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of Pikes Peak granite in the southern part of the Front

mostly characterized by the presence of medium grained

Compliments of
T. S. Lovering

COLORADO SCIENTIFIC SOCIETY PROCEEDINGS

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faults.

GEOLOGY AND ORE DEPOSITS OF THE BRECKENRIDGE MINING DIST.,COLO.
T.S.Lovering: USGS PP 176,1934.

Rock Competency.- For quartz monzonite and Idaho Springs formation see under Montezuma. Sed.column (exposed) at Breckenridge:

Cretaceous.	Pierre Shale
(Upper)	Niobrara limey shale and limestone
	Benton shale
	Dakota quartzite
Jurassic	Morrison shale, ss ls.
(Upper)	
Permian & Pa	Maroon conglom.and shale ,grit, ss. thin ls beds.
Precambrian	Granite and schist.

Pierre Shale. 3500' in SE part of district,but in special area mapped near Breckenridge Pierre not over 500'. Uniformly thin-bedded non-limey clay shale.

Niobrara. 350' limy shale and thin-bedded ls.

Benton Shale. 360'. Mostly fissile.

Dakota Quartzite.125-165'. (225) Top 100' medium to thin-bedded quartzite and shale; rest massive quartzite beds.

Morrison. Shale, ss, ls. Contains 450' porphyry sill.

Maroon. Shale between two massive conglomerates.

The porhyry and quartzite being brittle fractured well,forming open fault breccias. Shale bent or formed impervious clay-filled fissures. Quartzite and porphyry most favorable for ore. But along W part of Wellington vein,shales were hardened and strengthened by pre-mineral silicification. Good ore between shale walls;though vein width almost always decreases on passing from porphyry into shale,the tenor of the ore commonly rises. If a vein along a fault fissure of small disp.is followed into shale,it usually pinches out as the fault fades into a sharp flexure in the shale. A fault of large displacement may have ore in quartzite or porphyry but be barren in shale,although the fault may persist in the shale. Faults with a throw of 50-150' are more likely to contain ore in shale than those with greater or less displacement. Even in strong rocks as porphyry or quartzite faults with more than 300' disp. made much nearly impervious gouge. In pre-mineral faults of this class the ore made in bunches and chimneys "is commonly brecciated by later movements,and consequently is often mistaken for "drag ore' from some faulted vein." (p.26).

Structure.- Breckenridge seds. lie in a structural trough 10 mi. wide,NNW from S to Middle Park. Belt of seds.about 8 mi.wide,flanked on each side by pre-Cambrian rocks. Older formations in S Park (Cam.,Ord., Dev.,Carb.) thin rapidly to N and disappear successively,allowing younger and younger seds.to rest on pre-Cambrian floor. Of economic imp.,becaus ore-beds of Leadville,Aspen etc.(Ordovician and Leadville ls) are missing from Breckenridge.

Regional dip E thruout trough.(Isoclinal folding). Oldest formations rest on the pre-Cambrian and pass eastward under an increasing thickness of seds. until folded and faulted back on themselves at W edge of Front

Range. 5 mi.E of Breckenridge seds.limited by overturned fold that passes, a mile N of Tiger,into the Williams Range thrust. The overturned fold may be seen just SW of Georgia Pass:contact of Dakota qtzite and overlying pre-Cambrian gneiss dips 67°E.

Mosquito fault forms W boundary of tectonic block that is limited on the E by the Williams Range thrust and the overturned fold. Mosquito fault runs from Leadville to the Tenmile district and beyond. Normal fault near Leadville,but fault plane steepens going N,and in Tenmile district it overturns, becoming a reverse fault.

Trough of overturned synclinal fold was a weak zone, a locus for igneous activity. From S park to N of Tiger where the overturned fold passes into the Williams Range thrust,the axis of the fold is marked by an almost continuous series of large porphyry masses, This intrusion was preceded and accompanied by faulting,and most of the faults and nearly all the porphyry masses occur in the E half of the tectonic block defined above. The faults and porphyr masses form the westenmost part of the NW zone,Breckenridge to Boulder.

Special area mapped is on west limb of regional syncline,about 2 mi.W of the axis. Details of structure ommitted,but "There is evide ence of gentle doming on Gibson Hill..." (p.18).

In the region surrounding the mapped area,most of the NW faults are older than those trending N and NE. Commonest faults strike N40-80E; these are generally older than those striking N 10-20E. Latter system includes most of the normal faults with large displacement;much of the movement along them was post-mineral.

Most of monzonite in special area is part of one large irregular laccolithic mass, fed by many conduits,and formed of many distinct sills that have united. Base of this large intrusive sheet is irregular,following different horizons, but commonly occurs a short distance above or below the Dakota. Bulk of porphyry intruded after folding completed, and part of it is later than the initial ENE faults, but many faults in the district are later than the monzonite porphyry.

In general the crosscutting bodies of monzonite and qtz monz,por. followed the earlier lines of weakness indicated by the ENE faults,but in a few places the porphyries broke across the sediments in a N-S line.

<u>Relation to Front Range NW Belt.</u> Earliest record of the diastrophism that formed the Front Range is contained in the overturned fold that passes northward into the Williams Range thrust. General trend of the fault,N30W suggests a compressive force operating S60W or N60E. At Leadville Loughlin(PP 148) concluded a compressive force must have acted S60W because the folds that trend N30W have steep W limbs and several of those limbs are broken by reverse faults. (Why doesn't Lovering face the issue? If the Williams range thrust was an underthrust,then the lower plate moved 4 miles N60E. If Loughlin is right,then the ground near Leadville tended to move very strongly S60W. Where is the enormous hole thus created? Nuts.)

No evidence that regional compression acted at any later time in directions other than west-southwest or east-northeast.

The compressive and shearing forces that caused the unsymmetrical infolding,thrusting etc. had little effect on the large batholithic masses of granite in the Front Range,"but they greatly affected a northeasterly zone of incompetent schist and gneiss between strong granite buttresses. " "Compression was locally relieved by interlaminal movement in the soft schists,but the stronger ribs of granite and granite gneiss either transmitted the force without rupturing or absorbed some of the force by fracturing."(p.20). "Southwest of the pre-Cambrian rocks, in line with the mineral belt,the stresses that existed were, in effect, (1) compression from the west-southwest (?), (2) shearing directed to the east-northeast, and (3) tension or only slight compression in a north-northwesterly direction. The fracturing that would result from such a combination of stresses would have the most open fissures parallel to the direction of major compression and at right angles to the direction of tension." The fractures caused largely by compression would make angles of less than 45° to the direction of compression;steeply dipping compression fractures in this region should therefore trend east or slightly east of north."(last statement cuckoo). By compression cracks Lovering does not mean shear planes.

Mineral Paragenesis.- Pyrite earliest sulphide;then marmatite (dark ferruginous zinc blende);galena (marmatite usually earlier,s.t. contmp., occ. later) then most of light-colored blende;then quartz and ankerite in most places;but the gangue minerals form only a small portion of the ore in most veins.

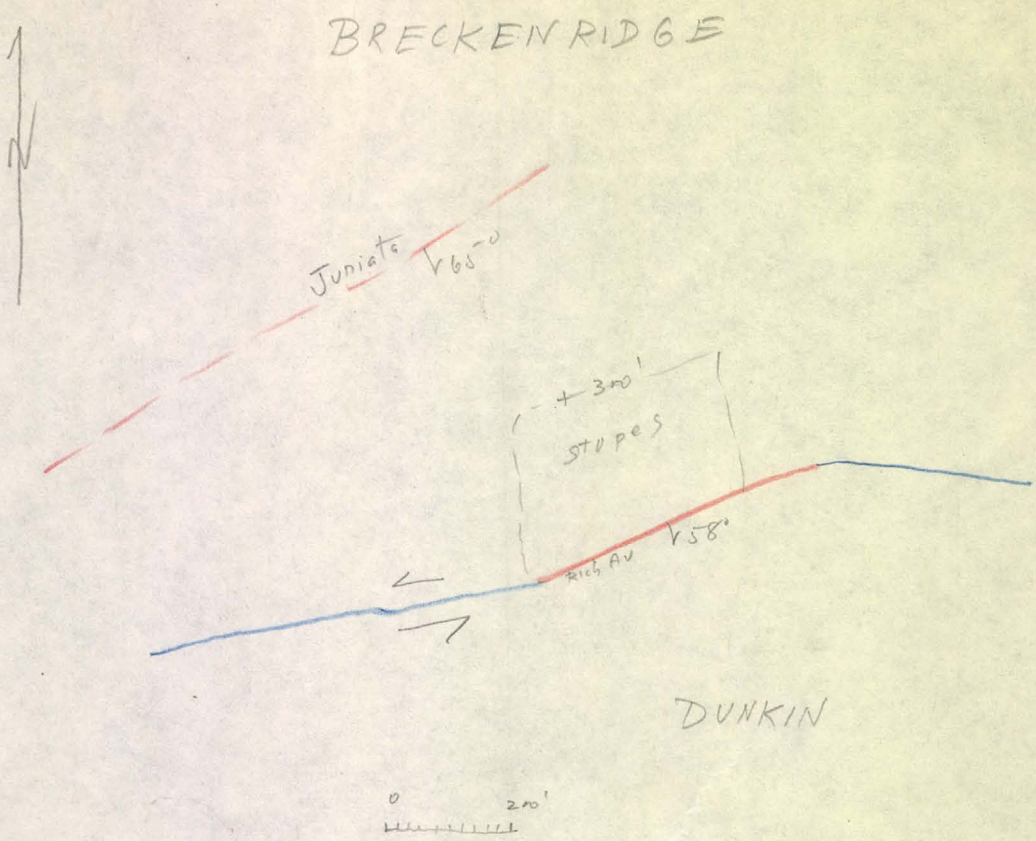
Veins.- Strike N40-80E;most show pronounced irregularities in strike and dip.

Most of the ore came from veins in the monzonite porphyry and Dakota quartzite;but a good deal of ore has come also from veins in the quartz monzonite porphyry, Pierre Shale,Niobrara, Benton shale and Maroon.

Major faults seem to have acted as channels,localizing ore shoots on lesser breaks at places close to the major fault. Ore solutions under high T and P followed the major faults,passing into the more open channels of moderate-sized faults at the first opportunity. More open character of the latter,and the large areas of their walls,which cooled the solutions,served to make the solutions unload their contained ores. Zigzag control, intra-mineral movement on cross faults.

Ores mainly lead,zinc and iron sulphides,with some native gold and some silver;commonest gangue minerals are ankerite,calcite,quartz and sericite.

Pyrite most abundant and widespread: in high-T deposits close to the monzonite stock N of Nigger Hill,in the zinc veins a short distance E of it,in the mixed lead-zinc ores nearby,and to some extent in the high grade galena shoots scattered throughout the district.


BRECKENRIDGE
N
Juniata
65°
300'
stopes
58°
Rich Av
DUNKIN
0
200'

Notes from: GEOLOGY AND ORE DEPOSITS OF THE MONTEZUMA QUADRANGLE, COLO.

T.S.Lovering: U.S.G.S. P.P. 178,1935.

Competency of Rock Formations.

Pre-Cambrian.

Is. Idaho Springs Formation. Older than Pikes Peak granite and the later Silver Plume granite. Largely quartz-biotite schist and quartz-biotite gneiss, with all possible gradations between. Even the schist is so injected by aplite, pegmatite and granite that it is a fairly competent rock, as is the gneiss. Nevetheless it seems to have acted as the least competent rock of the region, fracturing only where nearby buttresses compacted it; elsewhere it deformed by flow. Metasediments;schistosity parallel to bedding.

Sg. Swandyke Hornblende Gneiss. Overlies Is. Hornblendic gneisses and schists with 50% injected pegmatite, aplite, granite. Hornblende gneiss quite massive. A metamorphosed igneous rock intermediate between gabbro and diorite. Essentially conformable with Is;probably thick series of lavas. Considerably more competent rock than Is.

Mg. Quartz Monzonite Gneiss. Intrusive into Is and probably into Sg. More massive than the Sg.

Gn. Granite gneiss. Generally follows schistosity of enclosing schists or gneisses,and small masses are lenticular or sill-like,but contact of large masses that have broken thru the schists is very serrate;apophyses feather out along the schistosity. More competent than Is, perhaps on a par with Sg.

Ppg. Pikes Peak Granite. Intrusive into schist, but border almost everywhere parallel to schistosity of enclosing formations. Buttress.

Ssg. Silver Plume Granite. In contrast to the Ppg,the Ssg has sharp straight contacts with the older rocks in many places and probably followed fault lines and fracture zones more commonly than the older intrusive rocks. Inclusions of schist are common in the mass,and where they are abundant the schistosity is usually concordant in the different masses. Probable that both roof pendants and xenoliths are present. Buttress.

Cretaceous (?) and Tertiary.

Crawford,R.D.:A contribution to the igneous geology of central Colorado.Am.Jour.Sci.5th Ser.7,365-388,1924. Lovering gives a more detailed time-table. Post-Cambrian History: (1) Intrusion of porphyries from great depth;(2) large-scale folding and faulting;(3)

1. Early Denver (lowest Eocene).Intrusion of sills and dikes of silicic felsites (White porphyry,Leadville;felsites of Ward district).

Early,mid. Denver 2. Gradual vertical uplift,Front Range region,accompanied by intrusion and extrusion of calcic andesites and potassic basalts, such as the interbedded basalts of Table Mt. near Denver;Valmont dike E of Boulder;gabbro,diabase and ultrabasic dikes of Boulder,Central City and Georgetown quads.

3. End of Denver. Strong folding and thrusting,preceded and accompanied by intrusion of monzonitic magma (locally dioritic or granodioritic) such as Johnson Gulch porphyry,Leadville,diorite of Buckskin Gulch stock,Alma; diorite and monzonite porphyries of Breckenridge,dac-

cite of Georgetown quad.;hbl. and bi diorites of Central City quad.

4. (Age not stated;still Eocene). Minor faulting followed by intrusion of dikes and sills of porphyritic quartz monzonite such as Evans Gulch porphyry,Leadville;quartz monzonite porphyry (intermediate type) of Breckenridge;Elk Mt.porphyry of Tenmile District.

5. (Still Eocene). Faulting preceding and accompanying the widespread invasion of coarse-grained porphyritic quartz monzonite,mostly as stocks and dikes, rarely as sills:Lincoln porphyry (Mt.Lincoln, Park Co.) ,Princeton quartz monzonite of Crawford, Montezuma quartz mpnzonite,quartz mpnzonite porphyries of Georgetown quad.

6. Minor faulting; intrusion of dikes of porphyritic sodic quartz monzonite,such as alaskitic quartz monzonite porphyry of Georgetown quad. and porphyritic Brainerd quartz monzonite of Ward district.

7. Intrusion of dikes of sodic rhyolite and porphyritic sodic granite such as the alaskite of the Georgetwon quad.and the porphyritic Modoc quartz monzonite of Ward dist.

8. Intrusion of porphyritic granite and rhyolite such as those of the Georgetown and Montezuma quads.

9. Intrusion of alkaline syenites and trachytes such as the alkali syenite and the bostonites of Georgetown and Central City quads. and the trachyte of Sunset, Ward district.

10. Minor faulting and the formation of gold-silver-lead-zinc-copper ores throughout the mineral belt of Colo. (See Burbank,W.S.: Revision of Geologic Structure and Stratigraphy in the Ouray District of Colo.and its bearing on Ore Deposition. Colo.Sci.Soc. Proc.12, 213-232,1930).

11. Intrusion of felsites and related rocks,as the rhyolite agglomerate of Leadville,the biotite latite of the Georgetown quad., biotite andesite of the Bluebird mine near Nederland.

12. Fort Union (Upper Eocene). Cutting of Flattop peneplain.

13. Early Wasatch (Upper Eocene). Minor uplift,and widespread peneplanation during remainder of Eocene. (Medicine Bow peneplain).

14. Marked vertical uplift at end of Eocene,accompanied by faulting.

15. Denudation throughout Oligocene.

16. Vulcanism throughout Miocene in S.Juan,and periodically in the S and N-central parts of Front Range,locally accompanied by formation of important ore deposits (e.g. Cripple Creek).

17. Pliocene:denudation, minor vulcanism.

18. Faulting and regional uplift,early Pleistocene,followed by strong erosion.

Regional Structure.

Front Range an elongated dome. The Laramide events include strong folding accompanied by thrusting and related tear faulting; several stages of minor faulting preceding, accompanying and following the intrusion of quartz monzonite porphyry stocks and dikes;vein formation;minor post-mineral faulting.

NW en echelon folds and their associated faults are the earliest effects of the Laramide revolution. Witn moderate deformation,these are open, assymetric folds,but where severe,the folds are overturned to the SW and in many places are borken by reverse faults,downthrown to the west (hence dipping E:

).

In the Montezuma quad. the west edge of the Front Range coincides with a broken fold of this type. Thrust faults have been found on both borders of the range but the largest known,the Williams Range thrust,breaks this W fold. Traced from Breckenridge 50 miles NW to Muddy Butte,just beyond Kremmling. At its SE end it passes into an overturned fold that continues SE into S Park. Underthrust.

Narrow zone of porphyry stocks trends N40E across Front Range from Breckenridge to Jamestown. Nearly all the dikes,sills and mineral deposits except Cripple Creek Miocene ores lie in the region just SE of the zone of stocks in a mineral belt 3-12 mi.wide. Although persistent NW faults cross the mineral belt and extend for long distances NW and SE of it, E and NE fractures,which include most of the vein fissures,are abundant only in the mineral belt. The E mineralized faults in the W half of the range (including the Montezuma district) show N walls to have moved E almost horizontally. The NE faults commonly show less horizontal than vertical movement;both reverse and normal faults are common S of the Montezuma stock. The NW faults are commonly reverse faults dipping NE. Since the mineral belt comes to the W edge of the range in the Montezuma quad.where an overturned fold breaks and passes into the Williams Range thrust,it seems clear that these structural features are related.

The E faults of the mineral belt show presence of widespread horizontal shearing forces,and the Williams Range thrust, dipping NE at a low angle,also shows nearly horizontal regional stress. Both types of fracturing are thought due to regional compression,for when the overturned fold broke into a thrust near Tiger the movement of the fracturing rock masses was greater than in the adjacent folding layers,and strong tearing stresses developed between the areas of thrusting and folding. Thus as one part of the overturned fold broke loose and moved along the thrust fault past the less active part of the fold a transverse shear zone marked by tear faults was formed.

Where the side of a thrust-fault block ends against a tear fault it may be possible to tell whether the upper block was more active than the lower block. If the lower block has been pushed actively under an inert upper block,movement on the tear fault will not be the same as it would be if the upper block had moved actively over a nearly inert lower block. Points on the active side of a tear fault will be carried

past the inactive,or fold, side parallel to the dip of the thrust fault. If the upper ~~part~~ block moves over an inert lower block,points on the thrust-fault side of the tear fault will move up the dip of the thrust fault relative to the fold side of the tear fault,whereas if the lower block moves beneath an inert upper block,points on the active side of the tear fault will move down the dip of the thrust fault. Since direction of movement of tear faults in mineral belt shows N side E while the fold S of the Williams Range thrust was overturning to the W,and as this fold is deflected slightly eastward where it adjoins the tear-fault zone, it is probable that the lower block of the thrust was more active than the upper block;the thrust is therefore an underthrust.

Overfolding toward the SW accompanied by either overthrusting or underhrusting has been common in Colo. NW of a line from Gunnison to Boulder,nearly coinciding with the center of the Colo. mineral belt. In a wide zone SE of this line,persistent steep northerly faults,downthrown on the W,are common,but no thrusts;S limit of this zone trends nearly W from the N end of the Wet Mts. to the N end of the S.Juan Mts. Farther S overfolding and overthrusting toward the NE have been common. Thus in the Front Range the mineral and porphyry belts mark the NW limit of a transition zone between opposite types of deformation.

(Lovering ignores a difficulty here: if the Williams Range thrust is an underthrust,then the active member of his shear couple was a force from SW to NE. But if there was only overthrusting in the zone well SE of the Gunnison-Boulder line, combined with overturning of folds to the NE.the active force there too came from the SW;there was no shear couple,regionally considered.)

Local Structure.

The fault plane of the Williams Range thrust is domed up at the W edge of the major quartz monzonite porphyry stock;a window cut thru the gneiss of the HW by the Snake River and Jones Creek exposes the underthrust(?) Cretaceous shales.

A wedge of the Montezuma quartz monzonite stock projects west into the shale in the Snake River valley,cutting off the thrust. (See map). The shale dips away from the quartz monzonite at 10°-50°,showing that the wedge is near the axis of a domal uplift. It is known that the doming of the thrust fault was accompanied by faulting along Jones Gulch; it also seems probable that the dome was broken by an E-W system of fault either before or during the intrusion of the stock.

On the N and SE sides of the stock straight-line contacts trend N70°E,suggesting a pre-porphyry fracture system of this trend. These may be fractures related to the tear or transverse shear faults of the mineral belt. Mostly the contacts of the stock are steep;but the east contact dips 45° E (SW spur, Gray's Peak),thru an observed vertical distance of 1200'. In most places the stock breaks cleanly across the schistosity;there is no sign that the structure of the schist affected the shape of the stock. The upward bulge of the Williams Range thrust at the W end of the stock suggests the quartz monzonite was intruded near the center of a local E-trending anticline,and the primary linear and platy structure of the intrusive and the position of the aplite seams indicate that it was moving upward and N80E at an angle of about 25° to the horizontal in this locality.

Stock strongly jointed but has few persistant fractures. Since it was intruded after the period of strong stress when the thrust was for-

med,it was probably subjected to much milder fracturing stresses than the country rock nearby. (I think it acted as a buttressy. Fact that practically all porphyry dikes of the entire mineral belt are found only SE of the belt of stocks suggests stocks stood form, ground between them and granite masses to SE squeezed open).

Regional position of the stock in the NE zone of stocks suggests that its intrusion was dependent chiefly on regional shearing stresses between provinces of different types of deformation rather than on the presence of the thrust fault which it cuts.

Vein and dike belt zigzags. Thus,in NE part of quad.,concentrated in a narrow NE belt from Kelso Mt. to Brown Gulch (length,not width; same below). S of Kelso Mt. belt widens, 2 mi.,trends almost S to head of W Geneva Creek,where it swings SW and widens greatly. W and S of the head of W Geneva Creek many scattered veins,but best veins still confined to narrow belts. Near Montezuma best veins, usually NE,occur in a strip 1 mi. wide running nearly W from head of W. Geneva Creek to Glacier Mt., thence SSE thru Teller Mt. to Hall Valley. Scarcity of veins W of Glacier Mt. due to fact that pre-cambrian in that area terminates downward against the underthrust (?) plastic, impervious Pierre Shale,barrier to rising ore-forming solutions. The NW-trending belt of NE veins in Hall Valley area is probably related to the fault at the E side of South Park, with which it aligns and with which prominent regional NNW faults correpond in movement.

Pre-mineral faults in NE part of quad.,near Silver Plume,commonly trend ENE;in Gold Belt tunnel the N wall of the chief vein fissure apparently moved down and E. A few miles SW of here most veins strike NNE;in the Stevens mine the W wall of the main fissure apparently moved down and N at 60°. 5 miles S of Stevens mine,in the Pennsylvania mine,NW wall of the N30°E fissure moved up and NE at 30°.(Inconclusive data). This shows vertical componenet local affair, variable).

Near Montezuma the Bell-Meteor Wing vein, Bullion, Chatauque and Sts. John or Comstock follow reverse faults that dip NW;the Silver King follows a normal fault that dips SE,its SE wall moving down and to the NE at 70°. Thus with these the upthrown wall was consistently on the N and the angle of movement moderately steep. This movement was probably expressed by step-faulting related to the formation of the east-west anticline associated with the Montezuma quartz monzonite. The Ida Bell fissure (E slope of Jones Gulch) strikes nearly due E and cuts the Williams Range thrust. The north wall moved down to the east at a small angle. If the movement on these faults is representative of the region near them,it seems probable that they were formed in response to a regional shearing stress,modified later by local vertical stresses attending the intrusion of the stock.

The veins in the SE branch of the mineral belt in the Hall Valley area are transverse to a fault zone that parallels schistosity of Swandyke gneiss in this area (NNW). On the fault (2 out of 3 in zone) W wall moved down and to S. Transverse veins strike NE,movement unknown; ore occurrence in flatter parts of Missouri vein suggests a reverse fault in which NW wall moved up.

Ore Deposits.

Mainly lead-zinc-silver ores;some gold ore in SW part of quad.;some bismuth in a narrow belt from Hall Valley to head of W.Geneva Creek.

Most of ore deposits are fissure fillings. Many veins have a shallowed surficial enriched zone,but most of present ore primary.

Paragenesis.- Ores not injected but deposited from solutions over a considerable period of time.

1. Sericite, quartz, pyrite-largely metasomatic replacement of walls. Near the major channels solutions rich in Fe,silica,K and S attacked the wall rocks and added these elements. In such places the sericite and the quartz are in part earlier than the pyrite, in part contemporaneous. Sericite largely confined to walls,but quartz and pyrite occur both as fissure fillings and as wall rock disseminations.

2. Interval of movement,brecciating quartz and pyrite. Minor calcite and manganosiderite deposited.

3. Moderately coarse ccpy deposited;gold associated with it in some places. Much of this ccpy twinned,whereas later ccpy is finer-grained and untwinned. A little sphalerite contemp. with this early ccpy.,but most is later. Minor quartz crystallized with the base-metal sulphides, chiefly at end of ccpy stage.

4. At about time deposiion of early ccpy ceased, galena probably began to deposit;continued to deposit for some time after all ZnS had been deposited. Sphalerite epock. Barite within this epoch.

There was little movement during this ccpy-PbS-ZnS stage,but locally readjustment took place along the veins.

5. Gray-copper minerals, tennantite and tetrahedrite-during and after galena stage.

6. After deposition of bulk of ZnS,PbS,ccpy and gray copper,ankerite gangue minerals,usually with much iron and some Mn,were deposited. In may places this ended the period of mineralization,but locally veins were reopened and silver-bearing solutions deposited minor amounts of PbS,qtz.,argentite,native Ag,and the rubies,as proustite,pyrargyrite, miargyrite,stephanite,freibergite,stromeyerite,polybasite. Bismuth and silver minerals formed in S half of quad. in a qtz.gangue formed at this time.

Stockworks.- Only in SW part.(See map). IXL a shattered mass of qtz monzonite crowded with fragments of Dakota quartzite. Cut by complexly interlacing fractures cut porphyry and inclusions. Rocks strongly serictized,contain sporadic seams and masses of sphalerite ore;thin veinlets of py,ccpy,ZnS,galena,qtz.,locally bismuthinite. Stockeworks richer in gold near surface.

Jessie (less than a mile W of quad.) and the Hamilton,Cashier and IXL stockworks occur in a narbow zone trending ENE thru Tiger toward the S end of the Williams Range thrust,thus being directly in the line of shearing that resulted from the underthrusting of the Upper Cretaceous seds.;"but,as the quartz monzonite porphyry that contains them is younger than the thrust,the coincidence of alignment and position suggests that they probably formed in response to a relatively weak renewal of the shearong stresses that caused the easterly movement of the north walls of so many veins in the mineral belt farther east. As would be expected from the position of the stockworks,the dominant trend of the strongest fracture zones in them is east-northeast,but,in contrast to the area farther east,strong, persistent pre-mineral fractures in the quartz monzonite are comparatively rare." (p.60).

Note.- This admission throws a lot of doubt on Loverings mechanics for the short and non-persistent ENE veins farther east. (Tear faults above an underthrust). The resumption of movement postulated could scarcely have been resumption of the underthrusting;certainly any weak resumption in it itself is hard to swallow,and even if admitted,the horizontal movements postulated will hardly follow,since they depend on minor differential movements accompanying, by their very definition, extremely strong major movements. If weak later movements are necessary to explain the north side east movements of the stockworks,why cannot they explain those of the veins as well? Certainly weak horizontal shearing movements are more readily explained as partial movements in weak regional shear than as by-products of thrusting.

Veins.-Most productive veins strike N15-35°,dip steep west. In NE quarter of quad. lead-zinc-silver veins greatly predominate over other types. Mainly PbS,ZnS,Pyrite,with small amounts of copper and silver minerals,with a quartz gangue. In S half of quad,especially near E part of mineral belt,tetrahedrite is much more common than farther N,but here two above base sulphides are the most abundant. Quartz generally the most common gangue,but barite abundant in the SE branch of mineral belt from Hall Valley to Glacier mt. In SE quarter of quad.,Hall Valley and mountains at head of W Geneva Creek,veins with bismuth and silver mineral are common,generally associated with ccpy in a quartz gangue. Low grade pyritic gold veins in the mts. near Swandyke. A few veins in the HW of the thrust north of the N fork of the Swan River,although this area underlain by the underthrust Upper Cretaceous shales.Mostly galena. The veins in the S part of the stock mostly pyrite and sphalerite,but with moderate amounts of galena in a quartz-ankerite gangue. Farther N in the stock are sporadic rich silver veins.

Rude zonal arrangement of ore types around S border of stock. (As usual: deep transgressing discontinuity is a trunk channel). Veins in S part of stock have more pyrite and sphalerite than those outside the stock or within it but farther N,and were probably formed at higher T and P. (See time table, p.2. The quartz monzonite was cold as a coppee on a marble slab at the time of mineralization,but the zoners must have their way). Most of the rich silver ores are scattered irregularly thru a belt about 1 mi.wide bordering the stock on the S from Glacier Mt. to Revenue Mt.,thence swinging N and W into the stock,passing thru Cooper Mt. and on into Lenawee Mt. (See map). Barite and gray copper become common in the lead-zinc veins just S of the rich silver ores in Glacier Mt.and Revenue Mt.

Possibly the veins on McClellan Mt. are related to a center of mineralization to the W,between Kelso Mt.and Torrey's Peak (see map).Rich silver ores in the Baker mine,on the S part of Kelso Mt.;galena-sphal-qtz-ankerite veins occur on McClellan Mt.,a short distance to the E; veins of gray copper,fluorite and barite are common a little farther NE on the same mt.

Galena, sphalerite,pyrite quartz are found in nearly all the ores and are much more abundant than the other minerals. But deposits may be classified by means of the other minerals. Cu minerals most abundant of the minor constituents;in most veins,in very small quantity,but locally rather abundant. Further,gold and silver associated with ccpy,and silver with tetrahedrite and tennantite. Most of silver in latter,however, as sulph-antimonide or -arsenide.

~~Type of Ore~~ ~~Type of Gangue~~ ~~Locus.~~

Ore	Typical Gangue	Locus
ccpy, little or no gray copper	Quartz of ankerite	
Abundant gray cu	Mainly quartz, barite, moderate am't Mn-ank.	
Galena-sphal., with gray copper	Barite, fluorite	Hall Valley, Teller Mt., Glacier Mt., E slope McClellan Mt.
Galena, sphal., ccpy	Quartz, ankerite	From S end McClellan Mt. SW to Glacier Mt. These include most of successfully exploited veins.

The miargyrite, pyrargyrite, proustite, stromeyerite are commonly associated with a Mn-ankerite or rhodochrosite gangue. Some silver veins, as American Eagle and Winning Card mines in the stock, had little galena or sphalerite and consisted of stromeyerite and gray copper in a quartz gangue. In the lead-zinc veins on Glacier Mt. native Ag., pyraggyrite, proustite, miargyrite argentite are main Ag minerals. They are later than the bulk of the lead-zinc-iron minerals and are not disseminated evenly thru the galena-sphalerite ores with which they are associated. They are usually concentrated in rich shoots whose occurrence is independent of the amount or kind of the earlier base-metal sulphides found in the vein.

All the bismuth-silver veins on the SE or E side of the mineral belt contain silver and gold. Silver chemically combined with bismuth as emplectite or schapbachite. The moderately common occurrence of galena-sphalerite ores in the bismuth-silver veins may be fortuitous, as bismuth-silver ore shoots occur alone in many places and were apparently formed at a different time from the lead-zinc ores. Quartz, pyrite and ccpy are usually found in the bismuth-silver ores, less commonly tetrahedrite and galena, and very rarely barite and ankerite.

Veins of massive pyrite, or pyrite and quartz, occur on Wise Mt., in S part of quad. Primary gold and silver content less than $3.00 a ton.

In most of the lead-zinc veins sphalerite and pyrite increase with depth. CRITERION: Bottom of an ore shoot may be marked by an abrupt change into pyrite and quartz or the appearance of barren ankerite that completely fills the vein. Galena commonly much more abundant in the upper parts of the veins, but it is persistent and occurs throughout many ore shoots. With veins having notable copper content the latter increases slightly with depth. Where both ccpy and gray copper occur, ccpy becomes relatively more abundant with depth, gray Cu decreases. Silver content of the ores does not seem to be related to depth from the surface nor to distance from the bottom of the lead-zinc ore shoots, although in Glacier Mt. the ores are commonly richer in silver in the lower part of the shoots. In the Bell mine, on the E slope of Glacier Mt. ruby silver occurs at 11,600', about 130' below the surface; farher NE on the same vein ruby and native occur at 10,500', 300' below the surface. On W side of Mt. ruby and native occur at 10,900, 700' below surface; low-grade galena and sphalerite with sporadic streaks of gray copper extended from the surface down to the rich silver ore. However, in the Stevens mine, McClellan Mt., upper part of ore shoots appears to have been richer in silver than the ore now exposed in the lower levels; Ag content grad-

ually decreased with depth. In veins nearby, rich silver ore near the surface changed abruptly into low-grade ore 100-200' below outcrop.

Enrichment did not extend more than 100' below outcrops of veins in the schists and gneisses; in a few places silver enrichment to as much as 300'. Surface enrichment has been extensive only where the present surface coincides closely with the Flattop of Rocky Mt. peneplain.

Largest single ore shoots range from 600-1100' strike length, known vertical extent 400-850'. In some mines strike length greater than vertical, in others vice versa.

Mine	Strike Length	Vertical Dimension.
Stevens	600'	850' plus
Santiago	1100	700
Pennsylvania	800	400
Sts. John: Comstock shoot	1300	700 unbottomed

Several ore shoots occur in some of the largest, most continuous veins; some of these veins productive for over a mile in length.

Vertical Range of Ore Deposition. At least 2000', may be 3000'. Note: Pilot vein, near mouth of Jones Gulch at stock contact, 9500'; Ida Belle vein, less than a mile to south, 11,600. Lovering expected Pilot vein ore at stock to be higher T and P type than Ida Belle, 8000' from the contact; but the ores are practically identical. Too bad.

Hard, brittle rocks, as pegmatite, granite, porphyry and gneiss are the common wall rocks of the persistent shoots; soft plastic rocks, as mica and hbl schists, seldom form the walls. Intersections favorable. Zigzag control: horizontal at Bell: north side east, vein tightens where it swings NE, opens where it swings SE; ore shoots in E or SE segments. "ancient open space". Bell a reverse fault: ore in flatter segments.

Where vein fractures parallel schistosity: sheeted zone; ore shoots only where vein breaks across schistosity.

Close to the surface open fissures may be common in very soft rock; with increasing depth the fractures in such material become tight although open fissures may be abundant in much stronger rock much farther below the surface. Hence open fissures do not persist to as great depths in the relatively weak schists as in the stronger gneises and intrusives.

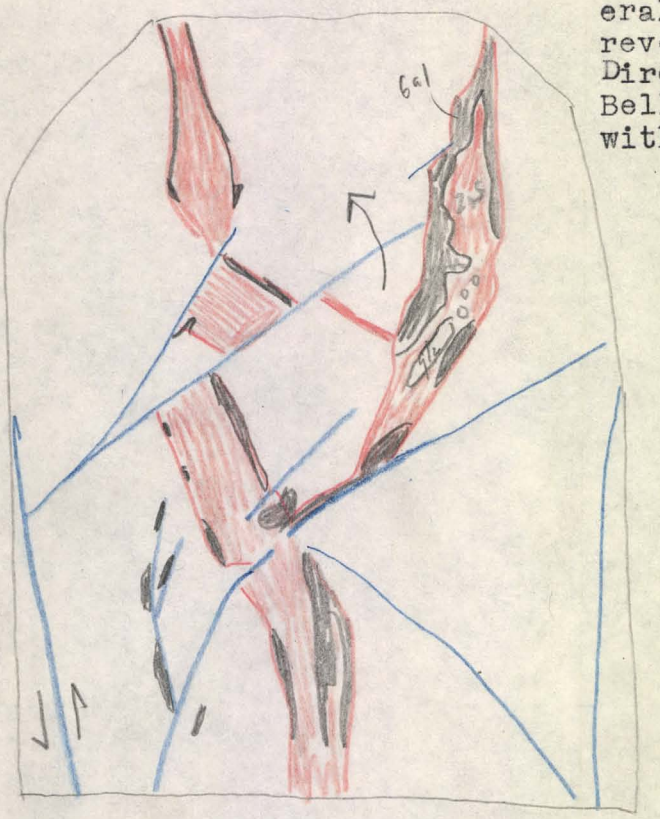
Suggestions for Prospecting: "If many periods of brecciation are shown in an apparently barren but strong vein, the chance of finding an ore shoot somewhere in it is much better than in a barren vein which apparently was never reopened after the barren filling was deposited; thus a study of the paragenesis of the gangue and ore may be very significant."

Mines.

Bell.- Flexuous surface, strike N30-70E, ave. 40; dip 40-80, 90 or even steep SE. Everywhere cuts schistosity of Swandyke gneiss. See on maps of mines sheet.

Ore seam commonly 4-12"; remarkably free from gangue except where the vein dips SE, and consists of sphalerite and galena. ZnS predominates in NE half, galena in SW half. Rich silver ore shoots. Wire silver, pyr-

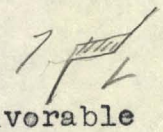
ragyrite,miargurite (dark rubies);also some argentite and proustite. Ruby silver as lenticular masses in center of vein. Ore mainly in single seam;but in places where "pre-mineral" movement developed strong branching gougy seams and slips between main vein walls,or branches or parallel slips to main fracture,sulphide veins may follow these.



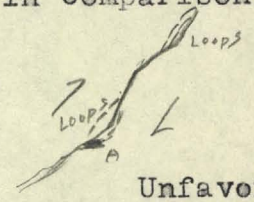
Bell vein looking SW. Showing intra-mineral antithetic faulting connected with reverse movement on the major fault plane. Directly connects relative movement of Bell HW NE and up (see underground sheet) with the mineralization.

x x x x x x x x x

Silver Wing and Spelter King adits are on the Bell vein half a mile NE of the Bell mine. See underground sheet. Vein cuts across schistosity on account of its gentler dip. Zigzag control rich ruby and wire silver pocket,marked A on map:brecciated sphalerite cemented by Mn-ank. Cementation not complete,vein open and vuggy;many vugs contain abundant wire silver. (Typical of segment of vein parallel to compression:R.D.M. E-W veins,wire silver, vugs etc.).
The map also shows looping at places of unfavorable or reversed zigzag control;I have discussed this elsewhere. Use this in comparison sketches



Favorable



Unfavorable Loops.

Chatauque.- Nearly east-west reverse fault,dipping 45°N. In places brecciated galena is cemented by Mn-ankerite and quartz,plus apparently argentiferous gray copper sulphides. .p.77:"Intermineralization movement on the vein was probably carried partly by the ore shoot and partly by the barren slips in the sheeted zone;and the ore solutions were more active in the open brecciated parts of the vein than in the tight seams of the sheeted zone."

Hunkidori.- See underground sheet. Little gouge on any fissure; all show strongly sheeted structures or a zone of slightly crushed and altered rock. p.82:"At the breast of the adit in 1928 the vein showed evidence of repeated movements during the period of mineralization. Dark-colored quartz containing abundant pyrite disseminated through it had been brecciated and cemented by pink manganiferous ankerite. Seams of light-colored quartz apparently contemporaneous with the galena that is disseminated through it follow the wall of the vein,but the relation of the quartz to the other minerals was not evident."

Ida Belle.- Faults William Range thrtust. Latter has horizontal component of displacement of at least 4 miles. Its fault breccia is 40-70' thick in the Ida Belle mine,dipping 5-40 W,averaging 16°. Striae on Ida Belle dip 10°E. This movement,5-40' north side E on Ida Belle formed,in the shale benath the williams Range thrust,2-6" gouge and sheeted zone; in the Williams Range thrust breccia,a crushed and sheeted zone 24-60" wide; in the overlying gneiss a fissured zone 12-45" wide. Interesting comparison of effects by same movement in different rocks, and brings out the fact that with slight faults, presence of gouge almost always means soft rock, either originally soft or softened by alteration. Shows how competent and favorable a rock the gneiss was.

Mineralization on the Ida Belle was strongest in the thrust breccia, weakest in the shale. The ore in the breccia close to the shale contact was much better than that 50' above,and was about 24" thick. PbS,ZnS, little waste close to the contact.

Missouri.- Country rock Swandyke hornblende and injection gneiss, N25°W, dip 65°-85°E. Several bedding-plane faults later than the vein fissures,although not certainly later than the vein fillings. The main fault,with two others,are shown on the map. The only ore shoot on the Leftwick vein was found close to the junction with the main fault;the Missouri vein is weak away from the fault,but increases in strength toward the fault, and the best ore occurs within 100' of the fault. All the small kidneys of ore found in other veins are close to the fault. Probably an ore channel.

Occurrence of rich bismuth-silver ore on the Missouri in the pocket above a roll in the fault surface suggests localization by reverse faulting.

Paymaster.- Ore on dump: 1. Silicification, pyritization;2.Mn-siderite in vein;3. Barite.4. galena, sphalerite and quartz. Much of the quartz is later than all the other minerals.

Pennsylvania.- Stoped for 800', stopes 6-14' wide. Pillar left shows character of ore. 12' sheeted zone in granite gneiss;numerous seams of galena, pyrite ccpy and qtz.;most parallel sheeted zone but several diagonal. Galena most abundant; as seams 1-12". About 30" of the sheeted zone is galena, 8" pyrite, 2" ccpy. Quartz, py.,ccpy are earlier than the galena;minor dolomite later than galena.

Ore in gash veins suggest localization by reverse faulting; striae pitch 30° down to SW. Hence W wall probably moved up and to NE relative to E wall.

Peruvian.- Same vein as Penn.(See map). Loop branches: Shaft loop branch,30' west of Tunnel branch;loop 330' long.N junction dips 40°S, S junction 60°S. Tunnel vein strikes N32E,dips 84W to 90°;Shaft vein parallel,dips steeply toward Tunnel vein. Most of ore close to S junction. Ore shoots in Shaft vein separated by low-grade or barren stretches of qtz;little gouge;Tunnel vein has many wide gouge seams between the ore shoots.(Main locus of movement,NW side NE. Shipping ore 20" wide;vein (Tunnel I suppose) ave.6' between walls and widened to 14' at the junctions. Below 4th level,more Zn than above,although galena still the most abundant sulphide. 1.Pyrite,quartz.2.Barite. 3 sphalerite, galena.

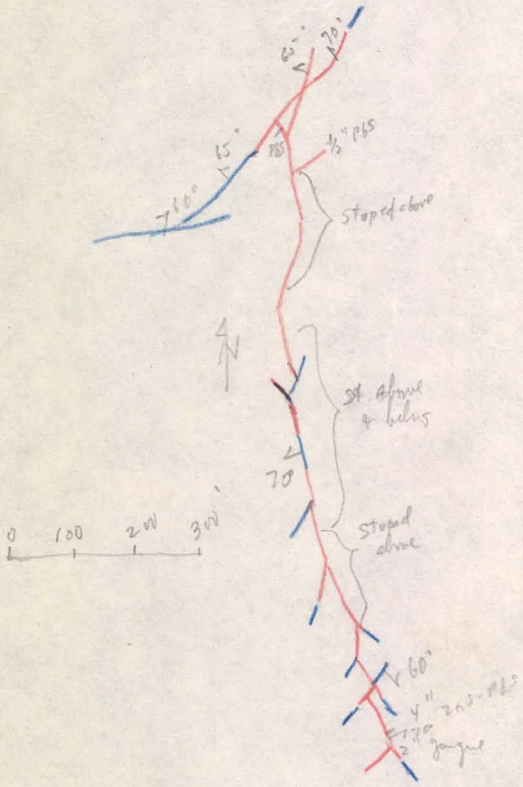
Sts. John.- CR hornblende gneiss and pegmatite of the Swandyke gneiss. Main vein (NE) is Comstock or No.5. This crosses No.7,but a NE fault in FW of Comstock faults No.7 NW side NE. No.7 contains much more barite than No.5,hence is probably older (see Paymaster mine, p.11). Lovering also says Comstock shown clearly later than No.7 at the junction.

Localization of ore in flatter segments of Comstock suggests reverse faulting. Richer silver ore on the lowest than on the higher levels.

Santiago.- Vein 2-8' wide;in widest parts filling is coarsely brecciated granite,strongly silicified and pyritized,processes earlier than the lead-zinc-copper mineralization,and not indicative of ore: the lead-silver-gold tenor was very low in a place where the pyritic silicified breccia was 8' wide. Sphalerite increases with depth. Gold in lower levels varied with abundance of light-colored ZnS.

Sarsefield.- Vein about 6' wide,but ore streak commonly less than 15" thick. Best ore shoot at change in strike more to NE;ore nearly free from gangue,24-36" wide,mostly galena and light sphalerite,with minor gray copper,pyrite, barite, qtz.

Stevens.- Nearly N-S,in Silver Plume granite. Very narrow but high in lead: large producer. While the general trend is N-S,the vein obviously made use of two conjugate fracture sets:



Whale.- Walls of vein 5-10' apart,but pay ore ranged from less than an inch to 36" in thickness. Apparently white barite cements "lumps" of galena and gray copper. Ore also contains quartz,dolomite,ccpy. Barite only gangue mineral where vein was wide,but where narrow quartz and dolomite appeared. Where the vein splits or divides around a horse it is almost always poorer.

Wild Irishman.- W continuation of E-W fault in Bell mine.(see underground sheet). Vein material very vuggy,open-textured. Ore in nearly vertical chimneys separated by barren stretches.

MONTEZUMA. GEOLOGIC HISTORY OF LARAMIDE INTRUSIONS.

The sequence of intrusion is shown in Table 1 and on the map. Prior to the Laramide intrusions, the area SW from Georgetown, to the Williams Range thrust, was one largely of incompetent Idaho Springs schist enclosed on three sides (NW,NE,SE) by pre-Cambrian granite, and somewhat elongated NE. The original strike of the schistosity seems to have been mainly NE. Upon this setting there operated a regional compressive stress in a direction slightly north of E, as shown by the strike of the Williams Range thrust, by the axes of anticlines and synclines in the schist, apparently formed at this time, and by the fracture pattern for the dikes of various ages, a pattern that remains consistent throughout the period of dike intrusion and indicates compression in the direction described. (See map).

It will be noted that NE shear planes greatly predominate over NW planes. This is probably because the NE planes adapted themselves to the NE strike of the schistosity; the latter made excellent planes of shear. Nevertheless, while simple compression may hafe started to act on the district, the great encouragement for NE shear planes, and the inhibition to NW planes would turn the simple compression into a shear couple, the members of which acted SW-NE, and the sense of which was clockwise.

The test of this idea lies in rotation of the NW shear set. The NE set should keep a fairly uniform common course, while the NW set should show bending (clockwise) and due to the heterogeneity of the rocks, the NW set should be bent or rotated to various degrees.

If we assume that the NW faults near Georgetown have the normal strike for simple compression (they are mainly in granite) then the NW fault at the Santigao mine keeps the normal strike where it is in granite, but in its SE part, where it partly leaves the shelter of the granite, it is decidedly bent clockwise. SW of the Santiago, near the Peru and Pennsylvania mines, a whole series of dikes, most of them apparently E-W tension joints, are distinctly bent clockwise, and the part that is bent is the SE part of each dike. Several other NW planes S of the QM stock show signs of similar bending. On the other hand, the NE planes, with one or two exceptions, are characteristically straight.

It would seem then that the general type of deformation in this area was a clockwise NE shear; this type prevailed in the enclosed body of schist. The mass of Silver Plume granite on the NW of the schist area remained fairly rigid and stationary, the schist, as shown by rotation of the NW shear planes and of the tension joints was subject to simple shear, moving progressively further and further SW with increasing distance SE of the Silver Plume granite mass. The deformation was essentially asymmetric shear.

This movement, however, was inhibited on the SE side of the schist area by the irregular masses of granite there. Along some line about along the NE axis of the schist area, the progressive shear reached a maximum; SE of the line it diminished because the inhibiting granite masses were increasing in number and size. It was along this central line of maximum shearing that the porphyry masses were intruded.

The induced direction of maximum elongation was slightly W of N. Had the schist area had an elongation in that direction, with granite masses on either side, a great series of tension joints would probably

have formed. As it was, the enclosing granite somewhat inhibited elongatio in the natural direction, so that from the start shear planes formed, as well as tension joints. Naturally the NE shear sets would form because of the preexisting NE schist planes. Referring to the map, tension joints predominate where the schist planes strike roughly N-S; in such areas the NE or NW shear planes had no preexisting pattern to help them form; the preexisting pattern was entirely in favor of the tension joints, for elongation could take place with great ease in the plane of the schistosity; with NE shear planes, N-S elongation would be greatly inhibited, but formation of NE shear planes correspondingly encouraged. This of course accords with experimental and field data showing that tension joints seldom form in the same places as shear planes. The Montezuma relation is shown in Table II, where 76% of the tension joints form with strikes at angles greater than 60° to the strike of the schistosity. (Prevailing dips of fractures and schist planes steep).

The conditions described above prevailed up to the intrusion of the quartz monzonite stocks etc., No.6. Table I shows that for dikes intruded up to and including Stage 6, from a thrid to a quarter of the dikes tabulated formed along tension joints, becuase of the comparative ease of elongation N-S. Few dikes followed NW shear planes because few of the latter formed; the majority of the dikes followed NE planes. Those exactly following the strike of the schistosity were omitted for fear they are sills, so that in reality the proportion shown with NE strike is too low; but since probably the same proportion of dikes of all stages followed NE schistosity, the relative numbers of dikes in each stage following tension joints is probably correct, although the % of total dike of each stage is too low.

With stage 6 the % of dikes following tension joints starts to drop. This stage marks the intrusion of the great quartz monzonite stock and a number of lesser ones. The belt of schist was materially strengthened and narrowed, so that the ability to elongate N-S was greatly cut down. The % of dikes of Stage 7 following tension joints is only half that in stage 4, while the % following NE shears is 11.2% greater.

In the granite, fracturing of any kind was slight due to the strength of the rock; there was no especial ease of elongation N-S so that tension joints formed but sparsely. At the start shear planes predominated in the granite, but short tension joints increase somewhat in proportion toward the close of intrusion.

The same tendencies are shown with the veins: at the start of mineralization there was still some tendency for formation of tension joints, so that the early pritic surge largely confined to tension joints; the later minerals only entered tension joints where the latter were again squeezed open, brecciating the earlier vein material..

Dikes tend to hug the borders of steep-contact igneous masses such as the Idaho Springs granite and the Montezuma quartz monzonite. This shows the tendency for openings to form where soft material is squeezed past a buttress. Where the edge of the buttress faces the direction of ground movement, as along the NE side of the quartz monz. stock, the soft schist, shown by the attitude of the schist planes parallel to the edge of the stock, was squeezed in two directions, NW and SE, flowing each was from an axis about perpendicular to the edge of the stock, and ~~loc-ated~~ about bisecting the NE edge of the stock. This strong disruptive movement opened tension joints, filled with dike material, precisely at the midpoint of the NE edge of the stock. (Baguio).

Shear planes became loci for dikes iin places where free slipping along them was impeded. The SW-trending irregular mass of Silver Plume granite near Kelso Mt. was a favored locus for dikes, and the irregular edges of many other masses of igneous rock are similar loci. In some cases straight borders of some of these masses seem to have conditioned the attitude of shear fractures with strikes somewhat more nearly parallel to the compression than natural; these were squeezed open. Dikes in tension joints may be localized along the edges of buttresses aligned normal to the compression, as in the case described, or they may be in the schist, far from buttresses, and where the schist planes strike N-S where ease of elongation N-S was not impeded; but dikes along shear planes are not found ~~in such places because shearing mo~~ far from buttresses and where the schist planes strike NE, because the shearing movement in such places was unimpeded.

MONTEZUMA

Table I Attitudes of Dikes not Paralleling Schistosity or Strike of Rocks seds

	~~N~~ 70W-N70W	N69W-N20W	N19W-N19E	N20E-N69E ~~N~~
Di., db, gab. 2	1	Db. 1 Gr 1	1	1
		Gr 1		
4	𝍸 𝍸 II Di, GD, Gnd. (12) 33.4% Gr 1	III (3) 8.3	III (3) 8.3	𝍸 𝍸 𝍸 III (18) 50% Gr 𝍸 [36]
5	𝍸 I 9/3 more. IM (6) 33.3% Gr 1	III (3) 16.7%	0	𝍸 𝍸 (9) 50% Gr 𝍸 [18]
6	QM-Lincoln Porph. Type 𝍸 IIII (9) 24.3% Gr 1	𝍸 II (7) 18.9%	III (7) 2.7%	𝍸 𝍸 𝍸 𝍸 (20) 54.1% [37]
7	III (3) Rhyolask. 16.6% Gr IIII (4)	III (3) 16.6% Gr 1	1 5.6% Gr III	𝍸 𝍸 I (11) 61.2 Gr IIII [18]
8	Alkali Syenite Gr II			1
9	1 Bostonite Gr II			1 Gr IIII

Min.

over

Table II Tension Joints (S70W - N70W) in Schist

∡ between joint & strike of Schistosity.

90-80	79-60	59-40	39-20
~~IIII~~ ~~IIII~~	~~IIII~~ IIII	IIII	IIIII
10	9	2	4
40%	36%	8%	16%

25

76% ∡ > 60%

Montezuma — Calculation of Strain.

Both shear sets in schist etc. conditioned by att. of schists — tended to use latter as shear planes. Hence to find "true" attitude, look in granitic rocks.

NE Plane — Santiago — mainly in Sp 6, but strike parallel Schist Bt. Dip 70° W. In strike, take vein in MQM. Ave N45W

Morgan Dips
65
70
80
45

4 | 260
65°

Kenkidri 65
Fisherman 90
Mazi flt 90
N of Mont 75

4 | 320
80° W ave N45° E

Reverse flts

Strike (Pen. - Penrose) dip 30° SW.

NW Set. Stevens flt N47°W

Kenkidri — cut across schists only; also in MQM N47°W

4 flts — 63
57
67
65

4 | 252
63°

NW breaks dip NE also in Miss & Kelsey (not used in average because controlled by structure of CR)

Take 63°E, N47°W

Strike (Miss main flt) dip 50° SE

(OVER)

NE of Nevada City.

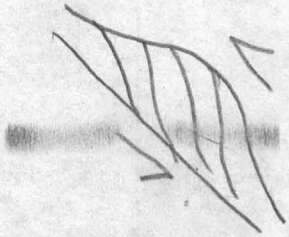
Tension joints		Azimuth clockwise
Yellowjacket		2/130 65
New York Zeatha joints	60 45 75 180 60° N	100
Morgan	65 N	82
Jerry	80	90
Bullion	65	105
Baker	65	72
Yellowjacket	65	105
Chat	~~45~~	85
Morewood	70	70
Rainbow	60	80
#7	55	80
	63°0 63° N	86'9 N87E

64
57
65
67
75
5/328
65

Sec.

Pennsylvania

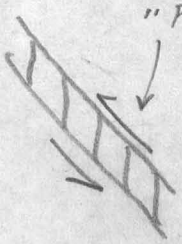
p. 93: "the occurrence of galena in diagonal fractures... Suggests gash veins in a reverse fault".



Sec.

Bell

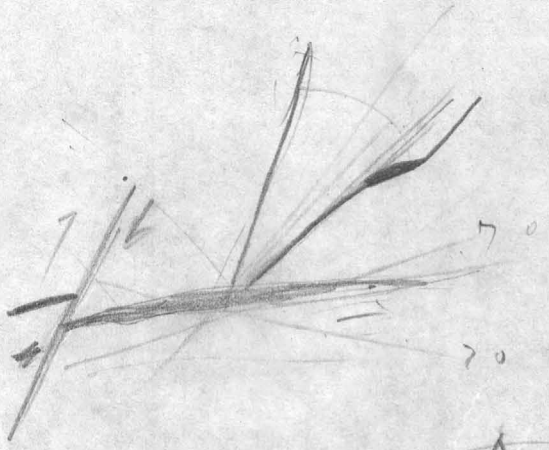
p. 72 "vein following S-shaped fractures of pre-mineral reverse fault"

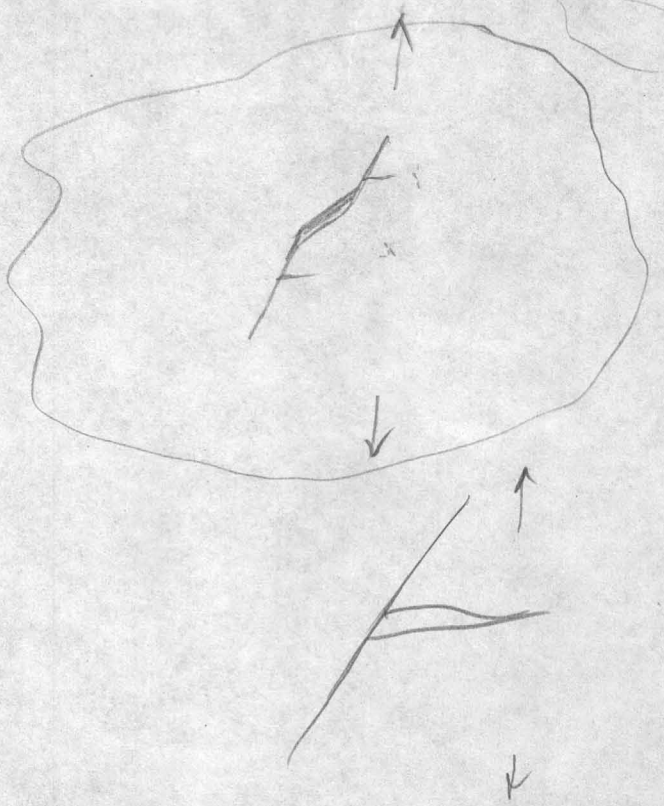


"Fractures in fault indicate this movement"

Silver King

Plate 37





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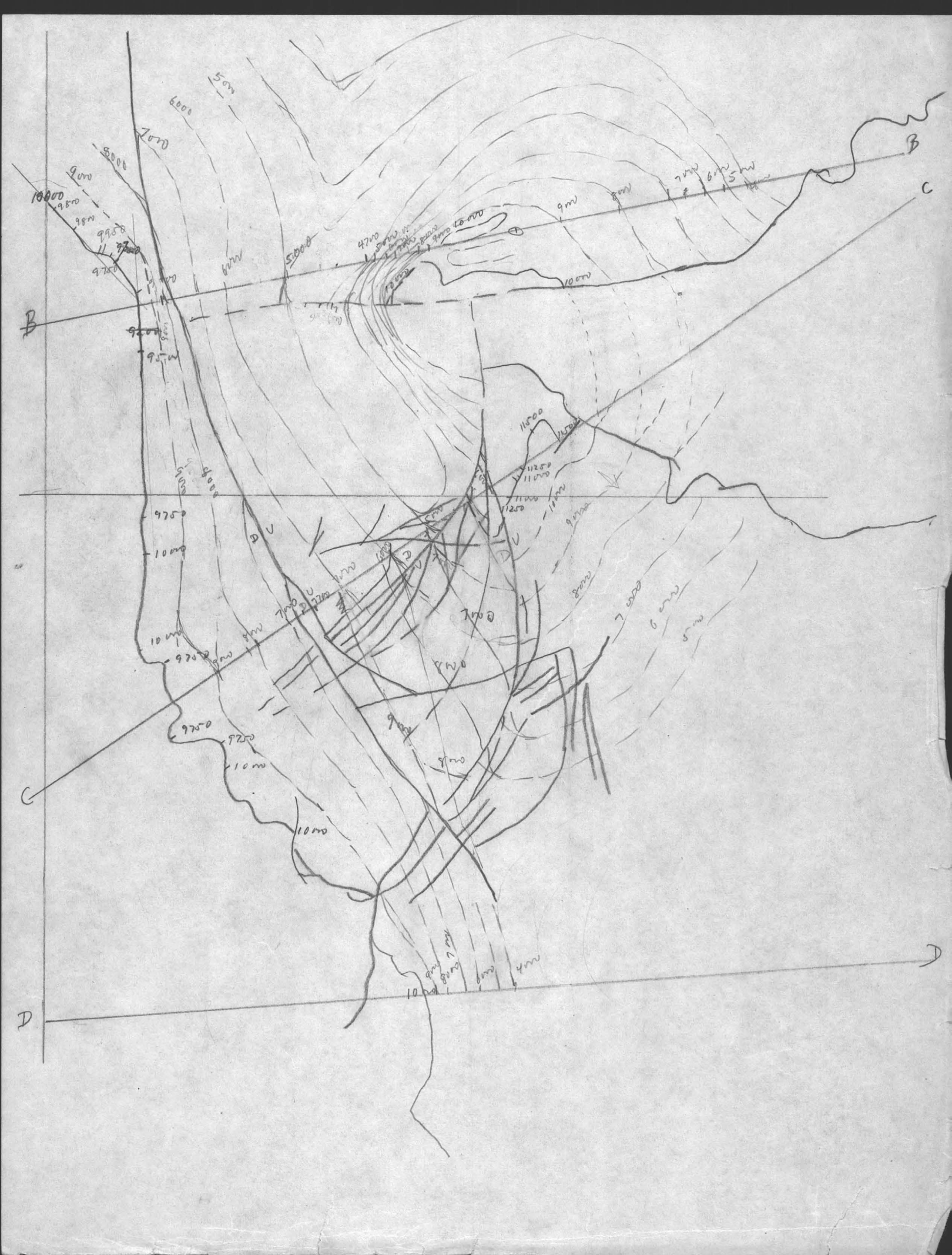
General Notes on Montgomery

(1) Ore characteristically free from gangue — can sneak in to unlikely places — masks the more obvious structural control where gangue is bulky.

(2) ~~Feather~~ Tension joints formed 1st — evidence of fitting by shears & min. paragenesis. Conditions of easy elongation. These must have cleared to make possible the later shear pattern.

Possibility — general filling of the tension joints with dikes — nearly all have the tension joint attitude.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SUMMARY OF VEIN CHARACTERISTICS, MONTEZUMA DISTRICT.

Strike ~~E-W~~ S75°E to N 70°E.

Vein	Nat	Dip	Nature of Vein	Tectonics.
Baker	N72E, N60E	65N 85N	Ave, width 16" but lensy, 3-15'. Pockets and chimneys galena and silver minerals. Quartz, fluorite. Ccpy, stephanite.	See map. E edge Sp gr. but press, but protected to E, and slightly off compressional direct.
Bell (minor vein)	N70E	30N	Vuggy; galena and sphal.	
Bullion (Yellow-jacket).	N75W	65N	Vuggy incrusted with py. Quartz-barite lead copper, 24" for 240'. Vertical dimensions exceed hor. Vein reaches 30" width in main shoot, Local abundant ccpy. Galena seam 1-20"	
Carrie.E.		90	Largely pyrite.	
Chatauque	N80E to E	45N	Strongly sheeted, brecciaed zone 2-10'. Mainly gal., minor gray Cu and sphal. Galena as stockwork or as breccia cemented by Mn-ank. and qtz. Gray Cu (with which Ag ass.) confined to breccia ore. Strong vein.	Intramineral reverse fault. Breaks across schist.
Herman.	N85E		5-6' wide, 20" paystreak. Gal., gray Cu, ruby, argent., quartz.	Cross schistos.
Ida Belle.	N80E	85N	24" ore in Williams Range T. breccia; gal and ZnS; little gangue.	
Jerry, Equity.	E.	80N.	6"-2'. Galena, rhodoch., ZnS, qtz. Local ruby.	Schist. N15E steep E. Faults parallel to this barren or very weakly min.
Lancaster.	E		Fissured zone 4' wide with 5" galena vein.	In Montezuma QM.
Mohawk.	W. Steep N.		Fissured zone 1-5' wide; 4-24" qtz., gal. Pb ore in chimneys, sep. by nearly barren masses of qtz. Little Ag., no copper.	Cuts across Sg.
More Work	N60-80E	NON.	Unstoped parts 5-12". Barite most abundant; cons. gal., sphal, qtz.	W end: schist. nearly parallels vein: weak. Center, schist. nearly at 90°, nearest to EPW strike; strongest; E end makes off on min. shear planes, NE paral. schst.
Morgan.	N80E, 55N.		Minor ore at crossings by NE shears with IM movement. Main OB a chimney, no such relation. Mainly qtz., py, sphal. also abundant; lent. bunches gal. 2-28". Vein to N, Mn-ank, 6%, cont. crustif. thin layers py, sphal. Vein N of that mostly qtz-py., but with abund. ZnS at NE shear vein: 8" wide, open and vuggy.	All in Mont. Q.M. Veins go to gouge seams in depth

Strike S75E to N70E.

Vein	Dip	Nature
Rainbow. N80E	55-65N	Upper adit 15' sheeted zone, 1-3' Pb ore. Narrow below.
Sta. John. No.7 Vein: N80E	55N	12-36", largely barite, with moderate amounts of qtz., sphalerite, galena. Only 12" wide above stopes, with little barite, and mostly rhodochrosite, witj mod. gal., sphal., qtz. Pinches to thin barren gouge, west end, main tunnel. Ore shoot 650' long
Silver King N70E (ave).	65-88SE	Appears to be splitting up in depth, and it does this by turning and running parallel to the schistosity, while it cuts the latter everywhere above. Quartz, pyrite, ankerite, with sparse galena and sphal. distrib. thru these. On upper level, gal. slightly more abundant than sphal., and the two were about equal to the qtz. gangue. Near end of ore shoots Mn-ank. abund. and said to have been associated with ruby sil. While ore seems to have preferred NE strike, width of total vein obviously preferred more easterly strike.
Toledo. N85E	80N.	In Mont. QM. Two NNE veins, 3-13" wide, contain py, gal, sphal, some freibergite. Strong 50" brecciated fault zone. "Like the other eastward-striking fractures, it is pyritic, but does not contain appreciable amounts of the lead, zinc, or silver sulphides." (p. 111.)
Whale N75E	45-60N	Walls 5-10' apart, but pay ore 1"-36". Ore seams often separated from wall rock by thin gouge seam. Abundant white barite cements lumps of galena and gray copper. Evidently reopened. Barite almost only gangue mineral where ore was wide; where it narrowed qtz and dolomite appeared, barite becoming sparse or disappearing if vein carried no ore. Where the crevice wide gangue is soft and strongly impreg. with pyrite; the metallif. minerals seem to be present in much greater %.
Wild Irishman. N75E.	Steep N	Mineralized fault breccia; vein vuggy, open-textured. Gal. moderately abundant, pyrite and sphal. rare; much of galena dissem. thru qtz. I take it gangue exceeded sulphs. Small am'ts. cse-grained barite. Ore in vert. chimneys.

Strike N25°-59° E.

Vein.	Dip	Nature of Vein	CR	Tectonics.	CR
Adder N45E	90	4-12" thick. Galena,Ag mins.			Sg.N30E
Altoona NE		4-8" galena,gray copper in qtz gangue			
Atlantic NE		4-18" qtz.,local galena.			
Baltic NE	45-75 NW	8-14". Barite,mod.ccpy and dk. ZnS,minor qtz.,gal.,gray Cu.			
Revenue N55E	75NW	6" More gray copper (ass,with Ag.) ccpy (ass.with Au) gal.ZnS.Qtz.		Parallel to schist	
Bell N30-70E	40-80NW	Usually 4-12";very little gangue.Light ZnS,PbS.Rare gray copper.Dark ruby silver.		Intra-mineral reverse faulting plus NW side NE hor.move	
Blanche N57-35E	58NW	N57E strike,2'wide,quartz and 3" sulphide seam. Gal.,ccpy, ZnS.			
Bullion. N35E (Bul.vein)	90	Barren 12"sheeted zone,2"go. Thin seam gal.50' long.		Mainly parallel to schistosity.	
Cable. NE		5-8".Quartz,galena,some gray copper.		Parallels schist.	
Cashier NE	Steep NW	12",up to 24". Galena,gray Cu,quartz,some barite. Barren, SW part of outcrop.Small blind ore shoots.		Cuts schistosity.	
Fisherman. N45-65E.90:		Very little gangue.1.Pyrite (2)2.Sphalerite (1), 3.Galena,(3) and quartz (4). Arsenp. Ore in lenticular swellings. Width not stated. (Map shows maximum between walls 30",at place of change, N45E to N63E strike,on latter course;20" ore in the 30".) N45E strike practically barren.			
Hunkidori.N57E,85S-90.		Barren stretches-2-12" iron-stained sheeted zone,or zone of slightly crushed and altered rock. Elsewhere qtz.,Mn-ank., py,gal,minor blende.10-30". IM movements: dark pyritized qtz.brecciated, cemented by Mn-ank.			
Lucky Baldwin. NE	Steep.	Thin and poorly defined in qtz.schist,but widens gradually as it enters Silver Plume gr, One stope 30' long,25' high. Vein well-marked, 6-12". Most of it is qtz.Chief sulph.py.;some ccpy,minor gal.,sphal.			
Missouri-Laclede NE Leftwick.	45-60.	Missouri a6 ' sheeted zone,but center 4.5' barren. Ave.FW high-grade Bi seam:3";ave,HW low-grade seam:15". Thin to thick gouge seams.Qtz.,py., ccpy,dark gray Cu.Ore rich in ccpy has more Au,Ag than the gray Cu and Pb ores. Localization by reverse faulting. Leftwick:mostly barren;near NE fault,6" gal.,gray Cu,ccpy,qtz-barite. Ruby,native Ag.			

Strike N25-55°E.

Vein.	Dip	Nature	Tectonics.
New York. N53-63E	75NW	For most of 900':sphal.,gal.,py., in qtz-ank.gangue. Ore seam generally 4-10" wide,but in main shoot vein 10-36" wide for 300'. 35% combined Pb-Zn.	In Mont.QM. NE shear plane (N.Y.)better than feather jts (Alladins Lamp). Ore on N63E strike; geom.openings best in competent QM.,feather jts.NG because no easy a-a relief.
Old Settler. N60-65E,steep N. (Intermediate between shear plane and tension jt)./		Ore streak 2' wide:gal.,sphal., gray copper,py.,qtz.gangue. Sulphs. much more abundant than qtz. More gal-sphal.than py.	
Old Timer NNE,	70NW.	6-10" gal.-qtz.vein.Gal.dissem. thru qtz.,with some light sphal. Py only in WR.Barite and Mn-sid. earlier than sulphs.and qtz.	Parallels schist. Mostly narrow barren sheeted zone.
Pennsylvania. N30E	St.W.	Stoped for 800';largest,6-14' wide,where vein splits. Vein actually a sheeted zone,and where ore, granite gneiss. Where the sheeted zone 12' wide,total of 30",gal.;8"py;2" ccpy.,total sulphs. 3' 4". Early pyrite and jaspery qtz. brecciated and cemented by white,vuggy, crystalline qtz.	Loc.by NW side NE and up 30°. (reverse). W E
Peruvian. N32E.	84W-90	Sipping ore 20" wide,but vein ave.6' between walls.(Hearsay).Some ore on dump silicified gneiss with disseminated sulphs. 1.Pyr.,sil.,2 barite,3 sphal. and gal. Nearly parallels schistosity. App.on same vein as Penn.	
Sta. John. Comstock: N40E	60NW	Sheeted zone.Gangue seems sparse:mostly barite, rhodochrosite,qtz. Sulphs galena,sphal.,gray Cu. ruby Ore less than 2' wide in most places.	
Sntiago. N15-35E	70-85W	3-8',3rd lev.,2P5,5th. In widest part of vein,3rd lev.,filling is coarsely brecciated granite,strongly sil.and pyrit. These places not ore.Gal., mod. ccpy, less than 5% ZnS,minor py. Lower levels ZnS most abundant.Quartz,ankerite. Wall rock largely Spg.	
Sarsefield. N32-43E.	80SE	Vein 6' wide,but pay streak less than 15".Ore nearly free from gangue;mainly gal.and light sphal.; minor gray Cu,py.,barite,qtz. Pinching at top of stope,12" down to 1". Ore localized where vein changed its coarse more to E.	
Silver Wave. N27-50E.	Steep NW	Vein very tight where it strikes more N-S,and parallels schistosity;where it strikes more east it cuts schistosity at large angle;ore in geometric opening. Open,vuggy;late barite common in the vugs. ZnS,abundant ccpy and py,some galena,arsenp.in siliceous walls.(Probably early). Fine-grained qtz. In general a mineralized sheeted zone. Ore shoots all widen abruptly from narrow seams to 12-24" in 5-10',and pinch as abruptly.	

Strike N25-55° E

Vein	Dip	Nature
Tiger N40E	70NW	6' wide,but two narrow pay streaks,6". Galena,sphal. in quartz-barite gangue.

Strike About N-S

Vein	Dip	Nature	Tectonics
Josephine N12E	67W	Well-defined;vein-filling in barren stretches between ore shoots is quartz;ore itself remarkably free from gangue. Ave.width ore is stopes 1'.Gal, some sphal.,py.and ccpy.	Very likely conditioned by steep N-S bdry Spg. On E side:schist pulled away.
Kelso.N10-40W	80E	1-8",mainly galena,py.,minor light ZnS;qtz-ank.gangue.	Like Josephine:attitude conditioned by granite and injection gneiss N-S bands in schist.
Stevens. Just W of N	60-75E.	Very narrow,tendency to branch;little gangue. Galena,some sphal.,ccpy;qtz pyrite where narrow, Mn-ank.where wide.	

NOTES FROM "LOCALIZATION OF ORE IN THE MINERAL BELT OF THE FRONT RANGE, COLORADO.

T.S.Lovering: Colo.Sci.Soc.Proc.12,No.7,1930,233-252.

The mineral belt extending from Breckenridge NE to Boulder includes Montezuma,Silver Plume, Georgetown, Idaho Springs, Central City,Caribou, Gold Hill and Jamestown districts

Regional Structure.-See Plate I. Most of the range consists of large masses of pre-Cambrian schist,gneiss and granite,and small bodies of late Cretaceous and Tertiary porphyry. Most of the schist and gneiss SE of the mineral belt has a monclinal dip to the N or NE at moderate or steep angles,but within the mineral belt the schist and gneiss as folded into sharp synclines and anticlines trending NE. On the NW side of the mineral belt a well-marked anticline trends N into Estes Park. Several large masses of Algonkian(?)granite cut the schists and gneisses.Their disteibution (Plate I) suggests that they acted as strong buttresses which withstood the stresses of Tertiary mt.building better than the less competent schists and gneisses,and thus helped to localize the fracturing of the mineral belt. Pikes Peak batholith extends from Georgetown south to Canyon City. It contains workable ore deposits only in or near volcanic pipes,notably at Cripple Creek. NW of Georgetown is the Silver Plume granite mass. Few ore deposits in it except near its SE border. Coal Creek granite area,Black Hawk to Gold Hill has ore deposits only in its N half. Granite area from Gold Hill and Jamestown to the Big Thompson river has veins only in its extreme S part.

No extrusives in the mineral belt,but dikes,stocks etc.of Tertiary porphyry are common. In the S and N such intrusives are rare except near Miocene volcanic centers like Cripple Creek.

Relation of Intrusives to Schistosity.

The intrusion of the Algonkian(?) granite was in large part responsible for development of schistosity in the earlier sediments;much of the metamorphism preceded the solidification of the granites. (Injection gneiss). Granite gneiss commonly grades into injection gneiss at its borders;this type,early,forms sills. The late granitic magmas,such as the Silver Plume granite and the Tertiary porphyries show much less tendency to break across the schistosity,and commonly occur as cross-breaking masses. Where the schistosity is NE and steep,however,Tertiary dikes are commonly found parallel to it.

Early Tertiary History.

The earliest Tertiary intrusives of the Front Range-felsites,basic andesites,basalts,peridotites are thought contemporaneous with the Denver formation (Eocene,USGS;Lovering thinks late Cretaceous). During the Denver epoch the Front Range was rising,and it is likely that the complex series of NW and N trending folds which finally developed began at this time,although the Denver formation shows no angular discordance with the underlying Laramie. Folding continued with increasing intensity during the Denver epoch,culminating in the Laramide revolution,when monoclinal folds,overturned folds and thrust faults relieved the orogenic stresses which had accumulated. The monoclinal folds strike from N to NW;the overturned folds and the thrust faults nearly everywhere strike NNW. The thrust faults dip NE,and the folds are overturned toward the SW and are commonly broken by reverse faults dipping NE. After the

formation of these folds and thrust faults,but still in the early Eocene,large bodies of quartz-monzonite porphyry were intruded. This intrusive activity was localized along the zone of folded and faulted schists and gneisses of the mineral belt between the Pikes Peak and Silver Plume granites and around the W and N border of the Coal Creek granite.Faulting preceded and followed the intrusions and produced the vein fissures,decribed below.

The larger stocks in the mineral belt caused feeble contact metamorphism of the country rock in places. These stocks were cut by later dikes of granite porphyry and alkalic andesite before the first strong wave of matallization occurred. These ore deposits were formed before the Flattop peneplain developed in the late Eocene and well after the Laramide revolution. Provisionally classed as late lower or early middle Eocene.

General Geology of the Mineral Belt.- The faults,among which are included the veins,formed in response to regional stresses and have a definite pattern related to the regional geology. The mineral belt as stated comprises sharp NE anticlines and synclines of pre-Cambrian rocks Within this belt the general trend of the veins is either parallel to the edges of the belt or parallel to the schistosity,which coincides with the strike and dip of the schists and gneisses. Thus where the belt strikes NE almost all the veins strike NE,but where the belt strikes E the veins strike both E and NE. However,NW-trending veins in pre mineral faults are not uncommon;since their prevailing dip is NE,they are probably related to the early reverse faults associated with the folds of NW trend along the borders of the range.

Meager data suggest that after the early period of reverse faulting,shearing movements occurred thruout the mineral belt,resulting in faults with large horizontal components for movement. Faults of this period generally have a more easterly strike than those of earlier or later periods. Normal faulting and some reverse faulting accompanied and followed the development of the shear faults,and continued actively thru the period of mineralization,but rapidly diminished in importance after metallization was complete. In the NE pasrt of the mineral belt most of the pre-mineral faults show much horizontal movement. In some the N wall moved east,in others west. In the central and SW parts of the belt,however,the movement in the shear faults was more uniform,and in general the N wall moved E. Vertical component differs:at Central City the N walls are commonly downthrown;at Idaho Springs, Georgetown,Silver Plume and Montezuma the S or SE walls are downthrown.

Local Examples. The Jumbo and Conger veins near Nederland strike NNE;Jumbo dips steeply E, Conger west.Movement horizontal,east wall moving S, In the Cold Spring and Orange Blossom veins a few miles NE of Nederland,the strike is N of E,and the veins dip steeply S and N respectively. The N walls moved west nearly horizontally. In the Central City district the Dyke or Pozo vein follows a strong S-dipping reverse fault. With veins that fault other veins,downthrown side is to the N. Consistent grovves in 3 widely separated places on the Kansas vein pitch 15°W. Much of the movement on the E-W veins and faults of the Georgetown quad. according to Spurr was nearly horizontal.(USGS PP,~~162~~ 63,p.162). The S side commonly moved west and slightly down. The movement was more nearly vertical in the veins of the Idaho Springs district than in the veins farther west.

In the Montezuma district the vertical E-W Ida Belle vein is later than the Williams Range thrust fault, and the south wall of the vein moved west almost horizontally. The Bell-Meteor-Wing, Bullion and the Saints John or Comstock follow reverse faults striking NE, dipping NW, while the Silver King vein, showing deep grooves pitching 70°NE, follows a normal fault strking NE, dipping SE. Some post-mineral normals faults strike NNE and dip E. Thus in the district in general, for the few cases where direction of movement can be seen, the downthrown wall was consistently on the S in the NE fissures, and the direction of movement moderately steep; in the E-W veins movement was hor, and the S wall moved west, corresponding to the E-W vein near Silver Plume.

Veins and Ore Shoots.-

Distribution of Veins: The porphyry belt and the mineral belt coincide. In some places the intrusive rocks are much more abundant than in others indicating local intrusive centers. The porphyries vary greatly in mode of occurrence, texture and composition, but generally a local center has a group of porphyries which is characteristic of that locality only. The local intrusive centers are commonly also centers of mineralization, and may have ores which are as characteristic of them as are their porphyries. Those intrusive centers marked by an unusual abundance of dikes and small porphyry masses are associated with more extensive mineralization than the centers where large intrusive stocks are exposed. Thus the Central City and Silver Plume districts are more extensively mineralized than the Montezuma or Empire districts. (Ore deposits are most abundant near intrusive centers where erosion has not gone too deep).

A zonal arrangement of ores is usually found around local centers of mineralization, and in many places the outer zones of separate centers overlap.

G.E.Collins (Relative distribution of gold and silver values in the ores of Gilpn Co.: Trans. Inst. Min. & Met., vol.XII, 480-499, 1903.) indicates a central area of pyritic gold veins, an intermediate zone of gold-silver deposits, and an outer surrounding zone of silver veins. Bastin, E.S. and Hill, J.M. (Economic Geology of Gilpin Co. etc., USGS PP 94, 133, 1917) show that the intermediate ones contains abundant lead and zinc, rarely important constituents in the ores of the inner pyritic zone. According to Bastin (ref.) pyrite is early, followed by Au-and Ag-bearing copper minerals, followed in turn by silver-bearing lead and zinc sulphides. It seems likely that the early iron-rich solutions took the most direct route to the surface (?) and formed pyritic deposits which largely clogged the more centrally located fissures. Hence later solutions had to find their way around the central pyritic area except where renewed faulting opened the pyritic veins. This relation suggests that in this area, where the ores are believed to have been derived from one central source, the greater distance traveled by the solutions that formed the outer zones would favor ore deposition at greater depths below the surface than in the central pyritic area. But such an ideal arrangement is obscured by other factors which control the localization of ore shoots.

Vertical Range of Ore Shoots: The vertical range of ore within individual Front Range mining districts is as much as 3500', but that of a single ore shoot may be great or small according to local controlling conditions. Bismark vein, Silver Plume, single continuous ore shoot with vertical dimension 1800'; California-Hidden Treasure at Central City, several shoots connected by thin or low grade stretches, mined to depths of 2200'.

Owing to mountainous topography, vertical range is better expressed in altitude above sea level than in depth below surface. Lowest altitudes at which ore has been mined differs in different districts.

District	Altitude of lowest mined ore.
Boulder	6500'
Nederland	7700
Central City-Idaho Springs	7300
Georgetown-Silver Plume	8700
Argentine	11500
Montezuma	10000
W of Montezuma	9350

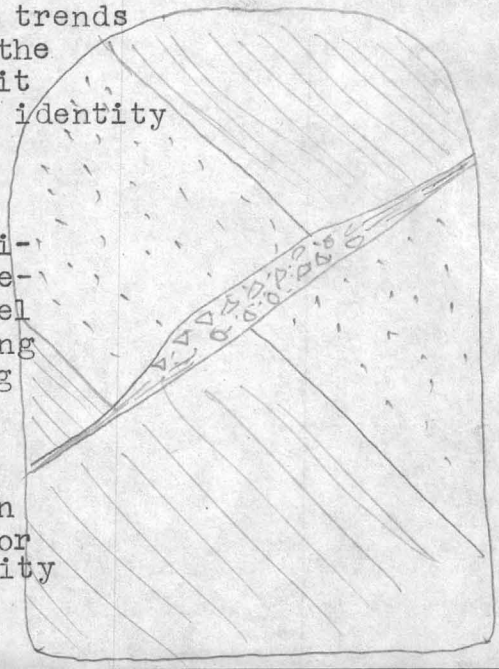
The lowest level of pay ore was therefore distinctly higher in the west-central part of the Front Range than on either side, but this may be due to the Pleistocene arching of a nearly horizontal zone of ore deposition.

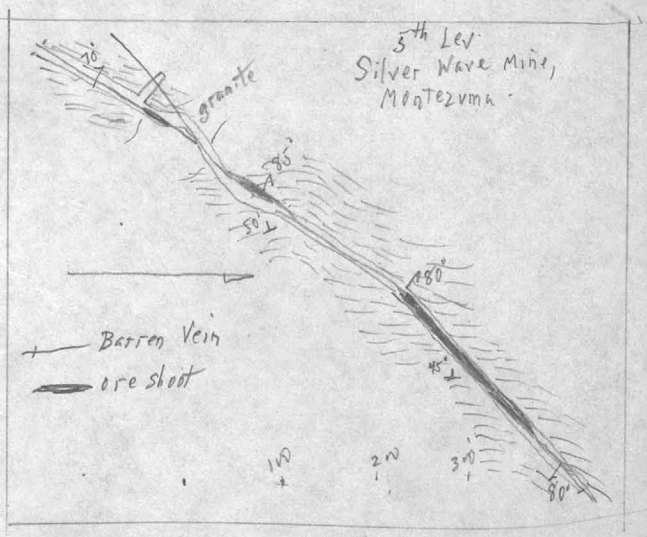
Localization of Ore: Lovering thinks these veins have no leached, barren zone at the surface; on the contrary, surface enrichment was important where the present surface coincides closely with that of the Flattop or Rocky Mt, peneplains. Wise Mt. veins of Montezuma quad. crop out on the Flattop peneplain; rich gold ore limited to a depth of 25', below which the ore turned abruptly into very low grade pyrite. Veins near top of Republic Mt. at Silver Plume rich secondary silver extends down 300', passing then into primary lead-zinc ore. The top of Republic Mt. corresponds to the Rocky Mt. peneplain.

Wall rock control is important; physical only, the mechanical reaction to the regional stresses of early Tertiary time. Hard brittle rocks like pegmatite, granite porphyry and gneiss are the common wall rocks of the persistent ore shoots, while soft weak plastic rocks like mica and hornblende schist seldom form the walls of persistent ore bodies. Intersections usually open, localized ore; marked changes in dip or strike

In the pre-Cambrian complex many different rock types may be traversed by a single fissure; the schistosity of the metamorphic rocks may be crossed at a large angle in some places, or run parallel to the vein in others. A fault cutting a strong rock tends to open well defined fissure whereas it usually narrows on passing into a weaker rock.

If the fault trends parallel to the schistosity it may lose its identity as a single fracture and the movement become distributed over several parallel or interlacing slips, forming a sheeted or reticulated zone. Unless the direction of the vein or the schistosity





changes,such a zone is unlilely to carry good ore in schist,although it is commonly productive in gneissic or granitic rocks. See sketch of Silver Wave,Montezuma. Ore shoots occur where the vein breaks across the schistosity.(Cf.Sombrerete).

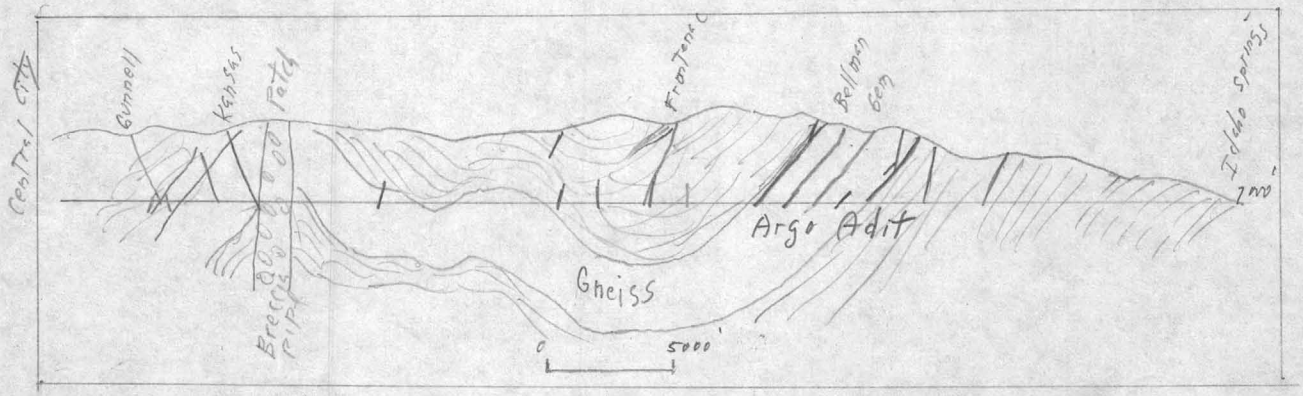
CRITERION: If many periods of brecciation are shown in an apparently barren but strong vein containinggangue minerals commonly associated with ore,the chance of finding an ore shoot somewhere in it is much better than in a vein which apparently was never reopened after the barren filling was deposited;thus the paragenesis may be very significant.

Alteration: 1.Pre-ore,little relation to ore channels-widespread chlorite and epidote in the porphyry belt. 2. Early stage of mineralization:garnet, magnetite, hematite,tremolite, epidote,fine-grained quartz near some of the large quartz monzonite stocks closely related to center of mineralization. 3. Sericite-preceded and accompanied ore deposition; strongest in gold district;commonly related to mineralization channels, though not necessarily to ore shoots. Pyritization and silicification of the wall rocks also preceded and accompanied ore deposition. 4.The formation of carbonate gangue accompanied and succeeded the ore stage. Post ore carbonates are not related to channels of mineralization and seldom are important constituents of the rocks.5. Alteration to clay minerals.

Strong silver lead veins-replacement of wall rocks by siderite and ankerite,rare near gold veins.

Rocks slightly replaced by any of the above minerals can be found throughout the mineral belt,but strong or complete replacement by sericite, ankerite,pyrite or quartz generally means proximity to a channel of ore deposition.

The relation of fissuring to kind of wall rock becomes increasingly important with increasing depth. Close to the surface,open fissures may occur even in poorly consolidated clays and sands,but with increasing depth the fractures in such material become tight,although open fissures may be abundant in stronger rocks much farther below the surface. In the districts discussed,open fissures do not persist as deep in the weak schists as in the stronger gneisses and porphyry intrusives. Hence in any one district profitable veins in schist are more abundant at high than at low altitudes. Deep exploration should be confined to the stronger rocks.



Note influence of gneiss on ore localization.Strong veins in the schist like the Frontenac follow irregular but persistent pegmatite masses.

The Central City district is on the cre t of an anticline in which the predominant rock is granite gneiss and injection gneiss. The gneiss is interlayered with schist;many vains cut alternare layers of schist and gneiss but carry ore only where one or both walls are gneiss. The bands of granite gneiss are reasonably persistent along both strike and dip. Deep ore on the Gem:veins parallels the gneiss. California,which cuts across: bottom level in gneiss,same as lowest band in section. The Gunnell horsetails in the schist,but it might revive in the underlying gneiss. Results in the Argo adit were poor;but the adit passes under the central pyritic zone of the district;better ores would be expected farther from the center;but some of these veins,explored in depth below the Argo adit,have been followed to the outskirts of the pyrritic zone, and results have been poor. It is notable that the ore in these deeper workings is more distinctly confined to strong wall rocks than in the upper levels.

Discussion by G.E.Collins. Emphasizes habit of veins to carry zones within which irregular ore shoots,small in relation to whole vein, lie, and tendency for these zones of ore shoots to pitch rather flatly. Doubts Lovering's 7300' elev.for bottom of ore zone.

Some pyritic veins in the central part of the (Idaho Springs-Central City district) contain very rich ore streaks;often clear evidence that the original pyritic veins had been reopened and shattered,and quartz, ccpy and free gold introduced. Thinks zoning described by him in 1903 (ref.above) was domical proceeding outward in all directions from a more or less definite center. If so the central veins were channels,but since erosion has removed their original upper part,the segments remaining do not show the composite lead-zinc mineralization.(Bastin and Hill note that many veins of the composite galena-sphalerite type at the surface,change to the pyritic type at the elv.of the Argo adit).

The ore-bearing zone in the Nevadaville veins pitches west,due to the W dip of the strata,for ore occurs mainly in the gneissic bands and is limited by the schistose bands. But considering the pitch of the ore zones as a whole,apart from individual ore shoots,there still seems to be a W pitch;this may be influenced by domical zoning.

Collins notes also tendency of veins narrow or disappear when vein attitude nearly coincides with that of schist laminations;he adds that veinsoften become narrow and tight in extensive areas of hard,rigid rocks. IMPORTANT POINT: Sudden contrast-schist to hard block favorable for important openings (cf. cross joints,Foepl's experiments,etc.) But in large areas of hard, rigid rocks,competency is extreme,tension fissures inhibited. The lubrication is lacking. Collins confirms this specifically:"...there is some evidence to suggest that uniformity of enclosing rock was unfavorable to formation of bonanzas;and that a change from schist to gneiss was more favorable for ore than a long stretch of gneiss or granite without any intermission of barren stretches The total load of mineral,capable of deposition under given conditions of temperature and pressure,may have been limited." There are important hints here for development of the general theory of fracturing and ore localization. For instance,the common unfavorability of granite as a container of ore deposits. No lubrication. This may have a bearing on the generalization of the geneticists ,that the interiors of batholiths are N.G. Reason my be structural, not physico-chemical.

IMP.

Collins makes a point concerning probably tenuity of ore solutions: while the schist is an unfavrable wall rock for ore deposition,still the trunk fractures where they passed thru schist were still able to

serve as channels;they solutions passing upward thru these narrow channels deposited ore in the better fractured receptacle rock.

One The California vein everywhere follows a wide porphyry dike,s.t. on wall ,s.t. on the other, s.t. crossing it. Where it crossed was especially favorable for ore.

Collins (p.262) puts his finger on essentials very well:" I believe that studies of the influence of structure on localization of ore bodies are centering on a dual conception;first,open spaces,created by fracturing, by solution, or by movement contemporaneous with passage of mineralizing fluids;and second,confining limits,which prevent or delay passage of the fluids. If this is true,the alternation of schistose and gneissic rocks may be more favorable than long uninterrupted stretches of either rock. The fractures, made by a zone of fissuring in the schist, intercalated with successive resistant beds of hard gneiss,enlarged by bed-faulting along the contacts(perfect description of the lubrication)seem likely to result in irregular open spaces between the laminated and massive rocks,of just such forms as I have observed in some of the old bonanza stopes of the Gunnell mine.

"Conversely- in a case like that of the Druid...where a vein system passes downwards from schist into granite gneiss, at a depth of about 350' from surface, and becomes poorer-the question suggests itself whether the blanketing effect of the relatively impervious schist may not have been a principal factor in the localization of ore;especially in view of the fact that the richer ore occurs in, and as a replacement of, the fractured schist itself, overlying and at considerable distances from the comparatively flat Searle vein,which was the main channel connecting with the ultimate source of mineralization.

"It seems to me that these ore bodies in the Druid mine,enclosed in schist,first described in 1912 (Collins,G.E.:Proc.Colo.Sci.Soc.,10, 226,1912) have received insufficient attention, as indicating the significance of the confining or damming effect of schist in localization of ore bodies."

Flat replacements in schist,on the under side of traps,were only just becoming recognized late in the life of many of the mines;may be a lot more. They were the highest grade ore bodies of the district. Collins suggests that the telluride ores, later than the sulphide ores, characteristically occured in such traps.

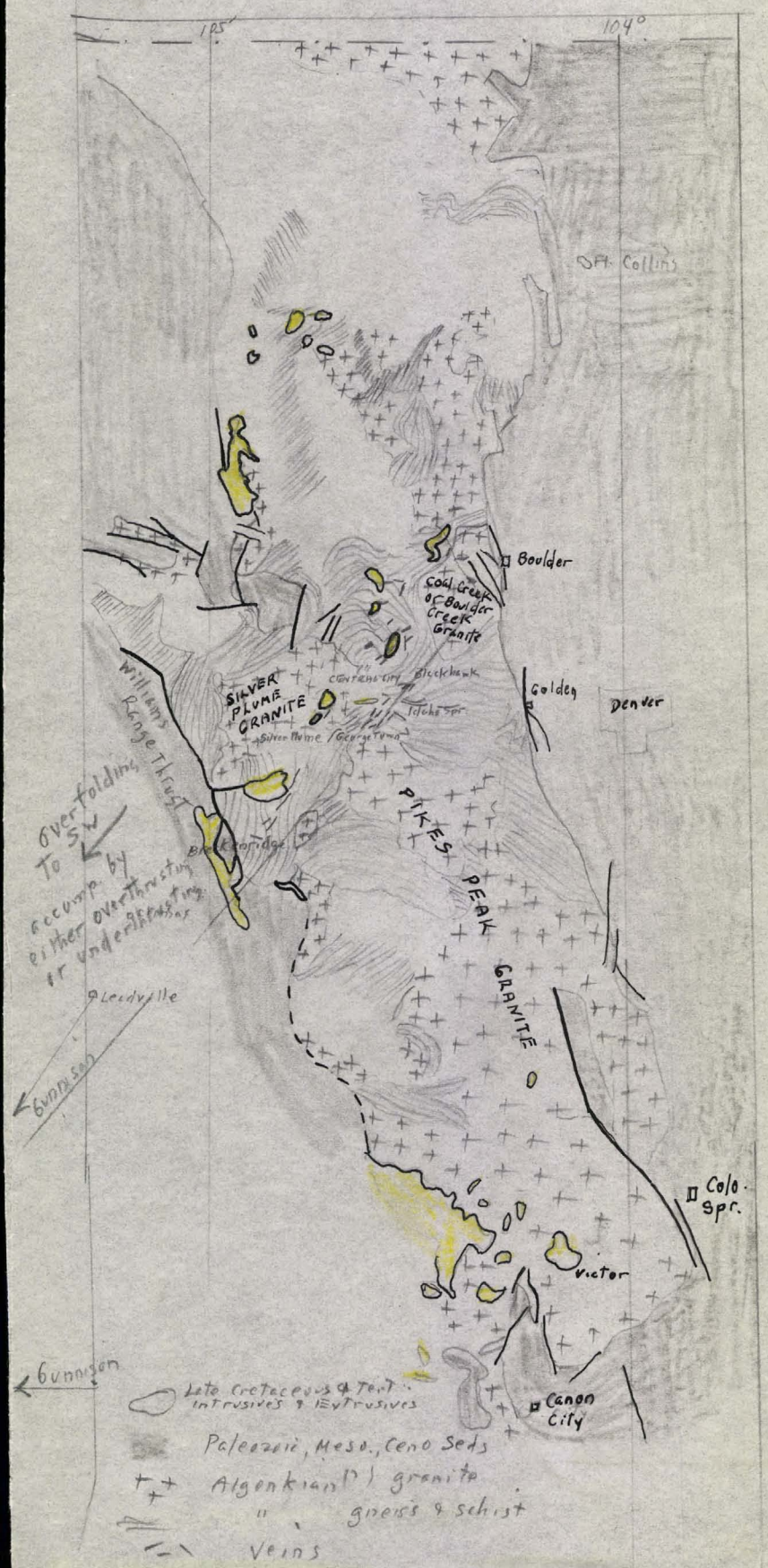

105°
104°
Ft. Collins
0 10 20 mi
Boulder
Coal Creek
Boulder Creek Granite
Contact
Blackhawk
Golden
Denver
SILVER PLUME GRANITE
Silver Plume
Georgetown
Williams Range Thrust
Black Corridor
PIKES PEAK GRANITE
Overfolding To SW
accomp. by either overthrusting or underthrusting
Leadville
Gunnison
Colo. Spr.
Victor
Canon City
Gunnison
Late Cretaceous & Tert. Intrusives & Extrusives
Paleozoic, Meso., Ceno Seds
Algonkian(?) granite
" gneiss & schist
Veins

PLATE I

NOTES FROM: GEOLOGY AND ORE DEPOSITS OF THE MAGNOLIA MINING DISTRICT, AND ADJACENT AREA, BOULDER COUNTY, COLORADO.

Albert S. Wilkerson (Rutgers University, New Brunswick, N.J.): Colorado Scientific Society Proceedings, vol.14, No.3, 1939, 81-101.

District lies immediately SW of Boulder. Lies near NE end of Colo. mineral belt. Most of the production has been gold, but a little tungsten was mined during the World War tungsten boom. No individual mine has produced as much as $500,000, and none has been a steady producer.

GENERAL GEOLOGY.

Algonkian granite gneiss and accompanying aplites and pegmatites cover most of the district. (Plate I). The Fountain formation, Pennsylvanian, rests upon the granite gneiss basement in the E end of the district. In general the Fountain is a rough arkose, individual feldspar often appearing in large crystals. Locally it passes on the one hand into conglomerate, on the other into quartzose sandstone. Micas are present, especially in the finer portions. Conglomerate may have pebbles of granite and schist, or of pure quartz only. The conglomerate of fragments of crystalline rocks is found only at the base, and there not universally. The fountain sandstone is characterized by very thick beds; cross bedding occurs at every horizon. (From N.M. Fenneman: Geology of the Boulder District U.S.G.S. Bul.265, 1905).

The gneiss is medium grained, composed of quartz, feldspar, biotite. It is believed to be a primary gneiss with tabular feldspar and biotite crystals indicating the direction of movement in the magma just preceding consolidation. There seems no reason for doubting that this gneiss is the source of the Fountain sandstone and conglomerate.

Pegmatite and aplite dikes are abundant (Plate I). Pegmatites range from fine-grained to coarse, and consist of microcline, quartz, biotite. Locally feldspar crystals reach 7" long, books of biotite 5". Most of these dikes are less than 15' wide; few exceed a length of 2000'.

The Iron Dike, a regional feature of late Cretaceous-Eocene (?) age, is a regional feature known to extend for about 36 miles, passing NW off Plate II to a point beyond Estes Park, 30 miles to the northwest. It has a maximum width of 50' over most of its length, gradually thinning to only a few inches at its known SE extremity. In most places it is a quartz-diabase, and varies in texture from medium- to fine-ophitic. Laths of feldspar which parallel the walls lie in a mosaic of pyroxene and magnetite. Closely jointed.

An intrusive sheet of rhyolite porphyry about 100' above the base of the Fountain formation, varying in width from 10-60', is of Eocene age.

STRUCTURE.

Regional.- Front Range a long narrow dome composed mainly of pre-Cambrian granitic intrusives and metasediments. The crystallines are surrounded by Paleozoic and Mesozoic seds, which dip away from the range at moderately steep angles but are locally vertical and even overturned. According to Lovering (Structural Relations of the Porphyries and Metalliferous Deposits of the Northeast Part of the Colorado Mineral Belt: Ore Deposits of the Western States, 301-305, 1933) the Front Range gained its

present outline as a result of the Laramide revolution. Regional compression NE-SW at this time folded and faulted parts of the range, especially in the foothills region; folds and faults trending NW are common on both borders of the range. On the E side, especially from the Wyoming line south to Boulder Creek, en echelone flexurs trending NW become more numerous and more closely folded and faulted, and the igneous-sedimentary contact is deflected westward. In Boulder county these faults are abundant and dip steeply, with the downthrown side on the west. Such faults on Plate II are the Maxwell, Hoosier and Livingston faults or "breccia dikes". The Maxwell is the NW extension of the Green Mt. fault, the Hoosier, the NW extension of the Boulder Peak. W to WNW reverse faults of probably the same age also occur, dipping steeply N.

Shortly after the formation of these faults a NE belt of porphyry stocks was intruded in western half of Colo, across the Front Range from near Boulder and Jamestown SW to Breckenridge. These stocks are thought to be approximately parallel with the deforming force of the Laramide revolution. (Lovering: Geology and Ore Deposits of the Montezuma Quadrangle Colo. USGS PP 178, 1935).

Local.- a) Pre-Cambrian. The granite gneiss within the Magnolia is a portion of the Boulder Creek batholith. A detailed structural survey of the gneiss in the Magnolia area was made, and a reconnaissance survey of the batholith as a whole. (Plates I and III respectively). In the Magnolia district many aplite and pegmatite dikes parallel the linear structure (cf. some at Paracale), but all the longest, and the greatest number of the dikes are normal to the pitch of the linear structure. Remarkably often the dip is complementart to the pitch of these lines. A great number of the aplite and pegmatite dikes in the foliated granite gneiss are unfoliated; a few aplites are foliated parallel with their own contacts and across the foliation of the gneiss. The change in strike and dip of many of the dikes, corresponding strictly with the changing direction of pitch of the flow lines in the gneiss, indicates a genetic relation between the dikes and the flow lines. Under the microscope the gneiss shows an order of crystallization characteristic of igneous rocks; the minerals are not granulated nor recrystallized. Throughout the district numerous small schist inclusions parallel the linear or platy structures. The gneiss thus seems unquestionably primary.

In the Magnolia district the platy structure trends west to N45W, in general. Dip is northward, average 60°. Linear structure pitches just W of N to just E of N, at angles from 5-75°, but at most places closely approximates the average, 35°. Field study indicates the magma ascended at a steep angle in the vicinity of Bighorn Mt. and Butzel Hill, N of the district, and spread laterally largely to the south. (Section).

b) Post-Cambrian. Foothills monocline. At E end of Magnolia district Fountain formation dips 50°E. This monocline and the en echelon faults of the foothills region are described by the following:

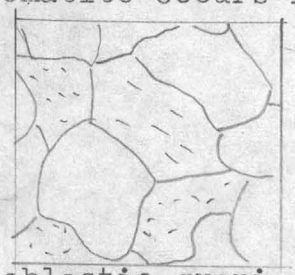
Marvine, A.H.: 7th A.R. U.S. Geo.& Geogr. Surv. Terr., 135, 1873.
Eldridge, G.H.: Geology of the Denver Basin in Colo. USGS Mon. 27, 115-118, 1896.
Fenneman, N.M., op.cit. 46-47.
Ziegler, Victor: Foothills Structure in Northern Colo. J.G. 25, 715-740, 1917.
Lovering, T.S.: Preliminary Map Showing the Relationsof Ore Deposits to Geologic Structure in Boulder Co., Colo. Colo. Sci. Soc. Proc, 13, No. 3, 80-81, 1932.

Breccia Faults.-Regional nature of the major NW faults shown on Lovering's Prelim. Map.(last reference,p.2). At least two are traceable SE to echelon faults in the foothills.One dies out in an echelon fold in the sedimentary beds at the foot of the mts. Lovering (op.cit) was the first to describe the faults in any detail. Beside the Maxwell, Hoosier and Livingston,the Copeland and Red Sign faults are "breccia dikes" as well.

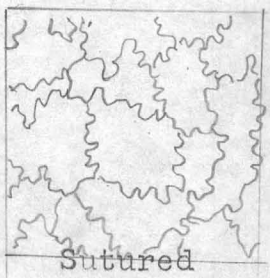
Maxwell: Iron-stained silicified fault zone,10-30' wide. In Boulder Canyon the fault is a shear zone 90' wide,marked by sheared,partly chloritized,slightly silicified and iron-stained granite gneiss. The more highly silicified portion is 25' wide,stands at surface as resistant wall 15' high.(Cf.Lordsburg: Lee Peak and other east-west faults). Footwall is highly polished and locally grooved;evidence indicates movement of the HW with reference to the FW down dip about 70° NW.(Late:see below Microscopic examination of this part of the fault zone shows it to be highly brecciated and fractured gneiss;largest unbroken fragments seldom exceed 1.5 mm.The quartz shows undulatory extinction,so this indicates shearing stress in this case, as I have suspected elsewhere.(Pachuca, Hog Mt.) The breccia os silicified with cherty quartz;iron oxide fills many of the fractures.

Hoosier: Also an iron-stained silicified zone,20-50' wide. The zone changes along its strike,from a slightly fractured to a highly comminuted granite gneiss;all varieties are impregnated with much hematite and silica. Quaetz was introduced twice:1st accompanied by hematite,second not,and slightly coarser than first. In several places,as N of Kossler Lake, zone looks like dense scoriaceous rhyolite due to weathering of portions of the granite feagments leaving cavities in an iron-stained microfelsitic groundmass. At other places there is much glassy quartz resembling the "bull" quartz of pre-Cambrian pegmatite and containing many crosscross veins of hematite.

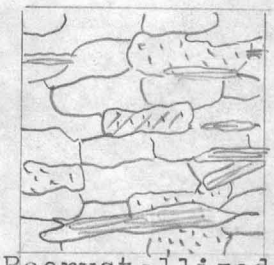
Livingston: Very similar to above two, Often shows coarse-grained glassy quartzseamed with hematite.30-70' wide. Vertical. Rocks of the zone minutely fractured and brecciated;mortar and flaser structures under the microscope. Stringers of sutured quartz with strain shadows indicate an introduction of qtz.that subsequently was strongly stressed. Hematite occurs in the sheared parts of the rock and along feldspar cleavage.



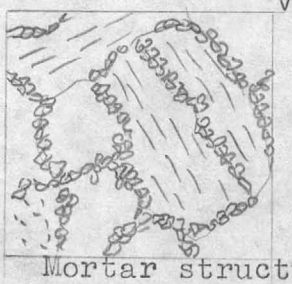
Granoblastic,granitoid (mosaic)



Sutured



Recrystallized under stress. (Schistose)



Mortar structure

Augen structure

Flaser structure.

Appearance in thin sections of textures resulting from progressive granulation and recrystallization.

Sketches from F.F.Grout:Petrography and Petrology,McGraw-Hill, 1932, p.354. Grout gives following definitions for textures of metamorphic rocks:

Crystalloblastic structure:All constituents lack crystal form in general; if crystal forms occur they are simple.

Granoblastic- mosaic,granulitic,hornfels,sugary grained.

Porphyroblastic:same as maculose,i.e. having metacrysts,large crystals formed by recrystallization in a finer ,atrix of schist or slat

Poikiloblastic:having large crystals with many large inclusions.

Sutured:Complex interlocking boundaries.

Mortar structure:a little crushing between grains,resulting in an aggregate like stones in a wall with mortar between.

Augen structure: Lens of some mineral in a crushed matrix.

Flaser structure:lenses of a mineral complex or rock in a crushed or sheared matrix.

Mylonitic structure: Crushed completely. Folded,faulted, sliced, sheared,shattered,healed,veined, replaced, pseudomorphous,radiating, feathered,with secondary growth, granulated.

Red Sign: 10-40' wide, locally dips 65°N. Brecciated and silicified about the same as those described. Striations on slickensides hard rock surfaces indicate horizontal movement,north side west(right wall ahead) just north of the Graphic mine.

Copeland: Iron-stained,silicified,45-70° wide. Half a mile SW of the Walker ranch the zone is 70' wide;an exposure of the HW for several hundred feet horizntally and 50-80feet vertically is highly polished, plucked,striated. Average dip is 65° here;footwall moved east down the dip at 25°. (Same relative movement as Red Sign). This movement took place after the introduction of iron oxide.Flaser and mylonitic structures common under microscope. Repeated fracturing accurred;at least 3 periods of mineralization.1.Hematite with a little qtz.;2 very fine cherty quartz;3 slightly coarser qtz,with some ferberite and alunite.

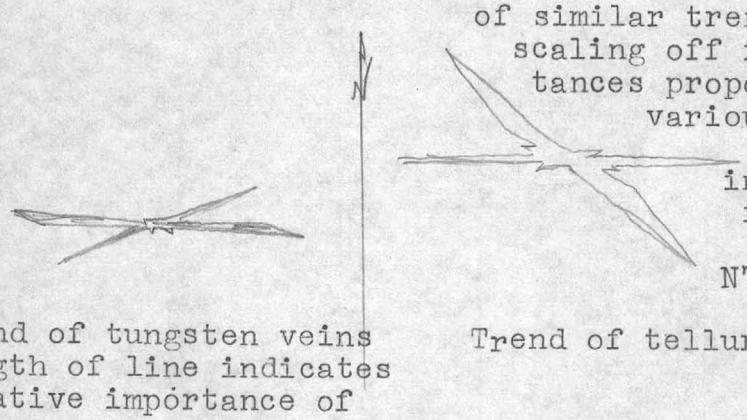
The Green Mountain is the SE extension,in the foothills,of the Maxwell,the Boulder Peaks, that of the Hoosier. Echelon folds (trending NNW,apparently)mark the Front Range north of Boulder. One about 15 mi.N is closely compressed and broken by a NW fault that has dropped its west side. This is characteristic of the other echelon faolds,and the amount of deformation increases as Boulder is approached from the north. These folds and faults N of Boulder originated as a result of the compression that created the master monocline during the Laramide revolution. Green Mt. and Boulder Peaks faults originated at same time. These faults have variable dips,east and west,but tending toward the vertical:they are undulating surfaces slightly concave toward the east.

The zone of weakness trendinf N40E across the Front Range,and into which the Tertiary stocks were intruded is the effect of tensional stresses resulting from strong regional compression NE-SW,Laramide.

At about the same time the rocks failed along planes of maximum shear that trend N30-35W. Since slickensides on some indicate oblique slip movement,the same compressive forcesthat first found release in horizontal movement along steeply inclined shear planes,later found release partially in vertical movement (?).

MINERALIZATION.

The trends of the ferberite and gold telluride fissure zones are shown in the diagrams:



Diagrams made by calculating the approximate area (ave.width x estim.length) of each vein of similar trend and mineralization,and then scaling off in appropriate directions distances proportionate to the sum of the various areas. The extremities of the lines were then joined in succession. Major telluride fissures trend W and N50W,major ferberite fissures,W and N75-80E.

Trend of tungsten veins Length of line indicates relative importance of veins.

Trend of telluride veins.

Paragenesis: 1. Persistent silicified and hematite-impregnated "breccia fault" zones.2. Telluride. 3. Major part of ferberite dep.

Gold Telluride.- Main ore mineral sylvanite,acc. by calaverite, hessite, petzite,coloradoite, altaite. Thesein blades 1.5-2 mm.long,0.5 mm. wide. Often so abundant that they resemble single large prismatic crystals. Also small amounts native Au,sphalerite, marcasite,disseminated pyrite. Gangue chalcedonic quartz, small amounts of fluorite, calcite. The fissure zones commonly consist of several narrow seams of telluride minerals;the ore seldom occurs in a single seam. Seams generallt 1/16 to 1/2 inch wide;some several inches wide are found. Telluride -native Au sequence:

1 Sylvanite (Au Ag)Te2
2. Calaverite (Au Ag)Te2
3. Petzite (Au Ag)2Te
4. Hessite Ag2Te
5. Coloradoite HgTe
   Altaite PbTe
6. Native Au

The tungsten fissures contain ferberite (FeWO4),pyrite,sphalerite, chalcedonic quartz and a small amount of alunite. Ferberite in very small blades 0.22 mm.long,0.10 mm. wide. At a few places the fissures contain a single seam,but commonly they have several,1/4"-3" wide.

All the Magnolia ore deposits are fissure fillings.Many of the veins do not exceed several hundred feet in length;few attain 1000',but the longest,the Kekionga,is at least 6000' long. They range in width from a mere slip to several feet. They dip steeply both north and south, ave,60-70°, and are mineralized portions of both normal and reverse faults that have had a strong horizontal component of movement. Aside fr

from a small amount oftelluride min. within the Copeland fault,all the gold deposits lie in NW part of district,close to one or another of the breccia fault zones.

All the tungsten veins occur within, or very close to,one or another of the E-W breccia fault zones. Most trend E or ENE,dip steeply N or S,and are mineralized portionsof both normal and reverse faults. Some of the veins not much longer than several hundred feet and are only 1 or 2" wide. Longer ones are a foot or more wide."They follow pre-mineral faults along which displacement was chiefly in a horizontal direction. Throughout the district the north wall moved W with reference to the S wall. Except the ferberite mineralization along the Copeland fault, all the tungsten veins lie in the NW part of the district.

Early barren (silica-hematite) stage of mineralization entered only the strong W and NW breccia faults;these served as channelways for the ascending solutions that silicified the zones. With continued stresses new W and NW systems of fissures formed. The writer thinks that a change in the direction of stresses then formed narrow fissures within the E-trending silicified fault zones,and also formed short,new E and ENE-trending fissures. The breciia faults were tightly silicified and almost closed at the end of the period of barren mineralization,and the solutions that continued to rise could deposit only where channels had been reopened within the silicified faults or where fissures had been formed nearby. In the newly formed openings tellurides,and then the major part of the ferberite, were deposited.

Vertical Range of Ore Deposition.-Greatest vertical extent know gold ore shoot is 400',but vertical range of ore deposition(from elevations of various shoots) is 1600' (known). Greatest proved vertical extent of tungsten ore shoot is 100',but in the district,minimum range of tungsten deposition is 1250'.

Partial oxidation extends 200' down. Secondary enrichment of telluride ores by leaching of tellurium and probably some silver was important in the oxidized zone,but no supergene deposition of gold was recognized.

Localization of Ore.- Both gold and tungsten ores are localized in shoots and pockets and show marked lack of persistence. They have only assay limits. Structural localization: junctions of fissures and irregularities of the fissures coupled with the pre-mineral movement. No chemical wall rock control.

Ore common at fissure intersections,but this is by no means the rule. At some junctions much gouge formed,but at many places the intersections were much more open than any of the individual fissures. Shoots at fissure junctions in Acme,Audophone,Ben C.Lowell and Poorman mines.

If apprciable horizontal movement along a sinuous strike fault occurred, open spaces formed same for sinuous-dip faults with dip-slip movements. Ore shoots in the Kekionga and Keystone formed thus. Deposition of ore in the Ben C.Lowell shoot was facilitated by the Iron Dike,impeding circulation of rising solutions:more complete pption of the ore below the dike. Same principle of impermeability of barriers explains why ore was most often confined between the gouge seams of the HW and FW without entering the adjacent rock. At many places where the vein was more open and gouge seams were absent ore was deposited as narrow feeder veinlets in the walls and locally enriched these portions. Evident inability of the

solutions to penetrate gouge is shown in the Bessie vein of the Acme mine,where the mineralized portions of the fissure zone end abruptly against the Red Sign fault gouge.

Largest individual ore shoot (Keystone vein,gold-telluride),150' long,up to 20' wide,500' pitch length 55°SE. Ore shoots usually not over 100' long,6-10' wide,250' in pitch length.Many small pockets 10-60' in strike length,10-30' in height,5-6' wide. General ration,pitch length to strike length varies from 3:2 to 4:1. All have been bottomed less than 600' from surface. Shape generally lenticular,and except that in the Ben C.Lowell vein,pitch to SE at 55°.A few are flat-lying, and the largest (Bessie vein in Acme mine),was 225' in strike length,5-10' wide, 20-25' high. Most of the ore shoots cropped out,while most of the pockets were blind. (All this apparently applies to the telluride veins.)

Tungsten deposits very erratic and occur as pocketsin the veins.The largest individual pocket seen was on the Ellis vein.Strike length 75', width 15-20',height 40'. Most are 40'long,6-10' wide,15-20' high.

Origin of the Ore Deposits.- Belt of stocks in the Front Range from Jamestown SW to Breckenridge,coinciding with the mineral belts suggests a genetic relation. The lack of persistanecy of most of the fissures indicates rupture under slight load. The fineness of grain of both ore minerals and gangueis doubtless a direct expression of the rapidity with which saturation was attanied and crystallization induced by rapid loss of T and P close to the surface. Flaser structure and undulose extinction of the qtz grains in parts of the breccia faults suggest deformation at shallow depths. Othe factors suggesting shallow origin for the deposits common vugs,drusy structure of parts of the veins,chalcedonic qtz,marcasite and alunite,total absence of heavy silicate gangue minerals and of large amounts of sulphides. Lower epithermal. Probable that highest parts of the resent surface are not over 3000' below mineralization surface (basal Eocene time).

MAGNOLIA DISTRICT, COLO. BIBLIOGRAPHY.

Exclusive of those given on p.2, my notes.

Baskin, O.L.: History of Clear Creek and Boulder Valleys, Colo. Baskin & Co., Historical Publishers, 1880, Denver.

Cross, W., Eldridge, G.H., Emmons, S.F.: Geol. Denver Basin in Colo. USGS Mono. 27, 1896.

Fritz, P.S.: Unpublished Doctor's Thesis, History Dep't., Un. Colo., 1933 The Mining Districts of Boulder Co., Colo.

George, R.D.: The Main Tungsten Area of Boulder Co., Colo. Colo. G.S. 1st Rep., 1908.

Henderson, C.W.: Mining in Colo. USGS PP 138, 1926.

Lovering, T.S.: Geologic History of the Front Range, Colo. Colo. Sci. Soc. Proc. 12, 1929,

: Tertiary Magmatic Sequence of the Front Range, Colo. Bul. GSA 42, No. 1, 1931.

: Structural Relations of Porphyries etc. Ore Deps. West. States, 1933.

: Geology and Ore Deposits of the Montezuma Quad., Colo. USGS PP 178, 1935.

NOTES FROM "PRELIMINARY MAP SHOWING THE RELATIONS OF ORE DEPOSITS TO GEOLOGIC STRUCTURE IN BOULDER COUNTRY, COLO.

T.S.Lovering: Colo.Sci.Soc.Proc., vol.13, No.3. 77-88.

General Geology.- The eastern edge of the Front Range at Boulder trends north-south and the structure has the appearance of a simple, sharp monoclinal flexure. At the W edge of the city vertical or steeply-dipping Paleozoic or Mesozoic sediments border pre-Cambrian rocks, which extend more than 30 miles to the west. Following Front Range N from Boulder, a series of NW trending en echelon folds gradually carries the contact between pre-Cambrian and Paleozoic toward the E. (Fig.1). Where the first of these ecehelon folds occurs, 15 mi. N of Boulder, it is closely compressed and broken by a NW fault that has dropped the W side. Such faults characterize the other echelon folds, although the deformation and faulting become less to the north. At Boulder NW-trending thrusts cut out much of the sedimentary section, but so far as know these faults do not swing W into the pre-Cambrian terrane. A few mi. S of Boulder, however, on Green Mt. and S Boulder peak (see regional map) the sediments are repeated along NW-trending faults whose arrangement and displacement are the same as those of the faults breaking the echelon folds far ther N.

Two large masses of (pre-Cambrian) granite occur in the region W and NW of Boulder, separated by a schist belt trending W and SW. As the writer was unable to trace the NW faults (entirely) across this schist belt anywhere, it is believed that the two granite masses acted as separate units during the early Eocene mt.-building when the faults were formed. A belt of cross-breaking porphyry stocks extends SW across the Front Range from Jamestown to Breckenridge. Of different sizes and shapes, and irregularly spaced, they nevertheless have a very definite regional alignment. Most of the ore deposits and porphyry dikes of the mineral or porphyry belt of the Front Range lie on the SE side of the belt of stocks; however, the important Ward deposits, and some N of Jamestown, are on the NW side. The occurrence of nearly all the porphyry dikes on the SE side suggests subjacent magmatic chambers in this region and their absence NW of the belt of stocks. Localization of most of the ore SE of the porphyry belt suggests derivation from the emanations of the subjacent magma chambers. The deposits at Ward and Jamestown are close to exposed porphyry stocks or within the narrow regional belt of stocks.

Although regional ore control depends on the regional distribution of the porphyries, local control depends on faults and fractures that made openings in the rock. The most persistent faults of the region are the NW faults that correspond in arrangement and displacement to the echelon folds and faults farther north. Associated with these NW faults are W to WNW faults; age of this set seems same as that of NW faults. The two sets are probably the earliest Tertiary fractures in the region and are clearly older than the cross-breaking porphyry stocks. NW faults are nearly vertical, but E-W set commonly dip N at steep or commonly low angles. Faults of both systems marked in most places by silicified rock and minor hemetaite. Silicified rock ranges from fine-grained chalcedonic quartz to dense glassy quartz resmbling bull quartz of pre-Cambrian pegmatites, and in places coarse-grained vuggy comb quartz is abundant. The granite, where well brecciated along these faults, is cemented by fine-grained hematite-stained quartz. The fault material looks like, and resists erosion like, the adjacent granite, and the two are difficult to distinguish. At other places the glassy quartz, typical high temp., resembles the pre-Cambrian pegmatitic quartz and hence its late age is not generally recognized. This kind of silicificatioj has led to the miners calling

these silicified faults dikes.

The silicification of the NW faults resembles an early barren stage of vein formation. In someplaxes, as at Glendale,the quartz is low in gold;elsewhere,as along the Hurricane Hill "dike" near Nederland,base-metal sulphides are found,and it is likely that the strong veins near Ward carrying base metal sulphides also represent slightly later mineralization along the WNW fault system.

After the early barren period of mineralization a disturbance closely associated with the intrusion of the porphyry stocks produced a wide zone of discontinuous NE faults on the SE side of the belt of stocks. These NE faults ~~are~~ may be in part contemporaneous with the intrusions,but are certainly in part later. They commonly have nearly horizontal movement of the walls. Few can be traced for more than a few thousand feet,although the fault or shear zone as a whole is persistent. Many NE faults were mineralized to some extent,and many are now covered by mining claims. A claim map of Boulder Co.brings out the NE and ENE trend of most of the veins;the belt is indicated on Fig.1,but on the geologic map only the more productive veins are shown.

Many of these fractures branch or intersect one another;the points of branching and intersection are commmonly more open than other parts of the fractures;nearly all the gold and tungsten ore bodies of Boulder Co. have been found in such places.(?) The regional map shows all veins which have produced over $50,000. Nearly all occur within less than half a mile from one or another of the NW or WNW faults-causal relationship. The persistance of the NW faults in strike suggests persistence in depth as well,and the nonpersistence of individual NE fractures suggests lack of persistence of individual fissures in depth. NW faults tapped sources of supply and guided rising ore solutions toward the surface. As these trunk faults were largely clogged during the early barren stage of mineralization,the later solutions had to make their way as best they could along these tight but deep fissures until they reached some of the less persistent but more recent and therefore more open NE faults,thru which they found an easier way toward the surface. In a few places,as at the Livingston mine on the Livingston "dike",the NW fractures were themselves reopened and gold telluride ores deposited in them.

A series of ENE fractures are of later age than the NE gold telluride veins,and are most prominent south of the NE shear faults in a belt trending ENE from Nederland to Boulder.The walls and vein material in these fractures are marked by horizontal or gently dipping grooves. Most of the tungsten ores occur in veins of this group,but tungsten ores also occur in veinsof the earlier fracture systems that were reopened at the time the easterly fractures were formed. Gold telluride and ferberite seldom occur in the same fissure,but in the few places they do occur together,as in the Kekeonga and Red Sign mines,the ferberite is the later. In the W part of the tungsten district,the only one studied in detail,there is a notable concentration of ore deposits close to the Hurricane Hill "dike".

The history of faulting in the district suggests a somewhat varied response to nearly horizontal compression applied from the WSW. The early NW faults,by virtue of their relations to the echelone folds farther north,suggest compression under sufficient load to cause folding accompanied by faulting. The later fractures suggest that compression either was focused on the Boulder region or lingered here longer than elsewhere. The discontinuous (NE) shear faults suggest fracturing under a lighter load than that connected with the major NW faulting. Picture of development of these two kinds of deformation and the resulting fractures:

As the persistent NW faults associated with the folding are found both north and south of the mineral belt and are plainly related to the earlier stages of mountain formation, they may be considered the results of failure at the edge of the region of folding that was produced by the uplift of the Front Range during the Laramide revolution: the NE shear fractures are localized in the mineral belt and are probably the result of relatively westward movement of the wedge-shaped mineralized area during long-continued compression. Failure along the northwest side of the wedge produced the NE shear faults, failure along the southern edge produced the late easterly fractures. (Fig.1).

The sequences of mineralization is in harmony with the ages of the faults. The early, base-metal deposits are found in the early NE faults, the intermediate gold-telluride deposits occur along the NE faults, and the late tungsten deposits are chiefly along the late E-W fractures.

Details.-

Maxwell.- 8-20' thick; an iron-stained silicified breccia easily mistaken for granite. The most productive properties along it are the Poorman, Sun, Moon, Tillie Butzel and Nugget.

Hoosier.- 15-50'. In many places resembles the Maxwell, but it commonly contains more glassy quartz. In someplaces (e.g. SE of Gold Hill, near Summerville) the "dike" is almost wholly vein quartz like the bull quartz of pre-Cambrian pegmatites. But close examination shows it is brecciated with numerous cross-cross veinlets of hematite, and that it lacks the coarse-grained orthoclase and muscovite intergrown with the quartz marking the pre-Cambrian pegmatite. Where the Hoosier splits, near its SE end, cross veins are present close to the junction; they contain fluorite and barite. Many productive gold telluride and tungsten vein are close to the Hoosier. Ohio, White Swan, tungsten, Yellow Pine, silver and gold, Logan gold vein, Dime, Tambourine, Great Eastern-Melvina, Victory, Cash, Slide, Cold Spring and Red Cloud gold telluride veins.

While several NW faults NW of the schist belt have been correlated with the Hoosier, but the latter is thought to lose its indentity in the relatively incompetent schist, and the NW fault breccia in the granite mass NW of the schist belt are thought to correspond only in a general way to the faults in the granite E and S of the schist.

Poorman.- Varies greatly in thickness and nature. At Logan Hill it is a highly silicified fault breccia, reported to carry traces of Au. Near the Poorman mine it is an iron-stained fault breccia cemented by fine-grained quartz, but toward the east, on the hillside south of the road in Sunshine Canyon, it is a coarse breccia cemented by white glassy quartz. At this last place Tertiary porphyries have been intruded alongside the fault breccia, and it is notable that early Tertiary igneous rocks also cut the sediments directly in line with the fault. The Poorman continues farther west than shown.

Blue Vein.- 5-7', chiefly glassy and fine-grained quartz; dips steep N. Junction of Interocean and American veins south of the Blue Vein, at Sunshine, localized valuable ore bodies on both veins.

Livingston.-Sil.fault breccia. 2-50'. In most places carries coarse grained glassy quartz seamed with hematite. Locally brecciated masses of granite cemented by quartz-hematite aggregates mark its course; at a few places vuggy comb quartz is abundant. (Near the Livingston Mill, in

Summers Gulch. Black diabase dike along the Livingston as shown. Veins of the Magnolia district;Black Prince and Red Sign tungsten mines; Nyanza-Livingston gold-telluride veins. The Livingston vein is itself part of the Livingston "dike".

As with the other "dikes", the Livingston butts on the porphyry,but as with the others an apparent continuation NW of the porphyry belt exists. This extension(?) has been locally reopened (it is a breccia like the Livingston) and in a few places has enough gold to be worked.

The NW fault near the Rogers No.1 vein is an iron-stained,sil. breccia like the others. Its NW continuation seems to be the NW break associated with the Oregon vein (tungsten);here though the NW fracture is a wide pre-ferberite quartz vein.

Hurricane.- An iron-stained shear zone marked locally by silicification. Except the tungsten of the Congor-Beddig group pf veins,NW of Nederland,and those in Beaver Creek,to the SE,nearly all the tungsten produced has come from veins close to this shear zone. On the NW side of Hurricane Hill the ores contain minor lead,copper, zinc minerals; these minerals are somewhat more abundant farther NW. This shear zone is little silicified on the SE side of Hurricane Hill;where cut in the Vasc No.5 mine,and in the Clark tunnel at Tungsten,it is a mass of gouge4-10'thick dipping 65°NE. In the Clark tunnel a few thousand pounds of hematite fo chemical use was mined during the war.

Copeland.- Low grade tungsten vein along the E-W vertical fissure. Strongly sil. fault breccia 5-20' thick,showing evidences of repeated brecciation. North wall moved down and to the west.

Standard.-Dips W at low angle. Iron-stained silicified fault breccia gold telluride ore occurs in some places where the sil.fault breccia has been reopened by later movement.

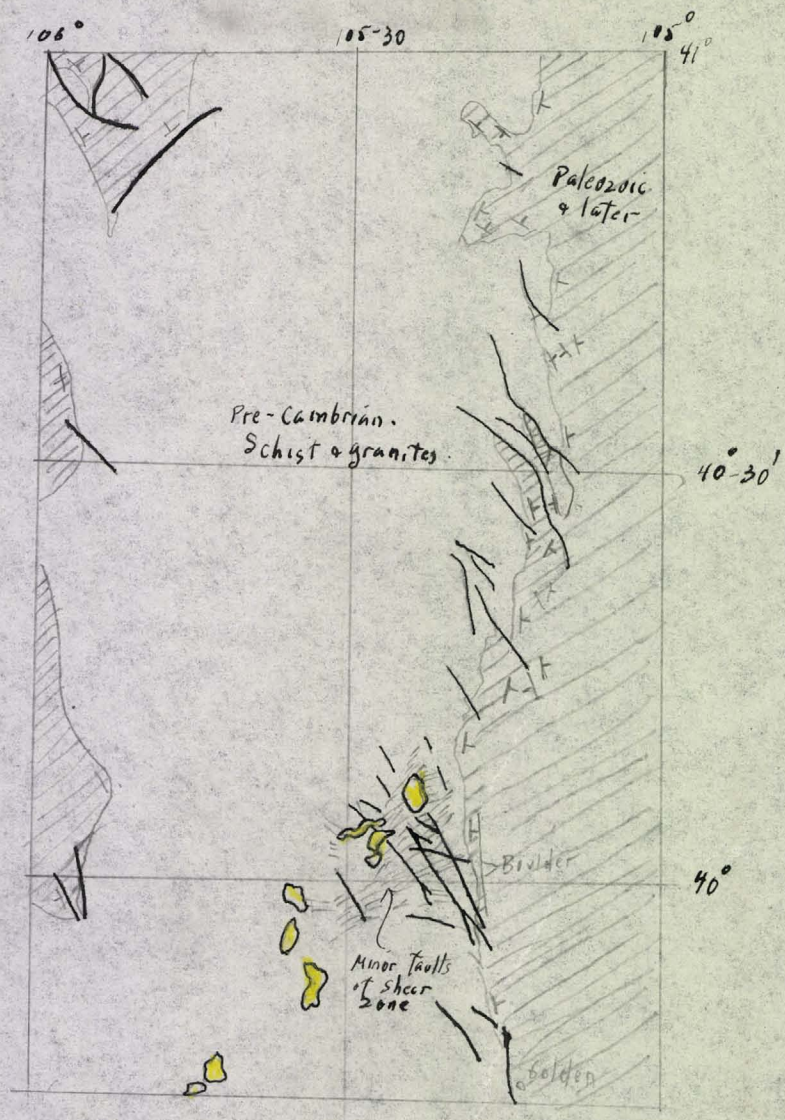


Fig. 1

0 10 20 mi

NOTES FROM: GEOLOGIC HISTORY OF THE FRONT RANGE, COLORADO.

T.S.Lovering: Colo.Sci.Soc.Proc.vol.12, No.4, 59-112.

Front Range: An elongated dome extending from Canyon City N into Wyoming, where it disappears shortly NE of Laramie. It consists of a long narrow mass of pre-Cambrian rocks pracyically surrounded by upturned Paleozoic and Mesozoic formations. All these formations are intruded in someplaces by Teriary igneous rocks, and in others are partly covered by Tertiary sedimentary or volcanic rocks which frequently overlap the beveled edges of the earlier sediments.

Pre-Cambrian History.-Van Hise and Leith: Pre-Cambrian Geology of North America, USGS Bul.360, p.824, 1909, divide the pre-Cambrian rocks of Colo. into four main groups:

1. Complex of gneisses and schists, oldest.
2. Complex of basic igneous rocks, now greenstone, schists, gneisses.
3. Series of quartzites, slates, schists, conglomerates.
4. Massive graniticrocks, in large or small bodies, cutting the gneisses and sediments in places; comparatively unmetamorphised. Youngest.

Spurr, Garrey and Ball: Economic Geology of the Georgetown Quad., USGS PP 63, 37-66, 1908, give following different pre-Cambrian formations, oldest to youngest:

1. Idaho Springs formation. (schists and crystallines, sedimentary or.)
2. Hornblende gneiss (mashed diabase).
3. Quartz monzonite gneiss.
4. Gneissoid granite.
5. Pre-Cambrian quartz monzonite.
6. Quartz-bearing diorite and hornblendites.
7. Rosalie granite.
8. Silver Plume granite.
9. Pegmatite and associated granite and granitic porphyry.

Broadly speaking, pre-cambrian rocks of the Front Range comprise a thick series of schists and injection gneisses intruded by a succession of batholithic and stock-like masses of grantic rocks. One great period of batholithic invasion.

Post-Cambrian History. The paleogeographic maps show the areas covered by various rock systems just before the succeeding formation was deposited. These maps emphasize old areas of erosion much more than the usual paleogeographic maps which commonly show the maximum extent of a given sea. Figs. 1-5 show that the area of the present Front Range was relatively high throughout Paleozoic and Mesozoic time. The Front Range highland, after sinking below the sea in Pierre (below Laramie) time, emerged and in places was wiped clean of post-Algonkian seds. before Laramie (highest Cretac.) time. The Laramide revolution followed the deposition of the Denver formation. In Tertiary time partial peneplanes were developed in Eocene, Oligocene, Miocene.

Upper Cretaceous and the Laramie Problem.

The Laramide revolution did not occur at the end of the Laramie epoch. The Denver formation, which followed the Laramie on the E side of the range, and the Middle Park, equivalent of the Denver on the west side, enable us to trace the gradual development of the orogenic forces that

culimnated in the Laramide revolution. Basal seds.of Denver have pre-Cambrian debris mixed with andesitic material. Latter is the first indication of volcanic activity in the Front Range since the pre-Cambrian, and is a fitting accompaniment to the increasing intensity of diastrophism. Pre-Cambrian material decreases in amount going upward;material more than 900' above the base is said by Cross (Emmons,Cross and Eldridge:Geology of the Denver Basin,USGS Mono.27,209,1896)to be entirely andesitic except the uppermost beds,where pre-Cambrian pebbles again appear. Cross,p.202,concludes that"the Archean and sedimentary rocks in the mountaneous area drained by the tributaries of the Denver sea must have been covered by andesitic lava flows,so that no material other than the eruptive debris could appear in the Denver seds, from this the prominent source until erosion had laid bare, here and there,small areas of granite, gneiss or ss." Present idea is that Denver sediments are alluvial,mainly gravel wash deposited where swiftly flowing mountain streams were checked by the lower gradient of the plains.

Laramide Revolution.

The Denver and Middle Park formations record the rapid arching of the ancient Front Range highland and an intense volcanic activity which covered the pre-cambrian core with a thick series of andesitic lavas. Rejuvenation of the streams caused by this uplift enabled some of them to cut trenches thru the lava cap before the end of Denver time,but the greater part of the higland was still lava-covered at the close of Denver time. The increasing speed of the uplift culminated in the sharp monoclinal folding and thrust faulting which outlined the Front Range area as we find it today.More xetensive thrust faulting on the W side than on the E. The great faulting and sharp folding must have created a mt.range higher than the present one. The folding and faulting is post-Denver and in the Montezuma quadrangle was followed by the intrusion of a large quartz monzonite stock which cuts the Williams range thrust fault. If the folding and thrust faulting mark the close of the Cretaceous,this stock implies the continuation of igneous activity into the Eocene, The ore deposits in the mineral belt of the Front Range,Breckenridge to Boulder were deposited from solutions emanting from the magma that gave rise to the late stocks and dikes in this region. General relations of pre-Tertiary rocks shown diagramatically in Fig.

Tertiary.-Erosion of the Front Range produced mature topography in the higher parts of the uplift before the end of the Eocene-Flattop peneplain;second peneplane along the mt. edges in Oligocene. Strong uplift, accompanied by volcanic activity in the Miocene,rejuvenated erosion; Rocky Mt. peneplane developed in late Miocene and Pliocene, Marked uplift in early Pleistocene;deep gorges cut in the mts. in this and recent.

General Summary.- Since pre-cambrian time Front Range region has been a positive topgraphic area,supplying sediments to the surrounding region thru much of the Paleozoic,Mesozoic and Cenozoic.

Cambrian,Ordovician,Devonian and Miss.seds, deposited on the W side of the range,and exce t the Devonian,on the E side near its S end. Improbable that any of the Palezoic seas covered the Front Range highland but if they did the erosion interval between succeeding periods was marked by the uplift of the same region,and in each of these intervals erosion uniformly removed the formation just deposited to a line within a short distance of the edge of the underlying formation.

Minor warping of the Front Range highland occurred between successive periods,but a parently none of magnitude until late Miss. or early Penn. At this time the Front Range highland was elevated while the adjoining areas were depressed and thick continental and interstratified marine delta deposits were formed during Penn, and Permian time.

Little erosion or diastrophism in the Triassic. In the Jurassic thin marine beds were laid down,and then largely removed by erosion before lower Cretaceous (?) continental sediments were spread over wide, featureless Piedmont hills on both sides of the series of low hills that then constituted the only exposed parts of the Front Range highland. Late in lower Cretaceous time the sea advanced from Texas across Oklahoma,E New Mexico,and SE Colorado to the SE border of the Front Range upland.

The upper Cretaceous sea advanced over a slowly sinking region,but the central part of the highland subsided less rapidly than the margin and, as in Penn, time, a much thicker series of seds.formed along the edge of the ancient land mass than over its center. Subsidence ended in middle Pierre time and uplift began. This soon pushed the central part of the Front Range highland above the sea and exposed the recently deposited shales to erosion. These were reworked into the upper part of the marine Cretaceous, and the pre-Cambrian core of the highland was rexposed as a source of sediments when the Laramie sands were forming. More rapid uplift, accompanied by marked vulcanism, ushered in Denver time. Thock flows of andesitic lava accumulated on the highland and covered the older rocks. Thrust faulting and strong monclinal folding marked the end of Denver time and the close of the Cretaceous. Intrusive and extrusive activity continued into the Eocene;the ore deposits of the Front Range were formed at this time. Late in the Eocene,after most of the ores of the mineral belt had been deposited,the Flattop peneplain was formed in the N and S parts of the range,argely by reexposure of the old land surface upon which the Cretaceous seds.were deposited. In the region W of the mt.front between Golden and Boulder,however,the topography was probably that of a mountainous upland.

Uplift and renewed erosion occurred at the end of the Eocene,but the period of erosion was too brief to impose a new peneplain far back from the mountain front. Volcanic activity and renewed uplift marked the Miocene,and ore deposition at Cripple Creek. The rejuvenated streams carved a new erosion surface (Rocky Mt.peneplain) on the flanks of the mts. During lower and middle Pkiocene wide Piedmont plain formed below the level of the Flattop peneplain. See fig.

Marked uplift in the early Pleistocene.

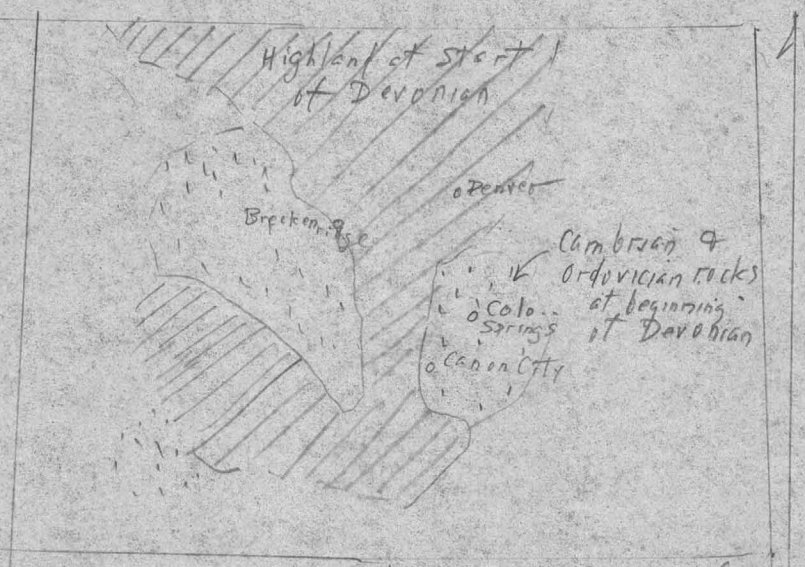


Fig 1 Paleographic Map of Cambrian & Ordovician Rocks of Colorado

Fig. 2 Devonian & Miss. Rocks

Fig 3 Penna Permian

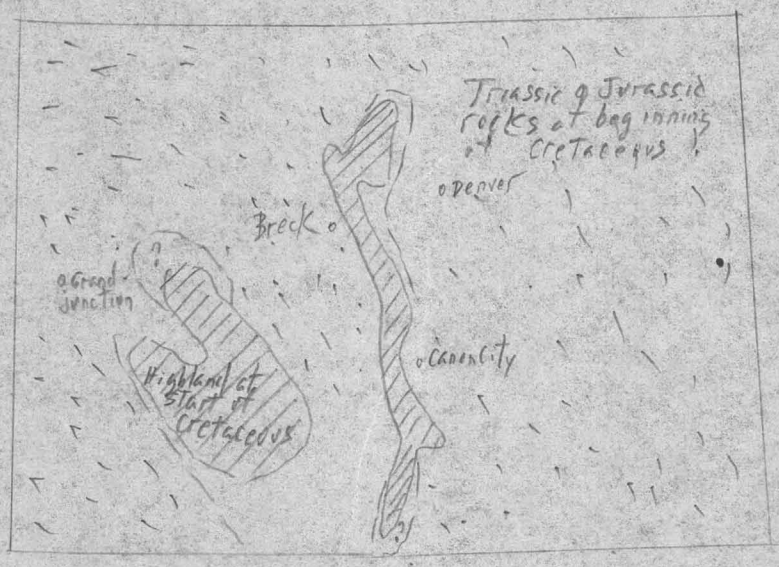


Fig. 4 Triassic & Jurassic

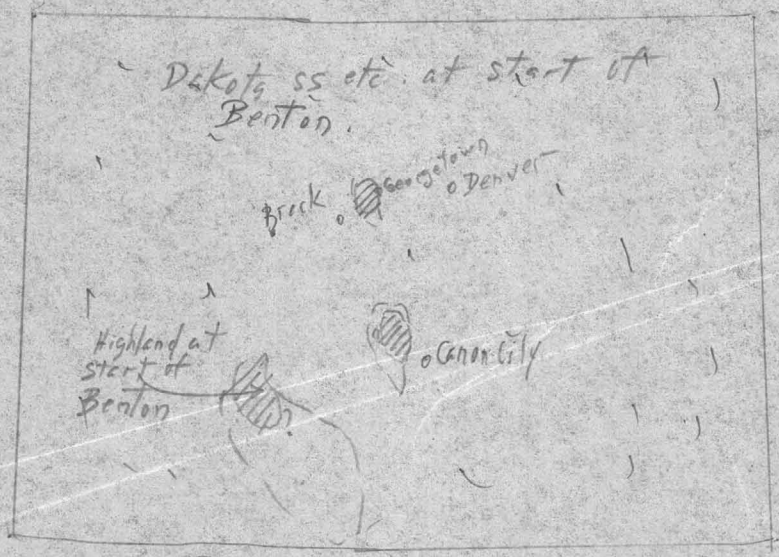


Fig. 5 Cretaceous Dakota ss

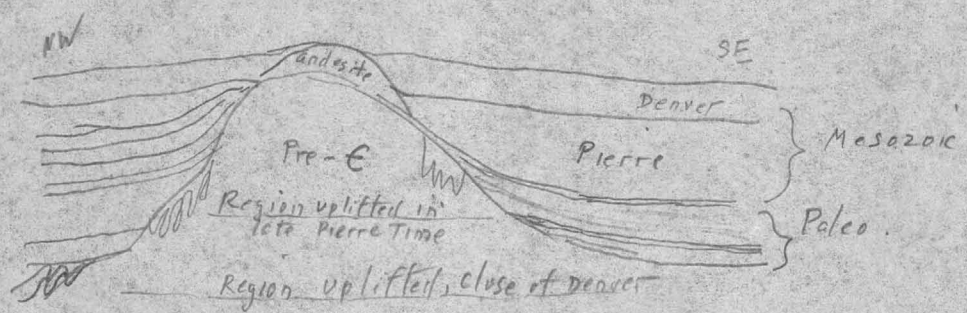
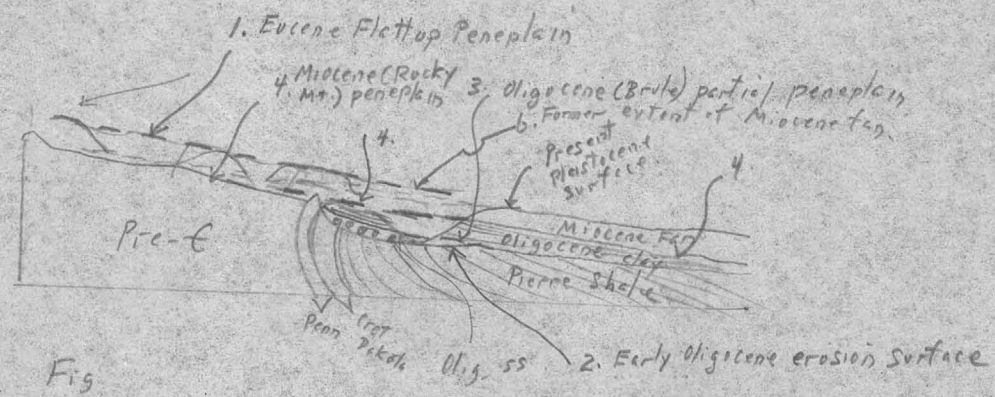


Fig.

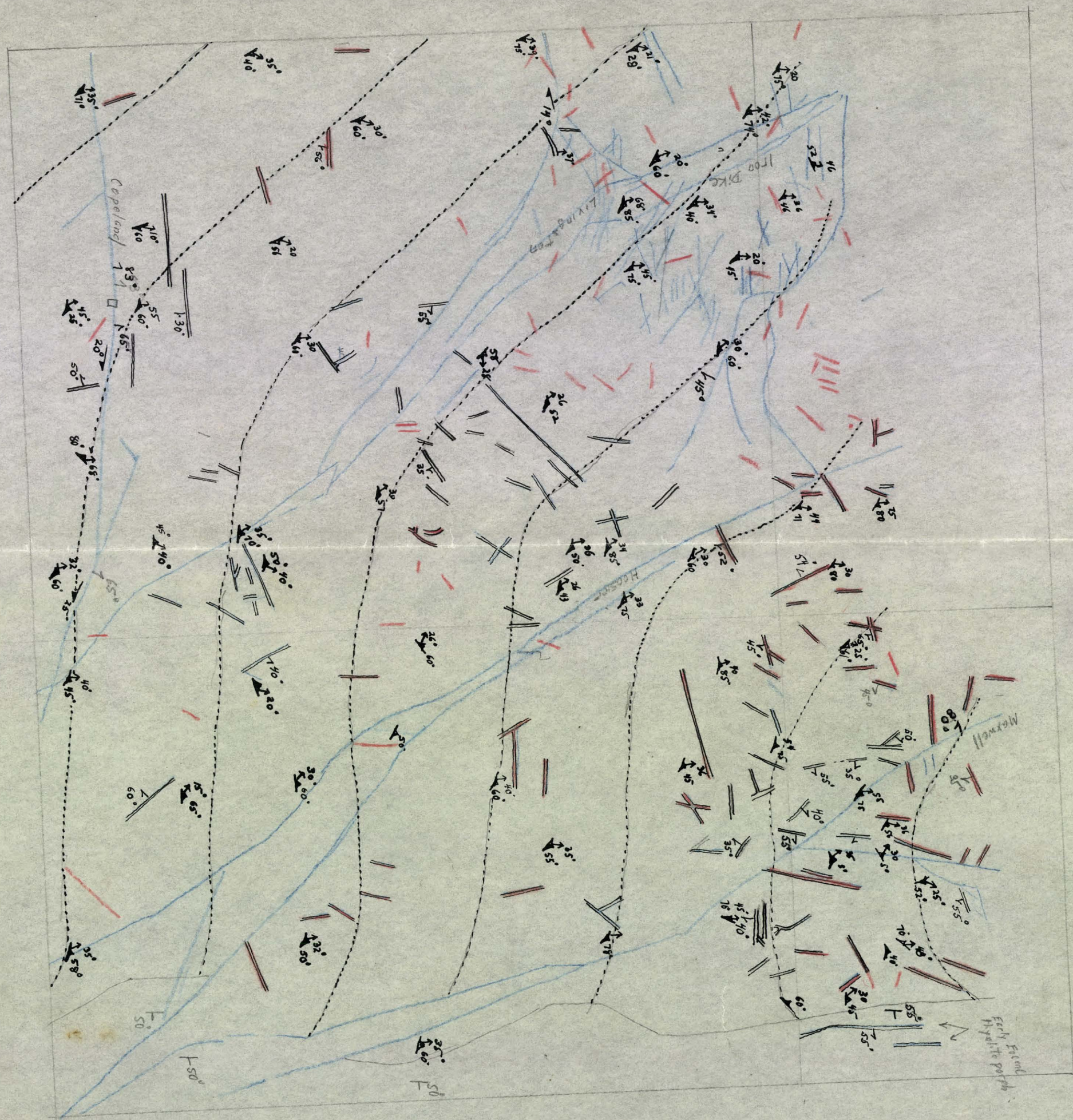
General Relations of pre-Tertiary formations of Front Range to Denver Time
Vert. scale greatly exaggerated



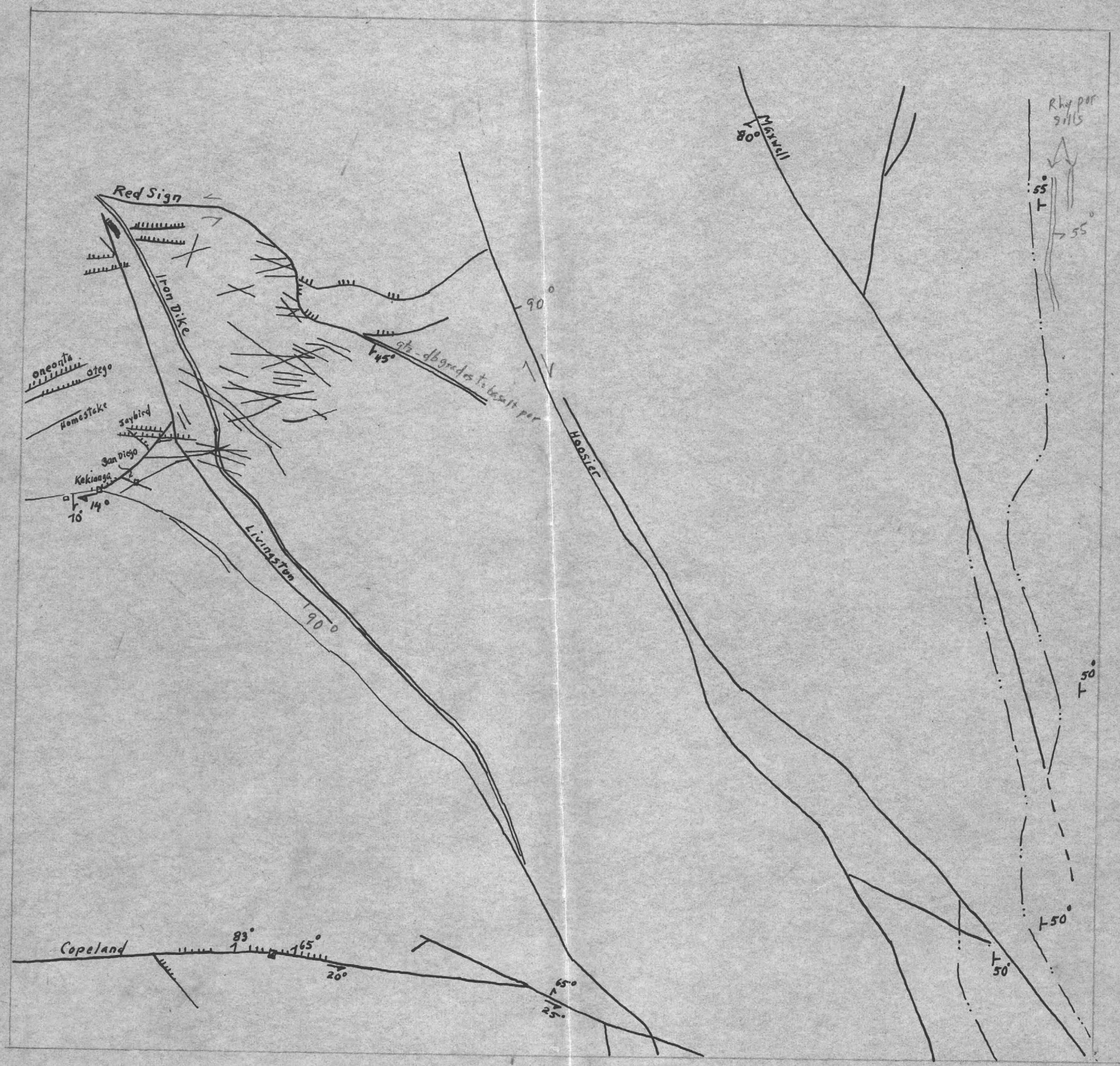
Fig

Horse Creek, Wyoming

Present & restored ancient surfaces of Tertiary beds


Copeland
Iron Dike
Hogsor
Maxwell
Early Eocene
Hydrotite porph

Dove
Empress
Aztec
Gold Coin
Floyd
Bonnie Blue Flag
S.F.C.
Laureace
Ridge
Kingston
H.R.B.
Twin Bros.
Sylvanite
Tunnel
Acme
Caledonia
Gold Bug.
Belmont
Dardanelle
Unknown #3
Sister Emma
Spring Bear
Poorman
Dunraven
Oneonta
Otego
Homestake
Bear
Lowell
Keystone
May Blossom #2
San Diego
California
Magnolia
Kekionga
Audophone
Telephone
Eclipse
Maggie


Red Sign
Iron Dike
Oneonta
Otego
Homestake
Jaybird
San Diego
Kekionga
14°
70°
Livingston
90°
45°
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90°
Hoosier
Maxwell
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50°
50°
50°
Copeland
83°
65°
20°
65°
25°

L - Mesothermal Silver-lead 4A with higher Tem-p in ... Mesot

Georgetown, Colo.
Spurr, Ore Magmas p 753 ff.

Silver Plume. Silver-lead-zinc district; in dozens of steeply dipping veins striae horizontal or under 5°. USGS PP 63, p167. Ore ass'ted with alaskite-monz dikes.

Idaho Springs. Adjacent district, aurif py veins occupy fissures of slight displacement, of strike and dip similar to Silver Plume, but striae steep to vert, ave. 60° to the SW on the NE striking veins (principal system). Ore associated with dikes of the alkali-syenite group. (Bostonite)

Central City-S Boulder Co. Northern part of great continuous mineralized belt from Silver Plume. Contains both types, aurif pyritic veins and silver-bearing galena-blende veins. 1st type main sulph py, subordinate ccpy, tennantite, rarely enargite. Main gangue qtz. Value in gold. 2nd type main sulphs shal and gal, some tennantite, less ccpy. Richer in silver than type 1, poorer in gold and copper. While qtz is main gangue, siderite, calcite, rhodochrosite and barite are abundant. Type 1 is the older; the two types are of distinct periods; later has filled separate fissures, or has reopened and filled older type fissures to form compund veins. Succession is 1 molybdenite, gold arsenic copper; 2 zinc lead silver; 3 qtz and mixed carbs. Little orderly sequence in first two stages, telescoped sequence and superficial conditions of consolidation In the Central City region Types 1 and 2 are more mixed geographically, but are stil somewhat segregated. Connection of pyritic ores with alkali-syenite dikes and that of the lead-zinc ores with the monzonite magma dikes is still roughly indicated in the Idaho Springs quadrangle, but is lost in the Central City map. USGS PP 94.

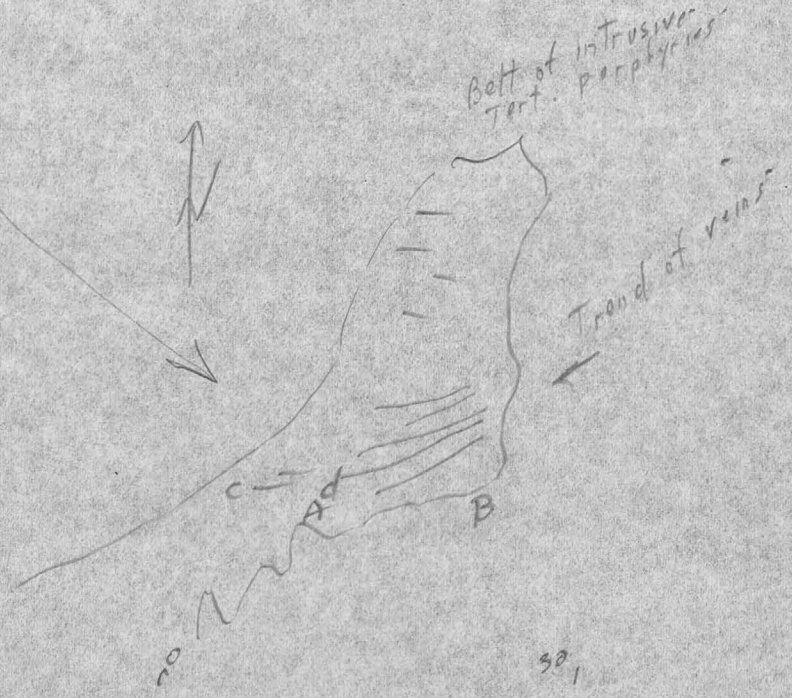
The qtz-monzonite intrusion, as abundant irregular dikes, as stocks up to 2 miles in diameter, is found in great quantity throughout this whole belt of igneous rks. Altho these dikes immediately preceded the silver-lead-zinc veins, these veins are not found where these dikes are most abundant; dikes etc increase in frequency and size to the N of the mapped area, and the veins fall off in this direction. Means that at the period of ore deposition the vicinity of the large masses of intrusive monzonite were at a T too high for ore dep, which took place mainly at a zone above, and rapidly. The systematic slight flt fissures which became the seat of this ore deposition were formed soon after the consolidation of the intrusion; the veins cross the monzonite dikes, although some of the later dikes, as the bi-latite dike at the Stanley mine are later than the veins. At Stanley mine a Bostonite dike is earlier than the vein, and all 3, the two dikes and the vein were injected along the same fissure. Blue Bird mine, 15 mi from Stanley, dike of biotite andesite cuts vein of gal-blende type. Stanley vein, containing qtz, py, considerable galena and ccpy, siderite-. Probably a compound vein, reopened and cemenetd, containing both main types. Sequence: 1 Bostonite dike, vein, minor dike. Pre-ore bostonite, post-ore bi-latite both have excess of K over Na. Same magmatic type. Shows ore dep as short episode.

The occurrence of a single type of igneous rk in many different dikes of the region points to a common body below, as long and wide as the zone of dikes. Dikes and veins follow the same fissure system, a predomiant NE set, and a subordinate NW set. But in general the different periods of dike intrusion and the different types of veins follow different fissures, and the 4 types, two of dikes and two of veins tend to occupy independent areas. All occupy flt fissures of slight displacement, frequently branching, of the linked habit. The predominant trend-NE- is parallel to the general trend of the central Colo intrusion and ore belt; the subordinate NW trend is transverse to it. Fissures are contraction-adjustment fissures, due to the progressive consolidation of the magma beneath. The stocks (all monz) trend parallel with the magmatic belt, while the dikes of both types trend transverse to the belt and to the elongated stocks; stocks are protuberant humps of the magma, but dikes are filling of fissures originating from contraction adjustment of magma mass while cooling. Vein fissures have same origin. Domestic veins and dikes.

Monzonite dikes were probably earliest--differ but little from magma of stocks. Bostonite dikes more highly differentiated. Then copper-gold-arsenic veins; pause, resplitting of some fissures, then zinc-lead-silver veins. Telescoping at each ore episode means shallow underlying magma and a vein horizon near the surface with rapid decrease of temp upward; limited total vertical ore zone, characteristic of all Tertiary veins. When gold-py veins were forming, silver-lead veins were being formed above, in a region now eroded; their subsequent superposition on the higher-T veins, due to migration downward with fallong T due to the downward progress of cooling of the magma below. Underlying magma reservoir came closest to surface at NE end of mapped area (Caribou Hill) shown by differentiation (to gabbro etc) of monzonite stock, and by local titanium, tungsten and copper ores.

Horizontal movement of Silver Plume vein fissures indicates lateral adjustment due to differential horizontal shrinkage on consolidation of the magma body beneath. This indicates a horizontal bulge in the belt. See figure. The horizontal differential thrust along line AB was continued into the magma belt and represents the Silver Plume vein-fissure zone cd. Accomplished by and during consolidation, for vein fissures are later than the Silver Plume qtz-monz dike. Horizontal adjustment fault fissuring. Where vertical component of faulting is larger, as at Idaho Springs, then vertical element of consolidating magma adjustment enters, and relative importance of the two factors determines the actual angle of flt movement in each case. Faulting down the dip indicates simply sagging of the magma below.(Vertical adjustment flt-fissuring)&

Dip of veins follows the rule for fissure veins (60-70), regardless of change in strike. This indicates that origin of fissures is in a vertically exerted force, regardless of the directions in which subsequent adjustments were made along these planes, as recorded by the striae. This vertical force may be result of underlying magma surgence, or of its subsequent sagging, or both.



Georgetown To Caribou.

Tertiary Intrusives in pre-Cambrian rks.

Ink - Bostonite.

Pencil - Minzonite & other types.

Georgetown District, Colo.

Spurr, Ore Magmas, p 125 ff.

General Geology. CR complex of crystallines: gneisses, schists, granites and peg matites (last two intrusive into others, which were partly sedimentary.) Pre-Cambrian. Alkaline-siliceous dikes intruded this mass in early Tertiary. Many veins.

Veins. Two types: Galena-blende, with some py, ccpy, gray copper and polybasite. 2. Py, ccpy, with subordinate gal and sphal. Former silver veins, little gold, latter gold veins with little or no silver. Former predominantly sulphide veins, subordinate qtz or other gangue; latter much qtz, st predominat. Galena- sphal veins mostly in Georgetown area, pyritic veins in region W of Idaho Springs. In district of silver-galena-blende veins occur alaskite and granite porphyry dikes; in district of auriferous py veins, occur dikes unusua ly alkaline-siliceous: bostonite, alaskite qtz monzonite, biotite latite and alkali syenite por. Veins of 1st type always younger than associated dikes; pyritic type veins also usually younger than associated dikes , but older than some of the dikes.

Veins of both types along flt zones of slight displacement. Many veins due to replacement of crushed rk or gouge: Pelican-Bismark vein system, one of the strongest and richest of the district. Ores of this system carry blende and gal with some py with a subordinate qtz gangue.

Same type of ores deposited in open fissures: Terrible vein group strongest lodes in District. Fissure veins: coarse-crystalline dark blende with little visible gangue. Some gal, ~~c~~ccpy, a little ccpy. 25 oz Ag, very little gold. Veins show in places only slip walls, barren; open up abruptly to strong blende veins, 1-4' wide, the blende enclosing angular fragments of the wall rocks. Wide parts are open fissure fillings, for: 1 Included frags are neither rounded, corroded nor replaced; 2 veins lined with thin band comb qtz, xxs perp to walls, not mixed with blende. 5000' eroded from this country since intrusion of dikes accompanying veins, and veins developed 2000' below their outcrops.

Blende veins opened and the fissures filled by massive crystalline galena or massive py; py seems later than the gal.

Griffith Mine: 2 periods of fissuring and vein formation. 1st nearly pure sulphide vein; 1st comb qtz, then coarsely crystalline galena, blende, py and ccpy, with little or no gangue. Then new vein followed roughly line of old one, which it split and shattered, or crossed, or ran parallel to, with horse between. New vein py and brown carbonates of iron, magnesia and Mn, with some qtz, occas. predominant, and a very little gal, blende, ccpy and barite; low-grade gold and silver. Carbs are fine-crystalline, forming dense granular aggregate in which py has also crystallized.

L- Mesothermal 4A

Forma 385 8.000 10 25

COPY

COMPAÑIA DE REAL DEL MONTE Y PACHUCA

PACHUCA, HGO., MEXICO

~~Epithermal 3~~

FOR.....

The Montezuma Mining District, Colorado.
Ettiene A, Ritter, EMJ 2-1-1908.
-S

Location. Continuation of Georgetown-Silver Plume belts westward ~~xxxxx~~d thru Argentine,(crossing crest of Front Range). Belt passes thru Montezuma and on toward Breckenridge. Surrounding mts (13000') belong to backbone of Front Range; composed of Archean crystalline and schists, cut by granite masses; and by long dikes of granulite, pegmatite and granite por.

Vein Systems. Veins are fissure veins closely ass. with the dikes. Two systems nearly at rt angles: main lodes, longer, better defined and richer, strike NE; ore found on minor or NW system is often at junction with main system. Bullion mine: OBs on NW veins crossed by NE veins. NW system mostly confined to a small area in center of district. Strike of NW system more nearly N in NW end of district, more nearly W at SW end. Width of veins varies 1'-15', but variations along same vein not marked. Good walls, slvage to 3" along FW; narrower or absent along HW.

Ore. Metals in general not scattered, but in one streak; when vein is poor, metals are not scattered--streak gets very narrow. Streak widens out to make oreshoots, and often is continuous for great distances between the shoots. Streak may be in center or along either wall. Minerals: Chief ~~m~~silver minerals are native, horn and ruby (veins only developed for a few hundred ft in depth) Lead often associated with the silver. Vein often has streak of this in high grade ore with no milling grade beside it. Some mines however do have milling ore, but this in at least many cases not associated with any high grade. (Silver King mine, e.g.) In all mines the Pb and Zn usually form separate streaks; these streaks st side by side, st on either wall, separated by 4' milling ore with lead and zinc well mixed. (Streaks not pure, but nearly free of the other metal)

Veins are qtz veins, with considerable pink flds. Py content is small, bit iron hats are striking. Upper part of veins well crustified; vugs. Cubes of gal, often with half inch faces, intimately mixed with matrix of flds, talc and qtz. Veins orginally alskaite dikes (qtz and flds).

NE system veins dip NW ,45 to vert. Most of shoots pitch to NE.

Sept. 10th,1940

Dear Wiss:

Had a letter from Johnny and he did not know if he was going to Mexico or not,it seems that it was a question of the money.

I spent last week in Montazuma Colo. on a Silver,lead,zinc, property and made a few dollars. The property was the first silver property in Colo. to be worked and has some nice ore. It has been mined down to the 600 level,the main adit level, but not below this. The samples on the floor after being corrected show several hundred feet of $ 30 ore. All the ore shoots are controlled by the change in dip, on some of the veins the movement is reverse and some normal so get ore on both flat and steep parts of the various veins. From what i could see it looks like there will be a change in dip below the 600 level that will cause the ore to pinch. They are driving a small dog hole out of a winze that was a few ft in the foot wall. The veins are very strong and the country rock in most places is a hornblende gneiss that is cut by a lot of pegmatites. I think the district will open up if the price of metals jumps a little. Most of the properties and ore shoots seem small but have high grade ore.

It is getting cold hear and dont think it will be long before the snow flies,the mining activity drops off during the winter so think I will head out Calif. way before long.

This is about all the news I have and hope you are having good luck in finding some jobs. Maybe some of thoes birds will cut loose from their money if we get a change in the White House next Nov.???.

Best regards,

Fred.

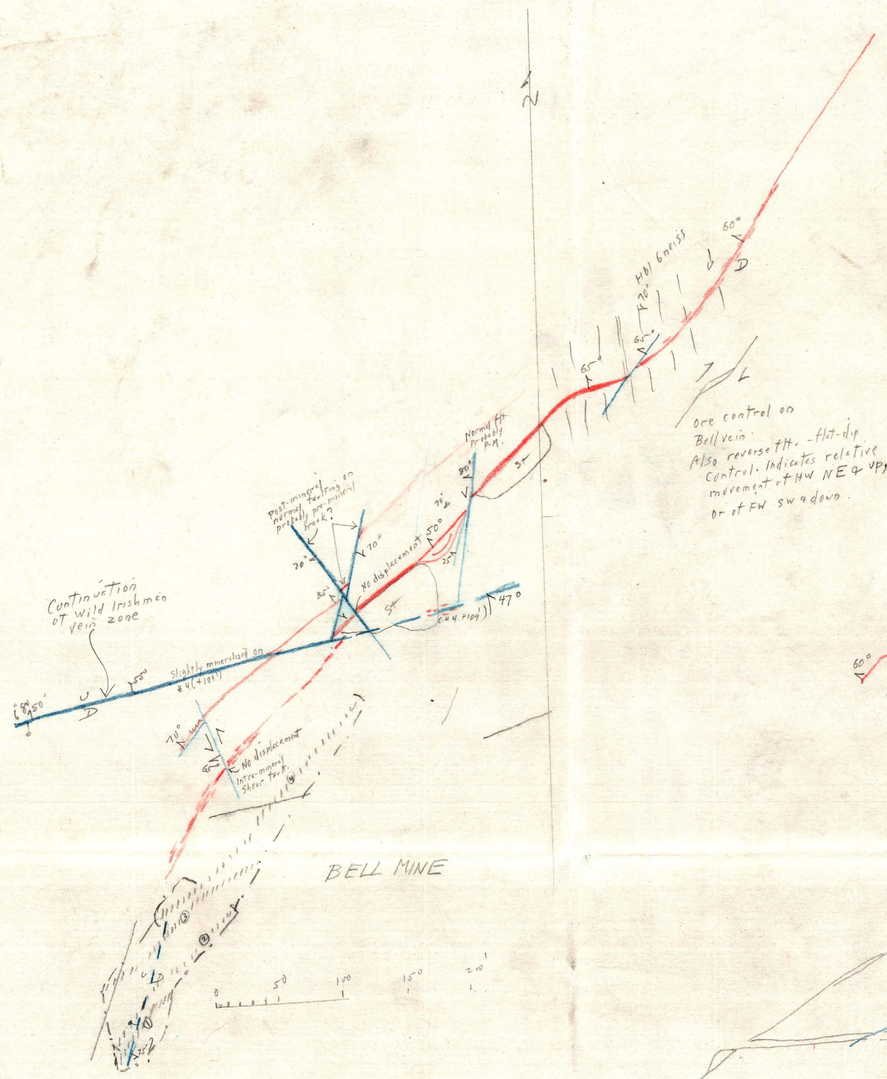
FRONT RANGE, COLORADO *- REFERENCES

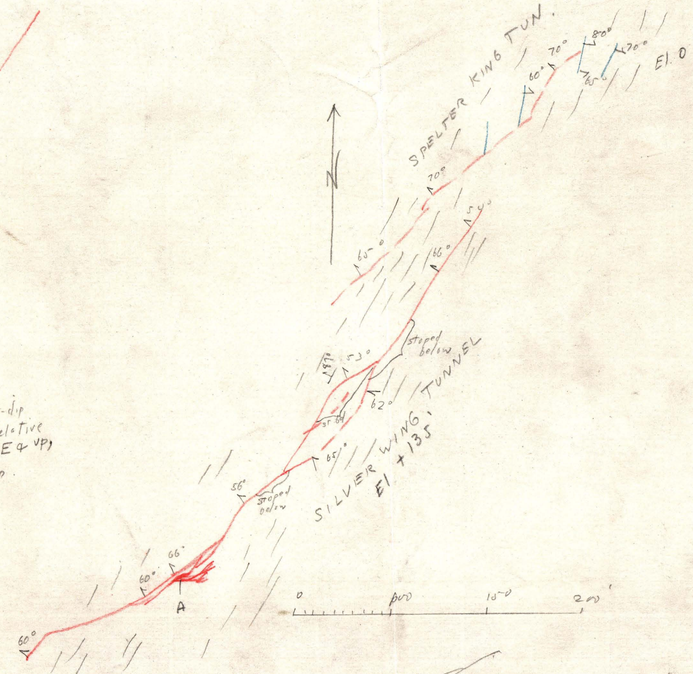
T. S. Lovering, "Front Range, Colorado" in Ore Deposits As Related to Structural Features, edited by W. H. Newhouse, pages 79-93, Princeton University Press 1942

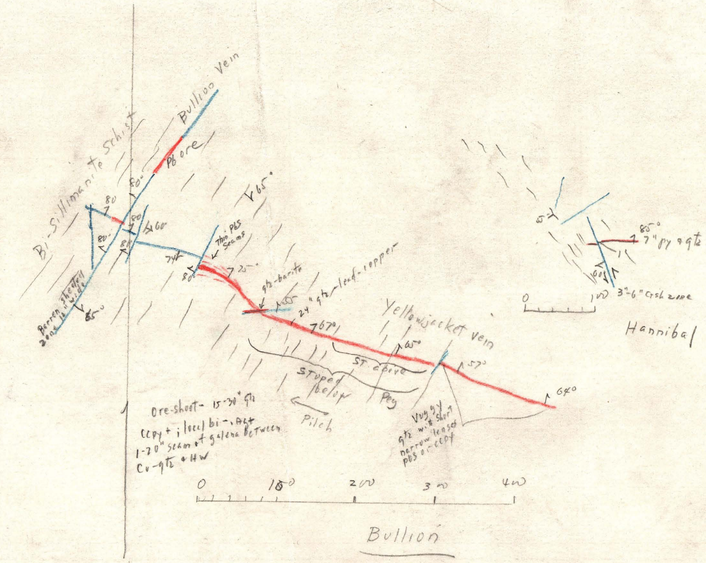
T. S. Lovering and E. N. Goddard, Geology and Ore Deposits of t he Front Range, Colorado, USGS Professional Paper 223, 1950 (Very good detailed study of the area)

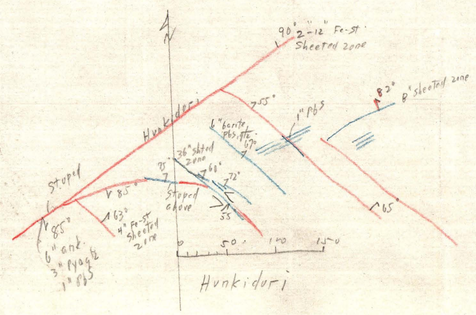
E. N. Goddard, The Influence of Tertiary Intrusive Structural Features on Mineral Deposits of Jamestone, Colorado, Economic Geology, vol. 30, pages 370-386, 1935

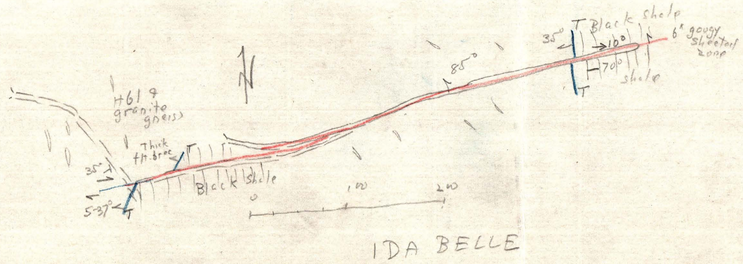
T. S. Lovering, Structural Controls of Ore Deposition in the Front Range Area, Engineering and Mining Journal, vol. 136, pages 411-413, 1935

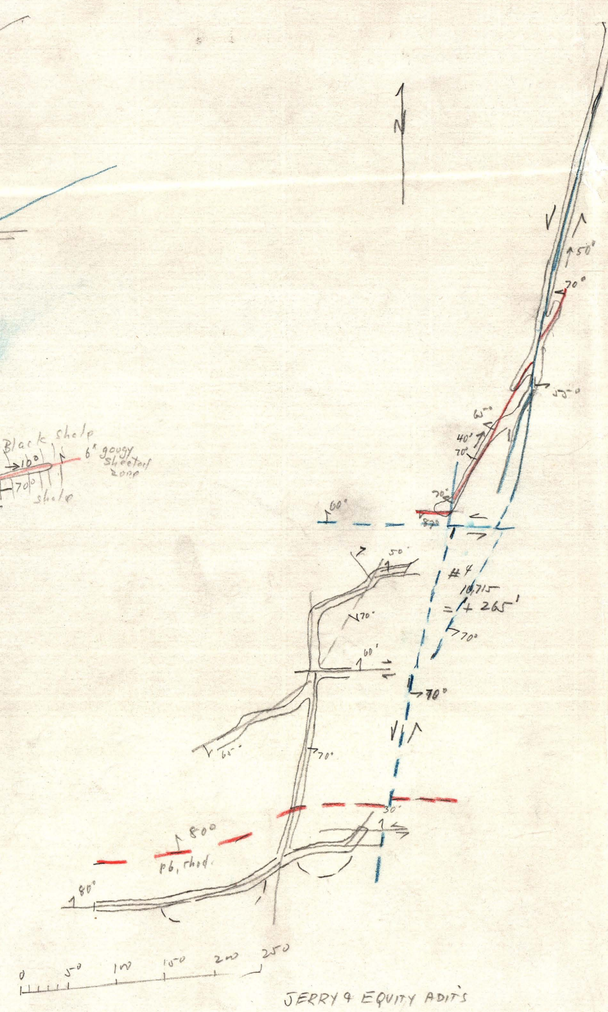

Continuation of Wild Irishmen Vein zone
Slightly mineralized qtz (+Pb?)
No displacement
Post-mineral fault (probably pre-mineral shear?)
No displacement (pre-mineral shear zone)
Normal ft. (probably post-M.)
Hbl Gneiss
Ore control on Bell vein. Also reverse ft. - flat-dip control. Indicates relative movement of HW NE & up, or of FW SW & down.
BELL MINE

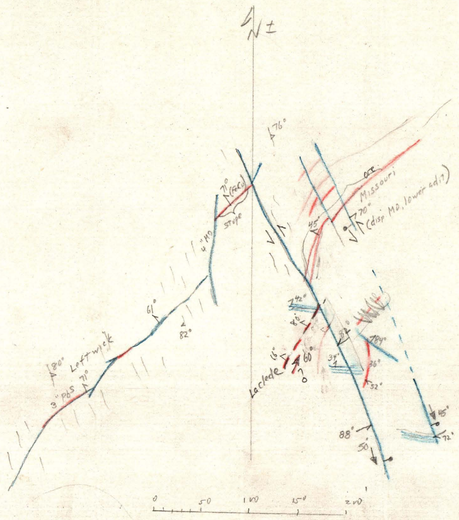

SPELTER KING TUN.
SILVER WING TUNNEL
El. 135'
El. 0
Stoped below


Bullion Vein
Pb ore
Bi-Sillimanite Schist
Yellowjacket Vein
Ore-shoot - 15-30' qtz
Hannibal
Bullion

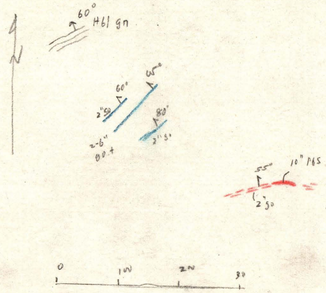

Hunkidori
Stoped
Stoped above
Hunkidori


Hbl & granite gneiss
Thick ft. breccia
Black shale
IDA BELLE

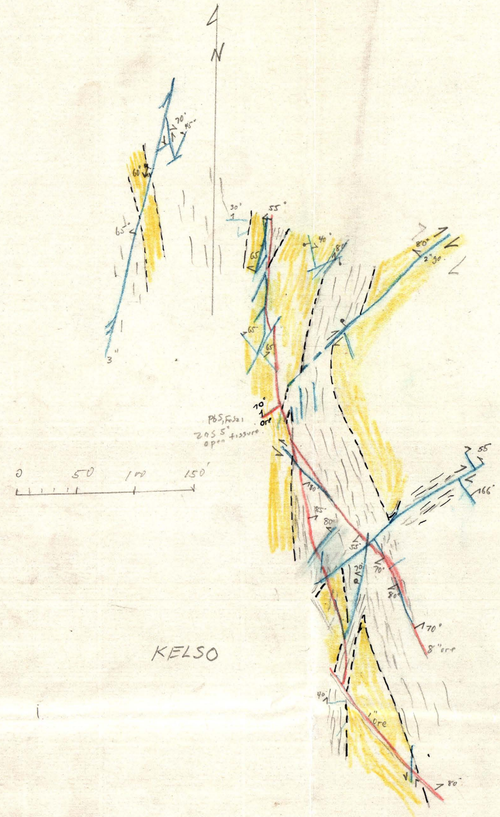

#5
#4
Pb, rhod.
JERRY & EQUITY ADIT'S



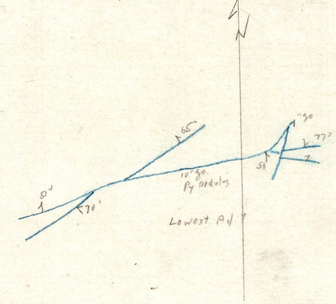
MISSOURI

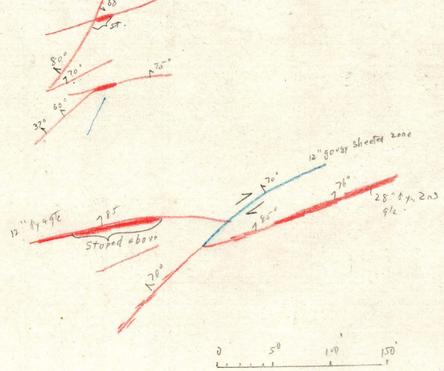


MOHAWK

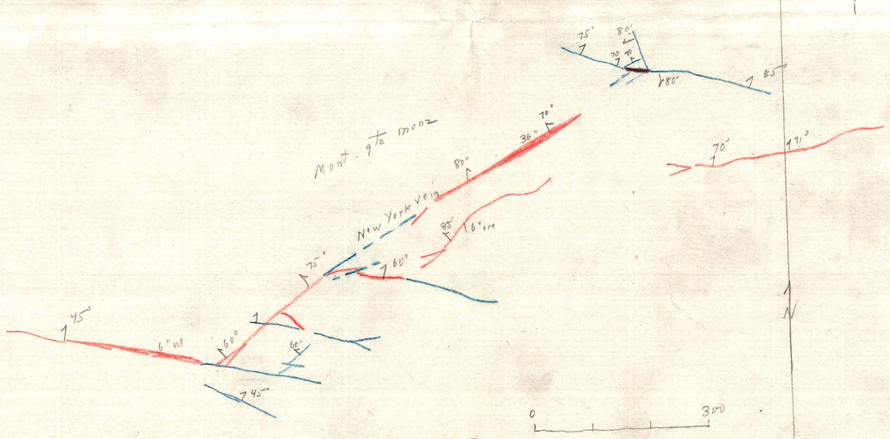


KELSO





MORGAN



NEW YORK TUNNEL

P-M N-S minor faults omitted