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COPY

Strong Vein in Hard Rhy.

PAÑIA DE REAL DEL MONTE Y PACHUCA

PACHUCA. HGO., MEXICO

THE BULLFROG MINING DISTRICT, NEVADA.

Claude T. Rice, EMJ 9-22-1906

General Geology. CR series of flows, principally rhyolite, with some andesite, basalt and dacite. Basalt dikes of variable strike cut these rocks. Veins are strong and persistent and usually wide. Strike northerly.

Ore Deposits. Gangue quartz with some calcite; much of gangue strongly stained by brown mn oxide. Gold is free, bright yellow. Occasional oreshoots rich in silver. Some sulphides found at bottom of some of the mines, pyrite and tetrahedrite. Ore as mined practically all oxidized. Veins have persistent outcrops. Ore 8 - 25 dls. Scattered thru milling ore are shoots of rich ore $100; seams of talc rich in gold occyr thru the qtz.

Most veins were very low grade near the surface, values coming in a short distance down.

Little or no faulting of the veins; E-W zones of brecciation cross thru the Original Bullfrog orebody. Many of the veins have been reopened.

Veins strike N-S with steep dips; also a series of NE-SW veins, dipping 60 W. Walls generally good; veins appear formed along a strong line of fracturing. Almost pure qtz at center with often a gradual transition into rhy CR ?Rhy. is hard.

Oxidation and Enrichment.

Bullfrog Mining District, Nev. (C.T. Rice, EMJ 9-22-06.) Gold-silver veins in rhyolite. Workings at the time down an maximum of about 200'. Veins still mostly strongly oxidized at that depth. Gold is free, bright yellow in color. Seams of talc rich in gold occur in the quartz. MnOx. Most veins were very low-grade near the surface, the values coming in a short distance down.

As some pyrite and tetrahedrite were found in the lowest workings, the depth of thorough oxidation was probably in the neighborhood of 300'. Many of the veins have been reopened.

ANTITHETIC FAULTING.

Geology and Ore Deposits of the Bullfrog District, Nevada. F.L.Ransome,W.H.Emmons & G.H.Garrey.USGS Bull.407,1910, pp.15-16:

The entire series of volcanic rocks is divided by faults into a large number of blocks in each of which the flows are in general tilted to the east at angles up to 40°.The fault planes strike from northwest to northeast and dip generally to the west. The displacement, as a rule, is normal: that is,the hanging wall in each case has slipped down relatively to the footwall. In consequence of this structure anyone travelling across the district from west to east will see the edges of the same flows repeated again and again in the successive western frontsof the ridges. To the production of this structure two types of deformation have contributed,according to Messrs. Emmons and Garrey...These were(1) a general tilting toward the east,such as would result from the development of a groad arch or monocline of which the eastern limb coincided with the Bullfrog district (Amargosa uplift-EW);and (2) step faulting with progressive downthrow to the west. The two processes were simultaneous andcompensatory. Their cooperation tended to minimize the actual vertical displacement of the flows from their original nearly horizontal position."

Tectonic Analysis of

BULLFROG DISTRICT, NEVADA.

From Geology and Ore Deposits of the Bullfrog District, Nevada, F.L.Ransome, W.H.Emmons and G.H.Garrey,USGS Bull.407,1910.

Add to this W.H.Emmons:Normal Faulting in the Bullfrog District, Science,n.ser.26(1907) 221-222.

From introduction,the volcanic rocks are divided in many fault blocks,in each of which the flows are tilted to E at angles up to 40°. Faults,striking from NW to NE,dip W;normal, so repetition of beds. Two types of deformation caused this structure:(1) genereal tilting to E, E limb of broad arch,(2) step-faulting, progressive downthrow to W."The two processes were simultaneous and compensatory. Their cooperation tended to minimize the actual vertical displacement of the flows from their original nearly horizontal position." (15-16).

Original Bullfrog fault, normal, dips N at only 19°. "It is difficult to understand how normal faulting could take place on a plane so slightly inclined unless the displacement had a large horizontal component".

Pre-Tertiary Rocks.-Closely folded (NE dip) 15°-35° qtz-biot.schist and qtzite,ble. Meta-ss,sh,ls. Overlying the schist,Silurian? ls,notfolded. This applies to the complex S of Beatty. S of the Original Bullfrog mine the schist, qtzite and ble incose sheared masses of diorite,and this complex cut by pegmatite, t o 100 ft. wide.This sheared also,but less so. Sheared rocks composed of qtz-bioschist and peg,large flds drawn out into eye-like bodies,form augen gneiss. Diorite dikes cut this complex, also branching qtz-porphyry dike,prob. Tertiary. Schistosity dips 40-60E. Peg.injected along schistosity.

Tertiary Flows & Tuffs.- Mainly rhyolite with IB basalt.

Top Qtz-basalt 70'
Rhy tuff No.2 40'
Dacite 250'
Plagioclase basalt No.5 50'(local)
Rhy No.16,flow breccia 300'.
Rhy No.15 Flow breccia, 125'.
Rhy No.14,green glass and pumaceous flow-breccia 100'.
" 13 Fissile flow 100'.
Ore in formations below only.
" 12 Bottle glass. 50'.
" 11 Pumiceous flow 400'.
Tuff No.1,sh.,ss,cgl.Thin rhy flow-breccia. 250'.
Plag.basalt No.4 250'.
Rhy.No.10,with basalt and other frags. 350'.
" " 9 Flow-breccia 100'.
Plag-basalt No.3 35'.Local.
Rhy No.8 500'.
" " 7, vitreous 40'.
Plag-basalt No.2,local.30'.
Rhy No.6,white,porous 150'.
" " 5,micaceous 500'.
" " 4 200'.
" " 3 600'.

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Plag-basalt No.1 30'. Local.
Rhy No.2,flow-breccia with frags basalt and rhy. 270'.
" " 1. 2600'. (Base unexposed). FG or glassy GM,flds,qtz.,mica phenos. Massive

Structure.- After eruption of the quartz basalt,near close of Tertiary or in early Quaternary,flows lay nearly horizontal.

Authors conclude from field facts that the plan of the present fault systems was outlined by fissures before intrusion ofthe basalt dikes (no dikes found in any formation younger than Rhy No.10;most dikes follow fault fissures;main faulting had displaced all flows including those later than Rhy 10). This fissuring might have taken place not later than Basalt No.4(just after Rhy 10,dikes then injected, main displacement some time after dike injection). Another view is "that the dikes are younger than any of the flows and were intruded while the main faulting was in progress or after it had been effected." p.72. They favor first view (Emmons & Garrey);Ransome favors second view % coincidence of dikes & faults and absence of offsetting of dikes by cross-faults

Original Bullfrog Fault.

Original Bullfrog vein on this.White qtz cements great number of brecciated frags of rhy.,sh.,ls. Stockwork in ls.FE. Brecciation shows tension, normal fault,not thrust.

Amargosa Fault.

Throw probably greater than at Original Bullfrog. Two are the same fault.

Bullffog Mt. Fault.

Seems to join Original Bullfrog.

Montgomery-Shoshone Fault.

Passes thru Montgomery-Shoshone mine

Mechanics.

pp84-85,excellent sketches and description of antithetic faulting. They think component of horiz.movement (heave) whereby W blocked moved S at 60°. "As there has been no appreciable change of density in the material of the rocks in consequence of deformation,it is evident that the thickness of a faulted block must decrease if the length or breadth increases."(Stretching). Estimate extension of surface at 16% maximum.(Compare my estimate, Section A-A', 14.5%).

Mineralization.-All ores oxidized. Native gold,small specks in center of spot of limonite. Formerly pyrite. Veins not rich in sulphides. Minor horn silver. Quartz,xenomorphoc aggregate with calcite. Much is cryptocrystalline, silification of rhy frags.Qtz of Orig-

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inal Bullfrog and Ali Baba shaft S of Bonanza Mt. exceptional: coarsely crystalline, largely amethystine. Original Bullfrog, vein banded, yellow chalcedonic layers alternating with crusts of radially crystallized transparent qtz to 4" thick. Not parallel walls: crustification around frags rhy and of shattered early calcite. "The quartz also belongs to two or more periods of formation separated by movements which shattered the vein and produced open spaces to be filled by fresh deposition of quartz." (p.94). Wad residual from oxidation & removal of calcite. Calcite with qtz., in fine-grained dull white aggregates. S.t. coarse cryst.

Structural Features.

Fissure veins in rhy. Mainly along sheeting or brecciation in the brittle rhy. (cf. Balk's sheeted cross joints). Larger veins have frags rhy, indistinct boundaries. Of 15 veins explored at any depth, all but two strike nearly N and dip at angles greater than 50°. Exceptions: Original Bullfrog, E-W, dip less than 20°, and contact vein in Montgomery-Shoshone mine, which strikes and dips with M-S fault. M-S Denver and Eclipse N-S veins nearly vertical; Polaris, National Bank, Gibraltar, Hobo, Lester N-S veins dip W. Decided and persistent dip to E is rare.

While veins & faults closely associated, not over 10% of the 100 faults on the map are veins. Most faults unmineralized; best veins in fissures of slight structural importance. Denver vein and Bonanza Mt. veins in fissures 100 ft. max. displacement, rare. N-S M-S veins converge to S into a fissure that is a minor fault crossing one of the tectonic blocks. M-S fault limits the ore of the mine on the N. Vein-fissures butt on this. Contact vein follows FW of M-S fault, mineralization related to end of N-S veins; main movement on fault in HW. Original Bullfrog, fractured rhy in HW of OB fault, above pre-Tert. FW. Many fault fissures occupied by basaltic dikes in part; pre-mineral. Post mineral faulting on Hobo, Eclipse, Gold Bar. Veins sheeted zones in rhy to QCBs. Little replacement of walls or larger frags. Smaller frags silic. Fine-crushed rhy powder between frags now cryptocrystalline. On Hobo vein, qtz veinlets in crack in older calcite.

Montgomery-Shoshone: Au:Ag::1:17.

E.W. Analysis.

The accompanying stereogram shows present conditions; the restored stereogram, conditions before the antithetic faulting. The dominant feature of the structure, shown on the restored structural map and on the sections, is a monoclinal fold dipping down to the east. The major (nearest to N-S) set of antithetic faults and most of the basalt dikes are associated with this monoclinal fold. The regional geology explains this.

S.H. Ball: Geologic Recommaissance in SW Nevada and E Calif., USGS Bull. 308, 1907. Amargosa Mountain System, 160-176. Called Grapevine Mts. NW of Boundary Canyon, Funeral Mts. SE of it. See Spurr, Descriptive Geol. Nevada S of 40th Par. and adjacent portions of Calif. USGS Bull. 208, 2nd edition 1905. Crest roughly coincides with state boundary. (Bullfrog 8-10 mi. NE of bdry). NE side or range, crrst line rises only 2000-4000 ft. above Amargosa desert, Sarcobatus Flat; but crest is 5000-7000 ft. above Death Valley (Death Valley trough, a graben). Paleo qtzite, ls. Above these, Siebert Lake beds and contemp. rhy. andesite. (latter the older). Rhyolite continuous with that of Bullfrog Hills.

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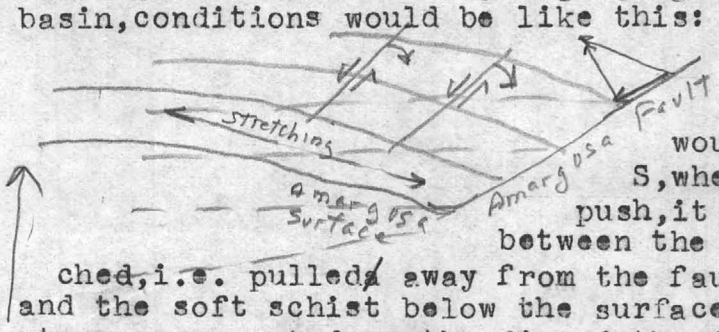
Basalt, later rhy.

Amargosa range subjected to two main periods of folding & uplift, 1st probably post-Jurassic, 2nd probably late Miocene (post Siebert Lake beds). Earlier period had reverse faults, later by normal faults. Early folds parallel to trend of range, with cross folds. Central part of range an anticlinorium, NW. Many of the minor folds are close, even fan folds, some with horiz. axes. Some isoclinal folds pass to reverse faults. Before 2nd folding period range worn down to low ridge. Owes present height to 2nd folding (uplift). Rhy dip 20-40° away from range. Siebert Lake cgl. dips up to 70° away from range. Bullfrog Hills form spur off Amargosa range, but trend E.

The principal antithetic faults are ~~xxkxx~~ pretty certainly connected with the Amargosa uplift. Most of the pre-mineral basalt injected fissures which formed part of the early fan pattern of tension joints. The main veins, two, filled similar tension joints

To be fan-pattern antithetic faults connected with a NW uplift, the major faults should strike NW. They strike E of north. As shown on the restored structural plan, the monoclinal fold is not simple. There is a NW ridge on it near the NW corner of the map, and the Original Bullfrog area seems to mark a high, with a bowl between there and the NW ridge mentioned; from the high there extends an E-plunging nose. This nose probably connects with the NW ridge and indicates arching along a direction visible in a section drawn along a NW plane. E of this complex region both the structural contours and the major faults strike N-S, in the NE part of the plan, but in the SE part they show a decided nose, apparently the E continuation of the nose mentioned above. This end of the nose trends more SE than E. The abrupt curve in the Amargosa fault may correspond fairly well with the axis of the nose.

It seems very doubtful whether the Original Bullfrog-Amargosa flat fault, apparently normal, can be a thrust as postulated by Ransome on the basis that the lavas were deposited in a basin extending well north of Bullfrog. Late Miocene thrusts may exist in this region, but I doubt it. The antithetic faulting with uplift suggests tension in a horiz. plane, not compression. This fault acts more like a Streckflaeche; the HW was probably pulled down the dip. The basin notion looks valid. If so, the flows would abutt on the south margin, younger flows overlapping older. Now if a plunging anticlinal uplift took place in the basin, conditions would be like this:



Where the old Amargosa surface was directly pushed upward, it would arch like a lava bed; but to the S, where it lay beyond the uplifting push, it was a surface of discontinuity between the lava flows, which were being stretched, i.e. pulled away from the fault surface, sice the butted on it, and the soft schist below the surface. The tensional pull would have a stong component down the dip of the fault, and a strong component away from it to overcome friction. A sliding down the dip of the fault would be inevitable, so that the fault would resemeble an antithetic fault; it would however not rotate and would be a synthetic fault like a Streckflaeche, aiding the stretching. At the Original Bullfrog mine a steep dome lies in the HW of the OB fault, and the mechanics would be similar.

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The antithetic faults of the district fall into two sets,one,the major faults, or most of them,striking NNE,while the second strikes NE to E by N. The two sets however tendto merge one into the other, It seems likely that the major set is related to a great N-S mpnocline mainly N of the Bullfrog district. Topographic maps show a north-trending curve in the Amargosa range,about at the intersection of the 37th parallel and 117th meridian. That this system of faults is ending toward the south is suggested (1) by the fact that they seem to butt on the OB fault surface and (2) by the fact that displacement on the Scepter and Hobo faults decreases rapidly toward the OB fault. The OB surface is older and served as a frame for the antithetic deformation.

In the Bullfrog district conditions change because of the local SE nose. Here longitudinal bending of the nose itself was dominant, so that many minor antitheticfaults are cross-faults to the nose.These are the antithetic faults shown in the sketch on p.4. That the nosing is probably later than the original major arching along a N-S axis is suggestedby the fact these minor faults butt on the major N-S faults.

There is really little or no distinction,as a matter of fact, between the two sets of faults except in the E part of the district where, due to the turning of the nose to t he SE,the conditions N of the nose enter the picture shown on the maps. (Except the Bullfrog Mt. fault in t he W part,which seems to belongto the N-S set), and the Rush synethticfault,which appears to have aided the uplift along N-S axis). Thus the Hobo, Montgomery-Shoshone and many other major faults are cross-faults to the nose. In the E part of the district,where the older N-S faults appear,the cross-faults butt on them, showing deformation in unit blocks (Bisbee, Aspen).

Structural Control of Ore Deposits.- This is one of Spurr's districts,where ore deposition came early in the cycle of diastrophism, and the major faulting probably came later.This follows for intrusion as well, for a simple reason: dikes and veins enter fissures(define this word) rather than shear planes. At the start of arching before rock competence is lost,fissures (fan patterns) develop;their walls separate giving channelways. Dikes come first,then veins. As uplift continues,antithetic faulting starts,and once started,cannot stop until uplift ceases. Since the basalt dikes are pre-mineral,and since some of them intruded along E by N fractures,the mineralization came after the SE nose started to form. Most of the veins however belong to the presumably older N-S system of fissures. What appears to have happened is this: the SE arching was intense and of such a nature as to form quickly a great number of E by N antitheticfaults. Only one vein strikes E by N,the contact vein in the FW of the M-S fault. But the older N-S arching formed many N-S joints,which were still in existence at the time of nosing. Thus the S ends of the Scepter and Hobo faults (Scepter to N-S set, Hobo apparently an intermediate type between the two sets) became loci of the veins named respectively after these faults,because at this point there was practically no faulting along these planes;they were fissures squeezed open by uplift. The typical brecciated nature of the veins shows pulling apart of the walls,in a number of stages.

X Latest movement on M-S fault (or part of fault zone) ~10°. See separate sketch.

At the M-S mine,this pulling apart was accentuated by free gliding on the M-S fault (Foeppl effect). X The National Bank ore body lies in a N-S fracture at the very crest of the nose. At the Original Bullfrog,referring to section on p.4,the brecciation etc. is easily accounted for by the stress diagram,showing large component of pull normal to the fault surface.

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TECTONIC ANALYSIS OF THE BULLFROG DISTRICT, NEVADA

W. S. Cavender

TECTONIC ANALYSIS OF THE BULLFROG DISTRICT, NEVADA

STATEMENT OF PROBLEM

The problem is to conduct an independent study of the tectonics of a selected mine, mining district, or structural unit. For this paper, the Bullfrog mining district, Nevada, was chosen because of its structural deformation patterns and the possibility of determining the ore controls.

Initially it was recognized that an analysis could meet with varying degrees of success. In this case, the paucity of detailed information proved a hindrance in making a more thorough study. The major source of information was U.S.G.S. Bulletin 407, by Ransome, Emmons, and Garrey.

LOCATION AND TOPOGRAPHY

The Bullfrog mining district, which includes the smaller districts of Rhyolite, Beatty and Bullfrog, is in southern Nye county, Nevada, between the town of Beatty and the California - Nevada state line. Extending east-west along the south flank of the Bullfrog Hills, the district was discovered in 1904 and actively worked until 1910. Since that time, only small leasing operations have been performed.

Production from 1904 to 1948 totalled $1,688,000 from 159,000 tons of ore. Of this amount, the Montgomery-Shoshone mine accounted for $1,344,000 from 129,000 tons of ore, or approximately 80% of the total.

Topographically, the Bullfrog Hills are composed of a series of parallel cuesta-type ridges, orientated in a north-south direction. Most of the ridges or mountains are fault blocks, uplifted on the west and tilted down to the east. Valleys are filled by thick alluvium.

STRATIGRAPHY

Pre-Tertiary

South of Beatty and south of the Original Bullfrog mine (southwest

and southeast portions of map, Fig. 1) are areas of crystalline metamorphic rocks -- quartz biotite schists, calcite muscovite schists, quartzites, marble, pegmatites and quartz veins. These complexes are highly metamorphosed, and correlation between them is difficult. Tentative age determinations classify the rocks as Ordovician or pre-Ordovician.

In the same areas, a 30 foot thickness of Silurian (?) limestone overlies the metamorphics. Age determination is based on fossils.

Tertiary

Overlying the Paleozoic rocks is an even layered interbedded series of basalt and rhyolite flows. In total, there are sixteen rhyolites, six basalts and one quartz latite. Beds of tuff occur at random intervals.

The sixteen rhyolites comprise the larger volume of flow rocks and are very similar mineralogically and chemically. Individual flows are identified by color, structure and slight petrographic differences. Ranging from 20 to 2600 feet in individual thickness, the rhyolites are persistant throughout the area and have a cumulative thickness of 6,000 feet.

The six interbedded basalts are mostly plagioclase basalts, identical in appearance. These flows have a total thickness of 470 feet.

All flows have been dated as early Miocene. It is to be noted that the base of the lowermost flow has not been observed, because of the fault contacts between all Tertiary and pre-Tertiary rocks.

The lack of extensive weathering and erosion of the individual flow surfaces indicates that the sequence of eruptions was not broken by long time intervals. This "rapid" deposition of varying rock types causes questioning of the theory that all the flows originated at one source or vent. Even bedding and relatively constant thicknesses show that tilting and/or faulting did not occur during emplacement of the flows.

After vulcanism ceased, the flow series was faulted, and basaltic dikes were intruded along fault planes.

Quaternary alluvium has accumulated to thicknesses exceeding 350 feet.

STRUCTURE

Structural studies at Bullfrog are confined to the deformation patterns of the Tertiary flow rocks. This deformation is caused by an extensive system of normal faulting and little, if any, folding. As previously noted, the faulting is post-volcanic.

Recognition and interpretation of the faults is enhanced by the ease of recognition of the different flow layers. Thus, faults are predicted accurately from outcrop patterns, even though the traces may be covered with alluvium.

The nearly 100 recognized faults are separated into two well defined systems, one striking north-south and the other striking N. 30-50° E. (see Fig. 1). A third small group is composed of the remainder of the faults, and will be discussed separately later in this paper. Plots of the attitudes of 65 faults show an absence of strikes between west and northwest, and that all dip angles exceed 35° (except for two special cases). Most dips are vertical or to the west. Note that all movements are normal.

Topographically, the fault blocks have formed a series of north-south ridges, in which the flows dip to the east at 23°.

Vertical fault displacements vary from two feet to more than one mile, the largest being along the Beatty, Bullfrog Mountain, Montgomery Shoshone and Rush faults. From the cross section in Figure 1, the sum of apparent vertical displacements of all west dipping faults is measured at 12,500 feet. The displacement for east dipping faults is 1250 feet, leaving a net of 11,250 feet of western downthrow.

Although dominant movements are normal, many fault blocks have oblique

striations, indicating a strike slip component of movement. Therefore, true movement would be oblique slip. Pitch angles on the striations range up to 70°, and plunge averages 60°. Topography and structure have combined to produce an areal pattern showing mostly left lateral offsetting.

INDIVIDUAL FAULTS

Detailed discussion of the individual faults is unnecessary for this paper; however, a few facts should be noted.

Striking anomalously to the district fault pattern, are the east-west Bullfrog and Amargosa faults (Fig. 1), which cross part of the south flank of the Bullfrog Hills. Possibly, the two are connected under the intervening alluvium. Dipping north at 10-20°, the faults act as contacts between the pre-Tertiary rock and the Tertiary volcanics. Emmons and Garrey predict that these fractures continue to the north, undercutting the entire district. Shafts and mine workings have not penetrated to a sufficient depth to prove or disprove this idea.

Cross sections parallel to the dip show the Tertiary volcanics in juxtaposition with the Silurian (?) limestone, thus indicating a normal movement. One possible explanation of the mechanism of formation involves reverse faulting instead of normal faulting. A thrust plate from the south could have been emplaced in the area, and subsequent downwarping or subsidence could cause the fault plane to dip to the north. The net result would be the situation now observed.

Major north-south faults and their apparent vertical displacement are: the Bullfrog Mountain - 2,400 feet, the Rush - 700 feet, the Denver - 50 feet, the Scepter - 100 feet, the Hobo - 100 to 300 feet and the Beatty - 5000 feet.

The Montgomery-Shoshone is a northeast fault and localizes the only known major ore body, that of the Montgomery-Shoshone mine. Composed of a near vertical zone of faults, the Montgomery-Shoshone has an apparent vertical

displacement of 2000 feet.

STRUCTURAL GENESIS

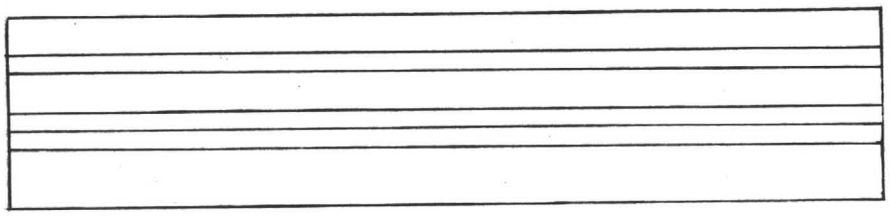
Although the Bullfrog district is not an economic success, it does possess the elements of an interesting structural problem. This problem relates to the choice of a deformation mechanism capable of producing the two systems of parallel faults, most of which are dipping to the west.

Through the use of the cross section in Figure 1, several values can be computed. By using each segment of rhyolite #7 as a hypotenuse of a right triangle, a horizontal and vertical component can be calculated. Vertical values total 13,000 feet, and horizontal values total 30,000 feet. True length of #7 is 33,600 feet. By placing these values in a triangle, #7 is seen to dip east at 23°, apparent dip (observed dip is 27°). The horizontal component plus the apparent horizontal fault displacements total approximately eight miles, or the length of the cross section. Comparison of the total apparent vertical fault displacement of 11,250 feet (down to the west) and the 13,000 foot vertical component of #7 (down to the east) results in a net lowering of the east end of the section by 1,750 feet. Thus, these figures indicate that tilting and faulting are nearly compensatory.

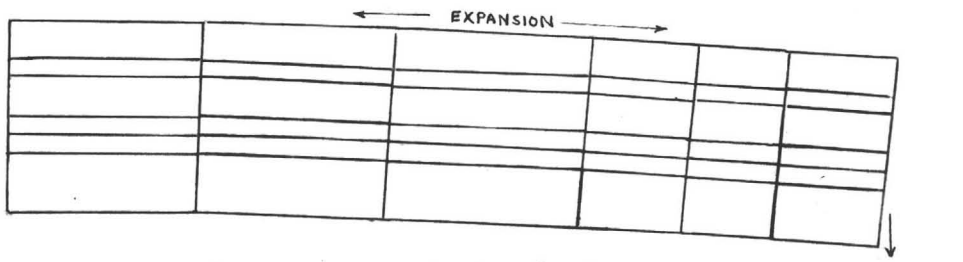
Emmons and Garrey use three sets of mechanisms as possible explanations of the fault patterns. Two of these systems involve tilting of the flows to the east and synthetic faulting, using the two possible sequences. However, lack of evidence of tilting throughout the surrounding region necessitates another explanation.

This third system involves the clockwise rotation of fault blocks while in place; simultaneously producing tilted beds and normal faulting (Figure 2).

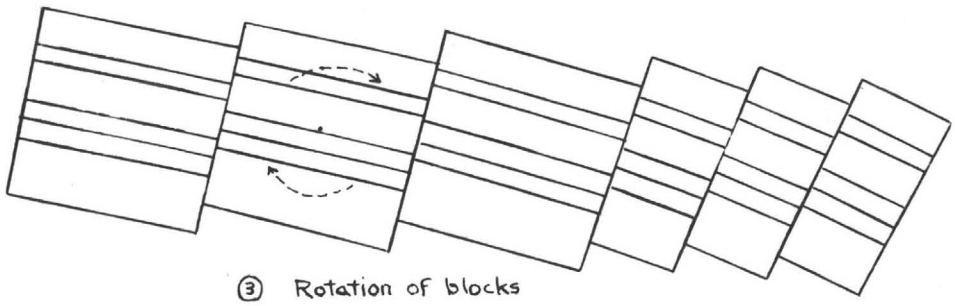
Initially, the flows can be considered as an even layered rock plate. Through the effects of expansion to the east and west, a series of north-south



① Horizontal rock plate



② Formation of tension fractures



③ Rotation of blocks

Development of Antithetic Faults

Fig. 2

Cavender 5-59

tension fissures would be formed. Continued expansion would allow a rotation of the blocks, producing antithetic faulting (Fig. 2).

The clockwise rotation at Bullfrog could be initiated by uplift on the west or subisdence to the east, creating a toppling effect. Uplift to the east would have created the opposite rotation.

Magnitude or amount of rotation is in direct proportion to the degree of block separation. Thus, rotation is actually dependent on the amount of expansion of the rock plate. Also, this degree of rotation controls the amount of normal fault displacement and the dip of the beds within the block. By rule of thumb, the shallower the dip of the fault, the greater the amount of displacement.

For the Bullfrog district, the expansion of the plate and the subsequent formation of the rotated blocks must be explained. The key to a probable solution is provided by close examination of the work of Emmons and Garrey. In one paragraph they state that the flow rocks maintain constant thicknesses. However, in the descriptions of the individual flows, at least five are noted to thicken to the east. This indicates that the source of the flows was east of the district. Supporting evidence can be inferred from the great volumes of volcanic flows in the Amargosa desert, which lies east and southeast of Beatty.

Extrusion of these flows would create a situation favorable to sag or subsidence, due to the removal of material from the crust and the emplacement of that material on top of the crust. Such subsidence would create a gentle arching (convex upward) and easterly tilt in the Bullfrog district. The arch would create expansion fissures and the tilt would initiate rotation and antithetic faulting.

From the cross section (Fig. 1) the length of rhyolite #7 can be compared to its extended horizontal length, or 33,600 to 42,240 feet. Thus, an expansion of 8,640 feet or 25.6% is calculated for the cross section block. Correcting the

figures to allow for apparent measurements, reduces the expansion to 16%.

The two systems of faults may be related to the same type of deformation. Mapped fault traces show the northeast faults to terminate against the north-south faults, indicating the north-south formed first. The axis of expansion must have been east-west originally and then shifted to a northwest direction. Fissures not belonging to these two sets probably formed along pre-existing lines of weakness.

Lack of information eliminates a discussion of the genesis of the two east-west faults. The only known relationship is that they are post volcanic in age.

Age relations show the most recent flows to be fractured by the northeast faults, and the basalt dike intrusions to be post-faulting. Fracturing of both dike rocks and vein fillings indicates recurring or continuous movements.

In summary, the proposed geologic history of the Bullfrog district is:

1) Extrusion of flows over the area, with no long intervals of weathering.
2) Possible and probable continued eruption of volcanics in the source area, east and south of Beatty.
3) Removal of large volumes of volcanic material from the crust produced subsidence in the source area.
4) Subsidence created gentle arching in Bullfrog area, and resultant tension fissures. Tension axis east-west.
5) Possible continued eruption (?) in source area. Shift of tension axis to northwest, creating northeast tension fissures.
6) Continued subsidence and expansion of plate by arching. Rotation of blocks to produce antithetic faults along tension fissures.
7) Creation of east-west faults. Time undetermined.
8) Intrusion of dikes.
9) Movement along faults.

10) Mineralization.

11) Movement along faults.

Undoubtedly, any discussion of this area would be greatly enhanced by geologic information for the surrounding regions. Unfortunately, such information is not available.

ECONOMIC GEOLOGY

The vein minerals of the Bullfrog district are few in number and lack the complexity of nearby mining district. They are:

1) Gold - Native gold with varying amounts of contained silver occurs as fine specks in quartz and limonite. The limonite and gold is the product of oxidized gold-bearing pyrite.

2) Pyrite - Scarce throughout the district and believed to have never been plentiful.

3) Cerargyrite - Thought to be widespread, but found only in minor amounts.

4) Quartz - Most primary vein quartz is cryptocrystalline. May be aggregated with calcite. Quartz in outer limits of district more crystalline and glassy. Secondary quartz occurs as crusts and druse linings.

5) Limonite - Found in all ores and cause of rusty appearance.

6) Calcite - Common primary gangue mineral. Also occurs as secondary crusts.

7) Wad - Hydrous manganese oxides produced by leaching of calcites.

8) Chalcocite, chryscolla, malachite - Found only in small amounts in the Original Bullfrog and Bullfrog West mines.

All ores mined or reported are oxidized. No primary or secondary enriched ores were reported in any of the deeper workings (down to 700 feet). The only mineral zoning indicated relates to the localized occurrences of calcite, wad,

fine grained quartz and cerargyrite in the Ladd Mountain - Bonanza Mountain area.

VEIN STRUCTURE

The Bullfrog veins can be classified as fissure fillings of simple fractures and sheeted zones containing rhyolite fragments. Deposition occurs in association with both rhyolite and basalt wall rocks, and also faults containing dikes. Mineralized zones vary in thickness from a few inches to over 100 feet.

Of the mapped faults, less than 10% are associated with mineralization, the remaining 90% showing no deposition of any type. Faults of minor structural importance and small displacement possess the more economic veins. Gouge in the mineralization is interpreted as evidence of post ore movement.

Vein structure varies from banded calcite, quartz and thin rhyolite sheets to quartz cemented brecciated rhyolite. Several stages of deposition have occurred.

With the exception of very limited devitrification of some volcanic glasses and the minor silicification of rhyolite fragments, wall rock alteration is absent. This lack of alteration, the scarcity of mineralization, both economic and non-economic, and the simple mineral assemblage indicate that the ore fluids were dilute, cool and not under high pressures.

STRUCTURAL CONTROL

Of particular economic interest is the structural control of the mineral deposits, if such can be determined. In this case, the published data is too incomplete to make a reliable analysis. All veins, grades and types of mineralization, and enclosing fissures should be plotted on a stereonet and studied to determine any possible controls.

Ransome states that of the 12 to 15 mineralized fissures, all but two strike north-south and dip at angles exceeding 50°. The Montgomery-Shoshone and

the Bullfrog veins strike northeast and east-west respectively. Except for the Eclipse vein and an upper section of the Denver vein, all dips are vertical or to the west.

Basically, the mineralization is related to the fault planes which provide the sites of deposition.

FUTURE POSSIBILITIES

As previously noted, the ore solutions were probably cool and dilute as evidenced by the mineral assemblage. A point of interest is the source of the calcium in the calcite. The lack of wall rock alteration eliminates the possible derivation of calcium from the plagioclase in the basalts. Therefore, the source must be the Silurian (?) limestones occurring beneath the undercutting Bullfrog and Amargosa faults, indicating that the solutions passed through the pre-Tertiary rocks.

When considering this and other theoretical implications, two possibilities are noted.

1) If all known ores are oxidized, is there a deeper unknown zone of secondary enrichment? Or of primary ore?
2) Were the solutions that passed through the limestone warmer and more concentrated? And did they deposit better grades of ore?

As noted by Wisser, oxidized ores are normally of higher grade than the underlying primary ores.

Detailed mapping and structural analysis could conceivably determine ore controls and indicate potential ore zones. To date, such mapping has not been performed.

Extensive expenditures of money for drilling and other exploration work is not justified on the basis of past performance of the district.

MINES

Only one mine has an attractive history, and then only from 1905 to 1910. This mine, the Montgomery-Shoshone, produced ore with values up to $700 per ton; however, the average grade was $15 per ton. Mine workings reached 700 feet in depth, where the water problem became insurmountable.

The deposits are localized on the south side of the Montgomery-Shoshone fault between two north striking feather (?) joints. These joints terminate against a "horse" of basalt within the fault zone. Rhyolites comprise the main fault blocks.

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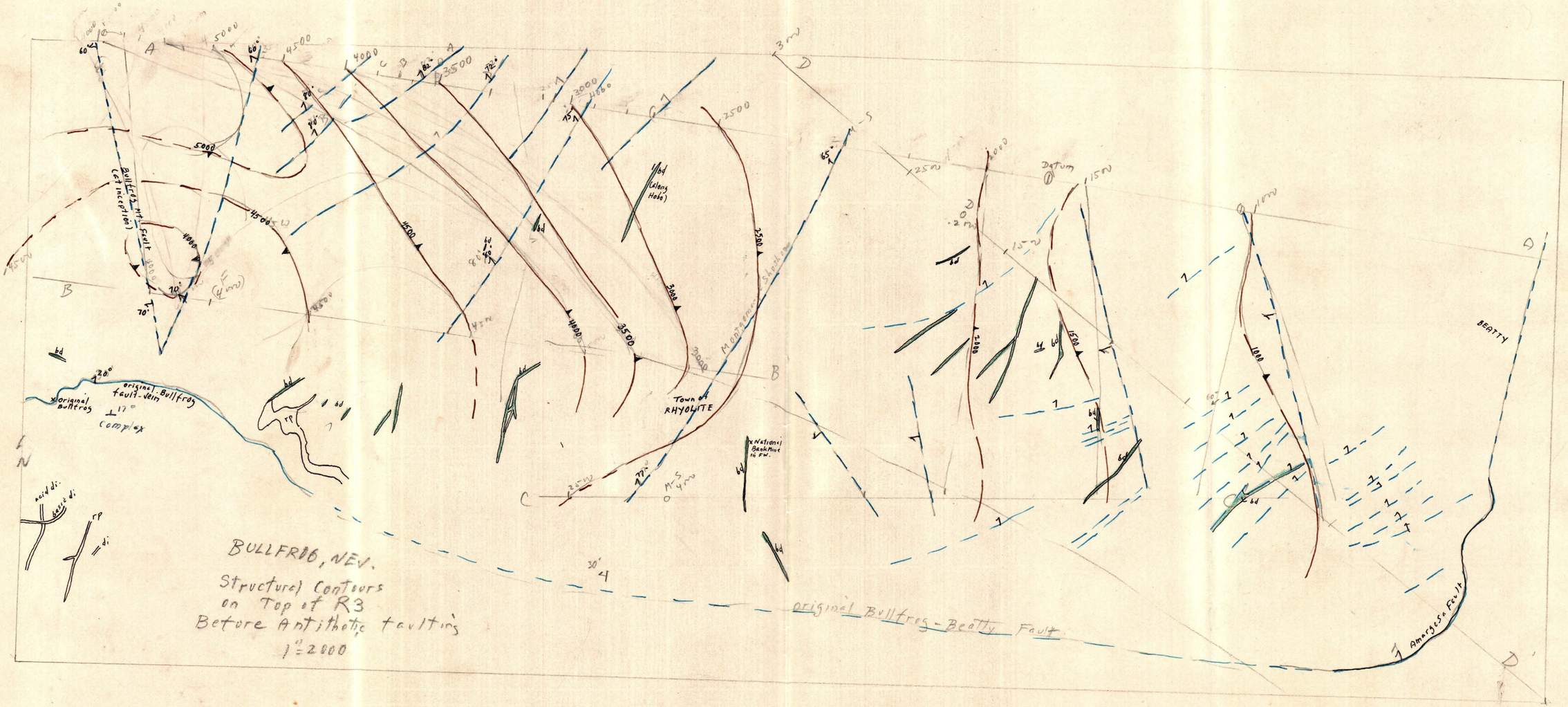
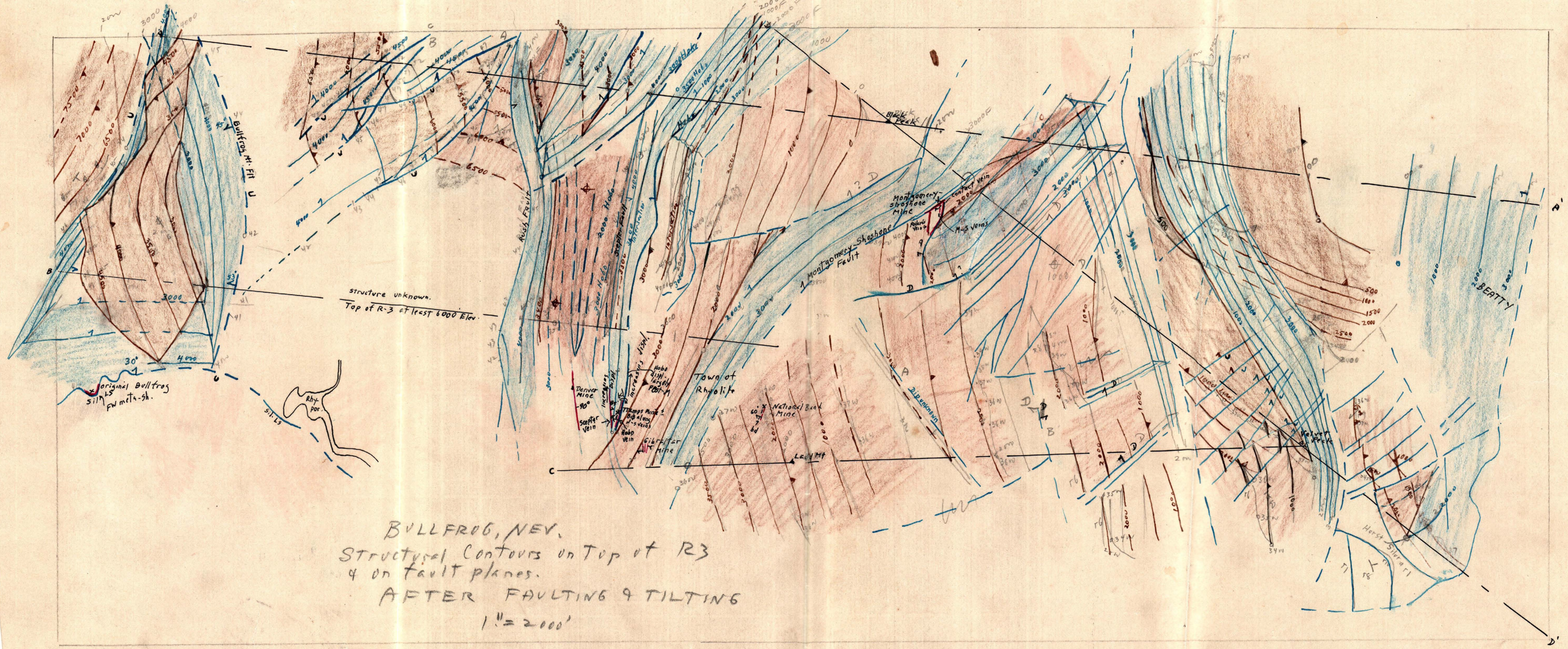
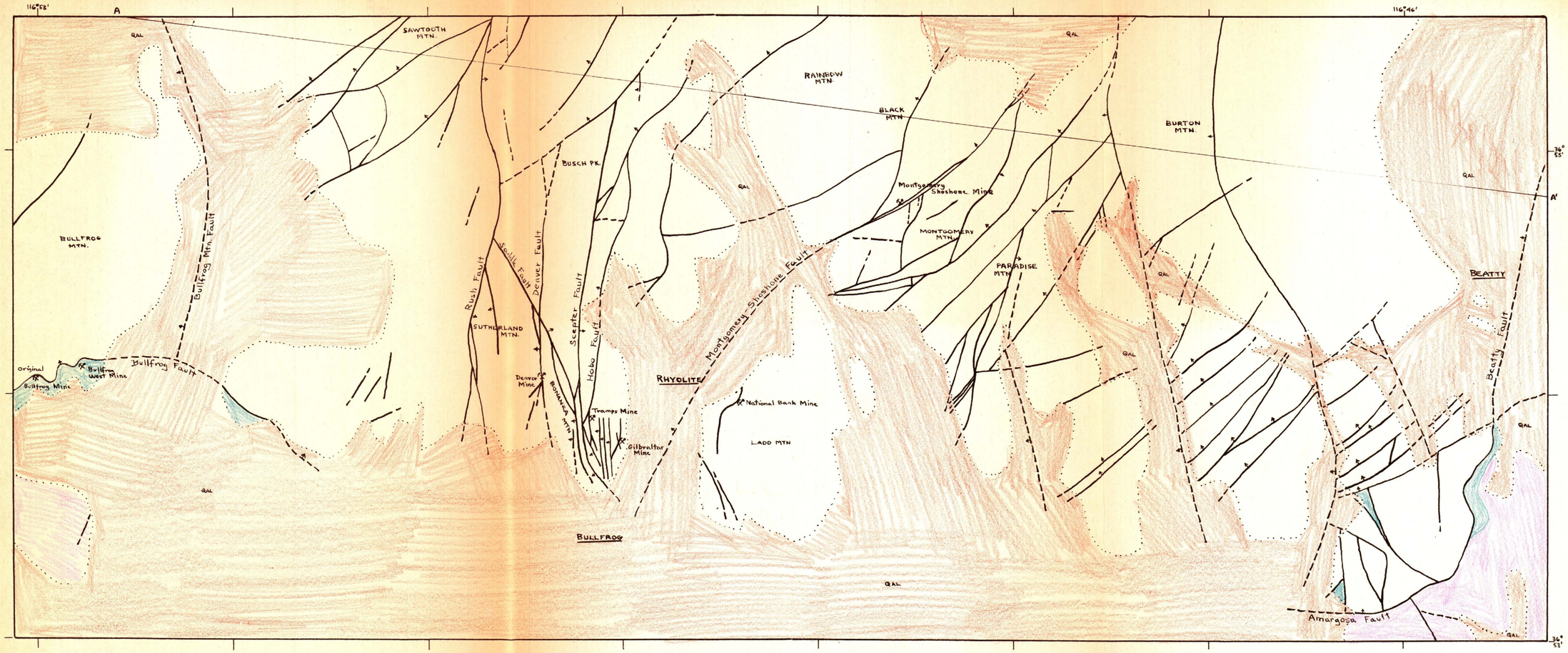
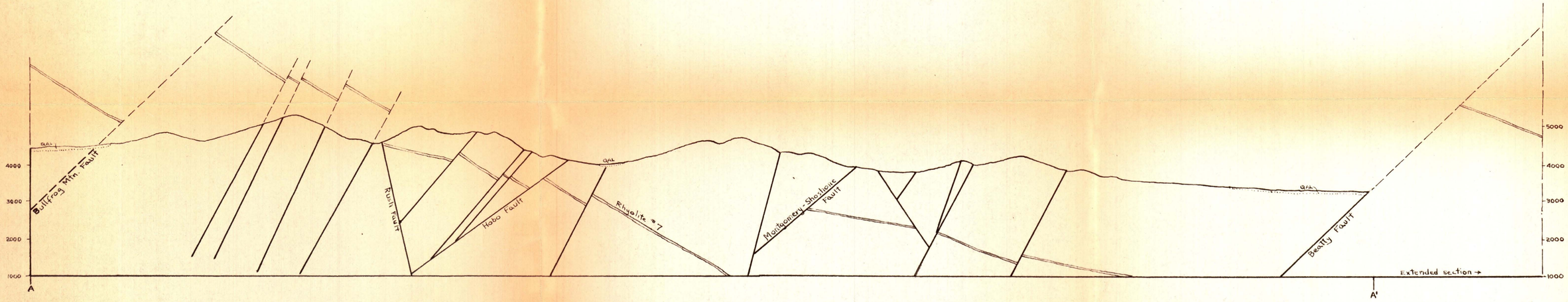

BULLFROG, NEV.
Structural Contours
on Top of R3
Before Antithetic faulting
1" = 2000
Original Bullfrog-Beatty Fault
Amargosa Fault
BEATTY
Town of RHYOLITE
Montgomery Shoshone
Datum
Bullfrog Mt. Fault (at inception)
Original Bullfrog complex
original Bullfrog fault-vein
Colony Hole
National Bank Mine in FW.
acid di.
base di.



BULLFROG, NEV.
Structural Contours on Top of R3
& on fault planes.
AFTER FAULTING & TILTING
1" = 2000'

stretching 2200 to 2520





From- Emmons and Garrey, 1910

STRUCTURE MAP & CROSS SECTION

BULLFROG DISTRICT, NEVADA

SCALE

0 ½ 1 Mile

FIG. 1

Cavender 5-59