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GSA Bull. v. 70, 1959, p. 1649-50

LEAD ISOTOPIC STUDY OF ORE AND IGNEOUS MINERALS AT BUTTE, MONTANA

V. Rama Murthy

[redacted]

FRACTURE PATTERNS-SHEAR IN HORIZONTAL PLANE.

3

BUTTE. (Plate IV-2).

Butte has up to now seemed to negative the thesis brought out that tension fissures parallel to c-c,or feather joints,cannot exist where antithtetic shear planes promoting flow occur,because the first means disruption by splitting of competent rock into fissures,the second, plastic deformation without loss of cohesion for the deformed block as a whole (Eisser: Criticism of McKinstry paper: Structural Control of Ore Deposition in Fissure Veins, Trans.AIME 144(1941), p.88 ff.)

The oldest Butte fissures are filled with quartz-porphyry dikes and by the rich copper veins of the Anaconda system (Plate IV-2). As shown in the abstract on the Boulder Batholith in this folder,these E-W fissures probably formed under E-W compressional stress dominant in the whole region at the time. The granite was competent, unaltered,for the HT solutions only reached the districts after cracking open of these tension fissures gave them channels (Plate IV-2). Reno Sales(Ore Deposits at Butte,Mont., Trans.AIME 46 (1913) 3-109) says the granite is full of joints older than the period of main deformation and metallization; but doubtless it was nevertheless a competent rock.

On the opening of these E-W fissures however (and the filling of a number of them by quartz porphyry dikes) hydrothermalsolutions ascended them,psread out and affected a profound alteration of the rock. As Sales says (p.30) "...there is an unmistakable close genetic relation existing between the widespread rock alteration and the Anaconda vein system.." P.31:",.. the entire rock mass,whether granite,aplite,or quartz-porphyry,hasbeen invaded by active metasomatic processes,resulting in a product differing markedly both in chemical and physical character from the original rock.The hard,dark-colored granite has been changed to a whitish or mottled gray, less firm rock..."Observations seem to indicate that the rock alteration is becoming more widespread as greater depths are obtained."

Sales states that in crushed,faulted regions one would expect to find the greatest alteration because of the apparent greater permeability of the broken country rock tosolutions traversing the fissures.This is not true because (1) earliest ascending waters more active chemical agents than later solutions due to higher P,Tmand possibly to their chemical comp. (2) earliest fracturestension fissures, slight displocation,lack of gouge. Easy access of solutions into walls,at all points along the fissures. Later faults (plastic deformation)gouge dammed off the solutions,narrow alteration halos if any.(3) Regions traversed by older fractures subjected to action of vein-forming processes over much longer period than regions adjacent to later fault veins.

Sales: The chemical agents greatly aidedin attack on granite by dynamic processes (point for Grigsby).

HT alteration: along andououtward from fissures-the channels from depth Followed oldjoint planes. 1st stage:chlorite-pyrite. Feldspars to sericite,qtz. Kaolinite.

It was after this profound alterationtook place that shearing began at Butte. While the plan (Plate IV-3) shows only portionsof the area so altered,there seems no doubt that at depth the whole region was

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softened up and made amenable to plastic flow.

The later fracture patternthat of flow indicates a counterclockwise shear couple,probably combibed with simple E-W compression.The first phase of this was the horsetailing off the Anaconda vein system fractures. Use of preexisting E-W fractures as poorly oriented (directions of shear) resulting in horsetail synthetic shear planes.

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RELATIVE AGE OF BUTTE FRACTURES.

1. Reno Sales: Ore Deposits at Butte, Montana. Tra.AIME 46 (1913),3-109.

1. Anaconda
2.Blue
3 Mt.View Breccia faults
4 Steward
5. Rarus Fault
6 Middle Faults

Anaconda

THE BOULDER BATHOLITH OF MONTANA.

Paul Billingsley: Tr.AIME 51(1915) 31-47

General Structural Setting: Granite intimately associated with the great mt.folds and faults of the Montana cordilleras. Most easterly is an outlying zone of gentle folds-Little Belt,Big Snowy Mts.Next to W, Rocky Mt.belt proper,Livingstone, Main and Big Belt Ranges-a belt of closely folded and faulted rocks overriding the E zone along great thrust faults.W border of this zone indefinite-folds decrease in intensity to W.This belt and these thrusts are E of Butte.Batholith is a massive, a plateau .(Note that the great Lewis-Livingstone SE belt of thrusts quits to the SE due E of the N end of the batholith;only the Lombard overthrusts exists E of the batholith and near it.) W of the batholith another zone of thrusts inaugurates a third mt.belt.(Phillipsburg and other thrusts between Idaho .(Here is perfect mechanics for Butte: general movement,west to east,opposed by Boulder massive.Butte probably ~~in~~ near reentrant facing west. ~~If N angle ofreentrant had sharp steep granite~~ contact,discontinuity,tendency ~~for disruptive faults, S side E~~

Early E-W Anaconda tension system-cracking of W edge of batholith under pressure from the W,whether or not there was a reentrant in the batholith just W of Butte (Check Weed, PP 74). Granite then competent. Later HT alteration softened it,caused "flow".See later. Compare with Baguio,Lordsburg.)

Time Table: 1. Mid-Cret.Main Rocky Mt.folding,formation of large NW earth folds (USGS Bull.470,Contrib.to Ec.Geol.: Geologic Relation of Ore Deposits in the Elkhorn Mts.,Montana. R.W.Stone, 75-98).

2. Middle-Upper Cret.Erosion,bevelling of folds. Shore deposits to E.

3. Upper Cret.Andesite extrusions on eroded surface.

4. " " ? Local intense erosion (local uplift);coarse andesite cgls.

5. " " ? Thrust faulting along NW lines ,local intensification of folding,including the andesitic seds.

6. Eocene? Intrusion of Montana granite.

7. Eocene-extensive erosion (uplift). Peneplain.Early rhyolite.

8. Oligocene. Normal N-S faulting,local accumulation of gravels. Peneplain beingeroded. (Uplift).

9. Miocene. Further river deposits.Later rhy.,dacite. Thru Pliocene.

Note: Billingsley thus places the thrusting before the intrusion of the batholith. But general considerations affecting this whole region give good reasons for thinking ~~xxx~~ west-east ground movements were taking place at the time of the major intrusion:

Lewis thrust:Willis,pre-Miocene,but in Tertiary,middle. G.R.Mansfield: Structures of the Rocky Mts. in Idaho and Montana. Bull.GSA 34 (1923) 269.

Osburn Fault (Umpleby,J.B. The Osburn Fault,Idaho.JG 32(1924) 601-614. Late Cret.but probably continued.

Phillipsburg Mont.(F.C.Calkins and W.H.Emmons,Geology and Ore Deposits of the Phillipsburg Quad.PP 78,141-151. Late Cret."with probably later thrusting" (Quot.from J.J.Beeson:Mining Districts and their relation to structural geology.Trans.AIME 75 (1927)757-792).

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Beartooth Thrust, Montana (A. Bevan, Summary of Geology of Beartooth Mts., Montana, JG 31(1923). Oligocene.

Heart Mt. thrust, Wyoming (D.F. Hewett, The Heart Mt. overthrust. JG 27(1920). Oligocene.

Chief Mt. (check) Montana. W.T. Thom Jr. Relation of deep-seated faults to the surface structural features of central Montana. Bull. AAPG 7, 1-13.

Lombard Overthrust, Montana. W.P. Haynes: The Lombard Overthrust and related geologic features. JG 24 (1916) 269-290. Look up.

Since the Butte fractures probably formed shortly after the intrusion had consolidated, it seems very likely that the west-east movement may have continued, in diminished strength, thru the period of fracturing

Note: There seems no doubt that the Idaho and Boulder batholiths have "shadow areas" E of them where there is little or no thrusting. Nevertheless there is thrusting between the batholiths (Phillipsburg) and not very far E of the Boulder bath lith (Lombard). This suggests that the notion of thrusting by deep-seated rock flowage is a sound one. The massives offered effective resistance locally, but in general the deep-seated flow persisted even past their "shadows".

Suggestion: two orders of thrust: (1) major, related to the deep-seated flow: Lewis, shove is not toward a basin but toward Sweetwater Arch. The antithetic faults west of the Lewis (tension) back up the notion of deep-seated flow; no other conceivable mechanism.

Phillipsburg: Shove is toward the Boulder batholith plateau.

Thrusts 100 mi. E of Idaho Falls: Shove is toward Teton and Gros Ventre uplifts.

While the great thrusts NE of Salt Lake head toward the Green River Basin, they are the S extension of the thrusts just mentioned, hence probably belong to Order 1, continental thrusts. The basin, if it existed at the time, doubtless aided the development of thrusts. On the other hand, it is possible the reverse is true: the great basin may have formed the thrusts, so strong that the extended N opposite the uplfts.

(2) Local thrusts related to uplift and heading toward basins. In the Bighorn region thrusts head toward basins regardless of direction They range in direction of shove almost thru 180°:

Beartooth, shove toward Crazy Mts. synclinal trough. N30E.
Bighorn, " " Powder River Basin N50E.
Beartooth, SE end: thrust turns thru 90° to adapit itself to the Bighorn Basin. Due E.
Owl Creek uplift, S side. Shove toward Wind River basin. S20W.

Billingsley cont. Some of Billingsley's sections do prove granite later than some thrust faults.

Granite intruded as a double dome; the high points E of Butte and N of Basin are separated by a deep trough .

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Batholith veins E-W. Widepread, uniforn distribution throughout the batho.

Discussion: Lindgren thinks there was doming, and points to Marysville (Barrell) and Philippsburg (Calkins) show that these minor intrusions domed their covers; he points also to Billinsgley Figs. 2,5,7. Billingsley admits doming. Cover 3000 ' higher at high pts. than on flanks.

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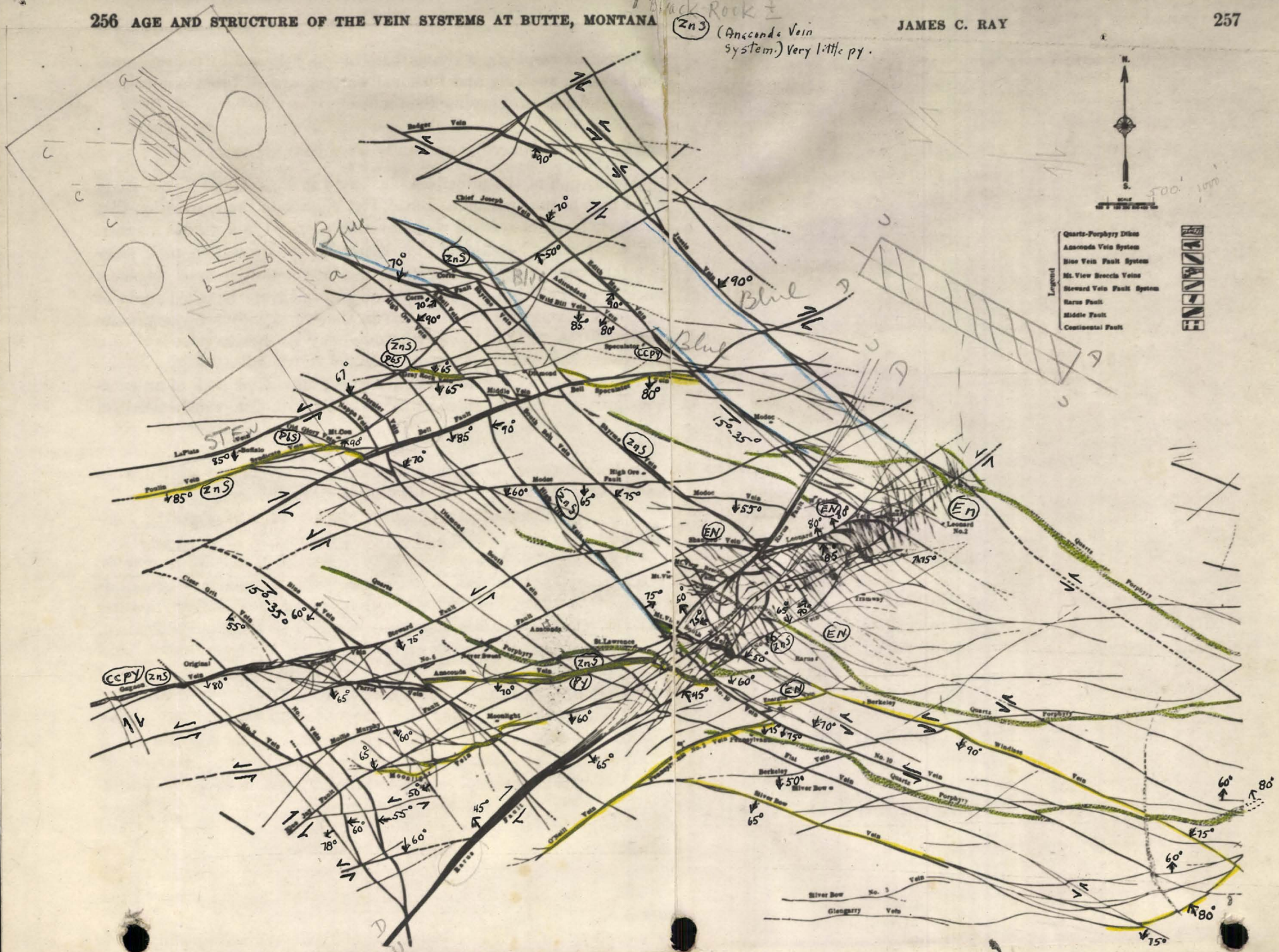


FIG. 3.—HORIZONTAL SECTION OF BUTTE DISTRICT (4600 FT. ABOVE SEA LEVEL, 1500 FT BELOW SURFACE) SHOWING STRUCTURAL RELATIONS OF FISSURE SYSTEMS (SALES).

~~Observations~~ OF GENERALIZATIONS FROM FIELD STUDY SPECIFIC

6. APPLICATION OF EXPERIMENTAL RESULTS, AND OF THEORIES, TO FRACTURED OR OTHERWISE DEFORMED AREAS.

Butte, Mont. James C.Ray, "Age and Structure of the Vein Systems at Butte, Montana", T.A.I.M.E.,1931,mentions Mead's experiments on shear and torsion and applies them to Butte in a general,not a detailed way. He says:..homogeneous crystalline rock masses,when subjected to sufficient strain,are fractured and faulted in a systematic manner;the local manifestations of the forces are often the secondary...rather than the major ones. Tension fractures...tend to remain open;compression fractures show the opposite tendency while the stresses that caused fracture remain active. When the stresses cease,the resulting blocks tend to settle. Rotary or torsional strain will develop combinations of compression and tension phenomena.... development of the Butte fracture systems was a local phase of regional diastrophism. In the Oligocene, the region was uplifted and great intermontane troughs were formed,accompanied by major north-south faulting.(Large scale diastrophism.)...fracture systems of the Butte type can be produced by strains brought into play during the adjustments of regional fault blocks.

Cloos's experiment for counterclockwise shear fits the Butte fracture pattern perfectly; (See plan).Set aa - the NW or Blue vein fault system; bb - Steward fault system;tension cracks c - Anaconda vein system. This is confirmed by L.H. Hart, Geol. Dept. Anaconda Copper Co.,in the paper "Mesothermal Copper Veins and Replacements", Ore Deposits of the Western States,A.I.M.E.,1933. He says,in effect: Leith and Mead have demonstrated that when a homogeneous mass is subjected to rotational stress two sets of structural failures are developed,one including tension cracks normal to the direction of elongation,the other including vertical faults with horizontal slips (for horizontal shearing) nearly parallel to the direction of stress application,and making an angle of about 45° to the tension crack Sometimes when the stress application is long continued a 3rd set complimentary and at about 90° to the second set is weakly developed. These experimental results apply ..well to the ore-bearing structures at Butte.The Anaconda set corresponds to the tension failures of no displacement;the Blue vein system to the best developed horizontal-slip fault set. The complementary NE horizontal-slip structures are of slight importance.A complex system of post-mineral faults exists...when these occur as strike fault along the Anaconda veins tension fault characteristics are masked.(Note: this is greatly accentuated when alteration alters the walls to soapy stuf E.W.)The orebodies of both the vein and horsetail areas (see plan)are combined fissure-fillingd and replacement,tabular in form.The (Anaconda) tension fractures are free from selvage clays;by reducing rock pressure in the affected areas they favor solution diffusion into the walls;they are therefore characterized by associated replacement bodies.The Blue veins,especially in the upper levels,where displacement is greatest,are filled fissures replacement is confined within definite gouge walls.(R.D.M.N-S veins).Fissure-making stresses acted before,during and after the mineralizing epoch, relatively short geologically,and related to the final stages of consolidation of the Teriary Boulder batholith,it followed closely the injection of quartz-porphyry dikes.(The latter followed in part set aa (Blue vein system);mostly their trend roughly parallels set c(Anaconda system),or intermediate between aa and c.They would follow mostly the tension fractures present in their time;the position between c and aa may be be explained by an earlier orientation of the shearing stresses,with the couple pointing more nearly N-S;this might happen if the tendency toward shear met stiff resistance at first. (E.W.)

Reno Sales (Ore Deposits at Butte, Mont.T.A.I.M.E., Vol.XLVI, 1914) gives the following data of interest: The Blue system of NW fault fissures ahow a notable uniformity of spacing; their strike is remarkably uniform, but the dip is variable. The fissures as a rule are steep, but the variations in dip along a single fissure may be great. Edith May vein dips 80 N from the surface to the 700' level; vertical from the 700' to the 1600' level; dips S below the 1600. These faults show some regularity in their habits of dip. The most southerly (Clear Grit, Flat and Blue) dip rather flatly S, 45-65°. The central ones (Skyrme and Edith May) are more nearly vertical; on the xtreme north the tendency is to dip steeply north in the upper levels, with a change to the south at greater depths. The Blue fissures are faults of marked displacement; their amount of movement (on imprtant members) ranging from 150-300'. The High Ore fault vein displacement is about 270', direction of movement making 35° with the horizntal. In all of these fissures the S or hangingwall has apparebtly moved to the SE and downward relatively to the FW, and the direction of movement of the hangingwall has been along a line making an angle of 15° to 35° with the horizontal.

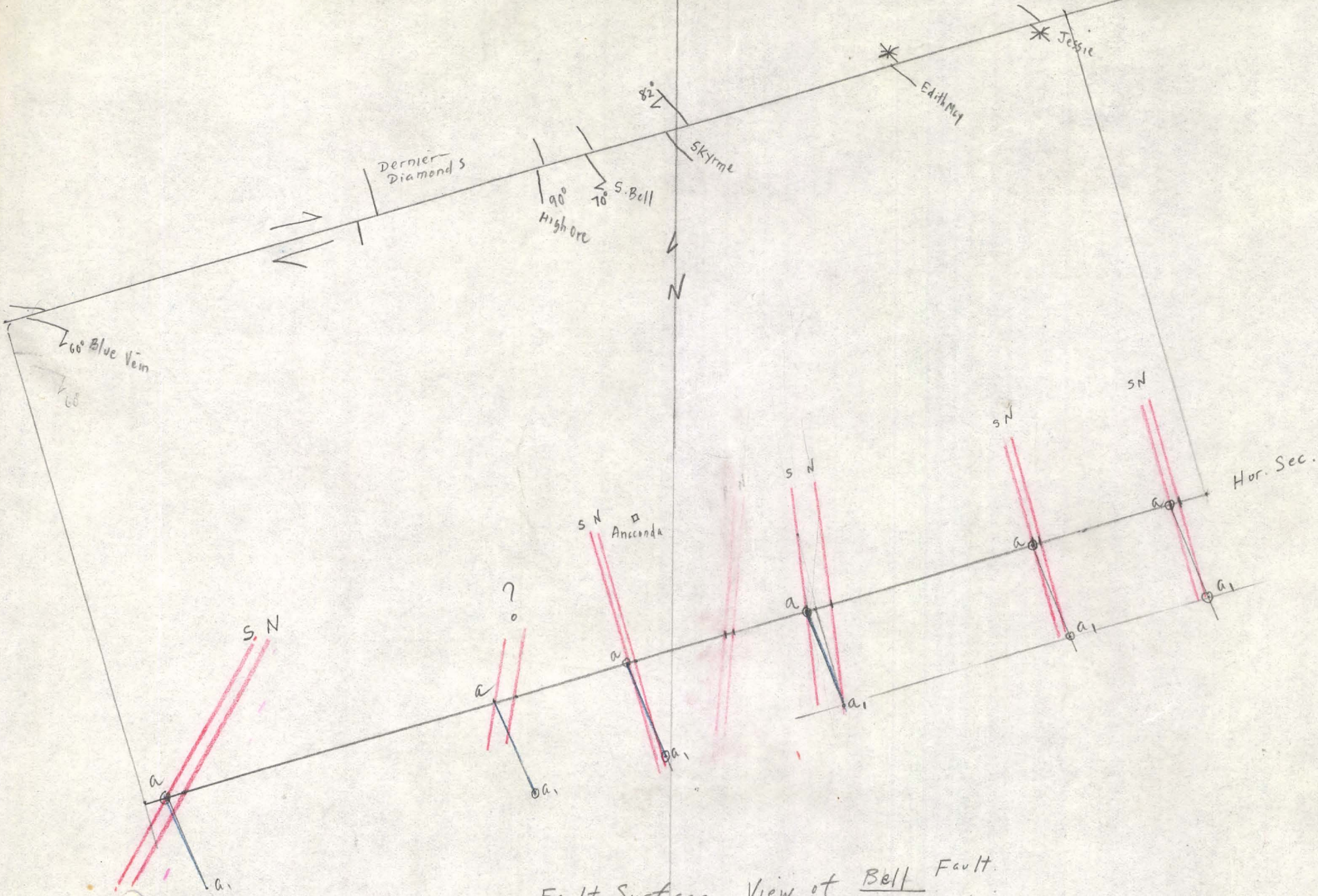
The Mountain View breccia faults occur north of, and parallel with, the Anaconda vein, in the Mt. View mine, and also as a weterncontinuation of the Anaconda vein itself (Gagnon vein) where the Anaconda is combined, by a mutual accomodation is strike, with the Steward fault. (Note in this connection Griggs observation on testing experiments, of the tendency for shear fractures to combine with tension fractures for certain shapes of the specimen. E.W.) These breccia faults or veins are presistent angular fissures filled with fragments of country rock with some fragments of the earliest veins. One foot in diamater down to fine sand.. Usually looks like concrete, rock fragments in a matrix of disintegrated granite grains; larger pieces often rounded. Sometimes all fine, resembling stratified sandstone. .... While the general N75E course is well defined, locally and in detail the strike is extremely irregular. They are angular and zigzag in plan, resembling streaks of lightning. A fissure 12"-18" wide may follow a regular course for several yards, when it will suddenly offset at right angles, following a joint plane or vein wall for several feet, when it again resumes its normal course. (These are obviously tension cracks, connected with the Anaconda system; for some reason they were not mineralized.)

The Steward fissure system NE fissures show even spacing; their average dip is to the S at 65°. (The Bell fault conforms to the orientation of the system, but is barren and its age doubtful. It's movement had a small reverse component.)The Steward faults are narrow zones of crushed granite with well-marked seams of attrition clay. (Width from a few inched to 10'.)Total displacements on important members 50-150'. Normal faults, movement at 70° to the horizontal. (Compare N-S R.D.M. fractures: practically no displacement, except settling.)

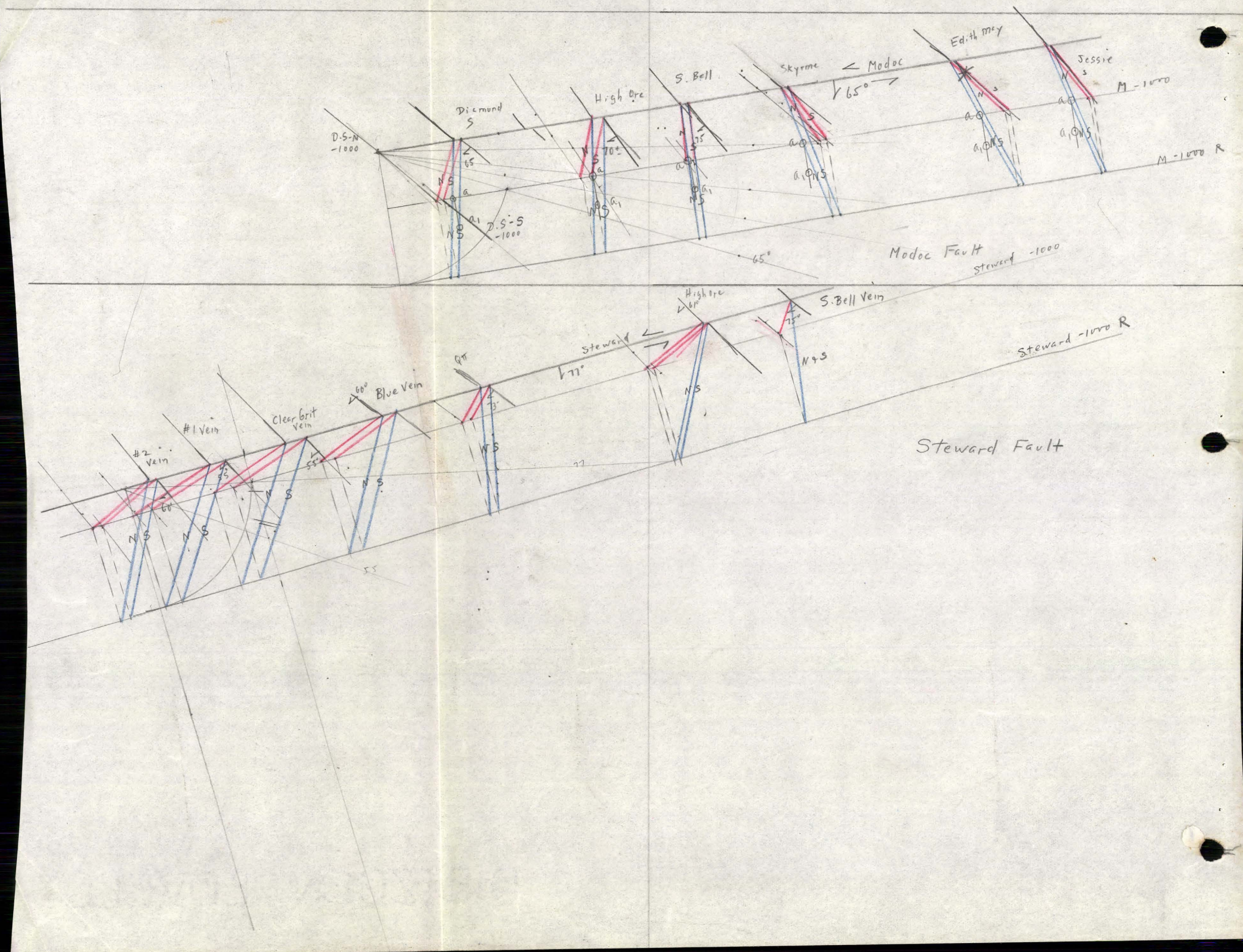
The Rarus fault seems to be later than the Steward system . Its displacement decreases from SW to NE; in fact the fault splits up and goes to pieces in the Colusa mine. The line of movement (HW down) is normal to the strike in the Belmont (SW part), where the displacement is 350'; but makes and angle of 60° or less in the Leonard (NE end) where the displacement is less than 120'. (This rotational movement suggests a torsional origin for the horse-tail fractures. See plan.)

Sales' Description of the Veins.

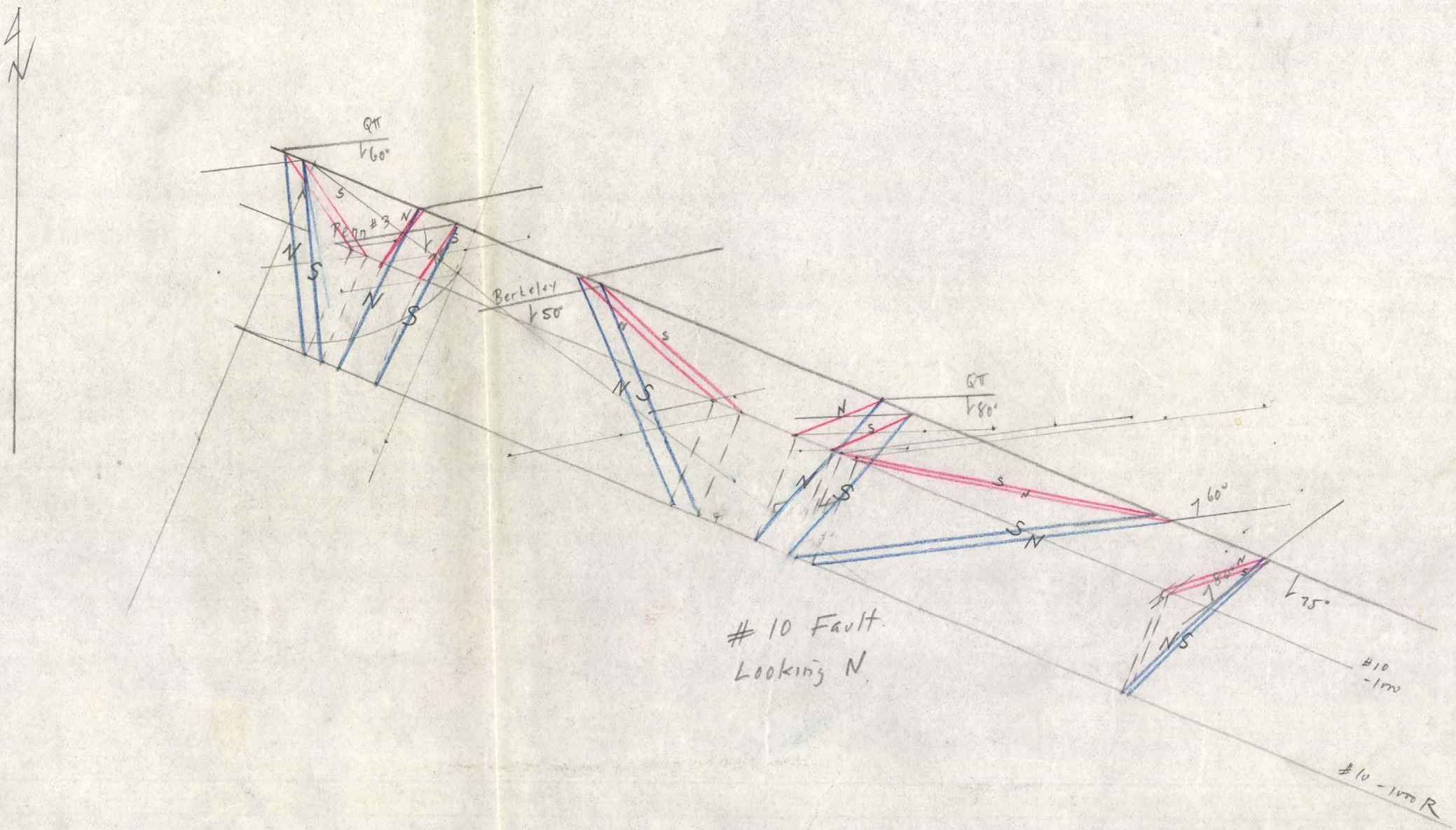
The "oldest" fractures (Anaconda system) are continuously mineralized and are free from sudden changes in vein filling, in marked contrast to the Blue and Steward systems. In the latter the ore occurs in great



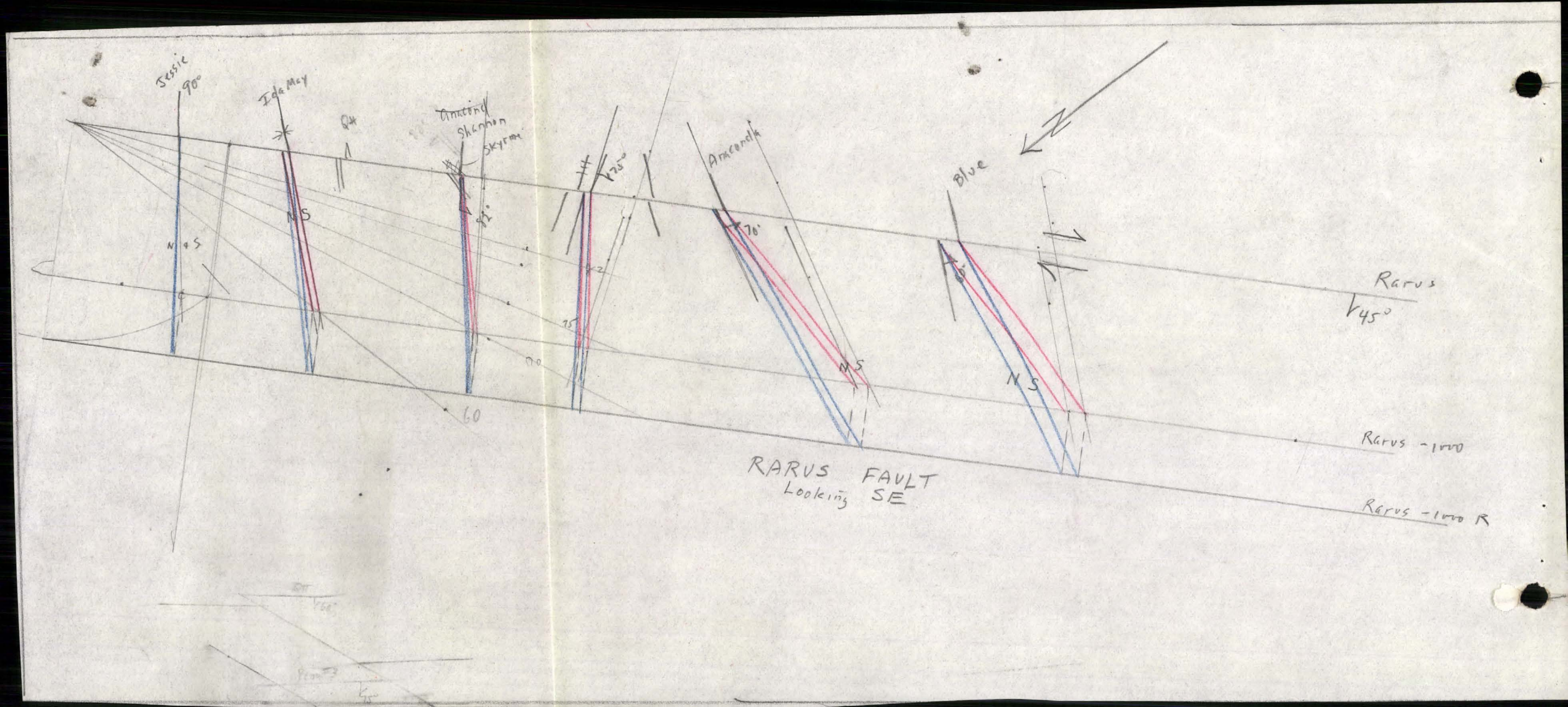
Fault Surface View of Bell Fault
Looking N All faulted veins
a those of Blue Vein System



Edith May
Jessie
Skyrme
Modoc
65°
S. Bell
High Ore
Diamond S
D.S-N -1000
D.S-S -1000
M -1000
M -1000 R
Modoc Fault
65°
Steward -1000
High Ore
S. Bell Vein
Steward
77°
Steward -1000 R
Blue Vein
Clear Grit Vein
#1 Vein
#2 Vein
Steward Fault



10 Fault
Looking N


Jessie
90°
Ida May
Q#
Anaconda
Shannon
Skyrme
75°
Anaconda
70°
Blue
N S
N S
N S
N S
Rarus
45°
Rarus -1000
Rarus -1000 R
60
RARUS FAULT
Looking SE

lenses, with intervening stretches characterized by crushed rock and gouge. 60-80 % by weight of the ore is altered granite, sometimes ore itself by impregnation, often not.

Anaconda System: Ore continuous, often for thousands of feet. Veins often split on strike and dip. Average stoping width, Anaconda and Syndicate veins 30'; average width for the system. 20'. The vein-filling is usually massive, showing little brecciated structure; the veins carry more quartz and pyrite than the "later" veins. The filling lacks fault clay and crushed granite. The Syndicate vein has more pyrite than has the Anaconda.

Blue Vein System: The fault zone, usually 5-25' wide, is often composed of 2 or more well-defined movement planes, with clay seams 0.25-2" thick. The rest of the zone is usually finely comminuted granite. Variations in mineral content are the rule; mineral content is a function of locality. ZnS is locally abundant. Ore less massive than that of the Anaconda system; being often a complete or partial replacement of crushed granite, it retains the brecciated structure: it is crushed altered granite netted by stringers and tiny seams of the ore sulphides, with minor associated quartz and pyrite. The ore soften shows rude banding, due mainly to replacement along closely spaced planes of movements, or to shearing of the early formed ore masses by intermineralization movements. The Blue veins show loop splits. Length of ore lenses 100-2000'; 10-20' stope widths are common.

Steward System: Ore in isolated shoots, separated by barrengougy stretches. Orebodies high grade. Primary chalcocite, enargite, quartz and pyrite (these two less than in "older " veins; little or no blende, chalcopyrite or bornite.

Ray adds the following: The Anaconda tension system formed the main mineral channels; their massive crystalline texture and vuggy structure shows that much of their ore was deposited between widely separated walls, sometimes as intersticial filling between country rock fragments which had settled between the fissure walls. This shows tensional stresses... The NW (Blue) and NE (Steward) vein systems were not formed initially as continuous fault fissures; ore was deposited only in ceryain areas along zones of maximum compression where intra-fault block adjustment or slight local movement relieved the pressure sufficiently to form limited open channels for deposition. In other places actual fractures were absent along the compression zones. Ray believes these shear fractures achieved continuity through post-mineral movements and shows that observed mutual displacements of the fractures could have occurred by simultaneous block settling. (See under Results of Experiments).

Concerning intermineral movements, Ray gives the following data: Brecciated ore; fragments cemented by later hypogene minerals. The east-west fractures, since they were the main ore-channels, were sealed early in the game; the NW and NE systems, results of compression, offered poor channels for circulation, and only at points of localized intra-block adjustment. Along thes zones of maximum compression, planes of weakness formed which yielded easily to later forces to form true fault planes. Movement could have been simultaneous along these later planes.

Notes. Ray's experiment may be sound, but drawing the traces of the intersected fractures on the fault planes of the various systems does hot confirm it. In few or no cases could the observed dipplacements be due to simple down-dip movement, proper to fault-block settling. There appears to have been more than one movement on most of them, and a strong suggestion of considerable horizontal movement. (Cf. Sales.)

Comparison of Sales' Relative Ages of Fractures with Experiments.

Sales.	Cloos and Mead.
1. Anaconda tension fractures c.	Set c.
2. Blue system aa	aa and bb nearly simultaneous, but according to Hart, aa the earlier
3. Mt. View Breccia faults; probably continuation of tension set c.	
4. Steward set bb.	See above. Probably set bb.
5. Normal adjustment faulting.	Not included in experiments but perfectly logical.

Evidence of Age by Mineral Paragenesis.

Paragenesis according to Lindgren:

1. Quartz (long continued). tent rhruout the mineral period, but largely earl
2. Pyrite, covellite. Also, syngenetic with bornite and chalcocite.
3. Sphalerite.
4. Enargite, covellite. Often syngenetic with bornite and chalcocite. (Hart.)
5. Tennantite. Sometimes replaced by sphalerite and galena. (Hart.)
6. Bornite.
7. Chalcopyrite.
8. Chalcocite. Sometimes replaced by chalcopyrite. (Hart.) Also syngenetic (with bornite.
9. Sparse Mg and Mn carbonates.
10. Calcite.

The Anaconda vein system was originally called the "quartz-pyrite" system due to the relative and absolute abundance of these early minerals. These veins also carry more enargite than do the veins of the Blue system, (Sales,) the latter having proportionately more chalcocite and bornite. The Anaconda veins often carry heavy sphalerite, as do the Blue veins, but more locally. The Steward veins carry abundant hypogene chalcocite, minor enargite and bornite, but no sphalerite, except in the Gagnon (west) district, where older vein ore also carry abundant ZnS.

Ray argues for a single period of mineralization, more a unit that Sales's. This is probably right. On the other hand, fractures opening at successively later times during the period of mineralization would show a varying mineral assemblage. Thus, the oldest fractures would have been open when the great bulk of the oldest minerals were depositing (pyrite, quartz, then enargite, sphalerite, bornite, chalcocite in that order). Since the oldest minerals usually kept on depositing nearly to the end, in minor amount, and since also slight reopenings in the sealed older fractures admitted younger minerals, in many cases, it follows that the proportionate amount of relatively older and relatively younger minerals, not the absolute amounts, is diagnostic of the age of a fracture, for both old and young fractures can have some of both old and young minerals. Considered in this light, Sales's age relations, as deduced (1) by faulting, (2) by mineral paragenesis, seem logical. After all, the actual differences in age of the various fractures are functions of the speed with which the various minerals succeeded each other; they probably followed closely on one another, and the different fracture systems are closely connected in age.

The writer believes the Butte fracture pattern originated through counterclockwise shear, as shown on the map. The case seems so clear that

recording of the physical data in this connection, as if it were a great laboratory experiment, seems worth while.

Country Rock: Quartz-monzonite ("granite"). Medium coarse granitic texture, in places somewhat porphyritic, especially in the SW part of the district. (Teward, Gagnon, Colorado mines.) The granite everywhere shows well-defined systems of joint planes, bearing no definite relations to the later fracture systems. The joints are old, often showing slight displacements caused by (later) readjustments within broad inter-fault blocks. While the joints have played no part in the determination of the larger features of the fracture systems, they are responsible for many large stockwork orebodies. (Leonard mine.) Mead's shearing experiment finally results in rotation of the shear planes in the direction of shear. In the west and SW part of the district the aa fracture set (Blue system) show marked rotation in that direction. This may possibly be due to the porphyritic texture of the granite there. A finer-grained groundmass might "flow" to some extent.

Attitude of Plane of Shearing Stresses. Since the shear and tension fractures are not vertical, this was inclined at about 30° to the north in the SW part of the district; in the N part it was much less inclined. (fractures much steeper here.)

Angle Between Shear Sets aa and bb. (Excludes Bell fault, and areas where bending apparently occurred.) 72°. (Cloos experiment, 65°-67°; Real del Monte, where sets are least bent, 82°.)

Angle between Tension Set c and Shear Set aa 37°. (Cloos 36°).

Angle between Tension Set c and Shear Set bb 29° (Cloos 26°.)

Note: Fowler and Leyden, in their paper "Sequence of Structural Deformation in the Oklahoma Mining Field", Mining and Metallurgy, Oct. 1934, give a different picture. According to them, the sequence of events at Butte was:
1. Deformation of the granite; formation of east-west fissure zones with complementary NW-SE relief. (Would be Anaconda fissure system c, and major shear set aa, Blue fissure set. E.W.)
2. Filling of fissures by quartz-porphyry which also replaced the contiguous granite. (E-W and NW dikes, as described above; Steward set evidently assigned later age because it carries no dikes; it may be that secondary shear sets like Steward are not adaptable for dike invasions; cf. Real del Monte N-S fractures. E.W.)
3. Second period of adjustment with reopening along old zones of adjustment and formation of new fissures. (The new fissures are evidently the Steward set, bb. E.W.)
4. Deposition of the vein minerals in favorable reservoirs.
5. Further deformation subsequent to ore deposition. (Rarus, Middle, probably Bell faults. E.W.)

The above seems to represent a sticking to Sales' ideas concerning distinctly different ages of the fracture sets.

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Age and Structure of the Vein Systems at Butte, Montana

By JAMES C. RAY
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DISCUSSION OF THIS PAPER IS INVITED. This paper was presented at the San Francisco Meeting, October, 1929. Discussion in writing may be sent to the Editor, American Institute of Mining and Metallurgical Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of the author. Unless special arrangement is made the discussion of this paper will close March 1, 1930. Any discussion offered thereafter should preferably be in the form of a new paper.

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Conclusions

Age and Structure of the Vein Systems at Butte, Montana*

By James C. Ray, Stanford University, Calif.

(San Francisco Meeting, October 1922)

[18] R. H. Sales: *Loc. cit.*, 17.
[19] *Loc. cit.*, Plate I.