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A

Regional Study of Portions of the
Silverton and Telluride Quadrangles,
Colorado----Continued.

W.E.Bush
Mining 198
4 June 1948.

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INTRODUCTION AND GENERAL DISCUSSION

This report is essentially a continuation of the report submitted last semester entitled "Regional Study of Portions of the Silverton and Telluride Quadrangles, Colorado." Additional pertinent data from published works of V.C. Kelley, W.S. Burbank, and F.L. Ransome are presented, in addition to some original work and compilations by the writer.

Attention is directed to the presentation in last semester's report of the proposed "Sneffels Sag Axis" of W.S. Burbank (8). A check of the maps accompanying Burbank's report (8) reveal a remarkable conformity to the proposed theory of a sag running along the general line Stony Mountain Stock-Campbird Mine. Veins on either side of the proposed axis dip steeply away from the proposed axis.

In the N.W. area, that was included in the report by V.C. Kelley (2), the dip of the veins is predominantly S.E. (toward the Treasure Mountain Graben and the Silverton "Caldera") with a few exceptions (e.g. Burrows Vein). This would be expected if an uplift to the S.E. was a part of the regional structure. It is difficult to determine if the Treasure Mountain uplift (and Graben) alone is responsible for this areal characteristic.

Reference is made Plate II, wherein the regional vein and fracture systems are depicted as presented by

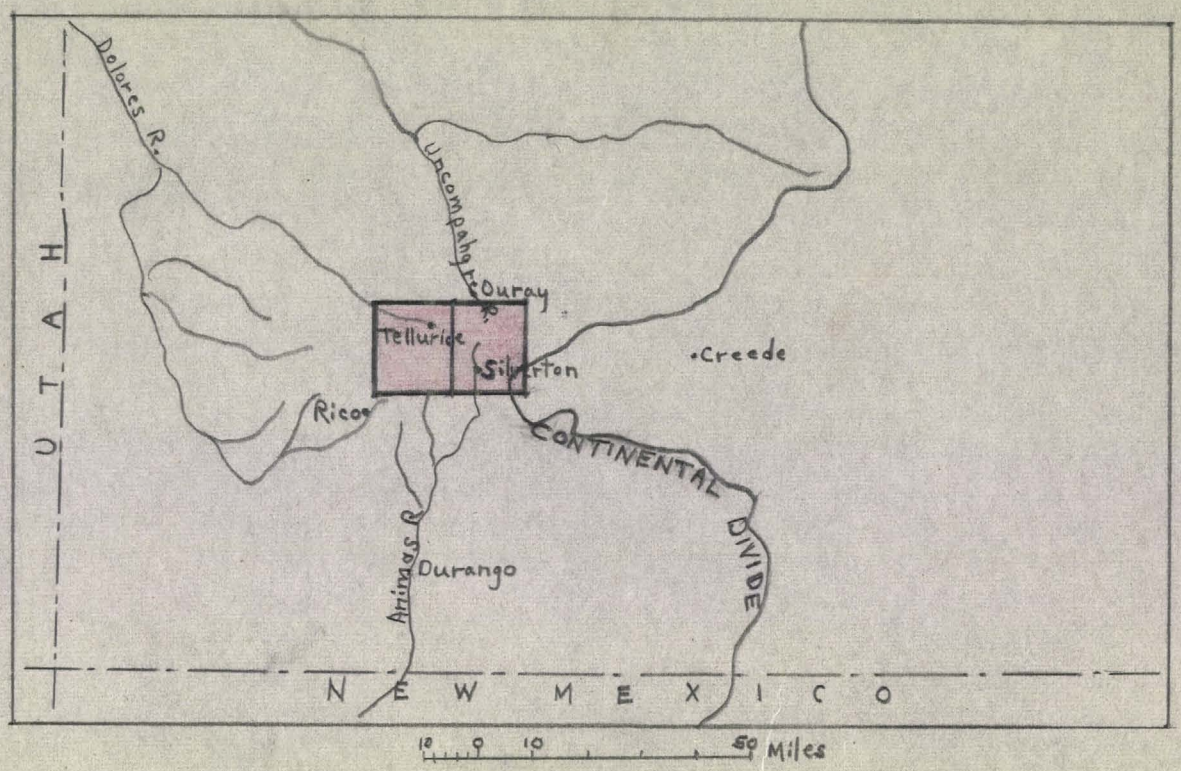


PLATE I-LOCATION MAP OF THE SILVERTON AND TELLURIDE QUADRANGLES, COLORADO

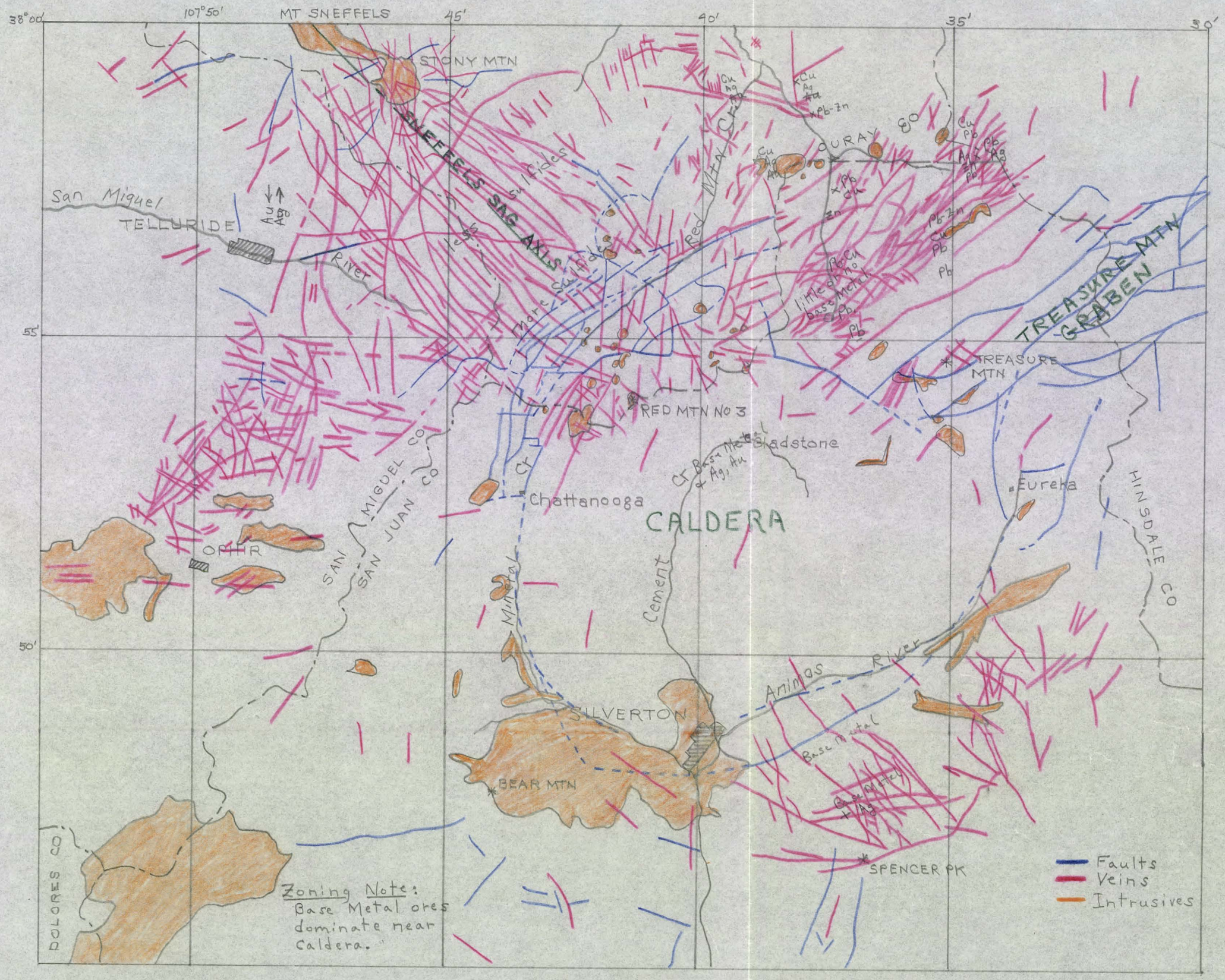
Burbank et al (2). The influence of the intrusive areas and the central "caldera" on the fissure systems is apparent. The noticeable alignment of fissures from stock to stock or stock to "caldera" is apparent in Plate II. Evidently the outlying intrusives have had considerable influence on the positioning of the various vein systems.

STRUCTURAL CONTOURS

Reference is made to Plate III, on which an attempt has been made to "uncover" regional structure through the use of contours drawn on the bottom of the San Juan Tuff.

The use of a volcanic rather than a sedimentary formation for this purpose was unfortunately made necessary by the absence of sedimentary formations through all but the western edge of the area. The San Juan Tuff itself is absent from the eastern edge of the area but appears to be the most widespread of the volcanics in the areas mapped in detail thus far. Its use was predicated on the facts that: while it is underlain by an erosion surface, that surface is presumed to have been essentially a peneplain; it is the most widespread of the volcanics and is largely water-laid; it is an important ore bearing formation (that is, veins make ore in it) and so certainly pre-whatever- it-was that resulted in the vein formation and ore deposition of the area. The bottom of the San Juan Tuff was chosen, rather than the top, since the top is a marked erosion surface. As stated above while the bottom likewise rests on an erosion surface, it is presumed to have been essentially a peneplain.

Pre-Cambrian rocks do not display sufficient exposures in the area to permit their use in this work.



After W.S. Burbank
with additions by W. Bush
June 1948

SILVERTON CALDERA AND VICINITY

PLATE II

Large portions of the area are as yet unmapped or are mapped on such a scale as to make structural contouring of these portions impractical.

In spite of the relatively great number of sections available for the northern part of this area (see Plate III), a great deal of doubt must attach itself to the results presented. The rather odd resultant contours perhaps indicate a great deal of interpolation and extrapolation by the various field workers in the construction of their geologic sections. On the other hand, assuming accurate sections to depths of several thousand feet below the mapped surface, the irregular contouring may indicate that the old erosion surface upon which the San Juan Tuff lies was not one of as low relief as was asumed. A third possibility attributes the irregular contours to crustal disturbances since the tuff came into existence. This latter is of course the most desirable and it was with this hope in mind that the work was originally undertaken. However, a comparison of Plate II and Plate III fails to disclose any apparent relationship between the vein systems or fracture pattern of the region and the structural contours drawn on the base of the San Juan Tuff. It is extremely doubtful that structural contouring on any surface available in this area would be of value as an aid in interpreting regional structure.

It will be noted from Plate III that no relation whatever is apparent between the proposed Sneffels Sag Axis of Burbank and the structural contours of the author. This is perhaps not too surprising in view of Burbank's statement (8 pg 217) that the "total depth of sagging is from 200 to 500 feet across a span of about 6 miles." Yet it would appear that, with a 500 foot contour interval, some indication of such a sag should be evident, this casts further doubt on the validity of this work.

Notes from: V.C.Kelley, "Geology , Ore Deposits and Mines of the Mineral Point, Poughkeepsie, and Upper Uncompahgre Districts, etc",
Proc Colo Sci Soc vol 14 no 7

STRUCTURE

FOLDS AND FAULTS IN THE PRE-CAMBRIAN ROCKS:

The quartzites and slates of the Uncompahgre formation are folded into a broad anticline which pitches 40° 50° in a N.65° W. direction. The dips on the limbs range from 40° to 90° but are most commonly between 55° and 70°. Two zones of slate are rather uniformly drag folded, A set of fan-shaped tension fractures is present in the fold; because of the pitch of the fold these fractures diverge in the direction of pitch and dip toward the core of the fold. These fractures are more numerous near the crest of the fold. Some are filled with dikes or veins or both. A few of the fractures are faults; the Dunmore fissure which lies near the crest of the fold has offset the beds on the north side about 4,500 feet west of those on the south side. This displacement appears to have been largely strike slip or horizontal and the white quartzite in contact with slate near the Sutton mill is the same bed as the one in contact with slate on the highway one-quarter mile south of the Dunmore ore bin. In section B-B-(21) the vertical offset is shown to be 2,800 feet. The actual slip on the fault could not have been less than this amount, but may have been more than 4,500 feet.

The divergent fissures are mineralized especially where the walls are quartzite, but a few large veins extend through the slate bands. Numerous bedding-plane displacements have occurred, and the younger beds on either limb

have slipped westward and upward toward the axis. Little or no ore deposition occurs on bedding-plane faults. Post-volcanic adjustments on the divergent fractures and bedding planes controlled the formation of many of the fissures and faults in the overlying San Juan tuff.

PALEOZOIC-MESOZOIC WEDGE:

The Paleozoic and Mesozoic formations are prominent and extensive to the north and west, but in this area they have been bevelled off between the smooth westward tilted surface on the pre-Cambrian rocks and the irregular base of the horizontal overlying Tertiary formations under the north end of Hayden Mountain. They thus form a wedge whose thin edge probably lies along a nearly north line under the east side of Hayden Mountain and extends toward Ironton Park. The beds are tilted westward at about ten degrees and the upturned edges are truncated by Telluride conglomerate and San Juan tuff. Burbank (9) has suggested that the late Tertiary ore-forming solutions in part rose along the more permeable beds of this wedge and into steep fissures in the base of the Tertiary beds. Fissures similar to those in the San Juan tuff occur in the sedimentary rocks of the wedge although they are not as numerous. The coincidence in direction of the Mineral Farm ore channel in the top of the Leadville limestone with the strike of underlying slate and quartzite bands of the Uncompahgre formation has been pointed out by Burbank, who has also suggested other possibilities of finding

ore south of the Mineral Farm mine under Hayden Mountain. Prospecting and development have as yet produced no ore from bedded deposits in this area.

TERTIARY FISSURES, FAULTS, AND TILTED BEDS:

UPPER UNCOMPAHGRE-CANYON CREEK AREA

A marked contrast exists between the number of fissure veins in the Tertiary rocks and the number in the pre-Cambrian rocks. In Uncompahgre Canyon most of the numerous fissure veins in the San Juan tuff bottom abruptly at the pre-Cambrian contact; furthermore, many of the fissures and veins terminate upward within the tuff, and fissures veins are therefore not so numerous in the upper part of the tuff or in the overlying andesites and latites. The major fissures are upward extensions of fractures and faults that existed in the pre-Cambrian rocks prior to the accumulation of Tertiary rocks. The most conspicuous of these are the divergent tension fractures in the Uncompahgre anticline; they include the Dunmore, Columbus, Thistledown, Chapman, and Ores & Metals fissure veins, and a few fissures that are practically barren or simply occupied by dikes. In addition, a few less extensive fissures are nearly parallel to the local strike of the quartzites and slates of the Uncompahgre formation; these were caused by renewed bedding-plane adjustments after the accumulation of the Tertiary volcanic rocks.

The Dunmore fissure, on which there was from 2,800 to 4,500 feet of displacement in pre-Tertiary time, was extended in to the San Juan tuff by a nearly vertical displacement of 80 feet. The numerous N.10° 15° W. minor fissures that branch from the Dunmore, Columbus, and other major fissures were probably formed by secondary stresses generated by the displacements along the major faults. In this sector no fractures that are radial with respect to the Silverton caldera are indicated, and the area is too distant from the Stony Mountain or Cow Creek intrusive centers of radial thrust to have fractures related to them. All the faults are normal, that is the kind in which the hanging wall has dropped with respect to the footwall. The graben-like structure along the inclined fissure veins in the area near the Sutton mine is probably due to a combination of displacement along the pre-Cambrian bedding planes and westward slipping along bedding-planes near the base of the Paleozoic sedimentary rocks induced by the wright of the superincumbent beds of tertiary age.

The prominence of fractures and hence fissure veins in the lower part of the San Juan tuff is the result of a combination of causes, among the most important of which are (1)the compact, hard, and brittle nature of the rock, and (2)the local impact of vertical and steep stresses generated from the top of the pre-Tertiary blocks. The dying out of the fractures in the upper part of the San Juan

tuff and overlying andesites and latites is caused by the upward dissipation of energy represented by the branching of fractures, and by the inability of clean-cut continuous fractures to form in the less compact shallower beds.

The bedding of the San Juan tuff is generally horizontal around Hayden Mountain, and the small components of dip that can be estimated locally are not uniform in direction. The original dips may have been affected slightly by the tilting of small blocks between fault fissures.

MINERAL POINT-POUGHKEEPSIE GULCH AREA:

The fissures of this area form an extraordinary system of branching, intersecting, and conjugate sets. Although generally of late Tertiary age, their origin is most probably the result of many stresses which changed with igneous activity and broader crustal movements. Some of the fissures of this area are probably upward extensions of older fissures in the non-volcanic basement; some originated with the earliest volcanic activity and were extended upward with and into successive accumulations; and some fissures probably continued to form until the end of volcanism. Late mineralization and the accompanying widespread alteration probably leached and softened masses of rock to an extent that allowed gravitational adjustments or slumpage and hence fracturing to continue long after volcanism and even mineralization had

ceased.

The most prominent feature of the fissure veins of this area is the northeasterly course of the principal set which forms in a general way part of the roughly radial arrangement of fissures with respect to the Silverton caldera. Several of the fissure veins of this set are as much as five miles long. These are neither as straight nor as individual as the Red Mountain-Sneffels or the Sunnyside-Eureka systems. They have principally steep to vertical dips to the southeast, and displacements on them are such that the southeast hanging walls moved down and, as indicated below, perhaps south-westward with respect to the footwalls. The northwestern fissures of this set have little or no measurable displacements in the lower Poughkeepsie and western Mineral Point areas, but displacements are larger in fissures to the southeast. Near the southeast edge of the area the Sewell and Hadley fissure veins dip to the northwest and the dropping of the northwest or hanging wall blocks is considerable. The Mountain Queen vein, dips southeast, but the amount of displacement along it has not yet been determined. In general these fissures are marginal to the more highly faulted and parallel Cinnamon-Rainbow Anaconda fracture zone to the southeast.

In addition to the northeastward-trending set of fissure veins there is an eastward-trending cross set which usually shows a broad convexity to the northeast. This set is principally in upper Poughkeepsie and California gulches and is

roughly parallel to the northeast margin of the Silverton caldera. The marginal eastward-trending fissure veins form a conjugate set; some of them dip southward, but northerly and vertical dips predominate. In general it appears that these fissures may be secondary to parallel but larger faults farther south, such as the Ross Basin fault.

The fissures are generally more numerous and intricate in their branchings in the Burns latite than in the Eureka rhyolite. In the pyroxene andesite unit fissure veins are less numerous and many lose their individual sharpness or identity in wide zones of altered rock. The remarkable exposures of braided, splite, and curved "horsetail" veins in the Lake Como area and on the glacial moors south of Mineral Point are almost without parallel. One of the most important and significant features of the northeast-trending fissure veins, especially near Lake Como, is a widening near or along sharp east turns. The widened turns appear to be a tendency of the northeast-trending fissures to "step over" on certain east-trending fractures, and the widening probably indicates a southwestward shift of the southeast walls.

In the Mineral Point, Poughkeepsie, and Engineer Mountain areas the Silverton volcanic series dips from 10° to 20° N. to NW. This may have been partly caused by a doming uplift in the early stages of deformation, but with the formation of the northeastward-striking fissures the tilting to the northwest was accomplished by dropping of the northwest edges of elongate blocks with reference to their southeast edges.

ORE DEPOSITS:

General Character of Mineral Deposits;

The ores of this general area of the San Juan Mountains have been described variously and in some detail by Ransome, Irving, Bastin, Burbank, Moehlman, and others. In general they are dominantly silceous and the gangue materials may consist of quartz, rhodonite, rhodochrosite, ankerite, pyrite, marcasite, barite, kaolin, sercite, and altered wall rock, which was impregnated and partly replaced by most of these minerals during several stages of vein formation. In addition, fluorite and hematite may be locally abundant. In the early history of local mining, sphalerite, chalcopyrite, and even galena were treated like ordinary gangue. The ore minerals may be auriferous and argentiferous sulfides and sulfosalts, such as galena, sphalerite, chalcopyrite, bornite, tetrahedrite, and chalcocite. Argentite, ruby silver, brittle silver, and gold are sparingly present. Argentite, native silver, and gold may have enriched some deposits near the surface, and cerargyrite, or horn silver, is said to have enriched a few outcrops. Locally, oxidized ore minerals of lead, zinc, and copper are present, as is native sulfur, termed sulfurettes by the miners. These minerals, however, are unimportant, and generally do not extend more than a few tens of feet below the surface. A few lodes have contained ore shoots of tungsten, usually huebnerite, the manganese tungstate, and a few others have

contained sulfbismuthites of lead and silver, such as alaskaite $(Pb,Ag_2)\ S.Bi_2S_3$). Very locally enargite and several rarer minerals have formed.

The usual vein of the region, however, consists dominantly of quartz with more or less pyrite, sphalerite, galena, chalcopyrite, rhodochrosite, or barite; however, concentrations of base-metal minerals (galena, sphalerite, or chalcopyrite) probably can not be depended upon to yield much silver or gold unless they include tetrahedrite or other sulfosalts. Gold and silver are commonly separated from the base-metal shoots in a vein or lode, and siliceous vein matter, particularly the gray quartz, may contain more gold and silver than high-sulfide vein matter. Recorded output from the mines shows no relationship between the tenors of any of the base metals and the silver or gold tenors. Highly argentiferous or auriferous sulfides, silver minerals, and gold usually form only local ore shoots.

The veins are typically vuggy and open. Banded and crusted structures are exceedingly common and well exemplified. Inclusions of shattered wall rock "frozen" in quartz are very abundant and the veins typically show many stages of mineral deposition in which quartz and pyrite are often repeated. One of the most common features of the lodes is the presence of late white coxcomb quartz cutting earlier gray to white quartz and sulfides. Deposition and leaching appear to have alternated in many veins. Although many walls are thoroughly impregnated with

quartz, pyrite, kaolin, sercite, and ankerite, the dominant process of vein formation seems to have been the filling of open fissures. Nearly all the larger or prominent veins have bands of gouge usually at one or both walls as the result of displacements after vein formation.

Silver and gold shoots are commonly separated from the base-metal bearing parts of veins, and it is possible to mine selectively for these in many deposits. Many of the very rich small shipments of the early days were made from deposits in which this separation was pronounced.

TYPES AND ORIGIN OF DEPOSITS:

Three structural and genetic classes of deposits can be recognized. Although these may be mixed in a single deposit, they are largely distinct. The classes described are (1)fissure and cavity fillings, (2)breccia-chimney and breccia-dike deposits, and (3)replacement deposits.

In the 25 square miles covered by Kelley (2) more than 125 miles of veins ranging from 1/2 to 150 feet in width have been mapped Probably the most common width is about three feet. Because of the great width of some vein zones the average width may be between 5 and 10 feet. There is about one billion tons of vein matter in these three districts. Most of the deposits were formed by the filling of open channelways along fault fissures; only

a few were formed in solution cavities in quartzite. The fissure openings were nearly all the result of displacements along curved or undulating fault surfaces. On some fissures the openings were more or less clogged by angular material broken from the walls during faulting. In other depsoits the openings were thin and closely spaced, forming sheeted zones. Most of the openings were along transverse fissures, but a few, especially in strong and prominently bedded rocks such as the pre-Cambrian quartzites, were along bedding planes.

The mineral-forming solutions entered and travelled through many differently shaped and sized channels, as can be seen from the multiplicity of structures in the deposits. Some of the smaller fissures were filled by a single deposition of coxcomb quartz, with a few sulfides interlocking in the middle of the vein. The large fissure veins generally had a longer history, involving repeated opening and filling. Fissures were reopened by expansion of veins barely filled to the middle, by fracturing along and in the walls, or by fracturing irregularly across the vein. Fissures along which movement occurred only once or twice had considerable areas in which the walls remained in tight contact. These areas were only slightly or not at all mineralized. Many of the smaller veins, as well as veins of average length and width, have barren areas or areas

in which the vein matter nearly pinches out. The "swelled" or wide parts of the veins represent areas of the fissure that were opened wider or opened repeatedly.

Mineralization followed a sequence controlled by deep magmatic actions, and any metal introduced at only one particular stage of deposition is obviously confined to channels through which the solutions passed at that time. Only the persistent metals and minerals, or those supplied more or less continuously or over several periods of a sequence, occur continuously along a vein. Pyrite and quartz are of this class.

Some of the early mineral fluids were especially corrosive to quartz in the wall rocks. In the pre-Cambrian quartzites open pockets, caverns, and channels are common. These openings are for the most part very irregular, small, and unrelated to bedding or fractures. They were later more or less filled by quartz and sulfides. At the Mother Cline mine a steep irregular solution chimney was formed by a fluid that was a ready solvent of the quartzite. Later this cavity was filled by vuggy quartz, pyrite, sphalerite, chalcopyrite, galena, and barite. The breccia chimney along the highway 1,000 feet south of the Dunmore tram terminal may have been opened by mineralizing solutions first and later perhaps enlarged and filled with breccia by violently and rapidly escaping solutions and gases. In many places the quartzites of the core of the pre-Cambrian anticline are locally rather porous or cavernous as a result of this early solvent action.

BECCIA-CHIMNEY AND BRECCIA-DIKE DEPOSITS:

In some places fragments ground from the walls of a fissure during faulting were carried through open fissures by rapidly moving solutions which may have expanded to gases during their ascent and escape to regions of lesser pressure. Fissures or channels filled with such transported material are known variously as breccia, clastic, or pebble dikes, chimneys, and pipes. Some fragments appear to have moved great distances as shown by their rounding to cobble- or pebble-like forms and their foreign nature with reference to the inclosing walls. Probably in some places because of constrictions in the channels, little transportation was involved, and rounding was produced by a combination of gas or solution corrosion and bumping of the fragments during boiling.

REPLACEMENT DEPOSITS:

Although fissure and general cavity filling has been the most abundant process of deposition, much "replacement" has also occurred. Replacement effects are common in the ores, as has been illustrated by Moehlman (6) and others in the adjoining districts. The principal replacements, however, have been of gangue by ore minerals or earlier minerals by later ones in a manner that enables the sequence of minerals of veins to be determined. Nevertheless, this replacement is largely confined to the veins and accompanies cavity filling; it is therefore not possible to demonstrate conclusively that a vein three or four feet wide has grown

by replacement of the fissure walls.

Alteration of wall rocks adjacent to the fissure is common along long stretches of one or both walls of many of the fissure veins. 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.

In many deposits small veinlets of quartz, sulfides, or other minerals penetrate the wall rocks in intricate and irregular fashion and appear to have no relationship to joints or fractures. These features are undoubtedly the products of replacement.

Dissemination and "replacement" in the wall rocks adjacent to fissure-filled veins have in a few places formed ore shoots even where the fissure vein is barren or relatively unproductive. The sampling of deposits should not always be limited to the filled part because in some places the adjoining zones of altered rock and the inclusions or "horses" of altered rock within the filled fissures constitute ore.

PERMANENT RECORD
SOUTHBOROUGH, MASS.

Although intersections of veins are well known as favorable positions for ore shoots, it has been pointed out (16) that they have commonly not proved to be ore shoots in most places in the San Juan region; however, the acute and intricate interlacing fissure veins in the Poughkeepsie and Mineral Point systems seem likely to result in ore shoots of this type. Furthermore, the widened turns of some of the veins are the consequence of intersections of fissures. Intersections may also control ore shoots by terminating them in one direction or another; thus, cross fractures or "crossings" as they are termed in some districts, may barren fissures, sheeted zones, or unproductive veins, and they may terminate an ore shoot simply because the displacement on the main fissure vein was limited in its extent by the crossing. The formation of ore shoots at such intersections has been illustrated for an ore shoot in the Sunnyside mine by Hulin (22).

The effect of the kind of rock adjoining the fissure has been emphasized by Moehlman.(6) The influence of the wall rock in the localizing of ore shoots along a fissure may be expressed in three ways: (1)the pattern of its fracturing, (2)its permeability, and (3)its chemical reactivity to ore-forming solutions.

(1)Some rocks such as massive flows may yield a single clean-cut fracture which will maintain a channelway for ore-forming solutions. Other rocks develop sheeting or multiple fractures with much breccia or heavy, impervious gouge. Still other rocks such as breccias or tuffs yield more by

flowage and fail to maintain channelways for ore-forming solutions. Burbank (1) has illustrated the general effect of the physical influence of rock types upon the character of fissuring. The physical properties of a rock and hence the character of the fracturing are also related to depth. Rocks of identical character are relatively less brittle at depth than near the surface.

(2)Some wall rocks, because of their permeability, may exert a sponge-like action and absorb mineralizing solutions rapidly. This action in turn may precipitate metallic minerals from the solution and thus cause a localization of ore; on the other hand, ore minerals may be so thinly disserminated in the adjoining rocks that no ore shoot results. 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.

(3)Moehlman (6) has pointed out that andesite is the most reactive and rhyolite the least reactive to the ore-forming solutions. The contrasts in chemical susceptibility between the volcanic rocks of the San Juan region, however, are not nearly as great as the contrast between limestone and shale, sandstone, or igneous rock. The degree to which differences in chemical or mineralogical composition of these volcanic rocks are influential in localizing ore shoots is doubtful; for example, such differences as those

described by Bastin (19) in which the silver content of a vein in andesite is as much as 150 times that in rhyolite, may be attributable to physical as well as chemical conditions.

The most important influence of the wall rock upon the localization of ore shoots is in determining the manner of fissuring. The manner of fissuring, however, may be more closely controlled by the depth below the surface than by differences in the kind of wall rock. The great majority of rocks in the districts are capable of maintaining open fissures, and the problem of deciphering anyspecific ore-shoot control is therefore more likely to be structural than lithologic. The important fact to bear in mind is that there is a control in each place and that ore shoots do not occur by chance or at random. The determination of control very early in the mining of an ore body is highly important. This determination, however, commonly requires experienced and continuous examination of the ore body and frequently precise and detailed mapping of the vein, including its structural and compositional variations. Occasionally very detailed and intricate methods, such as contouring the vein and even its parts, may be necessary and warranted in order to yield results that will enable extrapolation and successful exploration.

In these and adjoining districts some ore shoots appear to be localized beneath certain volcanic contacts,

and this is commonly ascribed to a damming effect on the rising ore solutions by the overlying rock unit. It has been noted in the Sneffels region, for example, that productive shoots tend to terminate upward below the base of the Potosi rocks. At the Camp Bird mine, although there is a fairly regular termination of the ore shoots at the base of the Picayune volcanic group, some shoots are mined above this contact. The upward termination at a change in rock may be due to a difference in manner of fissuring and maintaining of fissur openings. It may be due also to difference in permeability, but the termination or localization is not necessarily beneath a less permeable rock, for as pointed out by Burbank (8) in the Sneffels-Telluride districts the Potosi rocks are more permeable than the underlying ones in which the ore shoots terminate. The alteration of the "so-called" capping rocks indicates considerable penetration of permeable rocks by the mineralizing solutions, and as Burbank points out probably release of pressure in the porous rocks near the surface caused boiling and hence precipitation of ores immediately below.

In the Poughkeepsie Gulch district there is much evidence that ore shoots are localized in an irregular vertical range near the top of the banded Burns latite and that ore shoots do not continue into the flows, tuffs, and breccias of the overlying pyroxene andesite. As pointed out elsewhere, the veins are less prominent and alteration more

widespread in the upper rocks. The situation is similar along the Tuttle Mountain ridge. The Frank Hough ore shoot may have "mushroomed" in the permeable Henson tuff beneath the overlying rhyolite which again is extensively altered but poorly veined. The Polar Star ore shoot, however, was formed beneath the Henson tuff in the pyroxene andesite even though its altitude is higher than that of the Frank Hough ore body. The Wyoming ore shoot was still lower stratigraphically than the Polar Star ore shoot, and it has been suggested by those operating the mines that better ore made along the flow breccias adjoining the Polar Star and Wyoming veins than in the andesites. On the other hand, it is a noteworthy fact that in many places the rocks are more extensively altered above ore shoots than adjoining them. The depth beneath the surface or level of rapid release of pressure and boiling for the ore solution column may be of greater signnificance to the localization of ore shoots than the physucal or chemical character of the rocks immediately adjoining the ore shoot.

ORE IN DEPTH:

INTRODUCTION:

Kelley (2) states one of the most important geologic problems to be solved is that of the vertical range of ore shoots. Prediction of ore in depth is as difficult as it is practical because of the variable and even conflicting factors of control. At the outset the origin of the ores is a matter of prime importance. Mineral deposits formed by solutions derived from the same deep source as the volcanic rocks may extend downward beyond the limits of practical mining, but the different ore minerals and the structural conditions that permitted their concentration in mineable quantity may be not only irregularly distributed but also restricted in depth. Ore that was originally lean may be enriched at or near the surface through the action of descending water. In some mining districts the only ores worth mining are the result of such enrichment, and the suggestion has been made that the shallow, rich ores of the San Juan region belong to this class of supergene deposits. I believe, however, that the ore shoots of the Mineral Point and adjoining districts were mainly deposited without appreciable subsequent modification by solutions ascending from a deep source and are therefore to be classed as hypogene.

HYPOGENE DEPOSITION:

Early workers in this region, and Ransome (16) in

particular, suggested that the rich ore shoots were supergene and hence were formed by the leaching of primary (hypogene) metals from the deposits during prolonged erosion, and by the continued redeposition and concentration of these metals just below the progressively lowering surface. Ransome considered that such minerals are argentite, polybasite, stephanite, pyargyrite, proustite, and possibly even the tetrahedrite and such sulfbismuthites as alaskaite were supergene. Later microscopic studies of the San Juan ores by Bastin (19) demonstrated that many of the minerals responsible for the high silver content of the ores are hypogene; that is, they were original constituents of the veins formed during or shortly after igneous activity. He found that the minerals tetrahedrite, tennantite, enargite, and the sulfbismuthites were invariably hypogene. Native silver was interpreted to be invariably supergene, and argentite although supergene for the most part was believed to be hypogene in several occurrences. Similarly the brittle silver minerals, polybasite and stephanite were believed by Bastin to be mostly hypogenein the Ouray-Telluride area, in the Red Mountain district he considered them to be mostly supergene. Burbank (8) however, considered the ruby silver of the Red Mountain chimney deposits to be hypogene.

The recent tendency among those who have investigated

silver minerals is to regard practically all the sulfides and sulfosalts as hypogene with the exception of argentite which may be supergene. The fact that such minerals as the brittle silvers are among the last minerals to be deposited in the hypogene sequence makes it difficult to disprove that they might be supergene. The silver-bearing minerals, however, are not always late to form. At the Dunmore mine the ore shoot containing chalcopyrite and silver-bearing aikinite ($Cu_2S.PbS.Bi_2S_3$) is cut by veins containing sphalerite and galena. Native silver is commonly supergene especially if found close to the bottom of the oxidized zone. Chalcocite, which in the "sooty" variety is commonly assumed to be supergene, is uncommon in this area. Marcasite may be supergene in origin and its presence might be evidence of some secondary sulfide deposition, but the marcasite found at such mines as the San Juan Chief, Old Lout, and Emperor Wilhelm is intergrown with quartz and sulfides in a manner that makes its hypogene origin certain.

The silver content and perhaps the gold content have decreased to some extent with depth in certain ore shoots and this is one reason for suspecting supergene concentration of these metals near the surface. For example the average precious-metal content of ores shipped from a large number of mines is plotted against the altitudes of the different mines. The distribution of

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plotted points fails to show any definite relation between rich ore and high altitude; of the two richest silver ores one was mined at an altitude of 12,150 feet and the other at an altitude of 9,750 feet. Similar graphic analyses of ores shipped support the following conclusions:

(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.

Ores containing the gray coppers, tetrahedrite and tennantite, are found throughout almost the entire vertical range of exposures. Aikinite is found in the Dunmore ore shoot at an altitude of 9,250 feet, and alaskaite in the Alaska mine is at an altitude of 12,400 feet. Tungsten in the form of huebnerite occurs mostly at low altitudes in the areas under consideration, and its identification at the Mountain Monarch mine (9,993)-feet) is the highest definitely recorded. Its greater vertical range is indicated, however, in the Cement Creek area north of Silverton where in the vicinity of the Adams lode it is found at an altitude about 11,500 feet.

The decrease in silver content of certain ore shoots with depth has given rise to the idea that the rich silver ores are shallow and, therefore, that the base-metal content may be greater at lower altitudes. There is, however

no such consistent relation. Base-metal ores of good grade are found at high altitudes, for example, in the rich lead-ore shoot of the Mountain Queen mine at an altitude of nearly 12,800 feet and in the Frank Hough copper ore body whose altitude ranges from 12,500 to 12,740 feet. The output of base-metal ores, in fact, has been greater from veins at high altitudes than from those at low altitudes, but this difference undoubtedly is largely due to the fact that the area lying between altitudes of 11,000 and 13,000 feet is more than twice as great as that lying between altitudes of 9,000 and 10,000 feet. All the Mineral Point, California Gulch, and Engineer Mountain areas, and nearly all the Poughkeepsie Gulch area are above 11,000 feet in altitude. Partly for this same reason, the rich silver ores are less abundant below the 11,000 foot contour than above it. Another reason for this difference is that the Upper Uncompahgre and lower Canyon Creek areas, where most of the low-altitude ground is located, are underlain by Mesozoic, Paleozoic, and pre-Cambrian rocks, in which the fissure veins are less numerous than elsewhere. Some of the evidence for better grade in the deposits of higher altitude seems to be the result of the greater selectivity in mining which is necessarily practiced on the account of the inaccessibility of the region and the consequent high cost of mining. It may also be due to the very small amount of exploratory work that has been done be-

low the bottoms of the high-grade stopes.

Mining in adjoining districts seems to have demonstrated that silver ores are commonly richer in the shallower parts of the veins or in those parts that were closest to the surface when ore deposition took place. Although the relative position of this original surface and the irregularities and relief that is possessed are quite speculative, it is, nevertheless, of considerable significance with regard to both hppogene and supergene deposition to establish it at least generally. The restoration of the surface that existed at the time of vein deposition requires not only a knowledge of the age of the mineralization but also the former extent and thickness of the younger volcanic units that have been eroded from the region. The youngest premineral extrusive rocks within the region under consideration are the lower members of the Potosi volcanic series of Miocene age. Twelve miles to the east upper members of this series are overlain by the Fisher latite-andesite, which is also thought to be of Miocene but may be of the Pliocene age. The pre-mineral intrusive rocks of the region were intruded at different times, but some of them cut the local lower Potosi rocks; they may therefore be equivalent to the upper Potosi flows, or to the Fisher latite-andesite, or they may have been intruded still later, in Pliocene time. Hypogene ore deposition is believed to have taken place at the close of volcanic activity, either in late

Miocene or more likely in early Pliocene time.

Although the Potosi volcanic series locally attained thicknesses of several thousand feet far to the east, it is very doubtful whether its upper members extended as far west as Engineer Mountain, where only a part of the lowest member remains today. That an appreciable thickness did cover the region as late as early Pleistocene time is proved by the dominance of Potosi boulders in the moraines of early (Cerro) glaciers that eroded the San Juan Mountains before the present deep canyons were formed. It is doubtful whether any appreciable thickness of the Fisher latite-andesite ever extended as far west as Engineer Mountain. Because of this vagueness of evidence, the thickness of Potosi and any later rocks that covered the region at the time of mineral deposition can only be guessed, but it is not believed to have been much if any more than 2,000 feet. Such a thickness if restored would bring the surface of the region to an altitude of about 15,000 feet. The highest ore bodies now existing in the region would therefore have formed at a depth of 2,500 feet or less and the lowest about 5,800 feet below this surface. The following table shows the approximate depth of deposition and vertical range of altitude several prominent ore shoots.

VERTICAL RANGE OF HIGH-GRADE ORE SHOOTS:

Mine	Altitude of ore shoots (feet)	Average depth of deposition below the original surface (feet)
Polar Star	12,800-13,100	2,500
Ben Butler	12,100-12,200	3,000
Old Lout	11,000-11,500	3,500
Guadaloupe	11,000-11,100	4,000
Mickey Breen	9,700-10,600	4,500
Dunmore	9,100 - 9,300	5,800

As erosion was in progress at the time of ore deposition and as displacement along faults before and during ore deposition tended to accentuate relief, it may be that the highest ore bodies were formed at depths of no more than 2,000 feet. Many of the ore shoots thus far mined were bottomed or became of lower grade within a short vertical distance. Others were too costly to mine for more than a few tens or hundreds of feet in depth. Of the shoots mined to date, however, those that remain unbottomed are more numerous than those that have been bottomed. Individual ore shoots probably have a large range in both horizontal and vertical dimensions. Some may extend for only a few tens of feet below the present surface; others may not extend far vertically but may pitch at low angles for rather long distances; and others still may have deep continuous roots extending into the pre-Cambrian basement.

Since the aggregate vertical range of ore shoots already worked is over 4,000 feet, it is reasonable to wonder whether ore shoots similar to the Old Lout and Mickey Breen, which were mined at relatively moderate to

low altitudes, may not be waiting discovery at equally low altitudes beneath such high-altitude shoots as the Polar Star or Mountain Queen. It is quite possible that exposed shoots, and high-altitude shoots especially, are guides 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.

Most of the ore shoots end, or perhaps more appropriately are interrupted, in depth just as they do along the strike, some of them abruptly. As the horizontal distance between shoots may be tens or hundreds of feet, it could be argued that similar barren or low-grade vertical intervals are to be expected. Both the horizontal and vertical distributions of primary ore shoots, however, depend upon the courses followed by ore-forming solutions. These solutions, starting from a deep source and following the more open parts of fissures, maintained a general upward course but were locally deflected toward a horizontal course, and here and there may even have turned to a downward course for appreciable distances.

The suggestion of chainlike successions of ore shoots one above or beyond the other does not imply that an ore shoot found by deeper exploration will be of the same grade or metalcontent as one at higher levels in the same

MINE OR VEIN	SOURCE	ELEVATION	VERTICAL RANGE OF ORE
Treasury Tunnel	-AIME T.P. 2349	-12325-10625	1700
Silver Lake	USGS Bull 182		1000
Barstow	(8)	11200-10750	450
Virginius	(23)-(8)	12420-9120	3300
Humboldt	(23)-(8)	12625-11450	1200
Liberty Belle	(23)-(8)	12100-10600	1500
Smuggler-Union	(23)-(8)	11900-9600	2300
Campbird	(24)-(8)	11700- 8700	3000
Bachelor	(12)	9200-8000	1200
Calliope	(12)	9000-8700	300

vein; on the contrary, changes in metal content with depth are as irregular as horizontal changes along the same vein from one mine to another.

A similar tabulation of ore shoots with relation to altitude and vertical extent was attempted for the Telluride-Red Mountain area, and will be found on an accompanying sheet. It is incomplete owing to the difficulties encountered in assembling the necessary data.

In this area the Vertical range of ore is 3900 feet and the largest ore shoot has a height of 3300 feet.

The Guadaloupe ores, were chiefly of copper on the York level (alt. 10,983 feet) but on the Lucky Twenty level (alt. 10,315 feet) were of lead and zinc. Although it is still somewhat early for an appraisal, it appears that the Black Bear vein contains relatively more copper on the Treasury Tunnel level than in the blocked-out ores of the upper levels.

It is obvious from the foregoing consideration that the bottoming of a high-grade ore shoot is not proof that all the productive ground in the vein has been exhausted. The interruptions or discontinuties in ore shoots in depth, as along the strike, are largely due to structural factors. Further prospecting, whether along the strike, pitch, or dip of the vein should be based on a close study of the details of fracturing and mineral composition of the vein material. It is to be expected that the number of favorable openings decreases with depth, as the increasingly greater pressure tends to prevent them from forming or to close them soon after they have been formed. It is also theoretically true that the low-temperature silver minerals are to be expected in greatest quantity at shallow levels, but the differences in wall-rock temperatures to depths as great as that of the local pre-Cambrian basement surface are doubtless so small as to have little influence in determining the level at which ore-forming solutions would become sufficiently saturated by cooling to deposit the

minerals. In short the downward limit of mining is most likely to be determined by the scarcity of favorable structural features and the cost of exploration.

The distribution and grade of ore shoots may be more closely related to the different structural features as described under "Formation of primary ore shoots" than to depth or to distance from volcanic centers. Probably the most important overall structural feature is the fact, that most of the numerous veins in volcanic rocks of the Upper Uncompahgre district bottom at or slightly above the pre-Cambrian basement. A similar condition may be expected in the Mineral Point and adjoining districts. A greater proportion of the veins in these districts, however, may continue into the basement because displacements along them are greater and they are closer to eruptive centers where more continuous fissuring indepth would be expected. The surface of the pre-Cambrian basement beneath Mineral Point and Poughkeepsie Gulch probably lies near an altitude of 10,000 feet; much material therefore remains unexplored even above that altitude, and it is reasonable to conclude that deeper prospecting of veins with due regard to surface ore shoots and local factors of structural control is justified.

INDICATIONS OF SUPERGENE DEPOSITION:

The quantity of oxidized ore in the form of such minerals as cerussite, anglesite, cerargyrite, malachite, and smithsonite is small, and significant occurrences are restricted to positions very near the present surface, mostly along high ridges and vallye sides. The quantity of native silver or secondary sulfides in the form of argentite, chalcocite, and proustite is even much less. Cerargyrite or "horn silver," an undoubted supergene mineral, is unreported in these and immediately adjoining districts, a fact noted by Bastin who, however, suggested the absence could possibly be attributed to low chlorine content of most of the surface waters. The manganese minerals, rhodochrosite and rhodonite, are common in many veins, and their oxidation could start a process favorable to supergene concentration of gold. The high gold content (from several tenths of an ounce to several ounces to the ton) in some of the high-altitude mines of the districts has suggested enrichment to some observers.

During most of late glacial and post-glacial time conditions for complete oxidation, solution, and supergene enrichment have been unfavorable. On the other hand, the great relief, open channels, and vigourous ground-water circulation have made possible local partial oixidation and supergene deposition to great depths.

Local oxidation of pyrite to limonite is present in the Black Bear vein on the Treasury Tunnel level, and similar effects were noted commonly in the veins cut by the Frisco tunnel. Bastin cited examples of spotty oxidation to depths of 2,400 feet in the Smuggler-Union and Liberty Bell mines, and noted secondary silver minerals.

Small veinlets of secondary chalcocite and native silver replacing chalcopyrite were described by Bastin from a depth of 650 feet in the Wedge mine.

At the Lost Day mine at an altitude of 11,700 feet on the west side of Brown Mountain masses of cerussite were mined from landslide that is probably post-Durango and pre-Wisconsin in age. Although the cerussite was the principal ore mineral mined in the open cuts, remnants of galena were found 15 to 20 feet below the surface. Considerable dense gray anglesite has been found recently along the 1,700-foot level in the Shenandoah-Dives vein at depths of only a few tens of feet beneath the surface.

In the Engineer Mountain area ores in the Engineer and Wyoming mines, which are located in the high divide, contained secondary sulfur termed "black sulfurettes," small shipments of which are said to have contained 1.5 to 2.5 ounces of gold and 180 to 250 ounces of silver to the ton. In the Engineer mine the "black sulfurettes" formed coatings on and filled cracks in ore that had been honeycombed by the leaching of sphalerite.

In the Wyoming mine a narrow streak of gray porous quartz contained wire silver, which like the "black sulfurettes" is generally formed at or just below the base of the oxidized zone.

The Frank Hough mine, which is located near the head of the glaciated valley at the north slope of Engineer Mountain, was reported by Ransome, on the basis of specimens collected on the dump in 1899, to consist chiefly of chalcocite, most of it closely intergrown with quartz and associated with a little chalcopyrite and tetrahedrite. Although considerable mining had been done in the interim, my examination of the dump in 1942, as well as microscopic study of polished ore specimens, failed to detect any chalcocite. The specimens were of typical primary ore containing tetrahedrite and hessite which may have been sufficiently abundant in the ore mined in the early days to account for the high silver content. It is likely but not certain that the chalcocite noted by Ransome was supergene. In keeping with this evidence and the "black sulfurettes" and native silver in the Wyoming mine, it is possible that argentite and perhaps proustite in the Polar Star and neighboring mines were supergene; they could equally well, however, be products of hypogene concentration controlled in their position by structure, pressure, and temperature.

The description of the physiographic history of the San Juan Mountains by Atwood and Mather (3) in which they recognized several past periods of erosion in the region raises the question whether older oxidized and enriched ore shoots might not have formed with reference to the ancient surfaces. 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. According to Atwood and Mather there have been two long periods of weathering and one period of much shorter duration, though still long enough to permit deep weathering in places.

They concluded that the first period was sufficient for the former mountains, developed in late Tertiary or Pliocene time, to be worn down to a surface of low relief, named the San Juan peneplain. As the ore deposits also are believed to have formed in Pliocene time, it is doubtful whether this very old erosion surface was formed late enough to have permitted any weathering of the deposits. This surface was in part covered by post-mineral (?) lava flows of the Hinsdale volcanic series, large remnants of which remain 17 miles and more east of Mineral Point, but whether these flows once extended as far west as Mineral Point is not known. Atwood and Mather have suggested that the summit area called American Flats in

and beyond the northeast corner of the area under consideration, may be a remnant of the San Juan peneplain surface. If so, any rocks of the Hinsdale series that may have covered it and thereby helped to protect the local ore deposits from oxidation were removed during some later cycle of erosion.

Whether American Flats was really a part of the San Juan peneplain is also a question. It is probable that this area was still overlain by a very appreciable thickness of the Potosi volcanic series after the peneplain had been formed, and that these Potosi rocks remained until a late stage of the next, or Florida, erosion cycle. When these rocks were once removed the underlying soft Henson tuff was rapidly eroded, forming the present nearly plain surface floored by pyroxene andesite and lower members of the Silverton volcanic series. If all this erosion took place during later stages of erosion, it seems unlikely that the veins now exposed in the American Flats area could have been near enough to the surface during San Juan peneplain time to have been subjected to any weathering.

During the transition from Pliocene to Pleistocene (early Quaternary) time the San Juan area was uplifted markedly which started along period of broad valley cutting. This period was interrupted by the first and greatest of three stages of glaciation. Glaciers during the first or Cerro glacial stage covered not only the broad valleys but the intervening areas. Remnants of its moraines

are found in the foothills, particularly at Cerro summit and in the area east of the Uncompahgre River 1,000 feet above the present valley bottoms.

The Cerro moraines, or till, in this area are composed largely of latite fragments belonging to the Potosi volcanic series, which evidently still covered much of the mountain area as far south as Mineral Point.

The Cerro glacial stage was followed by a long period of weathering and stream erosion, during which the rocks of the Potosi volcanic series were largely removed from the higher mountains, and large quantities of gravel were deposited in the foothill areas and along the larger river valleys. The entire period, from pre-Cerro uplift to and including the deposition of the gravel, is known as the Florida erosion cycle. During the long, later part of this cycle the Cerro moraines became thoroughly weathered and the boulders in them were reduced to the softness of soil. It is noteworthy that Atwood and Mather do not mention the presence of any fragments of vein material in these thoroughly weathered moraines, especially as such durable material as vein quartz would have been conspicuous even though scarce, in contrast to the thoroughly decomposed rock fragments. It seems likely then that the veins of the Mineral Point and adjoining districts did not become exposed to erosion until the long interval of weathering that followed the Cerro glacial stage.

It appears, therefore, that such surfaces as American Flats and Mineral Point are the result of late Florida and later erosion. Their general level and development as flat surfaces may have been the result of the broad valley erosion of the Florida cycle, but they doubtless have been somewhat lowered and modified by subsequent glaciation and canyon cutting. The lowering of the Florida surface probably did not exceed a few hundred feet except in the late canyons.

The Florida erosion cycle was closed by another uplift which started a cycle of canyon cutting. During this cycle The Florida surface was widely destroyed, and all but the lower parts of the present canyons were cut before stream erosion was interrupted by the Durango stage of glaciation. During this stage the products of weathering in the districts under consideration were largely removed. This stage was followed by another interval of weathering which, although not so long as that following Cerro glaciation, was sufficient for the Durango till, notably in the vicinity of Lake City, to become deeply weathered and extensively eroded. During this post-Durango interval the Uncompahgre River deepened its valley more than 400 feet in the vicinity of Ridgeway. South of Ouray the deepening must also have been very appreciable, though the deeper canyon walls are so thoroughly merged with those cut in pre-Durango time that no separation of the two intervals has been recognized.

This deepening and the consequent lowering of ground-water level afforded further opportunity for the oxidation and enrichment of ore in the Mineral Point and Engineer Mountain area, which was beyond the reach of canyon cutting, but this opportunity was probably lessened to some degree by the cold climate that prevailed in these high areas.

This appreciable though relatively short interval was followed by still another uplift and by the third or Wisconsin stage of glaciation, during which any newly accumulated oxidized material was largely removed. Since Wisconsin time some additional canyon cutting has taken place. Local gorgelike deepening along the Uncompahgre River near the Connie mine is nearly 200 feet, and in Canyon Creek above Box Canyon it is somewhat more.

The conditions and opportunities for oxidation and sulfide enrichment of ore deposits were probably but little better during the interval between Durango and Wisconsin time than the recent and present time. Therefore, the most effective period for supergene deposition was during late Florida time, but the only remnants of the Florida erosion surface in the region have been so effectively scoured by the Durango and Wisconsin glaciers that little evidence of oxidation remains on them. Only at the summit of Engineer Mountain and in the high spurs extending northward and eastward from it would there be much likelihood of finding any remnants of oxidized ore; it is there that the "black sulfurettes" and wire silver in the Wyoming and

Engineer mines were found. Even these minerals are indicative of only the bottom of the zone of oxidation, and imply that an indefinite thickness of oxidized mineralized ground must have been removed.

The shallow ores in other nearby mines, like the Polar Star and possibly the Frank Hough, are so close to the oxidized zone that they may have received some enrichment during Florida time, as suggested by the presence of argentite and proustite; but, as already stated, the mere presence of these minerals is not proof of enrichment.

The same possibility exists for the Old Lout mine near the west edge of the Mineral Point surface, the Alaska mine high in Poughkeepsie Gulch, the upper workings of the Silver Link mine, and the Royal Consort vein at the Mickey Breen mine where in each place highvalues of silver and gold were contained in ores that were probably not far below the old Florida surface. At the Alaska mine the high silver content is known definitely tobe associated with the hypogene mineral alaskaite. Similarly the Old Lout ores have been described as containing bismuthites. At the Silver Link mine the best ore was in solid quartz, suggestive of a hypogene occurrence, and it seems likely that argentiferous sulfosalts may have been responsible for the high silver values in the Royal Consort as well as the Silver Link. The richest ores at the Wewissa mine (alt. 11,688 feet) contained pure sulfide intergrowths of tetrahedrite, galena, and chalcopyrite. The best ore in the upper workings of the Mickey Breen vein and in the Mother

Cline appear to be too far below the old Florida surface to have received enrichment.

Summing up the foregoing discussion, the very shallow ores protected from severe glaciation and canyon cutting along the remote Engineer Mountain divide may indicate some enrichment in or just below the oxidized zone related to the Florida surface. Although ores containing argentite and proustite at the Polar Star mine, native silver at the Wyoming mine, and chalcocite at the Frank Hough mine may owe their richness partly to supergene deposition, it seems more than fortuitous that the Wyoming ores consistently contained bismuthites known to be argentiferous and hypogene elseqhere and that hessite occurred in the Frank Hough ores.

A strong contrast to the Mineral Point and adjoining districts is offered by the Creede district, Colorado. There the Amethyst vein, which crops out in an unglaciated area approximating the level of the Florida surface, has been leached to a depth ranging from 150 to 300 feet, below which it has been oxidized and enriched to amaximum depth of about 1,000 feet (20). Nativel silver, cerargyrite, and gold are the principal minerals, and partly oxidized sulfides are abundant, especially on the lower levels. No evidence of much sulfide enrichment and none of the complex antimony or arsenic sulfosalts of silver have been fould either in the mine or during careful scrutiny of cabinets containg specimens of the

richer ores. "Argentite has been noted in the Mollie S ore and is doubtless present also as a secondary mineral in the ore of the Amethyst lode. This general absenceof sulfosalts, together with the lack of proof that even argentite is secondary, lends little support to the suggestion that these minerals might be secondary in the Mineral Point and adjoining areas.

It may be concluded that some oxidation and enrichment may be still preserved in the high and remote areas such as along the Engineer Mountain divide. Some of this supergene deposition may have formed in recent time, some during the post-Durango interval, and some during the Florida erosion cycle. Although the Florida period was the longest and most favorable in which supergene deposits could form, they have been so completely obliterated or modified subsequently as to leave much uncertainty as to origin. Most of the few deposits that could conceivably owe the high tenor of their ores to supergene deposition have been already rather thoroughly exploited so that their origin is of less practical significance than it was in the beginning.

From the viewpoint of successful mining a decline of silver and gold content in depth because of hypogene zoning is just as serious as a decline at the base of a zone of supergene enrichment. There is much evidence that what

greater silver and gold values do occur at high altitudes are the result of an original hypogene zoning, but as pointed out above, whether this condition actually exists in this area is not fully established by the records of shipments of ore. There is sound geologic evidence that much additional good hypogene ore exists below and beyond deposits already explored. It has been established on the basis of mining and the vertical distribution of deposits that there is a recurrence if not persistence of ore shoots of several varieties in depth through a 4,000-foot range in altitude. The ore shoots are dominantly hypogene, and in the matter of depth or vertical range show little or no relation to the present or past erosion surfaces. A thorough correlation and evaluation of factors that have controlled the distribution of ore shoots and the character and tenor of the ore require still further study. Deeper prospecting with due regard to local channels, centers of mineralization, and structural controls is justified.

Notes From: W.S. Burbank, "Revision of the Geologic Structure and Stratigraphy of the Ouray District, etc", Proc Colo Sci Soc vol 12 no 6

Although the actual age relations of the monzonite-porphyry intrusions to the surface eruptions has not been determined, we may conclude that an older group of laccolithic and volcanic mountains existed in what is now the site of the western San Juan Mountains, and that the porphyry intrusions at Ouray represent one of the centers of igneous activity around which these mountains were built.

The Ouray stock shows evidence of having penetrated the Mancos shale, and possibly may have penetrated some of the overlying formations. It would appear that fissures were formed reaching to the surface as indicated by the intense hydrothermal alteration in the vicinity of the intrusion. In the central part of the stock the sedimentary rocks have been displaced bodily upward, but are upturned slightly on the northern edge. At the base of the Mancos shale large laccolithic bodies spread laterally from near this stock. Parts of them are still preserved both to north and south of the stock on the east of the Uncompahgre valley and near Twin Peaks on the west side of the valley. It appears likely however that a considerable part of the Ouray stock and part of the laccolithic bodies are concealed beneath the San Juan tuff north-east or east of the "Blowout."

The sharp upturning of the Paleozoic formations on the north flank of the stock is not related to the intrusion

of this body, as is suggested by a view from the valley, although it has been locally accentuated by the intrusion of dikes and sills and by drag near the edge of the stock. It is mainly caused by a monoclinal fold of pre-Dolores (pre-Triassic) age, and it may be seen from Figure 1. that the overlying Mesozoic beds truncate the upturned edges of the Paleozoic formations. This sharp monoclinal fold is well exposed about a mile west of the "Blowout" on the opposite side of the Uncompahgre valley.

YOUNGER INTRUSIVE ROCKS:

General Features.

In the immediate vicinity of Ouray the younger intrusive rocks are represented by only a few dikes cutting the San Juan tuff. Representatives of these dikes are the "Germania" dike of The Amphitheatre east of Ouray, the Bridalveil Creek dike, and the Calliope dike just north of Dexter Creek. All of these dikes radiate from a later Teritiary volcanic center near the head of Cow Creek, 4 or 5 miles east of the Ouray district. Between Ouray and Telluride another group is represented by the Mt. Sneffels-Stony Mountain stock, and by numerous dikes occupying fissures in the Tertiary lavas in the vicinity of, and southwest of, this large stock. South of Ouray in the west central part of the Silverton quadrangle the late Tertiary intrusions are represented by the porphyry stocks and dikes of the Red Mountain district.

As yet there has been no further detailed study of the rocks of the late Teriary intrusive groups, and the following brief discussion is based upon the descriptions in the Ouray, Telluride, and Silverton folios, and upon recent preliminary examination of some of the intrusions.

AGE AND STRUCTURE:

As all of the intrusive rocks of the Tertiary group intrude the San Juan tuff, and those of Stony Mountain and Mt. Sneffels intrude the Silverton and Potosi lavas, it is presumed that the majority of the intrusions are of post-Potosi, hence of Miocene or later age. In the area between Ouray, Telluride, and Red Mountain the Tertiary intrusions have assumed the form of stocks and dikes, and so far as known have not been found as sills and laccoliths in the Paleozoic and Mesozoic formations. There are, however, no exposures of the under-lying sedimentary rocks near the stocks mentioned, so the form which these larger Tertiary intrusions assume in the underlying formations is not known. The number of dikes which occupy the northwest fissures in the area between the Stony Mountain stock and the Camp Bird mine suggest the possibility of some relation between the intrusion of this stock and the fissure system of this area. There are, however, a great many more fissures and veins than dikes. The close association shown between the Ouray stock and the Cretaceous mineralization either is lacking, or is less evident, between the late Tertiary stocks and the Tertiary

the Tertiary veins.

At the beginning of the earlier period of volcanic activity the western San Juan region was covered by Upper Cretaceous formations, which totaled at least 4,000 feet in thickness. These were unconformably covered by late Cretaceous or early Eocene formations, which contain volcanic debris, and so overlap as to indicate a domal uplift of the region. This uplift was accompanied by the intrusion of monzonite porphyry mainly in the form of stocks and laccoliths. At the close of this igneous activity the first period of ore deposition took place.

During Eocene time erosion carved this great dome into the first generation of the San Juan Mountains, and high altitudes gave rise for a time to glaciation, but continued erosion finally culminated in the formation of the Eocene peneplain. In the central part of the eroded dome, except where the larger and more resistant masses of monzonite porphyry remained as hills surmounting the peneplain and thus protected the underlying formations, the Upper Cretaceous formations were entirely removed, and the older formations were extensively eroded. In the Ouray district nearly all of the Upper Cretaceous formations and locally all of the Morrison formation were destroyed. During this long period of erosion in early Eocene time some of the mineral deposits also must have been totally destroyed, while others, notably those in the sedimentary rocks

at Ouray, were partly exposed to weathering.

In later Eocene time the Telluride conglomerate was deposited upon the peneplain. The deposition of the conglomerate was probably accompanied by minor transportation and concentration of gold in some of the stream deposits.

Following the deposition of the Telluride conglomerate there was another period of erosion, which was followed by the great Tertiary volcanic eruptions that formed the San Juan tuff, the Silverton series, and the Potosi series. These eruptions probably occurred during Oligocene or Miocene time, forming a volcanic plateau, and burying the ore deposits of the first epoch to a great depth, possibly greater than their original depth of formation. In late Miocene or post-Miocene time, following the eruption of the Potosi lavas, the second major group of intrusive rocks penetrated the younger volcanic formations. Widespread fissuring and some tilting of the formations occurred, and closely following these disturbances came the second major mineralization of the San Juan region.

With the cessation of the volcanism, erosion and dissection of the volcanic plateau began, and another generation of the San Juan Mountains was formed. According to Atwood these perhaps originally rose 3,000 or 4,000 feet above the present summits. After a considerable period of erosion, warping or doming of the mountain area again occurr-

ed and deep valleys were cut by the rejuvenated streams and were later occupied by the early Pleistocene glaciers. Uplifting of the range continued throughout Pleistocene time, and several stages of glaciation and valley cutting have been recognized. The present streams are still actively cutting their valleys. Transportation and deposition of debris during both Pleistocene and Recent time caused further concentration of gold in placers.

ORE DEPOSITS:

Metallogenic Epochs of the Western San Juan Mts.

From this historical summary it is clear that the two major epochs of primary ore deposition took place under very different geologic conditions. The conditions that favored laccolithic intrusions during late Cretaceous and early Eocene time also favored the development of "Blanket" replacement ore bodies. The Ouray stock, gives evidence of having pierced the Mancos shale, to the extent that fissures found in and close by it permitted the escape of gases and vapors to the surface; but in the surrounding area fissures penetrated upward into the yielding shales for only short distances, and ore-depositing solutions rising along them were forced to spread laterally and seek other channels to places of lower pressure.

Sedimentary beds of comparatively great permeability therefore served as channels for the lateral diversion of the ore-bearing solutions. Those permeable beds that were

overlain by impermeable shale horizong were especially favorable for diverting the solutions for great distances in nearly horizontal directions. Ore deposits of the blanket type were therefore formed in a number of these beds. In the Ouray district there were also formed some deposits more typical of fissure veins, and some contact-metamorphic deposits near the Ouray stock where higher temperatures prevailed.

The ores of the first period contain gold, silver, lead, zinc, and minor amounts of copper. The most important deposits, however, near Ouray have been lead-zinc veins and associated replacement deposits containing high grade silver ores. Low grade lead and zinc replacementdeposits with much barite are also particularly characteristic of this period. The gold-bearing ores, at least near Ouray, differ from the gold-bearing deposits of later Tertiary age in that they are generally pyritic and contain tellurides associated with native gold. Theyhave been of somewhat less economic importance than the silver ores, and comprise both veins and "blanket" deposits.

As mentioned above, the deposition of the Telluride conglomerate was accompanied by minor transportaion and concentration of gold in placers, and the period of formation of the conglomerate may therefore be considered as one of the minor metallogenetic epochs in the history of the San Juan region; but, so far as known, the concentration of gold in the Telluride conglomerate was not sufficient to produce placer

deposits of commercial value, apparently because of the finely divided state of the gold, and its occurrence partly as tellurides, in the primary deposits of the first period of mineralization.

The geologic conditions during the second important metallogenetic epoch are well shown near the Ouray district, where a large part of the Upper Cretaceous sedimentary rocks had been removed by erosion before the building of the Tertiary volcanic plateau. In a few places where the softer shales were protected by laccolithic bodies comparatively thin layers of them were preserved beneath the Tertiary lavas. The late Tertiary intrusions consequently invaded a cover consisting mainly of the more rigid Paleozoic and pre-Cambrian rocks, and great thicknesses of rigid volcanic formations. Under these conditions the fissures which were formed extended from great depths probably to the surface of the volcanic plateau. The conditions which were responsible for the lateral diversion of the metal-bearing solutions in the first epch had been largely destroyed by erosion, and as a result the tendency for the formation of the blanket type deposit was generally absent during late Tertiary time. Although some ore deposition did take place in the underlying basement of sedimentary and metamorphic rocks, the most important ore deposits of this period have been found within volcanic formations. These conclusions are obviously intended to apply strictly to those areas in the Ouray,

Telluride, and Silverton quadrangles, where the geologic conditions outlined above have prevailed. It is conceivable, though not proved, that in areas where greater thicknesses of the Upper Cretaceous formations were preserved from Eocene erosion, ore-forming conditions approaching those of the earlier epoch may have existed during late Tertiary time.

The ores of the late Tertiary period are like those of the first period in containing the metals gold, silver, lead, zinc, and copper, but the deposits are of somewhat different character mineralogically. The principal gold deposits of this period consist of native gold in quartz veins, as contrasted with the pyritic gold deposits of the first epoch. The silver-bearing veins appear to differ somewhat in the details of their mineralogy. The relative proportions of the different metals in the deposits of the two periods is as yet unknown, as the individual deposits of the two periods have not been completely differentiated in other parts of the San Juan region.

The final epoch of gold concentration in the western San Juan mountains was associated with the formation of stream deposits during Pleistocene and Recent time. Some placer deposits of this period have been mined in the San Juan region and have proved of greater importance than those in the Telluride conglomerate.

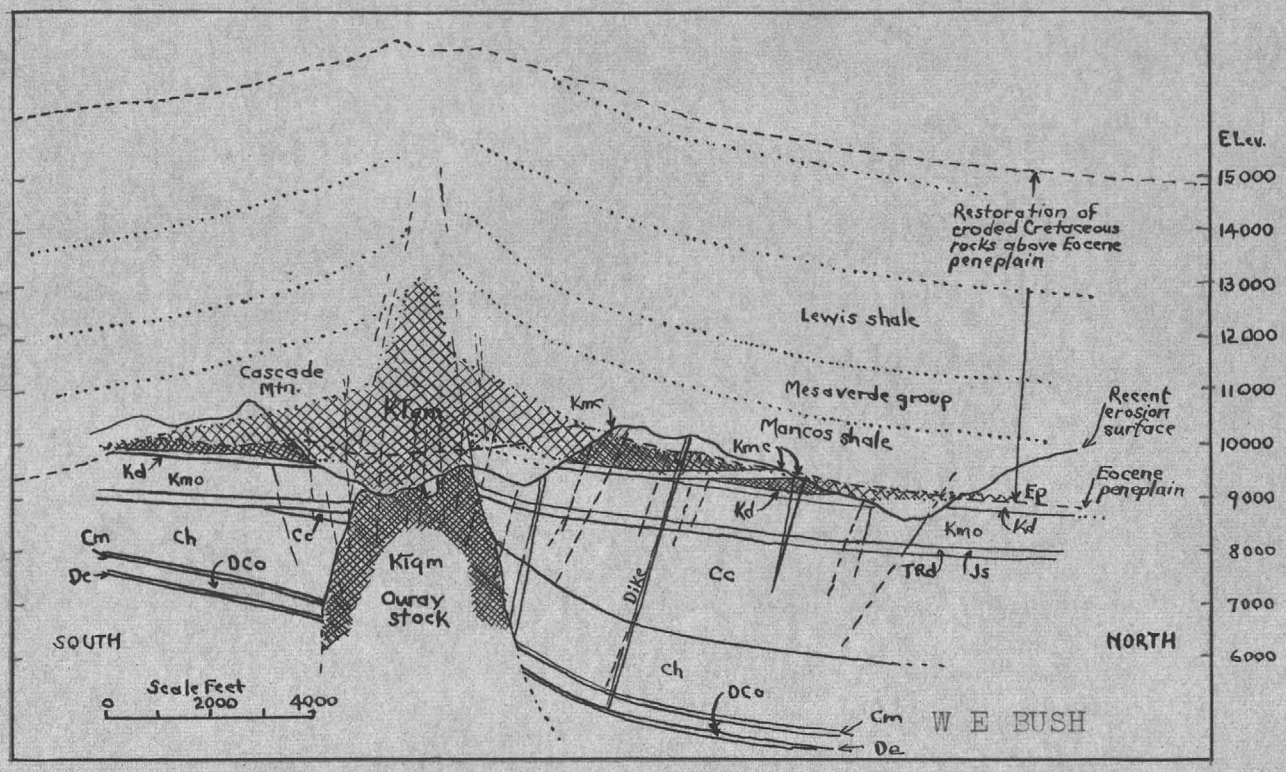
There is still another epoch of mineralization, repre-

sented by deposits in the sedimentary formations along the western slope of the San Juan mountains, which is of considerable importance. These deposits contain concentrations of copper, vanadium, uranium, and radium, but as they are not associated with those of known igneous origin, their relation to the other events in the metallogenetic history of the San Juan region is not known. They are found in rocks of Jurassic and Lower Cretaceous (?) age.

The close association that existed between the intrusion of the monzonite porphyry, the clastic dikes and the first period of mineralization, is clearly brought out by the conditions found near the stock and along the valley north of the stock and is reviewed in the following paragraphs.

Many ore deposits, the age of which cannot be proved directly, are found entirely within pre-Tertiary formations, and are of the same structural character and mineral composition as those of proved pre-San Juan age. Further evidence of a negative character is that not a single important fissure or dike associated with such deposits or responsible for this mineralization in the pre-Tertiary rocks can be traced into the overlying San Juan tuff. Where late Tertiary disturbances have reopened and extended fissures that were mineralized in Cretaceous or Eocene time, the continuations of these fissures in the overlying Tertiary rocks contain only minor, barren veins of quartz, barite, or calcite, and

these veins, where traceable into altered pre-Tertiary rocks, are later in age than the sericite, quartz, and pyrite veins of the first period of mineralization. This relation is well illustrated by veins in and near the "Blowout," especially where the basal beds of the San Juan tuff, entirely free of alteration, rest directly upon intensely altered and fissured rocks of the stock or "Blowout."



AFTER: W.S. BURBANK, "CAMPS OF THE SAN JUAN", E&MJ vol 136

Fig. 1

A zonal distribution of ore deposits, roughly according to their temperature of formation, is also shown north of the Ouray stock.z Within the central part of the stock itself the hydrothermal alteration is very intense, resulting in the feldspathization and silicification of included bodies of rock. This was followed by pyritization, and the development of other hydrothermal minerals, such as sericite, epidote, and hematite. Veins near or within the stock include barren pyrite veins, or pyritic-copper veins containing gold. The copper ores are mostly chalcopyrite and bornite. Nearest to the north flank of the Ouray stock are the contact-metamorphic deposits of the Bright Diamond and other mines. These deposits contain magnetite, hematite, garnet and other lime silicates, and low grade pyritic ores. Still farther north, and at a higher stratigraphic horizon, are the pyritic gold replacement deposits of the American Nettie mine. These deposits are replacements of the Dakota (?) sandstone and contain in addition to gold-bearing pyrite, some tellurides of gold, and small amounts of sphalerite, galena, and tetrahedrite (gray copper). The typical low grade baritic lead-zinc ores that replaced the sedimentary rocks, together with the silver-bearing lead-zinc veins containing tetrahedrite, are found about a mile north of the stock and extend several miles farther north. There is some over-lapping of these zones and gradations between the mineralogical kinds of deposits, as is especially shown by the presence

of pyritic veins within the zone of lead-zinc silver ores and of small bodies of lead ore with the pyritic zones. The positions of these different types of deposits relative to the Ouray stock.

The clastic dikes occupy the same system of east-west fissures in the sedimentary rocks that many porphhry dikes occupy, and none of the clastic dikes has been found in the Tertiary volcanic formations near Ouray. Based upon these geologic relations and upon the fact that many clastic dikes were intruded before the formation of silver-lead veins, their Cretaceous or Eocene age seems definitely established.

FISSURE VEINS:

The older fissure veins may be divided into two mineralogical types, the pyritic veins containing chalcopyrite and gold, and the silver-bearing veins. The gold-bearing veins are most numerous along the walls of the Uncompahgre canyon between the town of Ouray and the vicinity of Dexter and Corbett creeks, and the more productive ones are in the southern part of this area nearer the Ouray stock. They are found in both east-west and north-south fissures. The ore minerals are gold-bearing pyrite and chalcopyrite, and the walls, whether of sedimentary rock or porphyry, are considerably replaced and sericitized. Those veins that follow the walls of porphyry dikes are clearly later than the dikes.

The silver-bearing veins have been the most productive of the older fissure veins, and are represented by such veins as the Bachelor, Calliope, Pony Express, Newsboy, and Black Girl. The mineralogy of the Bachelor and Newsboy veins has been described rather recently by Bastin.

Bastin reports that the primary minerals in the Bachelor vein are galena, sphalerite, chalcopyrite, tetrahedrite, pearceite, quartz, barite, and manganiferous calcite. Pyrite is also present im many parts of the veins. The downward enrichment of some of these veins by ground waters has occurred, but except for some bodies of ore relatively close to the surface this process is believed to be unimportant, as some of the veins, such as the Bachelor, do not outcrop conspicuously and are protected by impervious cappings of shale. The minerals known or believed by Bastin to be products of downward enrichment are chalcocite, copper pitch ore, native silver, argentite, pearceite, chalcopyrite (finely crystalline), and calcite. Irving also reports ruby silver ore which was though to be a product of sulphide enrichment.

The most striking structural features of the Bachelor fissure and vein (also found in a number of other fissures), is a clastic dike, or the "Bachelor dike" as it is locally known, The relation of these clastic dikes to mineralization is very clear in a number of veins, in which all of the local vein filling followed the injection of the dikes. On the other hand, a number of clastic dikes contain fragments of vein matter and of silicified rocks enclosing small amounts of sulphides. Spurr reports that fragments of barite-silver ore are included in the clastic dike in the Neodesha mine, and upon this evidence interprets the dike as later than the

barite-silver ore, but followed by a second stage of sphalerite-galena mineralization lower in silver. Ransome, on the other hand, considers the silver ore of the Bachelor and Wedge mines to be definitely later than the Bachelor dike. The conclusions of Irving agree with those of Ransome. The sum of the evidence obtained by the writer from a number of different clastic dikes in other parts of the district, and from an examination of accessible parts of the Bachelor mine, agrees mainly with Ransome's and Irving's interpretation, although there is evidence of minor gas phase and hydrothermal metamorphism, including weak silicification that preceded and accompanied the intrusion of the dikes in parts of some fissures.

Another structural feature of great importance in connection with the fissure veins is the marked influence which the character of the wall rock has had upon the distribution of ore shoots within the veins. The ore is commonly of much better grade between walls of quartzite, limestone, or other harder rocks, whereas the fissures, or veins, contain larger barren areas between walls of shale. It was pointed out by Irving that in some fissures the vein suffers no appreciable diminution in size in the shales, but that the ore minerals were deposited only between the layers of quartzite, whereas in the shales the vein consisted of barren gangue minerals and clay. These particular conditions further suggest the importance of the horizontal movement of the ore-forming solutions as compared to their vertical movement, as suggested. Had the solutions been traveling directly upward across the alternate layers of sandstone and shale, the alternations of rich and lean layers in the veins would be difficult to explain except by some chemical theory for which we have no basis. If, however, the movements of the solutions were more nearly horizontal, corresponding to the lateral distribution of the more open parts of the fissures in the hard rocks, the absence of ore from the veins in shaly layers could be explained as due to approximate stagnation or lack of complet conitinuous corculation of the ore-forming solution

in the parts of the fissures between shale walls. The occasional finding of rich ore bodies within shale walls would appear to indicate the presence of local channels through the shale zones. The importance of open cross fissures and dikes of the north-south system in facilitating the local upward diversion of the ore solutions is particularly well shown in some of the mines containing "blanket" ore bodies.

LATE TERTIARY ORE DEPOSITS:

In the immediate vicinity of Ouray the late Tertiary ore deposits are mostly fissure veins, but it is not until areas considerably south of Ouray, or the region midway between Ouray and Telluride, are reached that important productive veins of this age are found. There are, however, several groups of late Tertiary veins of prospective interest nearer Ouray. These include in part the veins of The (Portland) Amphitheatre, that cut the San Juan tuff and underlying sedimentary rocks, and those along the canyon of the Uncompahgre River in the Algonkian quartzites and slates. Some strike north to somewhat northwesterly, and others more nearly east. The north-trending system appears to be the northward termination of the fissured and mineralized area of Bear Creek and the lower part of Poughkeepsie Gulch, where the San Juan tuff is cut by a strong nearly parallel system of north-south fissures.

In the San Juan tuff northeast of the Ouray this particular system is no longer recognizable, or at least has

become so weak as to be of little economic interest. In the area of San Juan tuff immediately east and north of the stock, there is a conjugate system of northeasterly and northwesterly fissures, some of which contain veins. Many of these veins, however, are barren quartz with a little barite, but some contain small amounts of base metal sulphides and are said to have been prospected because of their gold content. In this same area a few fissures and faults, of east and north trend, appear to represent the reopening of pre-Tertiary or Eocene fissures in late Tertiary time. Most of these fissures contain barren quartz and barite, and some only barren carbonates.

In the San Juan tuff on the slopes of Hayden Mountain southeast of Ouray two pronounced fissure systems are found, one striking north to north 15° west, and another north 50°-70° east. Farther southwest along Canyon Creek the northerly system has a strike of about north 35° west, and approaches parallelism with the important northwesterly fissures of the strongly mineralized area to the west. The late Tertiary fissure systems of the northeastern part of Hayden Mountain show a stronger mineralization than the late Tertiary fissures northeast of Ouray, but the few veins developed have not as yet been proved to be of economic value. The late Tertiary veins have thus far been given only a preliminary study so that the distri-

bution of the more strongly mineralized areas connot be considered in this paper.

The restudy of the mineralogy of these veins has not been completed, but some of them have been studied by modern methods and described by Bastin. Certain mineralogical changes that may take place in veins that are explored in depth, either toward the base of the San Juan tuff in the area southwest of Ouray, or beneath their present outcrops in other rocks near Ouray may, however, be mentioned. By driving of the lower Camp Bird tunnel and connecting this with the upper workings, the Camp Bird vein is now exposed throughout a vertical range of 2300 to 3000 feet below its outcrop. The change in character and texture of the vein in this vertical range is striking. On the upper levels the vein is a compound vein with an early stage of deposition characterized by sulphides of the base metals, and later stages characterized by gold-bearing quartz and barren quartz. In the intermediate and lower levels the gold-bearing quartz and base metal sulphides are closely associated with primary (hypogene) specularite. This appearance of specularite with depth is probably significant and indicates a tendency toward downward impoverishment of the commercial sulphides by vein deposition at higher temperatures. Microscopic examination of ore and altered rock from the lowest Camp Bird tunnels level shows the specularite to be an early vein mineral and to have been veined and replaced

by the later base metal sulphides. The association of the native gold with quartz containing specularite in the gold shoot at the east end of the mine, and the replacement of the early specularite as mentioned above, show that the minerals first formed at lower temperatures nearer the surface had later formed at greater depths within an earlier high temperature zone. The highest levels at which specularite appears in the vein are 1,000 to 1,200 feet above the lowest tunnel level, so that a considerable overlapping or telescoping of the temperature zones is apparent in this vein. Therefore there appears to be no reason to expect a sudden change from base metal sulphides to barren specularite at moderately greater depths below the lowest level. Also judging by the appreciable production of gold made by the Camp Bird from the deeper shoot, the first appearance of specularite in the Tertiary fissure veins in general is not a matter of immediate concern. Nevertheless, because of the absence of important gold shoots in the specularite zone on the lowest Camp Bird level, such a change in mineralogy when found in Tertiary veins suggests the need for considerable caution in deeper explorations, especially with regard to expectations of gold and silver content. Apparently not only a sporadic distribution of gold and silver is to be expected within this zone, but also a more gradual impoverishment of base metal suphides.

It was pointed out in previous paragraphs that owing to the removal of the Upper Cretaceous formations by erosion before the deposition of the Telluride conglomerate and the San Juan tuffm geologic conditions during Tertiary time did not favor the formation of the different types of replacement deposits found among the late Cretaceous or early Eocene ore deposits. The mineralizing solutions rising in the late Tertiary fissures were not subjected to influences that would cause them to leave the fissures and move through the surrounding sedimentary rocks. Accordingly wide fissures that have been productive only in upper parts of the San Juan tuff would not be expected to produce extensive lateral replacement deposits in sedimentary formations beneath the volcanic rocks. Some lateral enrichment might, however, be expected in extremely porous beds, such as the "Pony Express beds," or some replacement of the wall rocks might have occurred in formations such as the Ouray limestone, if these rocks were not so deeply buried at the time of ore deposition as to be in a zone of too high temperature. The Portland vein, a late Tertiary vein at the head of The Amphitheatre, shows lateral enrichments in the beds of the Telluride conglomerate and in the Ouray limestone, but these do not extend any great distance from the vein. Probably intricately fissured zones near Tertiary intrusive bodies that have penetrated through the sedimentary rocks and into the overlying volcanic formations would provide geologic

conditions more favorable to the formation of replacement bodies similar to those of the older period of mineralization.

Another type of Tertiary ore body that would favor extensive replacement of the surrounding deeper sedimentary rocks is the "chimney" or "stock" ore body, of the kind well represented in the Red Mountain district.

Notes From: USGS Bull 182 (1901),
by F.L.Ransome

The following pertinent paragraphs are taken from USGS Bull 182-by Ransome (16):

There occur in the Silverton quadrangle several approximately north and south, as well as nearly east and west, lodes, and if attention were restricted to certain small areas, such as Galena Mountain, it might be considered advisable to recognize one or both of these directions as characterizing distinct subordinate systems of fractures. Such a grouping, however, while valid for the very limited area named, is lost when the various directions of all the fissures in the quadrangle are taken into account. The possible number of such subordinate systems then becomes so large as to obliterate the divisions between them. For accounts of these minor directions of fracturing the reader is referred to the latter part of this section, where their coordination is discussed, and to the detailed descriptions of the various local groups of lodes in the later pages of this report. It is sufficient in this place to point out that the fissuring of the rocks throughout the quadrangle has been so thorough and has taken place in so many directions that two of these only stand out as dominant. Even these show a certain localization within the limits of the quadrangle, the northeast-southwest fissures notably predominating in the northeast quadrant, while the northwest-southeast fissures are the more persistent in the southeast quadrant.

In a region traversed by such a great number of fissures, trending in so many different directions, it is not difficult to construct fanciful relationships. Few of the latter are more popular than that which makes all the important lodes radiate from one or more points extinct volcanoes being generally preferred. That there is a certain radial disposition of the fissures will be presently shown, but this arrangement is very different from that which has been sometimes supposed, and which has been described in intendedly serious publications.

On the west side of Silver Lake Basin, in addition to the productive lodes, such as the Iowa, New York City, and Stelzner, the country rock is traversed by a great number of smaller fissures, striking from 20° to 40° west of north, and resulting in a pronounced sheeting of the rock, generally parallel with the lodes mentioned, but without recognizable regular or rhythmical spacing. These fissures are nearly vertical, but one group of them sometimes exhibits a steep northeasterly dip, while another group dips southwesterly. Many of them are ore bearing, and it is not uncommon to see on a clean surface of rock a vein an inch or so wide composed of quartz and galena in about equal proportions. Such mineralized stringers may be seen to branch or to wedge out completely in a distance of 40 or 50 feet and be succeeded by an overlapping veinlet a few inches to one side. On a smaller scale they repeat the phenomena observed underground in

the nearly parallel lodes, such as the New York City, belonging to Group 11 of the Silver Lake Basin lodes. They appear to belong to the same system and to have been formed at the same time as the latter.

Two prominent systems of parallel fissures, intersecting nearly at right angles, are noticeable in the cliffs at the head of Arrastra Gulch. One system with a strike of about N.32° W., and a dip of from 75° to 80° to the northeast, runs generally parallel with the trend of the gulch, and divides the compacted breccias of the Silverton series into great plates from a few inches to several feet in thickness. The width of this sheeted zone is from 30 to 40 feet. These fissures may perhaps be placed in the same system as those just described west of Silver Lake, and were possibly formed at about the same time. But they apparently contain neither ore nor quartz, and may be of later date. The second set of fissures, with a strike of N. 60° E., and a southeasterly dip of about 80°, crosses the gulch near its head, and may be seen also in Blair Gulch, in a considerably broader zone than the first set. Some of these fractures contain quartz, but, so far as observed, are not heavily mineralized and carry only a little pyrite. The relative ages of these two systems of intersecting fissures were not directly determinable in the field. It is not improbable that they were formed simultaneously as conjugate fissures.

Another area within which the fissures exhibit striking parallel coordination is on Treasure Mountain and at the head of Placer Gulch. The dominant northeast-southwest fissure system of this portion of the quadrangle is exemplified by a series of strong, persistent lodes, represented by the Sunnyside and Scotia, with a general course of about N.40°E. The dip of these is southwesterly at high angles. A second system of shorter, less conspicuous fractures crosses the first series almost at right angles, with a general course of about N.55°W. These fissures are nearly vertical, but the majority of them dip southwest at high angles. In their trends these fractures belong with the system of northwest-southeast fissures already recognized as a system characteristic of the quadrangle as a whole.

The parallel coordinated fissures or sheeted zones hitherto described all possess considerable width and are characterized by the division of the country rock into slabs of relatively great thickness as compared with the resulting fissures. But this is not always the case. The fissures may sometimes be very small and also very closely spaced, as in the col separating Lake Como from Cement Creek, where the thorough manner in which the rock, a much-altered andesite or rhyolite, has been sheeted is beautifully shown. This minor sheeting is generally parallel in strike with the larger lodes in the vicinity, and at

the particular point where best shown the fracture planes dip westerly at about 60°. As many as fifty such planes may frequently be counted within the width of a foot. There has been some infiltration of silica along these minute fissures, which causes them to stand out on weathered surfaces as little parallel ribs. The local strike of this sheeting is about N.35° E., but it is sometimes disturbed by irregular later cross fractures. No regularity or rhythm could be detected in their spacing.

Sometimes several nearly parallel fissures of considerable extent, originally containing open spaces ranging from a few inches to a foot or more in width, occur closely spaced within a comparatively narrow zone bounded by less fractured country rock. Such a sheeted zone forms a favorable place for the deposition of ore bodies, and the Camp Bird, Tomboy, and other lodes are chiefly of this type.

It remains to consider another manner in whcih the fissures of this region are sometimes locally grouped, not in parallel, but in more or less radial, or perhaps more accurately, branching, arrangement. This feature is well shown by the lodes of Silver Lake Basin.

Another case of conspicuous branching occurs at the head of Placer Gulch, where several lodes having an average strike of about N.25° E. split off from the main Sunnyside lode. The junctions in this case have not been exposed underground, but from the similar character of their filling it is highly probable that these fissures, like those of

Silver Lake Basin, were all filled at the same time, and were therefore probably formed practically simultaneously.

Still a third and interesting case of branching fissures is that at Lake Como.

RELATION OF FISSURES TO KIND OF COUNTRY ROCK & TO ROCK STRUCTURE:

It has already been pointed out that fissures carrying ore in greater or smaller amounts occur in practically all the rocks found in the quadrangle. Opportunities are rare, however, for observing directly the character of the fissures as they pass from rocks of one kind to another, and when such observations are possible no marked change is apparent. It has been stated by at least one observer, that the lodes of this region occupy contraction fissures in the volcanic rocks, and do not extend down into the underlying schists or sediments. Nothing could be much farther from the facts than this assertion. Not only does the distribution of the fissures disprove it, but at the Green Mountain and Highland Mary mines, in Cunningham Gulch, the lodes may be seen passing from the Algonkian schists up into the overlying volcanic rocks of the San Juan and Silverton series. In the case of the Green Mountain mine no difference was noted in the fissure itself, either in width, direction, or generalcharacter, in the older schists and the younger rhyolite flow-breccia. The exact point at which the fissure passed from one rock into the other was not seen. The Highland Mary lode, where originally worked in Algonkian hornblende-schist, is a simple vein filling a clean-cut fissure 2 or3 feet in width. Toward the northwest the lode passes into the volcanic rocks of the San Juan and Silverton series, and becomes a rather irregular

zone of fissuring about 12 feet wide where observed at a point some 1,500 feet in elevation above the mine. In general it is apparently true that the fissures in the Algonkian rocks tend to be simpler and narrower than those in the volcanic rocks of later age. The fissures as a rule cut the schists cleanly a t various angles with the schistosity, which apparently exercised no influence upon the direction of the fracturing.

No very definite differences can be observed in the character of the fissuring within the various volcanic rocks of the quadrangle. It is very rarely possible to study in any one mine the passage of a given fissure from one rock into rock of a different sort, and thus the kind of observations which could best establish such characteristic differences, if they exist, is wanting. The massive lavas and indurated flow-breccias seems to have a general tendency toward comparatively simple fissuring, such as results in fissure veins of moderate size and regularity or in sheeted zones. In the softer tuffs and volcanic breccias the fissuring tends to be irregualr, resulting in stringer or breccia lodes. Irregular fissuring appears to be favored also by alternations of harder and softer members of the nearly horizontal volcanic series, as at the North Star (King Solomon)mine. In this instance the softer rocks were regarded by the miners as the more favorable

for ore. According to Purington, in the northeast corner of the Telluride quadrangle the fissures passing from the San Juan formation and massive andesite up into the Potosi rhyolite series contain there less ore, and appear to have orginally formed with less open space than in the underlying andesitic rocks. There are no workings in the Silverton quadrangle which afford an opportunity to verify this statement, but the Potosi rhyolite is generally regarded by the miners as unfavorable to ore in the region where it prevails. Near the head of Porphyry Gulch, however, a vein carrying galena and sphalerite ore up to 10 inches in width has been prospected in the Potosi rhyolite. The vein strikes N.50°E, It can be followed for a short distance to the southwest, over the bare rhyolitic surface, when it either dies out or is cut off by a numerous series of small, nearly east-and-west fractures filled with white quartz and often showing excellent illustrations of linked-vein structure on a small scale.

In the intrusive stocks of monzonite, such as that of Sultan Mountain, the fissures are, as a rule, of simple regular character and moderate width. They are usually occupied by fairly simple fissure veins, subject to local contractions or enlargements, but seldom lose their simple linear character. As examples, may be cited the fissures of the North Star, Hercules, and Little Dora veins in Sultan Mountain, and of the Hamlet vein near Middleton.

The foregoing generalizations are admittedly based upon scanty data, and are to be considered rather as suggestions indicating lines of future inquiry than as authoritative statements of facts.

As a rule, local geological structure has had very little discoverable influence upon the fissuring. The lack of any regular relation between fissures and schistosity has already been pointed out. Contacts between rocks of different kinds and ages also appear to have had but little effect upon the fracturing and subsequent veining. This is partly due to the fact that the contacts are frequently nearly horizontal, while the fissuring took place along nearly vertical planes. Search was made in Cunningham Gulch, along the Uncompahgre, and at other points for any evidence of the diversion of fractures and mineralizing solutions along the contact of the older schistose terrane with the volcanic series, but with negative results.

Lines of fissuring in this region are occasionally determined by igneous dikes. Thus the Magnolia, a superficially prospected northwest-southeast lode just northeast of Silver Lake, follows for some distance an andesitic dike about 6 feet wide which curves across the gulch toward Round Mountain. Both this dike and a larger one which crosses it are irregularly fissured and traversed by poorly mineralized quartz stringers along the greater part of their exposed lengths. A similar occurrence was noted on the

south side of Kendall Gulch about a mile a little east of south from Kendall Mountain, where a vein about 6 inches wide lies on the south side of a nearly east-and-west andesitic dike. None of these fissures have yet proved of much economic importance.

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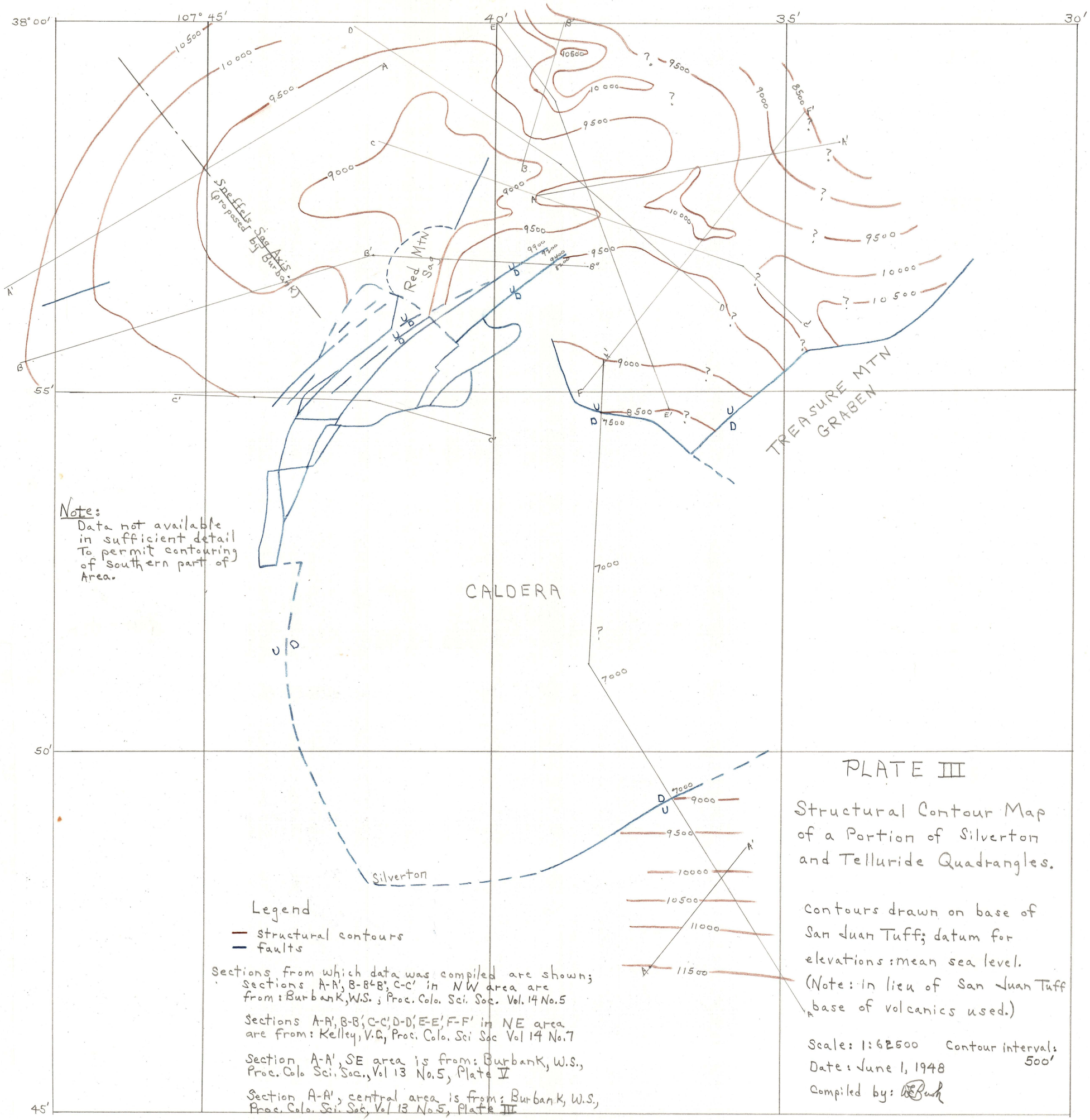

PLATE III

Structural Contour Map of a Portion of Silverton and Telluride Quadrangles.

Contours drawn on base of San Juan Tuff; datum for elevations: mean sea level. (Note: In lieu of San Juan Tuff base of volcanics used.)

Scale: 1:62500 Contour interval: 500'

Date: June 1, 1948

Compiled by: W.E. Bush