The Extraordinary Faulting at the Berlin Mine

The Berlin Gold Quartz Mine, Nevada, Shows the Result of Remarkable Movements after the Formation of the Vein

BY ELLSWORTH DAGGETT*

The Berlin Gold Quartz Mine is situated in Nye county, Nevada, on the west flank of the Shoshone range, about 40 miles south and 30 miles west from the town of Austin, the county-seat of Lander county. The distance from Austin is about 60 miles by stage-road.

The outcrop of the vein, at the top of the incline-shaft, is situated just at the base of the mountain proper, almost exactly at the intersection of the mountain-side with the gravelly bench that slopes for about three-quarters of a mile to the flatter sage-brush plain, or desert valley, below.

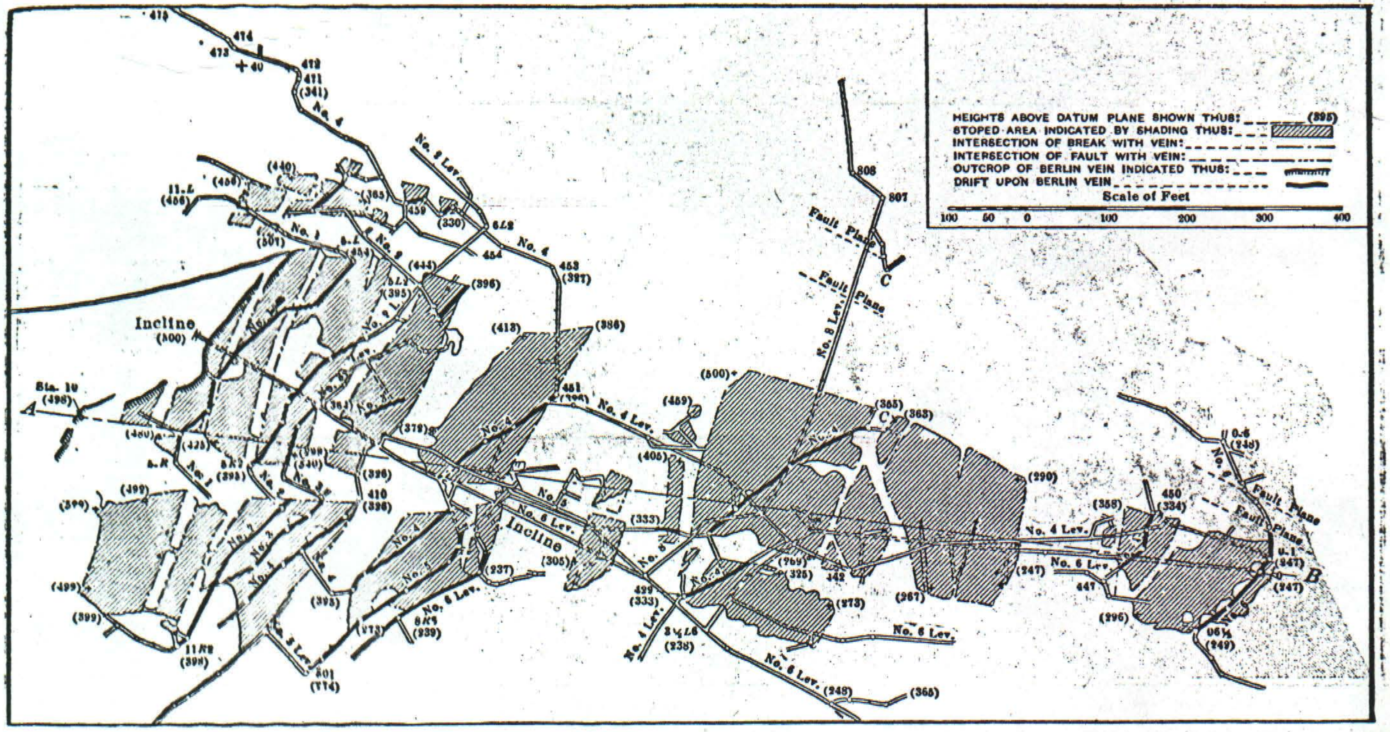

FIG. I. PLAN OF UNDERGROUND WORKING OF THE BERLIN MINE

The vein itself consists almost entirely of quartz, with perhaps 2 per cent. of sulphide of iron, copper, lead, zinc and antimony, and perhaps a trace of some of the compounds of tellurium with gold and silver, although none of the latter have been as yet positively identified.

The relative proportion, by weight, of silver and gold in the ores, varies in different parts of the vein, from 12 silver for 1 of gold, to 7 silver for 1 of gold.

The quartz vein-filling is usually frozen fast to the walls, and is very hard and compact, seldom showing the friable, fissured, or shelly structure often to be found in quartz veins.

Original Condition of the Vein

Comparatively little evidence of relative motion of one wall of the vein upon the other is to be found—a fact indicating that during the formation of the vein, and prior to the extensive movements herein described, little disturbance had taken place. No evidence whatever of metasomatic origin has been observed. On the other hand, occasional occurrences of comby structure, in which the axes of the quartz crystals are at right angles to the plane of the vein, rather indicate deposition from solution in a pre-existing fissure.

Spurs, or branches, and small parallel veins, while not entirely absent, are not thus far numerous, and not extensive enough to possess any marked practical importance.

The thickness of the Berlin vein varies from a few inches to 8 ft., but, over far the greater portion of the explored area, is tolerably uniform at from 2 to 3 ft., measured normal to its plane. The average thickness of quartz thus far stoped, as determined by all available measurements, is a little less than 2.5 feet.

The course of the vein is northeast and southwest, and its average dip about 45 deg. to the southeast.

The Berlin vein, prior to the extensive faulting described in this paper, was tolerably uniform in size, course and dip, and perhaps, on the whole, rather more regular than the average of gold-quartz veins.

It appears to have been a fissure filled with qnartz, and may be said to have originally been in shape, structure and origin, a typical "old-fashioned" fissure-vein of the books.

Throughout the entire field covered by the underground works of the Berlin mine, the rock is andesite, which is, however, in places, locally so altered by compression or movement as to change considerably its appearance and structure. Some very limited chemical changes may also have occurred in places, by reason of which the above-given classification might, to a small degree, fall short of completeness.

The Workings

The underground workings, including the stopes, of the Berlin mine, as existing July 1, 1906, are shown in plan in Fig. 1, which is a reduced copy of the working-plan of the mine, from which, for the sake of plainness, most of the survey-

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lines, station numbers and hights above the datum-plane have been omitted.

The stopes, shown by the shaded areas, have in general the form of a more or less irregular parallelogram, suggesting at a glance the extensive faulting in two directions, to which the vein has apparently been subjected.

The orebodies, properly enough called segments, are usually terminated on all sides by fault-planes. Those on the east and west sides, though just as truely fault-planes, have been locally called breaks, which term will be retained in this paper for the sake of identification.

The lines bounding the segments, as projected on the plane of Fig. 1, are mainly lines of intersection of the faults and breaks with the vein, and their projections do not at all represent the true course of either the fault-planes, the break-planes, or the vein.

The marginal figures in Fig. 2 show the hights above the datum-plane.

The plane of this section was carefully chosen so as to avoid the faults, and Fig. 2, considered by itself, shows only the disturbances apparently due to the breaks.

Dislocated Segments

The light dotted line passing out through the surface-line may be considered as an elevation, showing the minimum hights which the segments could have occupied prior to the faulting herein considered. The actual hight from which the present segments have dropped to their present position may have been several times as great, as shown by the dotted lines.

Nor is it yet certain whether the movement was due to the subsidence of the northwest or to the elevation of the southeast portion.

shown in Fig. 3, which, moreover, represents that portion of the fissure system which may be regarded as best known from the present developments.

If we imagine that, in the field covered by Fig. 3, the accidents of erosion had left the surface about at the plane of the No. 4 level, then the heavy black lines would represent the actual surveyed outcrop of a single vein that, before the faulting here described, was probably as regular, as uniform in strike and dip, as nearly in a true plane, and generally as free from eccentricities as the average quartz vein.

So far as my observation goes, this situation is without parallel in quartz mining.

The Mode of Faulting

It was at first supposed that the north and south fissures or breaks, dipping

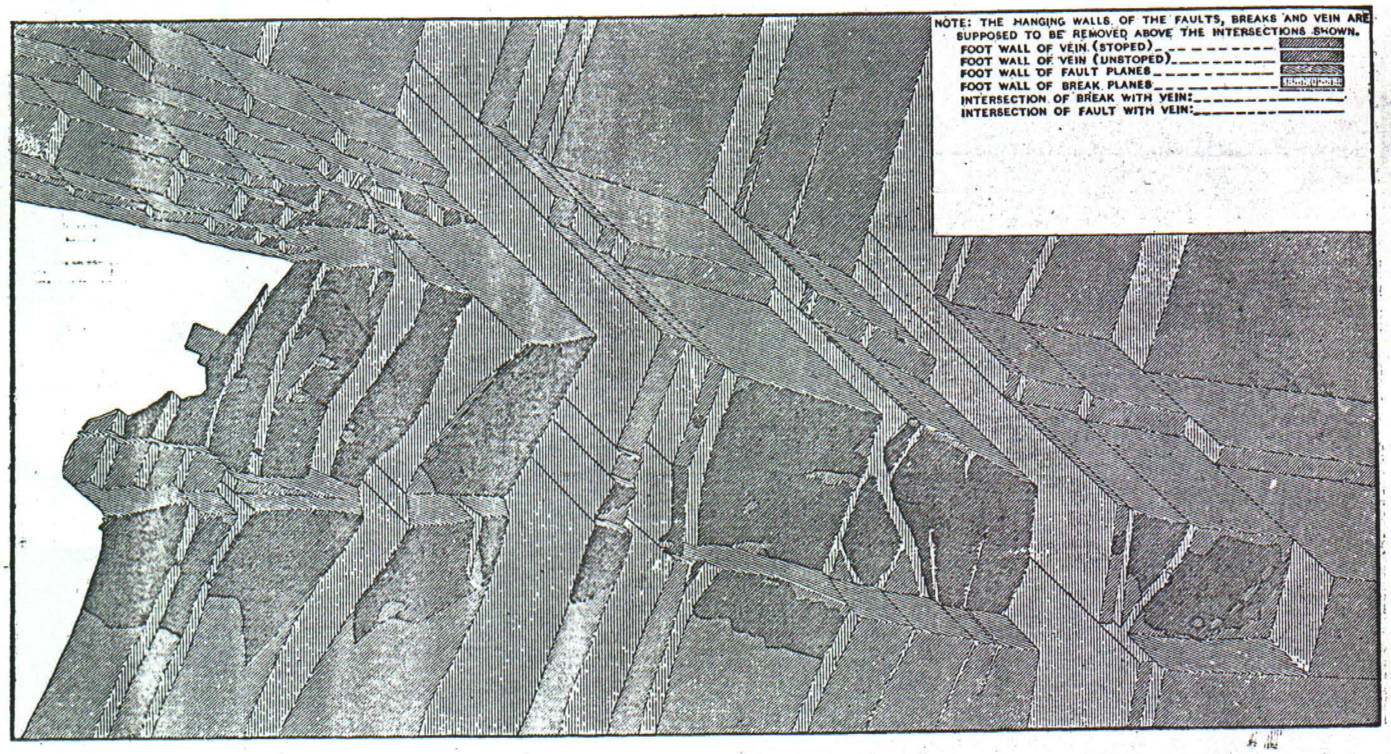


FIG. 1 A. STRATIGRAPHY OF THE BERLIN MINE

In Fig. 1, the hights shown in brackets refer to a datum-plane 500 ft. below the top of the Berlin incline-shaft. The hight of No. 8 level at the shaft is 137 ft. Figures not inclosed in brackets represent survey stations. The stopes, where limited by full lines, are not cut by faulting fissures, but end on account of poor or thin ore, or some similar reason.

Fig. 2 is a vertical section along line *A B* of Fig. 1 through Station 10, on the surface at the outcrop of the vein, and Station 0, on the No. 6 level, as shown in Fig. 1. In this section those portions of the Berlin vein actually stoped out are shown as a solid black line, while the probable position of the unstoped vein is indicated by two parallel lines. The marginal

Among many sections made in studying the Berlin underground work, there is one nearly parallel to section *A-B*, but further north, which shows it possible to drive a flat, incline-shaft, straight in line and grade, that would cut the vein no less than eight times.

Fig. 3 is a horizontal section, showing the intersection of the Berlin vein and of the break- and fault-fissures with the average plane of the No. 4 level, the average hight of which is about 165 ft. below the top of the incline-shaft, or 335 ft. above the datum-plane. The true course of the vein—viz., northeast and southwest; of the breaks, nearly always north and south; and of the faults, about north 60 deg. west., is therefore correctly

about 45 deg. west, had first been formed and had faulted the pre-existing vein, and that subsequently a pair of fissures had occurred, each with one or more branches having a general course about north 67 deg. west, and a dip of 63 deg. north 22 deg. east, cutting and faulting both the vein and the breaks. But as developments progressed, and additional intersections of the breaks and faults were found, or indicated, it was observed that in several instances the faults were cut and faulted by the breaks.

In the case of the so-called north fault, shown in Fig. 1, the segments of the Berlin vein, from its outcrop for a distance easterly of about 1300 ft., have been cut off. It was for a time believed that the south branch of this fissure was a continuous fissure, cut by the No. 4 level at its east end, near survey station 450, and in the north branch of the No. 4 level, near station 459, and again near station 454. But a consideration of the position of the surveyed and known lines of intersection of the fault with the vein forming the north boundaries of the stopes, shows that these intersecting lines were very far from being in the same plane, and that a single fissure, to have contained them all, would have had to be extremely—in fact, impossibly—crooked and irregular.

The conclusion was therefore forced that some of the larger breaks had faulted also the north fault, as well as the vein, and that, instead of one continuous fissure, with a course north 67 deg. west, there were several fissures with an average course of about north 60 deg. west, and a dip north 30 deg. east, of about 63 deg. from the horizontal.

If we assume that the planes of the break-fissures were in fact parallel to each other, and that the same was true of the fault-planes; that every fissure of each system has been cut and faulted by at least one fissure of the other system, and that the material fissured was rigid, incompressible and inelastic, it would appear that the line of any movement produced by gravity, or by an uplift from any cause, would necessarily be in both planes, and therefore in the line of the intersection of the two planes.

Now, in fact, the planes of neither the breaks nor the faults are exactly parallel. It is not known that every plane of each system has been cut or faulted by one or more planes of the other system. Moreover, andesite is far from rigid, being compressible, and capable of great distortion. Just so far, however, as the conditions existing in the Berlin field approach the hypothetical conditions outlined above, might we expect the direction of the movement to conform more or less closely to the direction of the intersection of the average fault- and break-planes.

the break the edge of a strong, faulting fissure, striking about north 60 deg. west, and dipping 60 deg. northerly. In this fissure, with some coarser material, was a layer of about 1 ft. of stiff blue clay, evidently the product of attrition. This layer of clay, without any parting whatever, and about uniform in thickness, was continuous around the sharp angle into the break, and up in the break to the quartz remnant, precisely as a layer of lubricant might be found in the V-groove of a planer. It no doubt continues up to the fault-plane on the north, and there turns down into it. Just southeast of point *C* a careful examination of the root and the floor of the stope showed that no sign of fissure existed in the foot-wall of the break. The fault-fissure at *C* is nearly enough in the plane of the fault, which cuts off on the north the next westerly stope, practically to identify it. On the hanging wall of the break, within a few inches of the sharp intersection of the fault and break, are lines of motion parallel to the fault-plane.

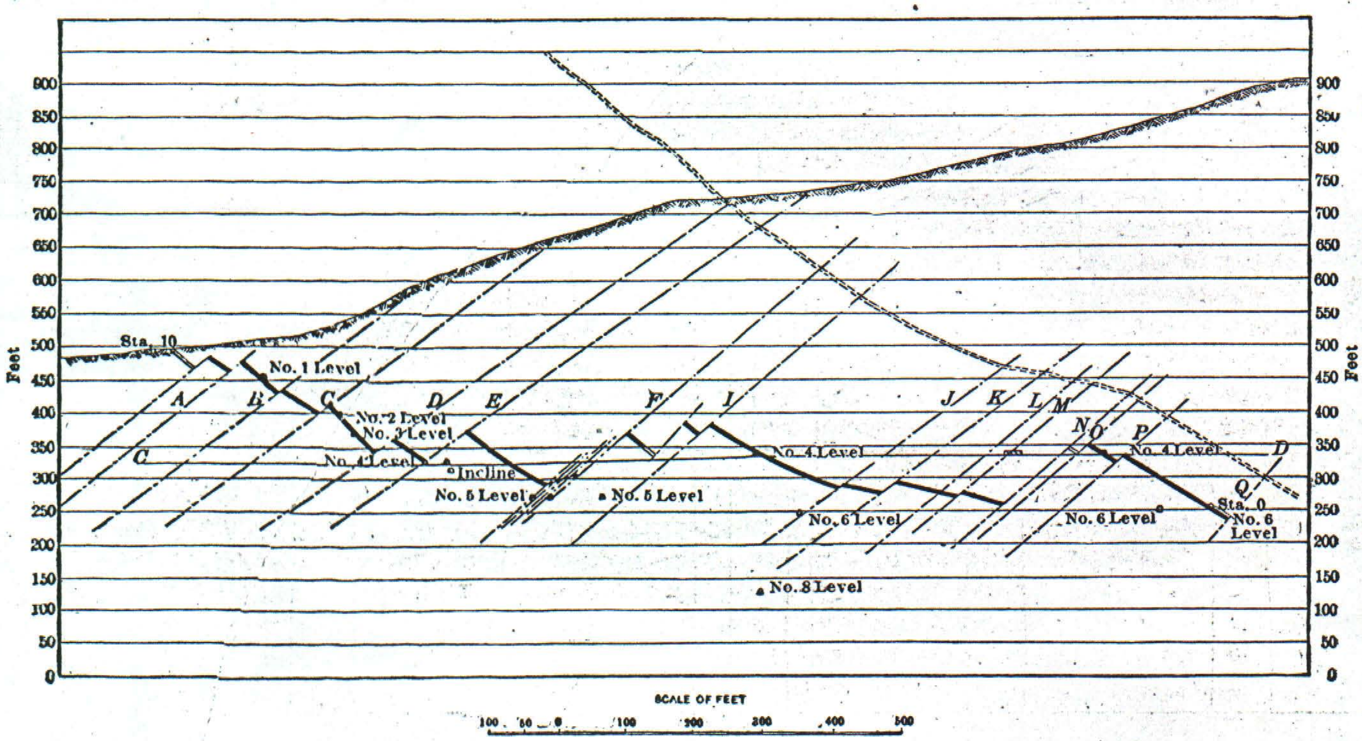


FIG. 2. VERTICAL SECTION ALONG LINE *A B* OF FIG. 1

In practical mining the main object is, of course, to find and extract the ore as cheaply as possible. It is not often that exposures interesting stratigraphically are incidentally made, or that special work for such a purpose is warranted. In the present case, while in many, perhaps in a majority of instances, the faults do cut and fault the breaks, there is no such uniformity as would enable us to establish the relative age of the two fissure systems. In fact, there are enough instances actually exposed, or undoubtedly indicated, of the breaks cutting and faulting the faults, to make it tolerably certain that the fissures of both systems originated at the same time, and in all probability from a single force.

Movement Upon Two Planes

Fig. 4 represents a very interesting occurrence, having a significant bearing on this point, which was recently uncovered by the accidental scaling-off of some slabs of clay and gouge in the northwest corner of the second large stope from the east end of the mine. The ore was stoped up to break *J*, but in the north corner, not quite to the fault-plane—perhaps to within 4 or 5 ft. of it. At point *C*, 12 or 13 ft. along the break southwesterly from the little corner of remaining quartz, there was plainly exposed in the hanging wall of

The above conditions indicate that the movement of the north country was one movement, upon both planes at the same time, and therefore in the direction of the line of intersection of the two planes.

Intersections

In Fig. 1A are shown the intersections, known and assumed, of the faults and breaks with the vein and with each other, and the entire hanging-country above these intersections is supposed to have been removed.

Figs. 1 and 1A were made about the middle of 1906, and represent the works and known or assumed intersections as of that date. One exception to this latter statement is, that the raise from the No. 8 level encountering ore at point *C* was begun and completed subsequent to the introduction of the lines of intersection.

Intersections of faults and breaks, where not surveyed and known, were then supposed to have the direction north 45 deg. west; and the average angle of the intersections of the vein with the breaks was taken as north 20 deg. east.

Some careful estimates, made since the preparation of Figs. 1 and 1A, and involving all of the principal vein and fault intersections, including both north and south faults, show these intersections to have an average direction of north 81 deg. west.

A revised consideration of the breaks shows that the more important breaks have an average dip of 40 deg. west with a strike, as near as may be north and south.

Taking the average course of the vein as north 45 deg. east, and its average dip at 45 deg. southeast, we may, with the average surveyed and known intersections given above, and the known dip of the faults—viz., 63 deg. from the horizontal—determine the average strike of the faults. This has been thus found to be north 59 deg. west.

The intersection of these planes of the average fault and break, as given above, strikes north 43 deg. west, instead of 45 deg. as shown in Fig. 1, and dips in that direction 29.5 deg. from the horizontal. The planes of the average fault and break, as given above, make angles with each other of 92 deg. and 88 deg., the upper angle being 92 deg. The line bisecting the obtuse angle between these planes runs south 12.5 deg. east, and dips in that direction 57 deg. from the horizontal. If these calculations be correct, this is the theoretical direction of the pressure or force which produced the two systems of fissures, here called breaks and faults. The existence, before erosion, of a rock-mass, known to be several hundred, possibly several thousand, feet in thickness would, through the weight of such a mass, supplemented by some lateral pressure, easily account for the fissuring; and gravity alone might be sufficient to explain the movement.

Practical Considerations

The miner, however, is more interested in the direction and extent of the movement, than in the question, just how it was produced.

In prospecting for the continuation of the Berlin vein, north of the north fault, the problem is complicated by the fact that the break-fissures found in either wall of any of the faults, do not necessarily correspond in their relation to each other with those in the other wall.

The same is also true of the faults. Thus, in the slab of andesite between the breaks *F* and *I* (see Fig. 2) are two known faults, and, in all probability, a third fault. At least two of these, if continuous, should be shown in the large open stopes on either side, but they are not to be found there.

It is also true that the north fault is probably nowhere in this field a single fault, but that the total movement has been upon two or more nearly parallel fissures, with a slab, or several slabs, of rock, and a segment, or several segments, of vein between them. Moreover, the vein as a rule, though not always, is uniform in direction and size; hence the identification of the opposite ends of a fault crossing any particular portion is not generally to be expected.

Three occurrences of the Berlin vein, beyond the most northerly known branch of the north faulting fissures, are known.

At a point 800 ft. north and 900 ft. west of the top of the incline, but not shown in the drawings, is a segment of the vein, developed by a short tunnel and a shallow incline. This segment is cut off by an abnormal fault, striking north 48 deg. east, and dipping about 80 deg. southeasterly, developed by the innermost 100 ft. of the lower tunnel, which is driven upon it. The movement here has been in the opposite direction from other faulting movements shown, and the vein from which the segment at the surface has been cut off has not been found, but is still below the bottom of the lower tunnel.

There is also at the same place an ab- a northwesterly course, and a dip of about 45 deg. northeast. This may be the southern edge of a series of reverse faults, with a reverse displacement of the vein.

Some work on the No. 8 level, east of point *C*, done since the preparation of Fig. 1, also indicates one or more faults with reverse displacement; but these are as yet not well enough defined to be described here.

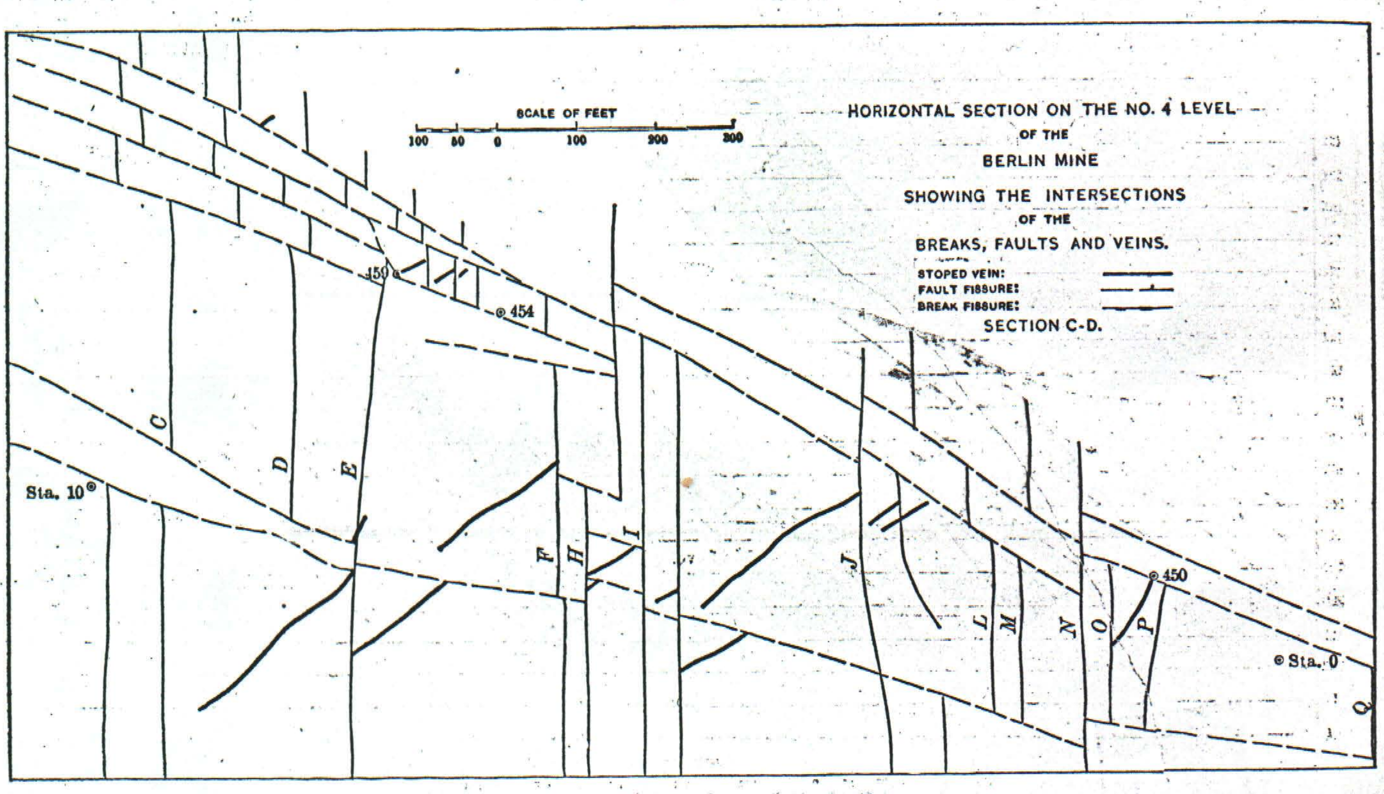


FIG. 3. HORIZONTAL SECTION OF NO. 4 LEVEL

Position of the Ore

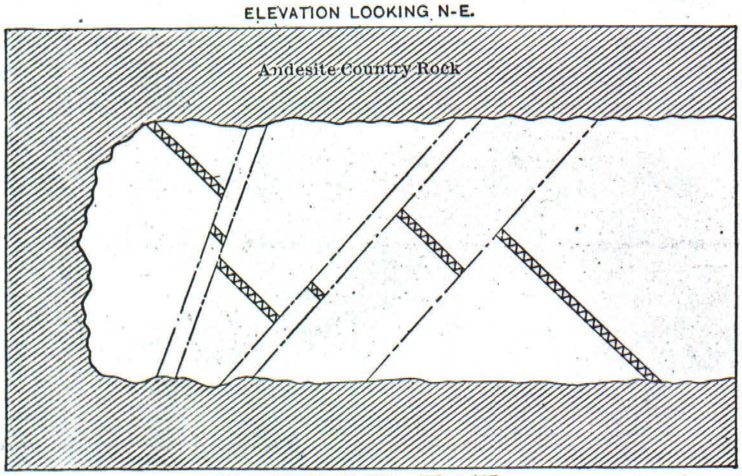
On No. 4 level, at a point marked (+ 40) in Fig. 1, is the south edge of a segment of ore which has been followed northeasterly, and upward for a few feet. The total movement of the north country, which has here been upon three, possibly upon four, presumably parallel fissures, indicated by this occurrence, is, as nearly as can be determined, about 400 ft. in the direction north 45 deg. west, at an angle of about 30 deg. from the horizontal. The total vertical component of the above movement is about 200 feet.

The vein at point (+ 40) was found by drifting along the most northerly branch of the north fault and breaking into its hanging-wall.

The third ore-occurrence, sought for by raise at *C*, and found since the intersection lines in Fig. 1A were outlined, is at Station *C*, in the raise from No. 8 level, at which point the intersection of the vein with a break was found 55 ft. above the level. Here also a normal segment starts off. Although it has been temporarily interrupted further north, by a reversed fault, it is without doubt a continuation of the vein from the northwest corner of the most easterly segment of the mine.

Opposite this point is doubtless a double fault with an intervening segment, as shown in Fig. 1A.

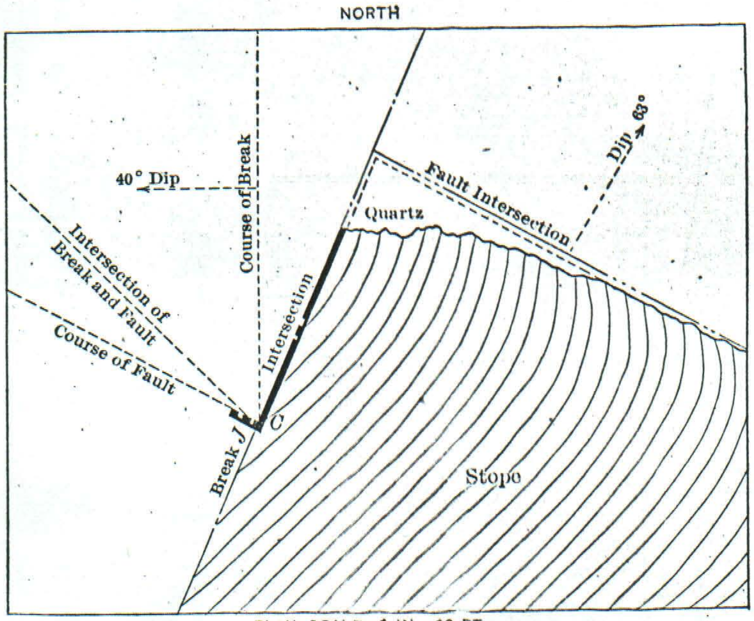
ELEVATION LOOKING N-E.



NO. 4 LEVEL AT STA. 475 + 137.
FAULTING FISSURES:
VERY SMALL QUARTZ VEINLET:
SCALE: 1 IN. = 5 FT.

FIG. 5

NORTH



PLAN: SCALE: 1 IN. = 10 FT.

FIG. 4

This ore-occurrence indicates a total movement of the northwest country north 45 deg. west, and at an angle of depression of 33 deg., of 420 ft., and a total vertical drop of about 220 feet.

The position of the ore at point *C* was therefore 20 ft. further in the line of the movement and had 20 ft. more vertical displacement than is indicated at the ore-occurrence at (+ 40) on the No. 4 level. It was, however, the probable extent of the movement, as indicated by the ore found at No. 4 level, that suggested the raise from No. 8 level by which the vein was recovered.

There are exposed in the stopes of the Berlin mine many instances of breaks and faults which fade or run out to nothing, one of which, not shown in the drawings, but clearly enough in evidence in the mine, is found in the southwest corner of the second stope from the east end of the field. In this case the break, normal in its planes, intersections and in all other respects, begins with a mere seam in the foot-wall of the stope, increases for 20 ft. or so to a point where the vein displacement is about 4 ft., then decreases for 20 ft. to a feather edge, leaving no noticeable fissure beyond its ends in the roof or floor of the stope.

One is here impressed with the fact that fissuring and faulting is the habit of the rock mass. In this connection is perhaps worthy of illustration an observation, shown by sketch in Fig. 5, of the freshly uncovered side of the No. 4 level then being driven. A quartz veinlet, about 1 in. in thickness, was in a few feet faulted normally three times, and by reverse faulting twice, between the roof and the floor of the level.

The bright, white quartz against the dark andesite told its story as though just from the press.

In Figs. 1 and 1A an attempt is made to show pictorially the underground works and stopes, and in the two together the relations of the works on the Berlin vein and the breaks and faults which have disturbed it. In this illustration all that is really known of the matter has been found in the underground works shown in Fig. 1. The structure remote from the underground works is entirely assumption, based, as far as possible, upon the known ground as it existed in the middle of 1906.

From a practical standpoint the extraordinarily disturbed condition of the rocks in the Berlin mine is very unfortunate. Without attempting to give details, it is evident that the prospecting and developmen of the vein in such a broken country must be unusually troublesome and expensive.

Capacity of the Washoe Smelitng Works

An illustrated pamphlet prepared by members of the Anaconda Copper Mining Company staff gives a series of totals showing the magnitude of the operations at that plant. The following are the requirements for a period of 24 hours: Ore treated, 10,000 tons; lime rock from quarries, 2300 tons; coke used, 650 tons; coal for reverberatories, 500 tons; coal for power, 500 tons; water, per minute, 35,000 gal.; men employed in and around Anaconda, 3000; monthly payroll, about $300,000.