Mineralization of the Bonanza Mine

H. M. Callaway

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MINERALIZATION OF THE BONANZA MINE

by

R. M. Callaway

A Thesis
Submitted to the Department of Geology
in partial fulfillment of the
Requirements for the degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
June, 1950
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INTRODUCTION

The Bonanza mine of the Emery (Zosell) mining district in Powell County is on the largest vein in the area, and is developed to a depth of 680 feet by an incline shaft following the dip of the structure. Sulfide ores carrying gold and silver values are mined throughout the area which is easily accessible by road from Deerlodge, Montana, ten miles west of the district.

Though the geologic structure is of interest, the wall rock alteration particularly interested the writer in connection with a study of sulfide mineralization.

The controls of sulfide deposition and the relation of ore to wall rock alteration are probably the foremost problem with which the economic geologist has to deal. The answer lies in the nature of the mineralizing fluid, and the writer believes that an investigation of the probable fluids as evidenced by their effects on wall
Plate I

EXPLANATION

TERTIARY LAVE BEDS
CRETAEOUS
AMGODALOID BASALT
POLHYRITIC BASALT

34 CREEK
35
36

37 DEERLODE

COTTERWOOD

1
2
3

K8

4
9

10

11

12

13

14

15

22

23

24

T 82

N

T 87
rock may reveal critical controls. Recognition of such controls would put prospecting and exploration on a more scientific basis.

In recent years much work has been done to augment the supply of knowledge and stimulate research on ore deposition. It is hoped that this small contribution may also arouse interest, and thereby challenge future investigations to study the problems presented herein.

The writer wishes to acknowledge his indebtedness to Dr. E. S. Perry for his guidance and helpful criticism and to Mr. F. S. Robertson for his assistance in the petrographic study of the mineral suites.

Thanks are extended to Mr. Charles Meyer who gave his time at an interview to aid the writer. His enlightening paper on wall rock alteration at Butte, Montana has been of prime importance in the writer's study of the Bonanza Mine.

Since the work herein included is primarily a laboratory study of mineral suites, most of the general geology of the area has been taken from theses of H. C. Elliott and F. A. Stejer.

HISTORY

The history of the Emery mining district began with the discovery of placer gold in Rocker Gulch by H. L. Hoffman in 1872. Though the gravel was far from rich, it supported many placer claims for a period of twenty years, and produced gold valued at $80,000.

With depletion of placer deposits vein outcrops were prospected, and in 1887 the first lode claim was made. The Emery mine, most productive in the area, was located a year later and developed by Emery, the man whose name the district bears. In 1895 Mr. W. T. Zosel discovered the Bonanza lode, the largest vein in the district. Since then gold and base-metal sulfides valued at $190,000 have been extracted. Many other discoveries quickly followed, and the district underwent a period of speculation and consolidation.
Early operators were interested mainly in the upper one hundred feet of oxidized gold and silver-bearing ore. Since the early stages of discovery the various mines of the district have operated only intermittently, but collectively have produced ores netting approximately $700,000. The strength of the structures and extent of wall rock alteration suggest possible undiscovered ore shoots at depth, and point toward renewed significant production in the future.

PHYSIOGRAPHY

The Emery district lies within the drainage system of Cottonwood and Baggs Creeks, and is on the western slope of the Continental divide. Numerous tributaries have cut rather steep and narrow gulches near their mouths, but to the east near the divide the land levels off to rounded, gently rolling hills and upland plains. All streams drain westward into the northward flowing Deer Lodge River.

The altitude ranges from 5500 to 6500 feet. Highest areas are east toward the divide on the upland plains, and the low areas are near the mouths of the gulches in the western section.
Though trees are scarce in the flat uplands, the pines of the valley slopes supply enough timber to satisfy local mining and building needs, and the upper plains support sufficient grass for cattle grazing.

GENERAL GEOLOGY

At the close of the Cretaceous, plutons intruded the Paleozoic and Mesozoic sediments of western Montana, folding and faulting the strata along the contacts. The largest such intrusion is the Boulder batholith, a quartz monzonite containing the copper deposits at Butte.

The Bonanza mine and the Emery mining district lie immediately west of the margin of the Boulder batholith. Basaltic volcanics of late Cretaceous age, designated "andesite" in the literature, cover the entire district, and westward they dip beneath Tertiary lake beds of the Deer Lodge Valley.
The Bonanza Mine

The Bonanza mine is on the largest vein in the district, which strikes N. 35 W. and dips about 40 NE. The hanging wall is well defined, but locally the foot wall grades into altered wall rock. As a structural feature, the vein lies in a sheared bedding plane between two basaltic lavas. In places it is filled with breccias of both ore and wall rock. The width ranges from one to six feet. Arsenopyrite, pyrite, sphalerite, galena, and gold values occur along the structure margin, and late carbonate veinlets cut the vein and latered wall rock.

Adjacent to fault planes and along joints, and extending out into country rock is a zone of hydrothermal alteration consisting of light-gray rock which effervesces vigorously in cold hydrochloric acid, the rock resembles limestone in appearance.

Rock Units

Two principal rock units are present in the Bonanza mine: (1) amygdaloidal basalt, and (2) porphyritic basalt. Porphyritic Basalt: This rock consists essentially of
Plate II

PHOTOMICROGRAPHS OF PORPHYRITIC BASALT

A. Unaltered porphyritic basalt showing feldspar laths, augite, and microlitic groundmass

B. Partially altered porphyritic basalt. Feldspar is partly replaced by fine-grained carbonate.

C. Thoroughly altered porphyritic basalt. Arsenopyrite crystals (black, triangular) replacing carbonatized groundmass.
Plate III

PHOTOMICROGRAPHS OF AMYGDALOIDAL BASALT

A. Partially filled amygdules and remnant feldspar laths in propylized groundmass.
B. Pyrite crystal occupying center of amygdule.
C. Radiating quartz (polarized light) of amygdule filling.
D. Coarse-grained, late ankerite veinlet cutting basalt.
plagioclase and augite phenocrysts in a microlitic groundmass. Its color ranges from black in fresh specimens to grey-green in altered ones. Weathering bleaches the feldspar, and produces a striking contrast with the black matrix. Identification of the plagioclase places it within the labradorite range (Ab 48, An 52). Magnetite is present as minute dissiminated grains.

Hydrothermal alteration has been intense. Though zones characterized by a particular mineral suite are not prominent, there is some gradation in alternation. Along the twinning planes of labradorite, carbonate, and clay minerals are found in otherwise fresh rock. Pyroxene appears to alter directly to chlorite, carbonate, and some epidote. Almost white bloches of an amorphous "clayey" substance replaces the dissiminated magnetite grains.

Within perhaps one to five feet the sulfide vein rather coarsely crystalline ankerite veinlets feather outward from the fissure. Here carbonate composes over 50 percent of the rock mass. Fine-grained quartz is intermixed, and chlorite and clay are present. Feldspar and augite (in fact all primary minerals) have lost their identity.
Sulfides have penetrated outward from channelways, and appear as irregular replacement patches.

Amygdaloidal Basalt Megascopically, the amygdaloidal basalt resembles a grey-green limestone, and were it not for visible amygdules even an acid test might lead to faulty assumptions. In this section, carbonate minerals are the most abundant and are followed by secondary quartz, sulfides, chlorite, and epidote. Late carbonate is clearly distinguished by its coarseness and high interference colors under polarized light. It is confined either by vein walls or amygdules, whereas the early wall-rock-replacing carbonate pervades the whole mass, and is finely crystalline with low interference colors.

Quartz, carbonate, and sulfides are the important fillers of visicules which range in size from a few millimeters to 1/2 inch. Most are incompletely filled and exhibit banding. It is common to see euhedral pyrite grains occupying amygdule centers, though it appears that other sulfides have replaced altered wall rock.

Mineral relations within the mygdules are the same as those within the central vein. Carbonate commonly is
Plate IV
ORE SPECIMEN I

Early quartz fills central vein. Brecciated area A contains both ore and altered wall rock. At extreme right is irregular ankerite vein. Left of central quartz are irregular sulfide replacements. Dark stringers in quartz vein contain pyrite.
Plate V
ORE SPECIMENS

Quartz grew outward into open space. Sulfide filled center. Ankerite vein cuts altered wall rock parallel to main structure.
Plate VI

PHOTOMICROGRAPHS OF THE BONANZA ORE

A. Galena and sphalerite replacing altered wall rock adjacent to quartz vein (right).
B. Irregular replacement of wall rock by pyrite and arsenopyrite.
C. Sulfide replacement veinlet in wall rock.
D. Arsenopyrite replacing quartz.
Plate VII
PHOTOMICROGRAPHS OF THE BONANZA ORE

A. Sphalerite in brecciated and altered wall rock.
B. Pitted galena crystal (left) and pyrite (right) separated by late ankerite veinlet.
C. Early wall rock breccia and late ore breccia traversed by late ankerite veinlet.
incrusted in the outer zone, and fine quartz of several varieties grows inward into open space. As was stated above, pyrite commonly occupies the centers. The typical visicule, however, is only partially filled and by a single mineral.

Remnant feldspar laths are visible under polarized light, and clearly show alteration to carbonate, and rarely to clay minerals. Such laths appear to be an attractive place for sulfide deposition.

MINERALOGY

Vein-forming minerals in order of their deposition are as follow:

- quartz
- pyrite
- arsenopyrite
- sphalerite
- galena
- ankerite

**Quartz** White to grey vein quartz is the most abundant of the vein minerals, and exists as massive veins with smooth parallel walls and crustifications in sulfide veins. Brecciated quartz also is conspicuous within the fractured zones.
**Pyrite:** The most prominent sulfide is pyrite which occurs as fillings within quartz veins, disseminations within the wall rock, and irregular replacement veins adjacent to the central quartz.

**Arsenopyrite:** Needle-like and diamond-shape crystals of arsenopyrite occur in altered wall rock. Commonly it is intergrown with pyrite. At places irregular grains and masses appear to replace pyrite (see criteria sheet).

**Sphalerite:** Sphalerite replaces altered wall rock adjacent to the central vein, and fills open space within the vein. There are many instances of it replacing pyrite.

**Galena:** The age relationships between sphalerite and galena are obscure. In isolated examples, each appears to be replacing the other, and so intimate are the relationships of mineral grains that it seems safe to say that galena is mostly contemporaneous with sphalerite. Its mode of occurrence is the same as sphalerite; that is, it replaces previous sulfides, and fills open space within the central vein.

**Ankerite:** Microchemical tests show the late carbonate to be high in manganese, iron, and calcium. Ankerite fills late fissures and cements ore breccia.
Precious Metals: According to both Elliott (2) and Stejer (3) gold is associated with the arsenopyrite throughout the Emery district. Elliott conducted extensive assays on the Emery mine ores, and obtained values in gold up to 0.65 ounces per ton. Ore samples examined by the writer failed to give such rich values. In several separate microchemical tests no trace of gold was found. However, both sphalerite and galena gave positive silver tests.

Criteria

The following is a list of observations made on polished sections and ore samples.

Specimen I Hydrochloric acid causes quartzitic groundmass in zone A to effervesce vigorously (exclusive of ankerite vein). Clay-like minerals, probably from altered feldspar are prominent in breccia and groundmass. In area B, to left of quartz vein, the groundmass is mostly quartz, but lacks the characteristics of vein quartz. In general this material seems more closely related to wall rock than to vein quartz.

Altered wall rock breccia in zone A.

Smooth contact with parallel walls of vein quartz (zone C), indicates cavity filling.

Disseminated grains of pyrite in breccia fragments indicate pyrite replaced altered wall rock.
Irregular veinlets of pyrite and other sulfides with included residual islands of quartzitic gangue (zone B).

Irregular contacts between gangue grains and pyrite with dissemination of pyrite throughout gangue.

Several small stringers of pyrite in vein quartz (zone C).

Pyrite appears to be unevenly distributed along small fissures as if incomplete cavity filling occurred.

Irregular contact between pyrite and arsenopyrite, embayments, and residual blebs of pyrite in arsenopyrite indicates arsenopyrite replaced pyrite.

Smooth boundaries between pyrite and arsenopyrite indicate simultaneous deposition.

Arsenopyrite diamond-shaped crystals in wall rock groundmass indicates arsenopyrite replaced wall rock.

Residual "islands" of wall rock material in arsenopyrite.

Galena grains disseminated through wall rock, galena embayments in otherwise euhedral pyrite crystal. Galena evidently replaced both gangue and pyrite.

Galena and sphalerite dissemination in relatively massive pyrite and arsenopyrite.

Smooth contact between sphalerite and galena grains indicate simultaneous deposition.

Ankerite veinlets with parallel walls apparently controlled by ore breccia. Veinlets are around sulfide grains and not, any instance, through sulfide grains.

Specimen II Sphalerite and galena fill cavity in comb-structured quartz vein.
<table>
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<tr>
<th>QUARTZ</th>
<th>PYRITE</th>
<th>ARSENOPYRITE</th>
<th>SPHALERITE</th>
<th>GALENA</th>
<th>ANKERITE</th>
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Ankerite fills cavity in comb-structured quartz vein; ankerite overlies sphalerite in cavity.

Specimen III  Ankerite vein has uniform width, and parallel vein walls.
Sphalerite and galena finely disseminated in wall rock.

Specimen IV  Pyrite grains finely disseminated in wall rock. Pyrite not related to ankerite veinlet.
Comb structure of euhedral quartz crystals growing outward from vein walls.
Galena veinlet through pyrite crystal.
Carbonate filling in quartz comb structure. Vugs present.

Specimen V  Carbonate filling around ore breccia.

Paragenesis
From the foregoing criteria, it appears that quartz was the initial mineral, and probably represents a stage far in advance of sulfide deposition.
The sulfides are intergrown so completely that it is difficult to establish a definite sequence. It is safe to say that pyrite and arsenopyrite, as well as sphalerite and galena, are partly contemporaneous. Though each sulfide to
some extent replaced all previous sulfides, preferential replacement was for the altered wall rock.

The mineral relationship as shown in the criteria list illustrates the fact that the ankerite fills fissure veins formed after the period of sulfide deposition.

See Plate VIII.

STAGES OF SULFIDE DEPOSITION

The emplacement of ore at the Bonanza Mine was not a result of any one simple process. In some places within the Bonanza vein, ore minerals show fairly symmetrical crustification, giving evidence of open-space filling. At other places the sulfides occur as disseminations within the altered wall rock. Irregular replacement veinlets are also common.

It is evident there are two primary features responsible for ore localization: (1) open space developed along planes of weakness within the wall rock; and (2) the propylized wall rock for which sulfides had an affinity.

Mineral grain relationships and structural features
attest four distinct stages of vein formation:

1. Brecciation, fissuring, and alteration of wall rock.

2. Cavity filling by hydrothermal quartz.

3. Sulfide replacement of the altered wall rock and of all previous sulfides, and sulfide cavity filling within the quartz vein.

4. Fissuring and brecciation with subsequent fissure filling by ankerite.

The initial stage gave rise to channelways that placed the hydrothermal solutions in close contact with wall rock. Brecciation increased the ability of the solution to penetrate outward from the channels of circulation.

Since brecciation is usually connected with compressive forces, and open space with tension, the following interpretation must be given.
Figure 1.

Diagrammatic explanation of brecciation

If vein varied in dip, and dip-slip movement occurred, then at where dip increased compressive forces would be exerted and brecciation would take place in area.

A, figure 1. A tensional component of the force would develop at A and open space would occur in areas of lesser dip. Drag would cause breccia to be carried into open spaces.

Specimens from the main structure bear out the above relation. In specimen 1, Plate IV, wall rock breccia is
Characteristic of the zone to the right of the quartz vein, but no breccia exist to the left of the vein.

After entrance of the solutions, and thorough alteration of the wall rock, quartz was deposited in open space, and partially blocked the channelways of the solutions. At some places the quartz veins have smooth, parallel contacts and totally fill the fissure. At other places euhedral quartz crystals have grown outward from the vein walls leaving open space that was subsequently filled by sulfides.

The third stage of vein formation is marked by extensive replacement of the altered wall rock and by fissure filling within the vein. It appears that circulation of the ore-forming fluids were by no means confined to open-space channels, but penetrated many feet into the wall rock. Fine grain disseminations of pyrite are prominent throughout the altered wall rock, and seem to be localized in the zones highest in carbonate.

Irregular replacement veins occupy areas adjacent to the central quartz vein. The active solution apparently migrated along a weakness plane adjacent to the
main fissure and spread outward from the fissure through the porous altered walls. Stejer (8) believes this zone to be early quartz rather than altered wall rock, but the occasional occurrence of carbonate minerals and claylike material suggest that it is merely silicified wall rock.

At the close of the first period of active mineralization a second generation of fissuring and brecciation occurred. The solutions, depleted of their metallic sulfide content, and enriched in carbonates, deposited ankerite as cementing material around the breccia, and filled fissure veins. Open space within the initial quartz vein was also filled with carbonate.

In general, the ankerite veinlets are parallel to the main structure, and seem to indicate successive movement along the same weakness plane.
NATURE OF THE MINERALIZING SOLUTION

That wall rock examination is not a separate study from ore deposition was expressed by Meyer (7):

Alteration is the first stage of mineralization and is as intimately related to vein formation as sulfide precipitation.

Obviously the problems of alteration and deposition have their explanation in the nature of the mineralizing solution.

Mineralization in the Bonanza Mine

Undoubtedly, carbon dioxide was the principal active constituent of the solution in the Bonanza vein. Probably hydrogen sulfide was secondary in importance, and water was the transporting vehicle. The writer believes that quantitative examination of sulfide and carbonate minerals now present in a given cross section would give the relative importance of carbon dioxide as compared to hydrogen sulfide which were active in the solution at the time of mineralization.
Metallic constituents were iron, manganese, arsenic, zinc, lead, gold silver. It is difficult to say whether calcium, magnesium, and silicon were original constituents or represent additions to the solution through leaching of the wall rock. However, the prevalence of quartz as visicule filling suggests that it, at least in part, was introduced from the solution.

The rate of supply of fluid is probably the chief control that caused such a wide zone of propylized rock to develop. Evidently the fluid was unconfined to the central structure. Brecciation, fissuring, and presence of visicules provided auxiliary channelways for the mineralizing solutions.

Nature of Mineralizing Fluids in General

It is not to be construed that the following discussion attempts to prove, but rather it presents problems of wall rock alteration and sulfide precipitation. But, before a problem can be solved, it must be understood.
Apparently, alteration depends on two factors: (1), the nature of the altering solution, its temperature and its composition; (2) the characteristics of the wall rock, its reactivity and permeability.

In his description of alteration of the Comstock Lode, Coats (1) has this to say:

Most processes of hydrothermal alteration have been named from the characteristic mineral developed by them. The name thus comes to express the concurrence of two factors, process and material, rather than process solely.

Wahlstrom (9) defines propylitization as the following:

Propylitization is a form of hydrothermal alteration involving the introduction or formation in place of carbonates, secondary, silica, chlorite, and sulfides. It reaches maximum development in fine-grained rocks in the vicinity of upper mesothermal or lower epithermal veins.

By the above definition, the alteration process at the Bonanza Mine is typically propylitization. Through Wahlstrom's definition gives the term a mineralogical significance it is generally accepted that the term is a process name. The characteristic minerals that are assigned in the literature to the process differ widely, but all investigators seem to agree that carbonate has the
dominant role.

The present writer believes that descriptive terms should be applied only to process, for it has been demonstrated by many investigators of recent years that, contrary to Coats, one term cannot include both the process and the mineralogy.

Butte, a typical area of wall rock alteration, exemplifies this idea. Sales and Meyer (7) state that the alteration envelope of the Butte veins includes, in definite order outward from a central structure a silicified zone, a sericite zone, a clay-mineral zone, and a zone dominated by carbonate and chlorite that the writer believes comparable to a propylized zone. Though only one process was active at Butte, the wall rock was "sericitized", "kaolinized", and "propylized". Zoning is attributable to changes in the character of the solution laterally outward from the vein by reaction with the wall rock, fresh rock representing complete neutralization.

Of course, the various zones are not of uniform width, and a cross section (as in the deeper, central areas at Butte) may show scores of feet of sericite and only inches
of clay minerals and carbonate. In the zones radially outward from the center of mineralization, the lateral zoning pattern is upheld, but the sericite zone is inconspicuous in comparison to the kaolinite-montmorillonite zone. Investigators, therefore, quite naturally name the alteration according to the most prominent zone, failing to realize that the other zones are present.

If a more thorough and extensive study was made of the Bonanza vein, evidence of a zoning pattern of alteration would probably be found. Extending the idea stated above, the propylitization in the Emery mining district simply represents a wide zone comparable to the outermost lateral zone of alteration of Butte veins.

It has been seen that the altering of solution laterally outward from the structure causes lateral zoning. It is not logical that progressively upward and radially outward from the source of mineralization the solution confined to main channelways will undergo similar changes? If the suite of ore minerals change upward and outward from the source, would not a corresponding change in the type of alteration of the wall rock be expected, since both changes are dependent on change in the nature of the same.
mineralizing solution? Since we find carbonates dominating the outermost lateral zone of the alteration envelope we would expect to find carbonates predominant in the upper and outer radial zones. If the writer's assumptions are correct the Bonanza mine represents such a radial zone.

There are suggestions that the carbonate content of hydrothermal solutions is held relatively inactive by hydrogen sulfide, however, by subtractions from and additions to the solution, its nature is radically changed, and at some critical point it is sufficiently depleted of hydrogen sulfide to allow carbon dioxide to assume the principal active role. Supporting examples are the propylized lateral zones, and the abundance of rhodochrosite of the outer radial zone at Butte. Additional evidence is the late ankerite mineralization of the Bonanza structure. After sulfides were deposited, the solution had the ability to deposite carbonate in open spaces.

Most publications on wall rock attempt to correlate a specific type of alteration with a specific type of wall rock, and indeed there seems to be good reason for doing so. But "type" of rock not only denotes chemical composition, but also depth and temperature of formation as well. Therefore,
one should not jump to the conclusion that chemical composition solely determines the kind of alteration. Possibly the only reason that propylitization is associated with fine-grained volcanics is that both propylitization and occurrence of volcanics are characteristically near-surface phenomena. In a great number of cases the wall rock factor can be held constant, and the variation in alteration can be attributed solely to the changing composition and temperature of the mineralizing solution.

Not ignoring the importance of reactivity of the wall rock, one can see that at successive depth zones a different mineral dominates the alteration envelope. At Butte (7) though the wall is a quartz monzonite throughout, sericite characterizes the deeper radial zones whereas kaolinite dominates the more shallow zones. Thus it seems that similar to the "ideal vein" concept for ore minerals, depth and temperature are the radical zoning controls of alteration minerals.

Concepts of Alteration

A concept of wall rock alteration, as stated below,
may be pieced together from these data.

1. Mineral zoning laterally outward from a structure is characterized by domination of one particular material or mineral zone.

2. A mineral zoning exists radially outward from the seat of mineralization that is characterized by domination of one particular material or mineral zone.

3. Zoning, both lateral and radial is a reflection of changes in the character of the mineralizing solutions through reaction with wall rock changes in temperature.

4. There is a close correlation between the lateral and the radial zones; the lateral zones close to the central vein being analogous to the radial zone at greater depths, and the outer lateral zones corresponding to the more shallow radial zones.

CONCLUSION

Mineralization of the Bonanza vein was through the processes of open-space deposition and replacement from ascending hydrothermal solutions. Ore and alteration minerals were localized by successive openings and brecciation along one principal weakness plane that appears to be a
contact between two basaltic flows. Visicules played an important role in circulation of the solution through wall rock.

Extensive propylitization of the volcanic wall rock indicates that the deposit should be classed as lower epithermal.

From concepts drawn from the study of wall rock, the writer concludes that classification of alterations should be based on a system similar to Lindgren's classification of ore deposits; that is, the recognition of kinds of alterations to depth and temperature of formation rather than to simple recognition of the mineral present.

In the light of this study the writer recognizes that both lateral and radial zoning is fundamental, and is controlled by changes in the composition of the solution through reaction with wall rock.

Propylitization is not a distinct type of alteration but only a later phase of alteration that greisenized the hypothermal zone and sericitized the mesothermal zone.

On the basis of the hypothesis drawn relative to wall rock alteration, and on the strength of alteration at the Bonanza mine, the writer sees a good possibility that ore
value will increase with depth. It is not likely that the hydrothermal solutions effecting mineralization and intense alteration of the vein and wall rock of the Bonanza structure ascended from depth without vigorous alteration and mineralization along its channels of ascendance.
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