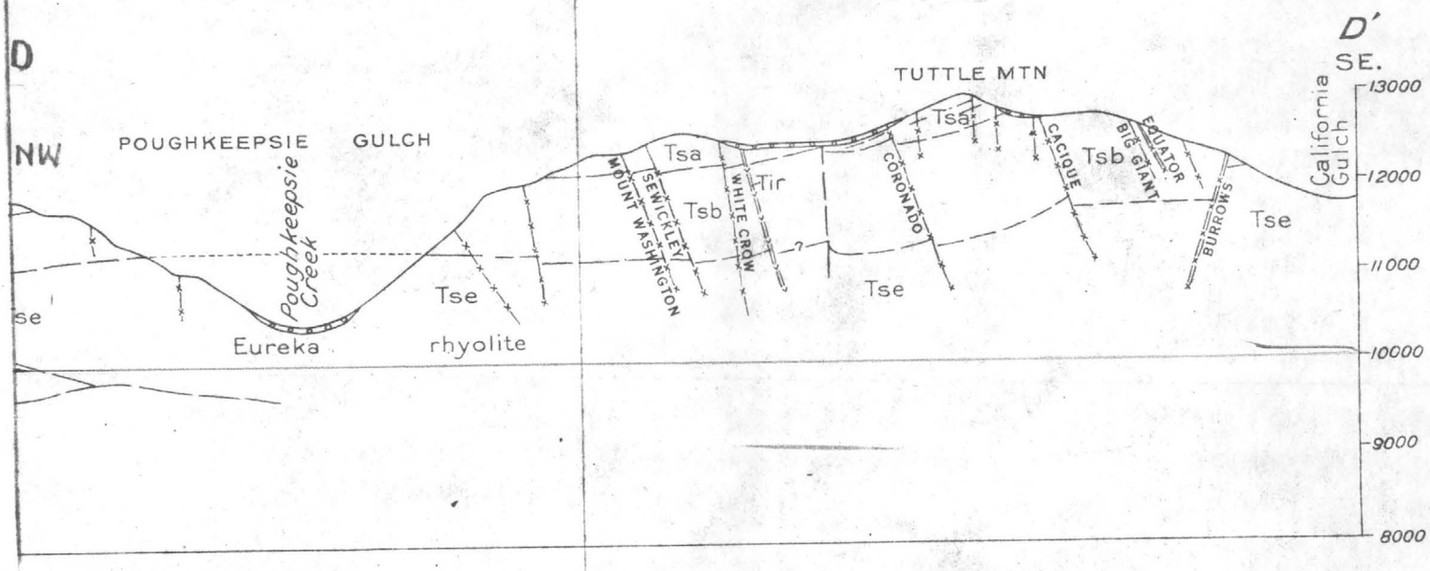
LINE OF SECTION SHOWN APPROXIMATELY ON ACCOMPANYING MAP

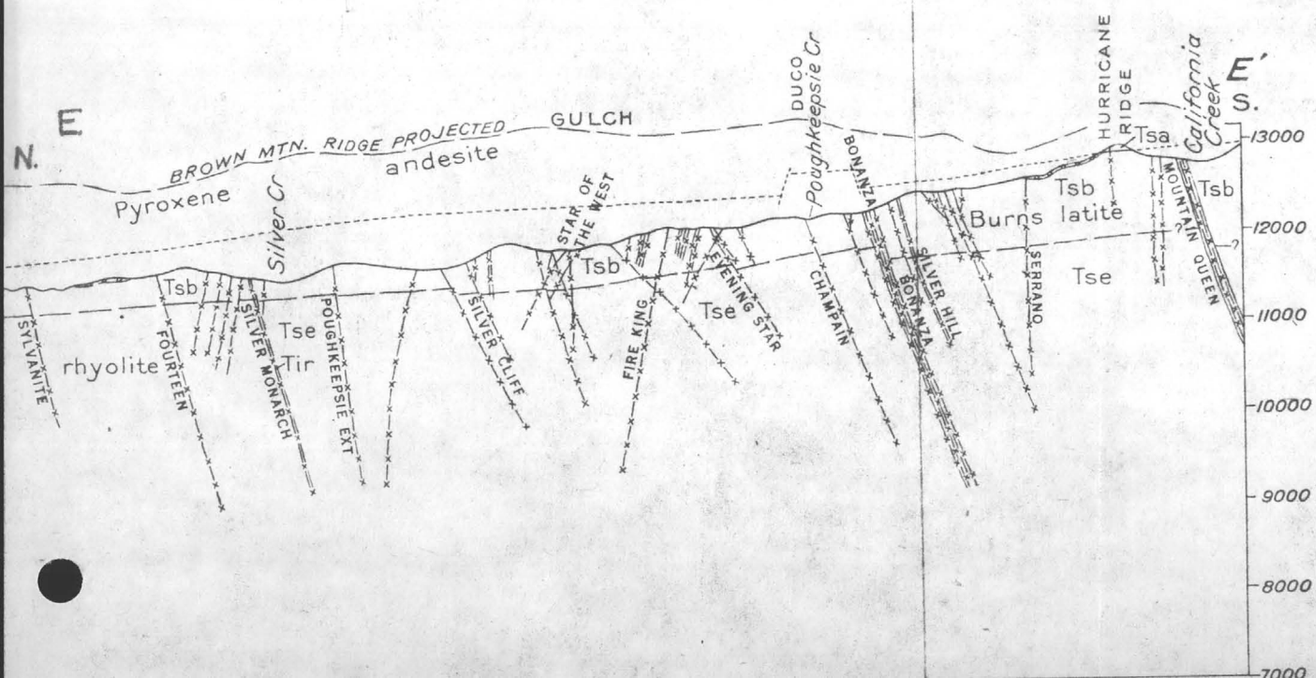
fig 14



SECTION ALONG LINE B-B′







SECTIONS FROM: PROC COLO SCI SOC, vol 14 No. 7, V.C. KELLEY

fig 15

From these considerations it may be concluded that the tuff and any part of the underlying formations of equal competency could not undergo simple rotational deformation as a unit if any appreciable strain was generated parallel to the stratification of the rocks. One direction of maximum shearing strain as shown in figure 12 is nearly horizontal and hence parallel to these planes of stratification. Accordingly, a tendency would arise as the blocks rotated for dividing planes of shear to form within the most prominent of the weakly bonded layers that bound the main block of the San Juan tuff. Such layers lie either at the base of the tuff or of the Telluride conglomerate, and also above the tuff (fig 8B) at or near the relatively incompetent rhyolitic and latitic flows and breccias of the Pocayune volcanic group, or in places near the base of the Potosi volcanic series. Therefore the competent blocks of tuff-breccia subjected to uniform rotational strain under the conditions of sagging had a thickness ranging from 2,200 to 2,700 feet, according to local thicknesses and minor variations in the weakness of the horizontal dividing layers in different parts of the districts.

On the assumption of average thicknesses cited and average dips of the tension fissures between 50 and 60 degrees, these fissures according to Becker's theory should be spaced from 1,000 to 1,500 feet apart. In general this deduced spacing of the fissures is in close agreement with that observed in most parts of the Telluride and Sneffels districts.

HYDROTHERMAL ALTERATION

Rock alteration is widespread in this area. According to Moehlman (6) the regional alteration shows an areal variation corresponding to the zoning of the ore deposits. Alteration is intense for long stretches along one or both walls of many veins, for widths of 1 to 10 feet. Kelley (2 pg 317) states it is more common in the hanging walls of inclined veins. The most common alteration products are finely disseminated pyrite, kaolin, sericite, quartz, epidote, and chlorite. For the most part these alteration products are the result of decomposition of the original minerals of the rock under the action of the corrosive solutions and gases that passed along the channels of the fissures. These solutions and gases were usually the same ones that deposited minerals in the fissures. The altered aggregate of the wall-rock minerals, however, generally contrasts strongly in composition and texture with that of the fissure filling. Reaction of the mineralizing solutions with the walls is considered to be one reason for mineral deposition in the vein. Wall-rock reactions, however, may result from changes in the solution that are caused by mineral deposition in the vein. In an alteration product of the type described here, quartz, although abundant in the veins, is commonly absent or so fine grained and so mixed with sericite as to be quite inconspicuous in the walls.

Burbank (1 pg 169) states: "Nearly the entire western border of the sunken block over a width of several miles is broken by innumerable fissures that provided channels for

the escape of volcanic vapors and solutions, which altered the Silverton volcanic rocks to an unusual degree. Ransome (16) has described the alteration that took place in the vicinity of the Red Mountain mines and on Anvil Mountain, showing that the rocks were altered in various degrees to aggregates of quartz, kaolin, sericite, barite, diaspore, epidote, rutile, pyrite, and other minerals. Where the rocks are not brilliantly stained at the surface by iron oxides, as on the Red Mountains, they are gray or white, and the different lavas are so changed from their natural appearance that many structural features and volcanic members were not differentiated on the Silverton folio map. This alteration has resulted from emanations earlier than those that deposited the valuable ore minerals, and because of its widespread nature it offers little clue to the most favorably mineralized zones. The exploration for and development of ore shoots in this region are hindered by difficulties of determining structure and in distinguishing between alteration produced by ore-depositing solutions and by earlier emanations, by the softening of the volcanic rocks by alteration, and by the presence of acid ground waters. The region therefore presents many unsolved geologic and mining problems.

No ore guides are indicated by the meager detailed mapping and reporting of hydrothermal alteration in this area.

OXIDATION AND SUPERGENE ENRICHMENT

V.C. Kelley (2 pg333-341) states that the quantity of oxidized ore in the Mineral Point, Poughkeepsie, and Upper Uncompahgre Districts is small. Significant occurrences are restricted to high ridges and valley sides. No cerargyrite is reported in these districts. The high gold content in some of the high-altitude mines has suggested enrichment, due to the agency of manganese minerals, to some observers. The validity of the process of gold enrichment owing to its oxidation and migration is a matter of extreme doubt.

Spotty oxidation to depths of 2400 feet has been reported in the Smuggler-Union and Liberty Bell Mines. This and other examples of local partial oxidation and supergene deposition at great depths are probably due to the great relief, open channels, and vigorous ground-water circulation.

The work of Atwood and Mather (3) raises the question whether older oxidized and enriched ore shoots might not have formed with reference to the ancient surfaces. Kelley suggests that although the vigorous erosion that formed the present rugged mountains and deep canyons, obliterated most of these old surfaces and associated supergene ore shoots, there is still the possibility that remnants may be partly preserved along some of the remote protected divides."

However, the stream cutting and glaciation have so

completely removed or modified most such deposits as to leave much doubt as to their origin. There is much evidence that what greater gold and silver values occur at high altitudes are the result of original hypogene zoning. The secondary nature of some of the so-called "supergene" minerals is open to serious question. This is in marked contrast to the Creede District, where the Amethyst-Veins outcropping in an unglaciated area is known to be leached for 300 feet and oxidized to a depth of 1000 feet. Kelley concludes that the ores of Mineral Point and adjacent Districts are dominantly hypogene and pending further study, that they bear little or no relation to present or past erosion surfaces in the matter of vertical range or depth. This conclusion seems equally valid for the entire region under consideration in this paper.

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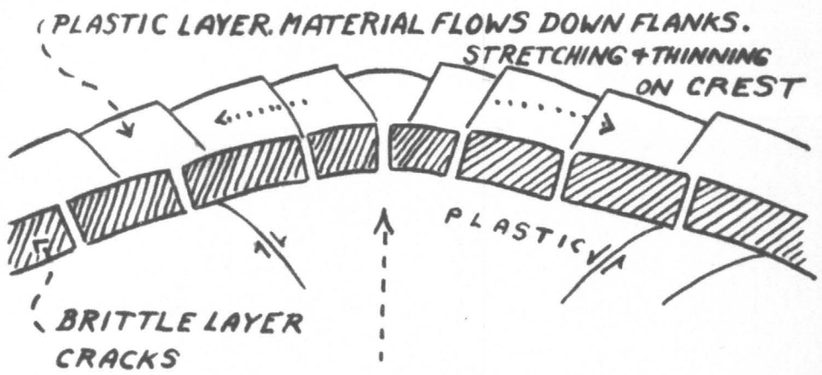
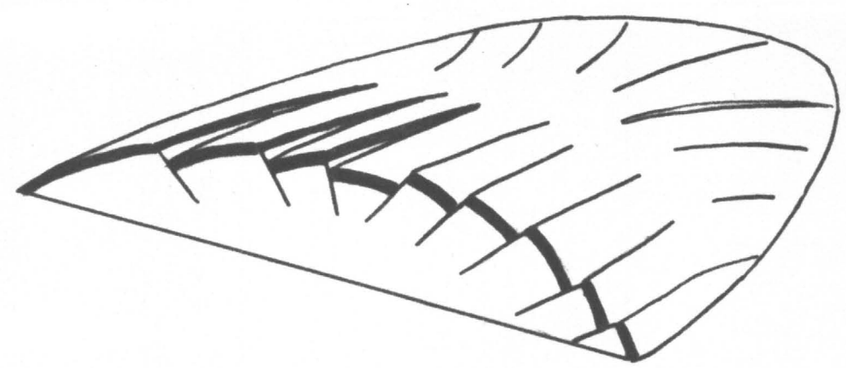
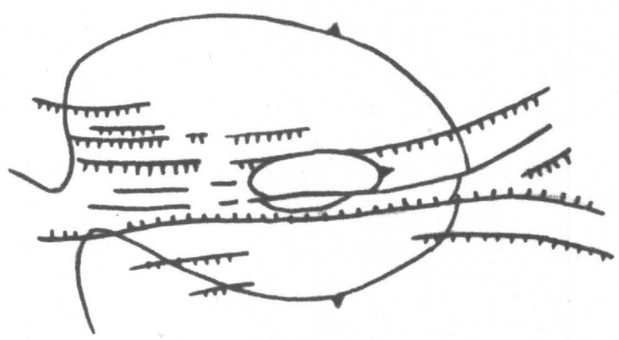


FIG. 7 ARCHING OF PLASTIC AND BRITTLE LAYERS.

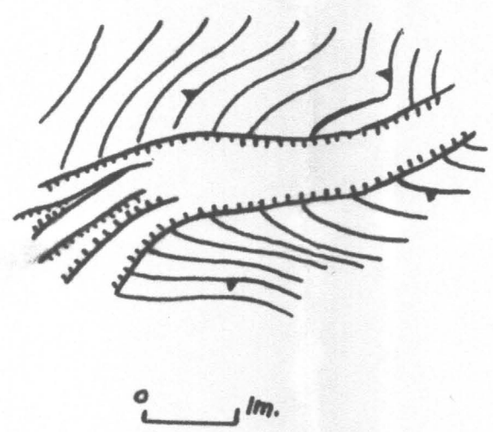
FIG. 5 AFTER H. CLOOS.



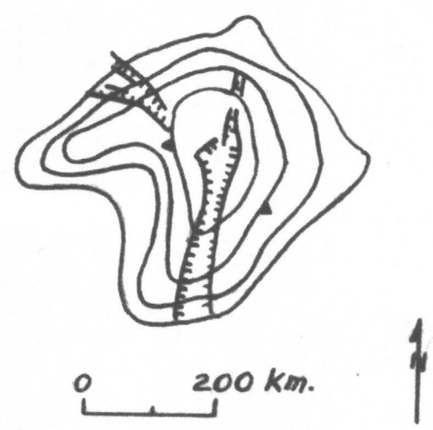
ELONGATED DOMAL UPLIFT.
LONGITUDINAL + RADIAL FAULTS.



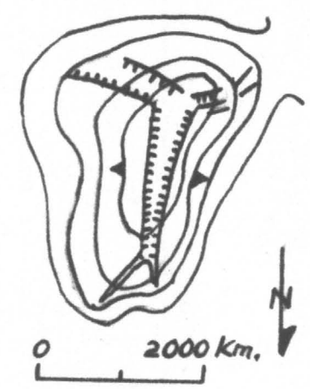
DOME - N.W. NEW MEXICO. AFTER J.S. IRWIN.



SALT VALLEY ANTICLINE, UTAH. (T.S. HARRISON).



RHINE UPLIFT + GRABEN. (H. CLOOS).



NUBIAN - ARABIAN UPLIFT. (H. CLOOS).

FIG. 6 TYPICAL UPLIFTS + GRABEN.

From tracing by E. Wisser

U.S. GEOLOGICAL SURVEY
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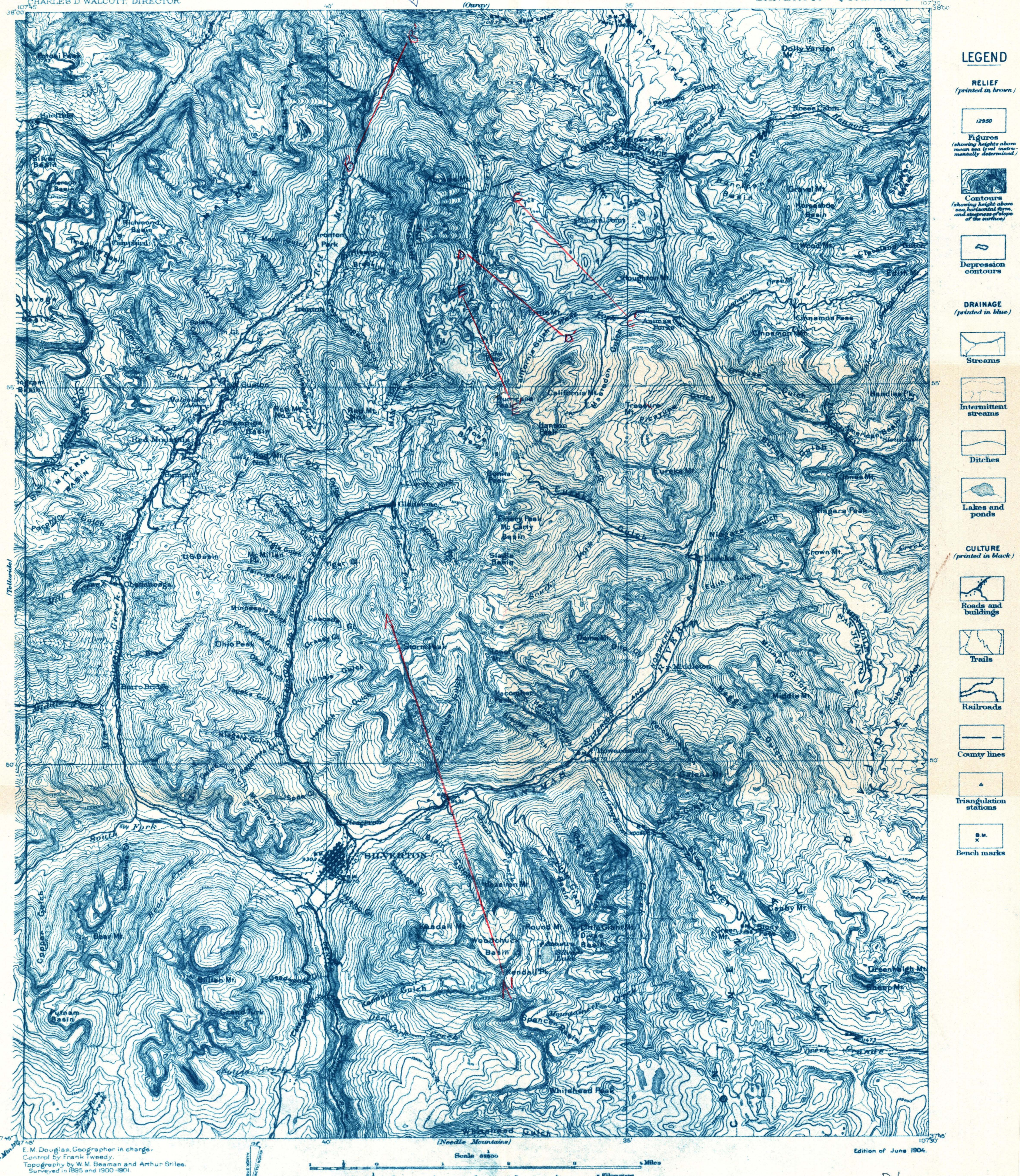
TOPOGRAPHY

COLORADO
SILVERTON QUADRANGLE



E.M. Douglas, Geographer in charge.
Control by Frank Tweedy.
Topography by W.M. Beaman and Arthur Stiles.
Surveyed in 1895 and 1900-1901.

(Engineer Mtn.)

Scale $\frac{1}{62500}$

Miles / Kilometers

Contour interval 100 feet.
Datum is mean sea level.
Projection based on U.S.C.and G.Survey data of 1900.
Projection of Telluride sheet based on earlier data.

Edition of June 1904.

Plate II b

U.S. GEOLOGICAL SURVEY
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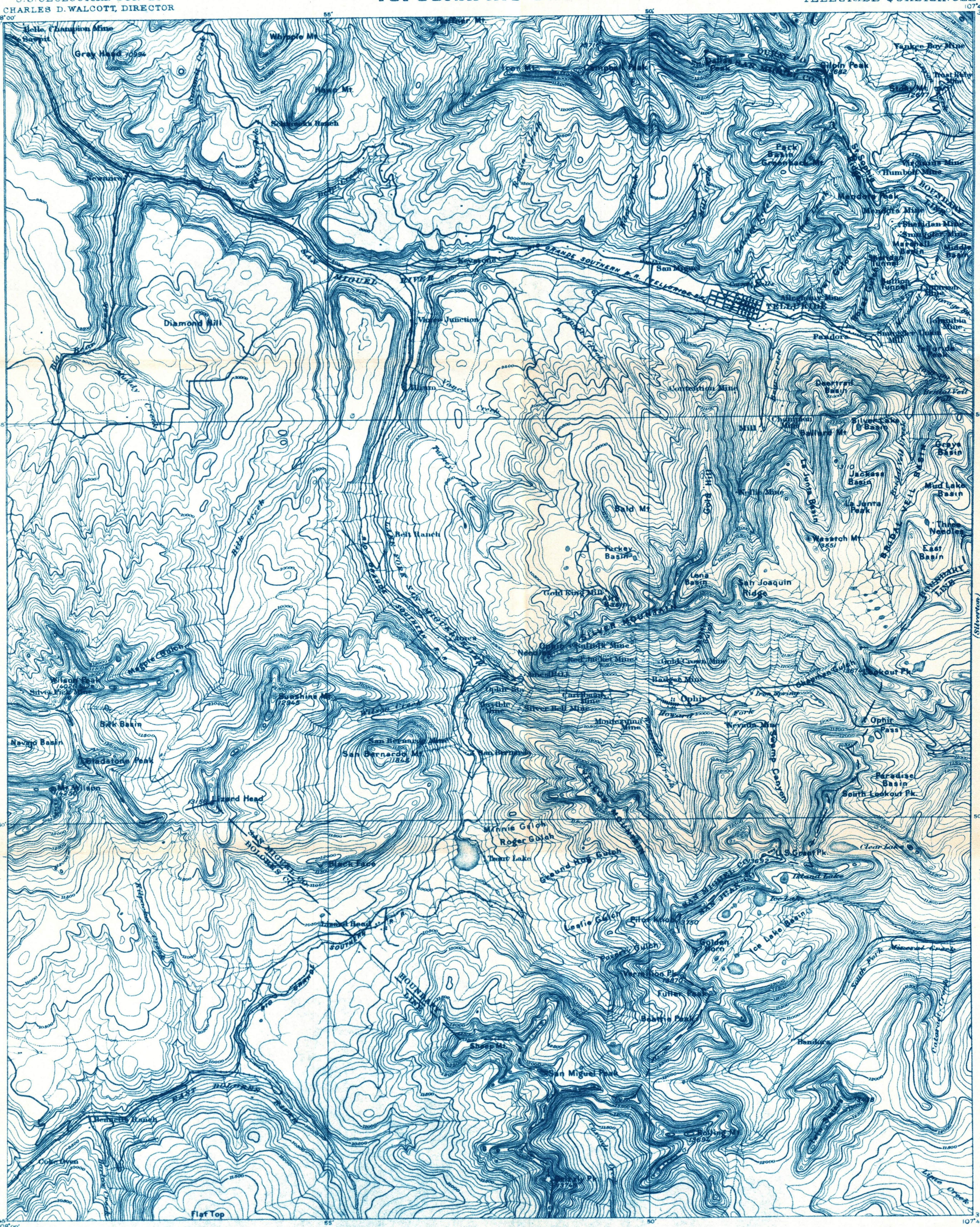
TOPOGRAPHIC SHEET

COLORADO
TELLURIDE QUADRANGLE



LEGEND

RELIEF
(printed in brown)

13750
Figures
(showing heights above mean sea level instrumentally determined)

Contours
(showing height above sea, horizontal form, and steepness of slope of the surface)

DRAINAGE
(printed in blue)

Permanent streams

Intermittent streams

Lakes and ponds

Ponds sometimes dry

CULTURE
(printed in black)

Towns and cities

Roads and buildings

Trails

Railroads

County boundary lines

Triangulation stations

Names of adjoining surveyed sheets are printed on the margin.

(Rico)

Henry Gannett, Chief Topographer.
E. M. Douglas, Topographer in charge.
Triangulation by Hayden Survey.
Topography by Frank Tweedy.
Surveyed in 1894.

Scale 1/62500
1 ½ 0 1 2 3 4 Miles
1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.
Datum is mean sea level.

Edition of June 1898.

Plate II a