[Presented before the Society, September 28, 1929.]

REVISION OF STRUCTURE AND STRATIGRAPHY IN THE MOSQUITO RANGE AND THE LEADVILLE DISTRICT, COLORADO[1]

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INTRODUCTION

One of the projects of the cooperative topographic and geologic work (1922-1931) by the State of Colorado, the Colorado Metal Mining Fund, and the U. S. Geological Survey is a comprehensive study of mineralized areas in the Mosquito Range, in which the famous Leadville district is situated. Geologic work was begun on both sides of the range in 1928 and is being continued through 1929 and 1930. The writer was assigned to the west side of the range and spent his time mainly in the upper part of Iowa Gulch, which adjoins the Leadville district on the southeast, as shown in Figure 1. A short time was spent in the study of new developments at the Ibex mine, in the Leadville district. Less than half of the area under investigation had been mapped by the end of the 1928 field season, but certain features of stratigraphy, structure, and ore occurrence that supplement or revise tentative statements regarding Iowa Gulch made in the U. S. Geological Survey's recent report on the Leadville district[3] are made public now for the benefit of those interested in the development of the region.

Much of the credit for this revision belongs to the cooperative spirit of Mr. E. P. Chapman, mining geologist, of Leadville. Complete acknowledgment of the courteous as-

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[1]Published with the permission of the Director of the United States Geological Survey and the Directors of the Colorado Metal Mining Fund.

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[3]Emmons, S. F., Irving, J. D., Loughlin, G. F., Geology and Ore Deposits of the Leadville Mining District, Colo. U. S. Geol. Surv. Prof. Paper, 148, 1927.

sistance given by mine operators and geologists would occupy several pages.

STRATIGRAPHY

The sedimentary rocks within the Iowa Gulch area, shown in columnar section in Figure 2, are the same as in the Leadville district, and their generalized distribution is shown in Plate II of Professional Paper 148. Owing to the thoroughly altered condition of these rocks and their obscurity due to faulting and concealment beneath glacial deposits throughout much of the Leadville district, advantage was taken of the better exposures and less complex structure in the Iowa Gulch area to measure thicknesses and to note beds that would be valuable horizon markers in both surface and underground mapping. The thicknesses and details of bedding shown in Figure 2 may therefore be regarded as more than local revisions of those stated in Professional Paper 148, and they should be kept in mind during future development in the Leadville district as well as in Iowa Gulch.

Perhaps the most significant feature both locally and regionally is the thin bed of sandstone or quartzite approximately 75 feet above the base of the Leadville or Blue limestone. It ranges from 2 to 12 feet in thickness and averages about 8 feet. The sandy bed was noted locally in the Leadville district (see Prof. Paper 148, p. 34), but nothing definite could be stated regarding its continuity. It is now known to be of widespread occurrence, as it is not only persistent in the Iowa Gulch district but is present on Zion Mountain, 4 miles north of Leadville, and at Gilman, 20 miles farther north. At these places it is 70 to 80 feet above the "Parting" quartzite. The typical sandstone is white, with sugary texture and medium to coarse grain, but nowhere resembles a conglomerate. Its grains are held in a calcareous and siliceous matrix. In some places it approaches quartzite in character, and in others it is little more than a limestone with numerous quartz grains. In parts of the Leadville district it seems to be represented by

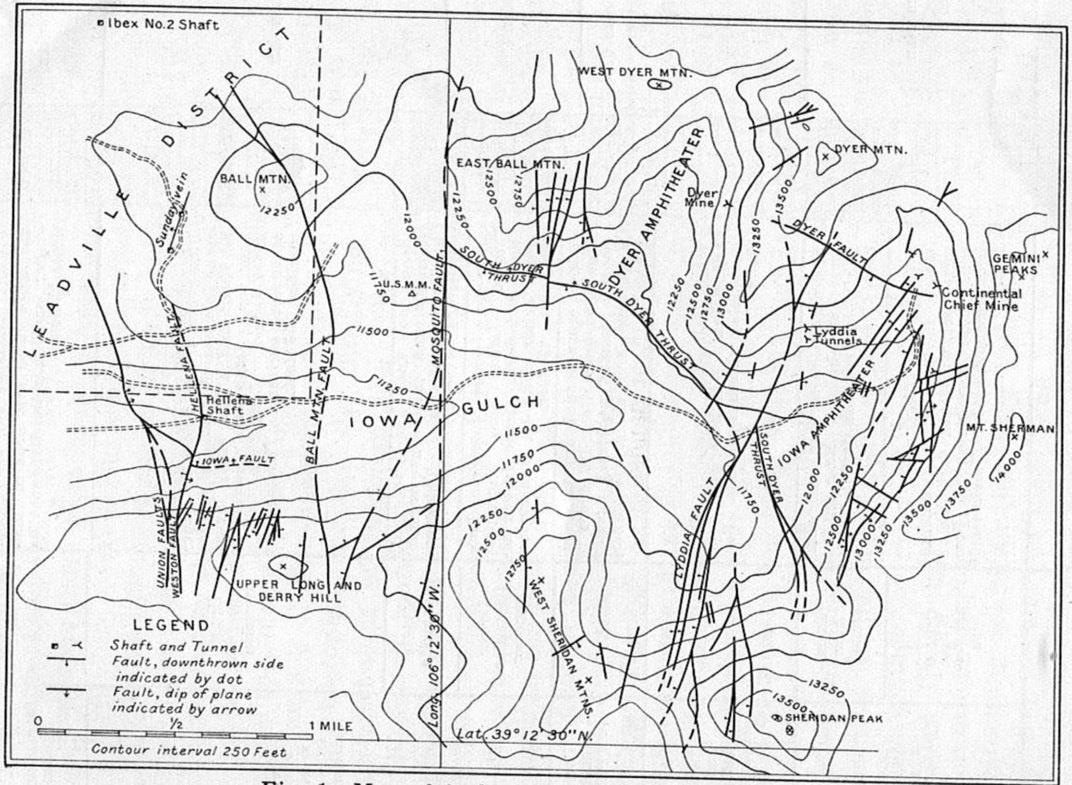
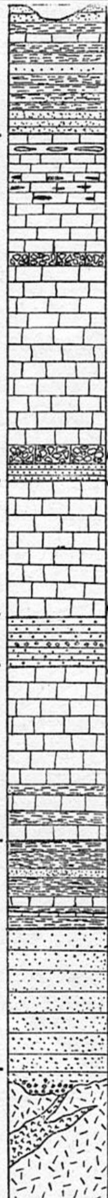


Fig. 1—Map of faults in Iowa Gulch district.



Age	DESCRIPTION	Member	Formation
Pennsylvanian	Arkosic sandstone and conglomerate above, with thin beds of limestone; sandstone and carbonaceous shales below.		Weber (?) formation (Not measured)
Mississippian	Blue-gray dense dolomitic limestone in massive layers, with thinner beds and a few shaly layers near top. Some beds bear black chert lenses. Limestone breccia at several horizons. Thickness of member 155 feet.	Upper limestone member	Leadville ("Blue") limestone (238 ft.) measured
Mississippian / Devonian (?)	Sandstone and quartzite, with siliceous and calcareous cement; locally conglomeratic. Thickness of member 8 feet.	Middle quartzite	
Devonian (?)	Blue-gray dense dolomitic limestone. Lower beds alternately light and dark. Some layers assume ocher color on weathering. Thickness 75 feet.	Lower limestone member	
Ordovician (?)	White cross-bedded quartz sandstone and quartzite with layers of poorly rounded pebbles. Locally calcareous and shaly. Weathers pinkish.		"Parting" quartzite (27 ft.) Approximate
Ordovician	White dolomitic limestone. finely crystalline. Weathers light gray, developing siliceous ribbing. Base shaly.		"White" limestone (95 ft.) Approximate
Cambrian	Alternately calcareous and shaly layers, thin-bedded. Near top "red cast" beds are numerous. Thickness 45 feet.	"Transition shale"	Sawatch quartzite (135 ft.) Approximate
Cambrian	White, fairly pure, well-cemented quartzite, with one dark bed at top. Base conglomeratic. Some beds near top shaly. Thickness 90 feet.	White quartzite	
Pre-Cambrian	Porphyritic or equigranular, gray or pink granite, commonly gneissoid. Small inclusions of schist. Numerous pegmatite dikes.	Granite, gneiss, and schist	

Fig. 2—Stratigraphic column of Iowa Gulch district.

shaly instead of sandy layers, a fact which may account for its previous inadequate recognition. Immediately above this sandstone there is generally a conspicuous limestone breccia from 2 to 5 feet thick, composed of variously colored fragments of limestone set in a sandy calcareous matrix.

The widespread occurrence of this horizon has also been confirmed by the detailed observations of Mr. E. P. Chapman, of Leadville. It strengthens the suggestion, which was made in Professional Paper 148 (p. 34), and which is repeated in Figure 2 of this paper, that it may mark the base of the Mississippian, and that the underlying 75 feet of the Blue limestone is of Devonian age. This suggestion is further supported tentatively by the paleontologic studies[4] of Dr. Edwin Kirk of the U. S. Geological Survey. The usefulness of the sandstone as a key bed in a formation that is poor in distinctive markers is obvious to those doing development work in the Blue limestone.

Another key bed that is of importance to the miner is a gray, limy shale about 15 feet below the top of the Blue limestone. This bed, as shown in Figure 4, marks the top of the main ore zone in the Continental Chief mine and may have a similar significance throughout the district. It is not known to be continuous over larger areas, however, and where it is thin or missing the black shale at the very top of the Blue limestone should have proved effective as a roof to any ore shoots. The black shale is overlain by a continuous thick sheet of White porphyry, whose base corresponds to the "first contact" or main ore horizon in the Leadville district. In the Continental Chief mine the gray shale, or local "second contact," was so effective a barrier to the ascent of ore-forming solutions that very little ore was deposited at the "first contact" of black shale or White porphyry above.

One conspicuous result of alteration in the Blue limestone is "zebra rock," which originates through a recrys-

[4]Recent work by Dr. Edwin Kirk also strongly suggests the presence of a marked unconformity between the "Parting" quartzite and the underlying White limestone and raises the possibility, already privately expressed by J. E. Spurr, Consulting Geologist and until recently editor of the Eng. & Min. Jour., of New York City, that the "Parting" quartzite is of Devonian age. [Chas. H. B., Jr.]

tallization of the original even-grained rock into parallel or concentric layers of white, sparry dolomite. It forms masses as much as 2 feet in diameter and is found in the general vicinity of mineralized rock. In this respect it is more of a favorable sign than otherwise, but it is too widespread to serve as a definite guide to ore.

Igneous Rocks

The igneous rocks in Iowa Gulch, as in the Leadville district, include a basement pre-Cambrian granite and related rocks, intrusive sheets and rarely dikes of an early White porphyry, later Gray porphyry, dikes of still later rhyolite, and irregular intrusive masses of rhyolitic agglomerate. Subdivisions of each kind of porphyry can probably be more clearly distinguished in Iowa Gulch than in the Leadville district, and the distinction may have some economic bearing, but this problem requires more extensive study. The White porphyry especially and the Gray porphyry to a noteworthy degree also show extensive local alteration marked by the development of small lenticular spots or "eyes" of bluish quartz and of sericite. Similar alteration of White porphyry on Printer Boy Hill, described in Professional Paper 148, page 45, has been regarded as the last stage in crystallization of the White porphyry and as distinctly earlier than the alteration that accompanied ore deposition. The question whether this form of alteration has any direct relation to ore deposition will receive further critical attention.

Rhyolitic agglomerate, like that forming pipes in upper Evans Gulch in the Leadville district, is exposed in the Hellena and neighboring mines in Iowa Gulch but does not crop out. Here, as in Evans Gulch, it was intruded subsequent to ore deposition and probably interrupts or cuts off ore bodies.

Dikes of dense white rock tentatively correlated with the late rhyolite but resembling White porphyry on the weathered surface were found on East Ball Mountain, filling faults that offset sills of typical White porphyry. General structural evidence implies that this and similar dikes, like the agglomerate, probably cut across ore bodies.

STRUCTURAL FEATURES

All the faults that have been closely studied in the Iowa Gulch district are shown in Figure 1. More work must be done before a systematic discussion of these faults and their interrelations is justified, and it will suffice here to present certain descriptive data and especially revisions of mapping shown in the atlas accompanying Emmon's Leadville monograph[5] and quoted on Plate II in Professional Paper 148. The faults will be described in order from west to east, regardless of their character or relative age.

Weston-Union-Iowa fault complex. As stated in Professional Paper 148 (pp. 77-78), there was a suspicion that the Weston fault as originally mapped was a composite fault representing movements of different kinds that were distinct in age, and the writer was therefore directed to give close study to this and adjoining faults in Iowa Gulch. This study was aided by new developments in the Hellena mine but hindered by the inaccessibility of the Ella Beeler, Clear Grit, and other mines.

Comparison of these faults as shown in Figure 1 with the earlier maps shows considerable revision. The Weston fault is the principal reverse fault of the group, but instead of extending north-northwestward from Upper Long and Derry Hill it trends northward, passes through the Big Chicago, Little Alice, Middle Ella Beeler, and Lower Little Fred tunnels, and is continuous with the reverse fault dipping 70° E. along which the Hellena vein has been mined. (See Figure 3). The displacement on the north slope of Long and Derry Hill is at least 200 feet and probably much more. This fault, called the Hellena fault, is also thought to have been exposed in small openings on the American New Orleans and American Continental claims. If projected northward it would approach the Sunday vein on the west slope of Ball

[5]Emmons, S. F., Geology and Mining Industry of Leadville, Colo., U. S. Geol. Surv. Monograph No. 12, 1886.

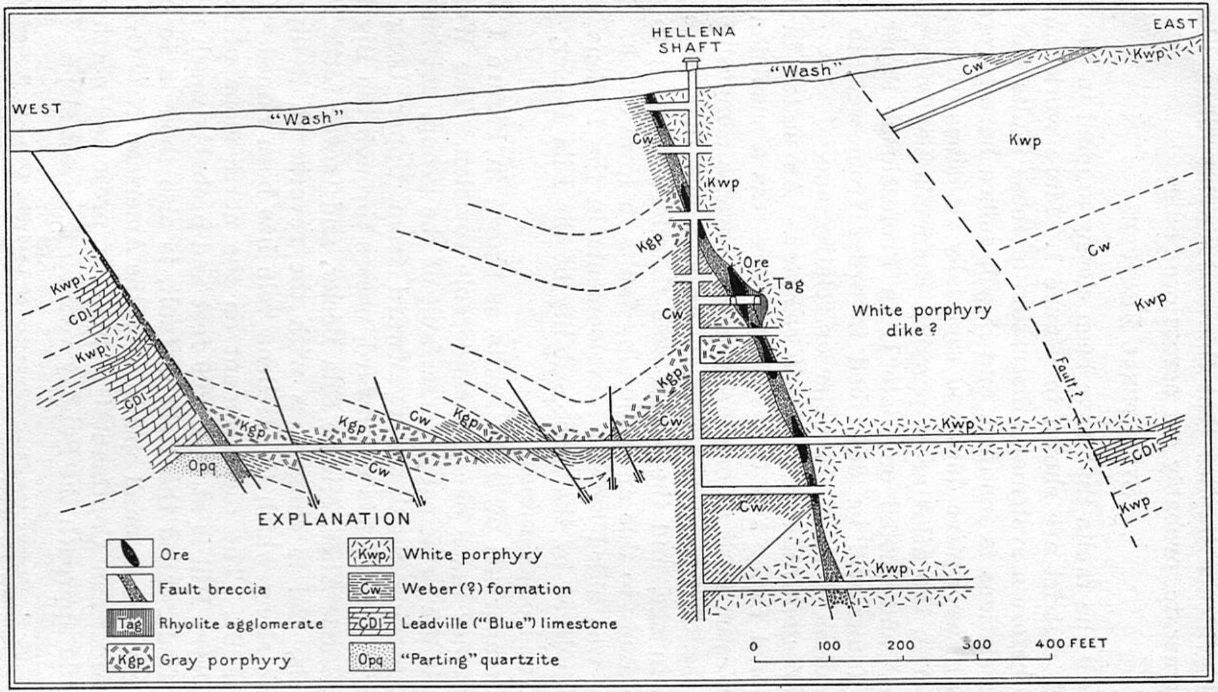


Fig. 3—East-West section through Hellena shaft, in part after C. W. Jordan.

Mountain. The Sunday vein, however, strikes N. 18° E. and dips 88° W., and its exact relations to the Hellena vein are not known. As both veins have been productive the intervening ground is likely to contain shoots of similar ore.

The Union fault on Long and Derry Hill has a northward trend and a downthrow on the west, but it curves to a north-northwesterly trend across Iowa Gulch and joins the fault with downthrow on the east that Emmons called the Weston fault. Whether the Union fault is normal or reverse has not been determined.

The Iowa fault, east of the Weston-Hellena fault zone, has an eastward trend with a great downthrow to the north, as previously mapped. The great downthrow continues a short distance northward along the Weston-Hellena zone and then follows a fault of northwest trend to the Union fault, where it turns northward. In spite of the direction of throw along the fault of northwest trend, the drag as shown on the 5th level of the Hellena mine is characteristic of a reverse fault, and the evidence is similar to that along the Mike fault, in the Leadville district (see Prof. Paper 148, p. 80), implying that an original reverse movement was followed by a greater normal movement, so that the net downthrow is on the northeast wall. According to this interpretation the fault of northwest trend was originally a west branch of the Weston reverse fault, and the Hellena fault an east branch. If so, the northwestward-trending fault was formed before the Iowa fault, although subsequent movement along it was contemporaneous with the forming of the Iowa fault. An alternative interpretation would be that the fault of northwest trend was originally a part of the Iowa fault and became offset when the Weston-Hellena fault was formed; but this implication that a great normal displacement preceded reverse faulting is contrary to evidence in the region as a whole.

Mosquito fault. The Mosquito fault was mapped by Emmons in this area as a single fault, but it evidently splits into two branches that diverge southward, as shown in

Figure 1. The west branch, which was mapped by Emmons, crosses the saddle east of Upper Long and Derry Hill, where its east wall is pre-Cambrian granite and its west wall Cambrian quartzite. The east branch also has an east wall of granite and west wall of quartzite. In Iowa Gulch, both appear to be normal faults with westward dip; as they here cut only the granite and quartzite they are of no economic interest.

South Dyer reverse fault. The South Dyer and Dyer faults are exceptional in having northwesterly trends. The South Dyer fault has been traced southeastward from the Mosquito fault on the west slope of East Ball Mountain nearly to the saddle south of Mount Sherman, on the crest of the range. It strikes N. 40°—45° W. and dips 55°—60° NE. Its northwesterly continuation is deeply buried in the down-faulted block west of the Mosquito fault, but rough calculation suggests that it may be equivalent to the Colorado Prince reverse fault or an underlying parallel reverse fault in the Ibex mine, a mile northwest of Ball Mountain. (See Figure 8). It is also offset by other normal faults of northeast trend, as shown in Figure 1. The beds on its northeast side have been raised 300 to 700 feet on East Ball and Dyer Mountains, but to the southeast it splits into at least three steeply dipping branches, along which displacements diminish until at the crest of the range none are recognizable. The South Dyer fault, like other reverse faults in the region, is of premineral age, but as it is probably sealed by impervious premineral gouge and is mainly flanked by granite and quartzite it is not likely to contain ore shoots of promising size. Premineral fault fissures that cross it, however, and that can be traced up the slopes into limestone, are more worthy of consideration.

Lyddia fault. The northern part of the Lyddia fault, not shown by Emmons, can be traced down the south slope of Dyer Mountain and across the South Dyer fault, which it offsets. The southern part, mapped as the Sheridan fault by

Emmons[6], extends up the north slope between Sheridan and West Sheridan Peaks, where it splits into three or more parallel branches. Its northern part also splits, but the branches can not be readily traced where both walls are White porphyry or "Weber (?) grits." The fault strikes N. 15° E. and dips about vertically. The downthrow on its west wall is approximately 400 feet along much of its course, but increases to 700 feet where it offsets the South Dyer fault. The fault itself is not mineralized. The Lyddia ore body was formed by the replacement of Blue limestone west of the fault, and there are other workings, also in Blue limestone, higher up near the east wall. These relative positions suggest that the two ore bodies might have been parts of one ore shoot offset by a postmineral fault, but faults that are parallel and apparently subsidiary to the Lyddia fault on the west side of Sheridan Peak contain barite as a breccia cement, a fact which indicates their premineral origin and suggests a similar age for the Lyddia fault.

Sherman thrusts. There are three minor thrust faults on the west slope of Sherman Mountain. In general their strikes are northerly, but the strike varies greatly, even in a single fault. Their dips are commonly eastward, in places at angles so low as to be nearly parallel with the beds. The movement has had the effect of raising the east side, the stratigraphic throw nowhere exceeding 50 feet and generally being much less. Similar thrusts are also observed in mine workings in the same locality. There are probably many more than can be mapped from the surface, because the fault planes are in many places very nearly parallel with the bedding; hence, except where distinguishable strata are offset, they are likely to be overlooked.

These thrusts are helpful in ore hunting, for, although they are themselves probably tight and filled with impervious premineral gouge except locally, the associated fissures and minor faults of northeasterly trend in the disturbed ground along them have served as local conduits through which ore-

[6]Leadville Atlas, published 1883, to accompany Monograph 12, published 1886.

forming solutions reached the Blue limestone. An illustration is furnished by the numerous ore-bearing fissures of the Continental Chief mine.

Minor premineral faults and fissures. Normal premineral faults of slight displacement are irregularly distributed over the area, and small ore bodies have been mined in some of them. Most of them strike north and dip steeply to the east or west. They are most numerous east of the Weston fault on Long and Derry Hill and are also conspicuous in the Cambrian quartzite on East Ball Mountain. Several fissures of northwesterly trend in pre-Cambrian granite in Iowa Gulch, a little above the mouth of Dyer Amphitheater, were once worked for gold. Another group striking N. 15°—35° E.

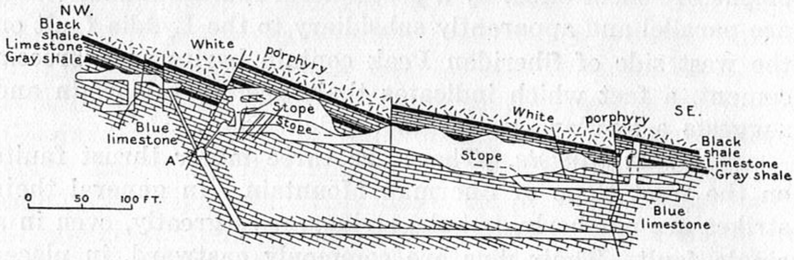


Fig. 4—Section through stopes in the Continental Chief Mine.

is present in the bottom of Iowa Amphitheater at an altitude of about 12,500 feet.

Ore Deposits

Regionally there are two principal groups of ore deposits —a western and an eastern group. Both are found in or near reverse or overthrust faults and the associated minor faults and fissures. In each group three kinds of ore have been produced—oxidized silver-lead ore, oxidized gold ore, and zinc-lead-iron sulphide ore with small to considerable contents of silver and gold. The oxidized gold ore has come mainly from the superficial parts of veins in quartzite or granite, most of which were small and not worth working below the oxidized zone. The oxidized lead-silver ore has come mainly from replacement bodies in Blue limestone and to a minor extent from the oxidized parts of the larger veins. The mixed sulphide ore, accompanied by a quartz gangue, with or without barite, has come from unoxidized replacement bodies and veins, the upper parts of which have been enriched to some extent in gold and silver and locally in chalcocite.

Western or Hellena group. The western or Hellan group of ore deposits is in the Weston-Union-Iowa fault complex

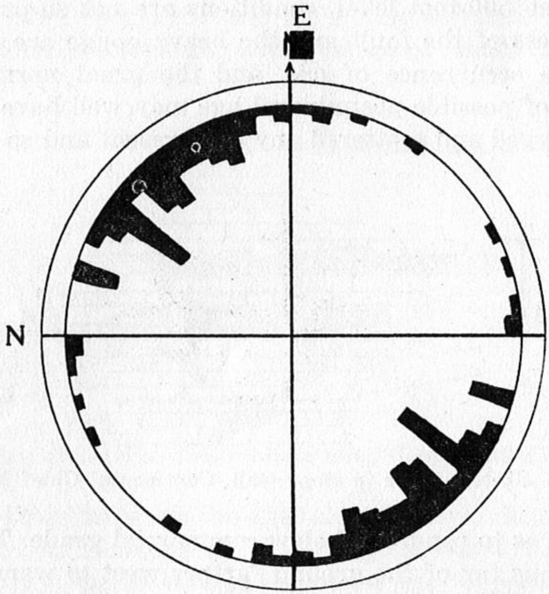


Fig. 5—Azimuth circle showing strikes of 77 pre-mineral fissures in the Continental Chief Mine. Radial lengths of black areas proportional to number of fissures with corresponding strikes. Note northeast dominance.

and includes the Hellena, Clear Grit, Ella Beeler, and Fortuna veins. Of these only the Hellena vein could be examined in 1928. This, as already noted, occupies a reverse fault which on the lowest or 500-foot level has a hanging wall (probably a dike) of altered porphyry and a footwall of "Weber (?) grits." See Figure 3. The strength of the vein at this level and the fact that the Blue limestone is an in-definite distance below suggests the advisability of drilling to determine the position of the limestone where the vein is likely to widen or to be closely associated with replacement or "blanket" deposits. Owing to the position of the mine in the gulch bottom and to the greatly faulted ground, the cost of pumping is high, and the mine was shut down at the end of 1928.

To the west, where the northwestward-trending fault is cut on the 500-foot level, conditions are not so promising. The tightness of the fault and the heavy gouge are unfavorable to the occurrence of ore, and the great normal fault movement of possible postmineral age may well have so thoroughly dragged and scattered any ore present and so mixed it

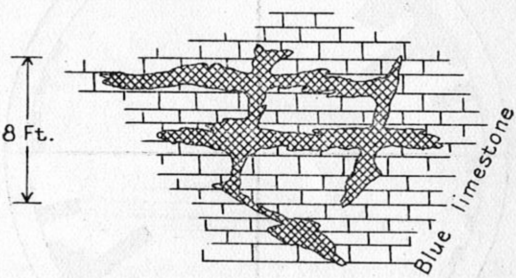


Fig. 6—Sketch of ore in stope wall, Continental Chief Mine.

with gouge as to render it below commercial grade. Too little is known thus far of the ground farther west to warrant any suggestions regarding its possible content of ore.

The other mines in the group mentioned above contain veins in reverse or closely associated normal faults. The country rocks in the workings are granite and quartzite, Blue limestone and porphyries, so far as known, and present information does not warrant a definite statement regarding the position of limestones and possible ore bodies in them on the west or downthrown sides of the faults. This problem will be considered as the work progresses.

Eastern group. The eastern area of ore deposition contains some valuable deposits in limestone but no fissure veins worthy of further description. The replacement deposits include those of the old Dyer mine, the Lyddia and old Mammoth mines, and the Continental Chief mine, shown in Figure 1.

It is a significant fact that the principal ore bodies of this group are in ground influenced by reverse faults. The thrust faults themselves are too impervious to contain large or continuous ore shoots, but associated fissures in either wall are more open and form an intricate system of conduits along which ore-forming solutions could reach replaceable limestone.

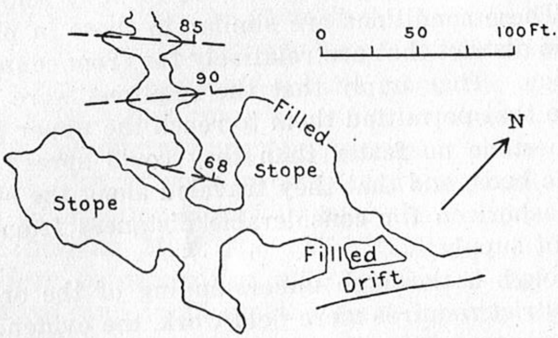


Fig. 7—Plan of stope on intermediate level, Continental Chief Mine.

The Dyer mine, on the east slope of Dyer Amphitheater, was stated by Emmons (U. S. Geological Survey, Monograph 12, p. 213) to be in White limestone, but its portal and several small prospects nearby are in Blue limestone 60 feet above its base, and the ore was evidently in the upper part of the Blue limestone. None of the workings were accessible, however, and nothing definite can be said regarding the structural control of the ore bodies, but pieces of ore on the dumps are similar to ore of the other mines and consist of lead sulphide and zinc carbonate with barite and quartz. The Lyddia ore body is a replacement or "blanket" in Blue limestone, just beneath the capping White porphyry sill and cut off to the east by the Lyddia fault. The occurrence of ore in the Continental Chief is illustrated in Figures 4-7. The upper part of the Blue limestone on the east side of Iowa Amphitheater, south of the Continental Chief mine. Several prospects, especially along the small Sherman thrusts, show ore in place in the uppermost beds of the Blue limestone. The structural situation favors the finding of ore resembling in general that of the Continental Chief mine, both in composition and in the form of the shoots. Furthermore, the limestone here exhibits the "zebra rock" structure, as well as some recrystallization of the uppermost beds; and, though these features are by no means absolute proof of ore deposition, they may be regarded as favorable indications rather than otherwise. In view of the northeasterly dip of the beds, and the northeasterly trend of the faults in this area, work should be started a little below the contact; and horizontal adits should then be driven southeastward, so as to crosscut possible ore-bearing fissures.

Another area of some promise, though probably of less than the one just mentioned, is near the crest on the west slope of Sheridan Mountain, along faults of the Lyddia group. Here oxidation and silicification of the limestone are extensive, and in places the fault breccias are heavily cemented with barite. Ore bodies parallel to the faults may well be expected in this locality.

In the neighborhood of the Dyer mine, now long abandoned, on the east wall of the Dyer Amphitheater, the Blue limestone is capped by a thick sill of White porphyry. This structural condition should be a favorable area for ore, but premineral fissures have not yet been located here.

New Developments in the Ibex Mine, Leadville District

Developments on the northern lower levels of the Ibex mine disclosed some unexpected structural conditions which could not be readily explained, and the writer was asked to study them and correlate them with the structure already worked out and shown in Professional Paper 148. The structure, as outlined in that report and based on data obtained on and above the 7th level, exhibited a syncline of

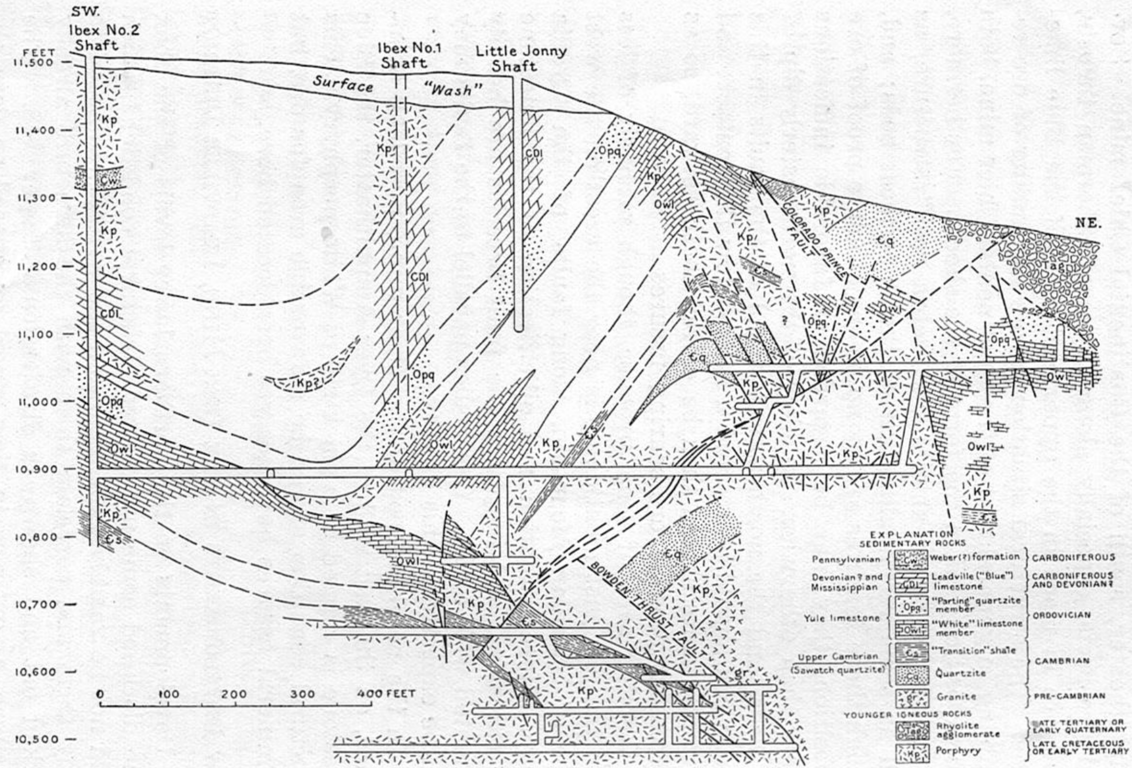


Fig. 8—Section North 25° East, through Ibex No. 2 shaft.

northwesterly trend with a southwest limb dipping about 25° NE. and a northeast limb dipping 50°-60° SW. and cut off by the Colorado Prince reverse fault, which trends parallel to the syncline and dips northeastward. The new work disclosed another reverse fault well below the Colorado Prince fault, and subsequent normal faults, as shown in Figure 8.

As the intersection of veins with shattered White limestone and "transition shale" close to the footwall of the Colorado Prince fault had been mentioned as worthy of prospecting, drifts were driven northward, but the northeast limb of the syncline could not be found below the 7th level. Limestone and shale beds on and below the 10th level maintained the low northeasterly dip for a long distance under the southwestward dipping beds. The 12th level, driven along a narrow vein with the intention of reaching the Colorado Prince fault, finally cut a reverse fault which brought granite into contact with the thick porphyry sill that splits and underlies the "transition shale." This fault, however, as shown in Figure 8, can not be connected with the Colorado Prince fault and is named the Bowden fault, after its discoverer. It is probably continuous with the reverse fault exposed in the Yak tunnel a little NE. of the Little Jonny shaft. (See Professional Paper 148, plate 15, Yak section.) Minor parallel faults were traced up to the 10th level, and the main fault was found again on the 4th level of the Kyle winze, where its position indicated that it was offset somewhat by normal faults exposed on the 10th level. It reaches the 7th level just southwest of the axis of the syncline and continues parallel to the bedding along the southwest limb. As bedding slips are numerous throughout the district, the amount of movement at this place had never before been realized.

New work above the north end of the 7th level exposed the east limb of a much faulted minor anticline, for which there had been no previous evidence, and showed that the White limestone and Parting quartzite extend farther northeast than was expected, until they are cut off by rhyolitic agglomerate of postmineral age. The Colorado Prince fault has not been exposed, but it is doubtless offset to some extent by the local normal faults, as suggested in Figure 8. If the displacement is less than shown, the Colorado Prince fault must dip much less steeply than at any other known place along its course.

The steeply dipping normal fault at the raise from the north end of the 7th level has a northward trend. It has a considerable displacement, which can not be closely measured from the available evidence and may be obscured by a local cross-cutting of strata by porphyry. This fault is evidently cut by a later normal fault of moderate westerly or southwesterly dip, which is exposed at several places. The two faults mentioned account for the unexpected distribution of White limestone and "transition shale" in the northeastern part of the mine.

The development of the local structure is summarized as follows: The syncline and minor anticline were formed by pressure in a northeast-southwest direction; continued pressure broke these folds and formed the Colorado Prince fault, along which Cambrian quartzite was thrust over the upturned limestone; simultaneous or later pressure broke the rocks at a lower place, forming the Bowden fault, along which the overlying ground was thrust as a unit for an undetermined distance; after compression ceased fissures and minor faults of north-northeasterly trend were formed, and at the same time or later the first stage of normal faulting noted above took place, with downthrow on the east side; later the second stage of normal faulting took place, offsetting both the reverse faults and the normal faults of the first stage. The explosive eruption of agglomerate that occurred near the Colorado Prince fault may have preceded the last stage of faulting, but too little of it is exposed for its structural relations to be fully determined.

Ore deposition, which preceded the agglomerate eruption and at least the last stage of faulting, took advantage of the earlier structures, rising along the fissures and minor faults of north-northeasterly trend. In the workings under consideration it replaced limestone beds in the "transition shale" beneath porphyry sheets, down to their northern extremity under the Bowden fault. The continuation of these shales above the Bowden fault appears at and above the 7th level northeast of the Kyle winze. The only remaining place where they would also be expected is in the down-faulted block beyond the northeast end of the 7th level; but any ore in this block is probably cut off within a short distance by the agglomerate, as in the Ollie Reed ore body, not far away. Prospecting of White limestones in these new workings has been done only above the 7th level in the same down-faulted block, but the small veins found failed to spread into replacement bodies.