CONTENTS

ILLUSTRATIONS

[Read before the Society October 24, 1931]

THE WESTON PASS MINING DISTRICT, LAKE AND PARK COUNTIES, COLORADO[1]

CHAS. H. BEHRE, JR.[2]

INTRODUCTION

Recent work by the writer on the western slope of the Mosquito Range included a study of ore deposits at Weston Pass, about which almost nothing has been published. Here some ore of good grade has been mined, a small additional amount has been developed, and a definite ore zone is exposed. It therefore seems that further mining, if carried out on a moderately large scale, may be warranted whenever economic conditions are favorable.

The ore deposits here described are chiefly replacement bodies at a definite horizon in the "Blue" or Leadville limestone, a short distance west of the Weston fault. The ore consists of galena, which contains some silver; and oxidized zinc minerals.

LOCATION OF THE DISTRICT

The area described lies on both sides of the line between Park County and Lake County, at the crest of the Mosquito Range, about 10 miles south-southeast of Leadville. It is approximately 19 miles by wagon road from Leadville on the Denver & Rio Grande Western Railroad, and about 22 miles from Fairplay on the Colorado & Southern Railroad. The intersection of latitude 39° 08′ N. and longitude 106° 10′ W. lies in the northeastern part of the area. The area in which most of the mining has been done extends about 1¼ miles in a southeast direction by half a mile in a northeast direction.

FIELD WORK AND ACKNOWLEDGMENTS

Incidentally to work at Leadville, in 1928-1931, the

[1]Published with the permission of the Director of the United States Geological Survey and that of the Colorado Mining Association.
[2]Assistant Geologist, U. S. Geological Survey.

writer made short visits to the area, assisted at different times by E. N. Goddard and A. E. Sandberg.

Special thanks are due to the officials of the E. J. Longyear Co. for making available maps and other data prepared by R. D. Longyear and G. M. Schwartz; to Mr. E. P. Chapman for help in the field and many valuable suggestions; to Messrs. J. Marvin Kleff and Fred J. McNair, mining engineers of Leadville, for the use of mine and claim maps; and to Messrs. J. B. McDonald and Alfred Tonkin, of Leadville, for information regarding operations and production.

With the altitude of the portal of the Ruby mine given on an old map as 11,800 feet as reference datum[3], a topographic map was prepared for a base.

Topography and Physiography

Weston Pass, at an altitude of 11,930 feet, is a gap in the main crest of the Mosquito Range, between Weston and South Peaks. Weston Peak, a rugged triangular mass to the north, rises to an altitude of about 13,600 feet. South Peak is about 12,900 feet high and has steep walls to the southeast but gentle slopes elsewhere.

The mining district occupies the saddle between these two peaks. In view of the generally rugged topography of the Mosquito Range, the high altitude of the pass, and the steep-walled and steeply graded canyons through which the approach is made, the topography of this saddle appears surprisingly smooth and featureless. The west slope of the divide over all the district is an almost table-like meadow—the gathering ground of Weston Creek, which drains westward into the Arkansas. On the east slope also the sources of the South Fork of the South Platte River are not deeply intrenched. A steep escarpment sloping southeastward separates these eastern sources from the pass, but it also flattens within about 600 feet to a uniformly sloping surface which has a gradient of approximately 800 feet to the mile.

[3]This datum was afterwards found to be 6 feet low when referred to the figure given by Emmons for the crest of the pass (Emmons, S. F., The geology and mining industry of Leadville, Colorado: U. S. Geol. Survey Mon. 12, p. 173, 1886).

In the neighborhood of the mines the western slope shows none of the effects of glaciation. Rock, somewhat weathered and evidently in large part talus, covers the slope and decomposes to form a rich and moisture-laden soil yielding excellent pasture land. On the eastern slope, however, there are two prominent cirques—one against the south slope of Weston Peak, the other against the east slope of South Peak. The former lies largely within the area mapped. The eastern lateral moraine extending from this cirque mantles a rock bench and, coupled with talus blocks subsequently accumulated from the steep bluffs of Weston Peak, covers much of the eastern part of the district. The western lateral moraine leading from this cirque joins the eastern lateral moraine of the South Peak cirque, forming a medial moraine, which is shown in the southwestern part of Plate I.

The material making up these moraines consists chiefly of granite and quartzite boulders, as both moraines are flanked by cliffs of these two rocks. The morainal matter nowhere exceeds 75 feet in thickness and does not seriously mask the possible ore horizons.

Postglacial stream work is virtually negligible here, as there has been no deep stream cutting, and fluvial deposits are very shallow.

Geology of the Bedrock

Stratigraphic Section.—The sedimentary sequence is essentially that given by Emmons, Irving, and Loughlin[4], with the modifications more recently recognized by others[5]. To the earlier descriptions little need be added. Detailed stratigraphic work, however, which has been carried on during the last four years, makes it desirable to put into print new formation names and to apply to the rocks of this part of the Mosquito Range the terms given to their equivalents in other parts of Colorado.

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[4]Emmons, S. F., Irving, J. D., and Loughlin, G. F., Geology and ore deposits of the Leadville mining district, Colorado: U. S. Geol. Survey Prof. Paper 148, pp. 22 et seq., 1927.

[5]Behre, C. H., Jr., Revision of structure and stratigraphy in the Mosquito Range and the Leadville district, Colorado: Colorado Sci. Soc. Proc., vol. 12, pp. 38-42, 1929. Singewald, Q. D., and Butler, B. S., Preliminary geologic map of the Alma district, Colorado: Idem, pp. 295-304, 1930.

At the base of the section, followed by an unconformity, are pre-Cambrian granite and schist, with associated pegmatites and aplites.

The lower part of the succeeding Cambrian formation (Sawatch quartzite) consists of quartzite which shows the characteristic white, glassy quartzitic facies at the base and grades upward into brownish quartzitic sandstone. Its thickness is 110 feet. A small collection of brachiopods from the sandy beds near the top of this member in the Leadville district, near enough to justify correlation, indicates Upper Cambrian age, similar to that of the Eau Claire formation of the upper Mississippi Valley and its equivalents[6].

The upper member of this formation ("transition shale" of earlier reports) consists of sandy and shaly dolomitic beds and calcareous, shaly beds, with prominent fucoid markings. At Weston Pass the thickness is 50 feet. This and the underlying quartzite are already well recognized as separable lithologic units. The writer therefore proposes their separation as individual members and suggests that the lower 90 to 135 feet of quartzitic rock, including at the top the dark-red ("purple") quartzite bed recognized by Singewald and Butler[7], which is a constant feature in the Alma and Leadville districts, be regarded as the lower member. As the term "transition shale" is descriptive, it is recommended that the upper 30 to 50 feet of the Cambrian, ending above at the top of the well-known "red cast beds," be designated the *Peerless shale member* of the Sawatch quartzite, from the typical occurrence of these beds on the northwest slope of Peerless Mountain, 6 miles east-southeast of Leadville. It is to be noted that the upper limit of the Peerless member is lithologically gradational.

The Ordovician "White" limestone, having now been definitely correlated with the Manitou limestone by Dr. Edwin Kirk, of the Geological Survey[8], is called Manitou in this

[6]Resser, C. E., written communication, 1928.
[7]Op. cit., p. 297.
[8]Kirk, Edwin, The Devonian of Colorado: Am. Jour. Sci., 5th ser., vol. 22, p. 222, 1931.

PLATE I

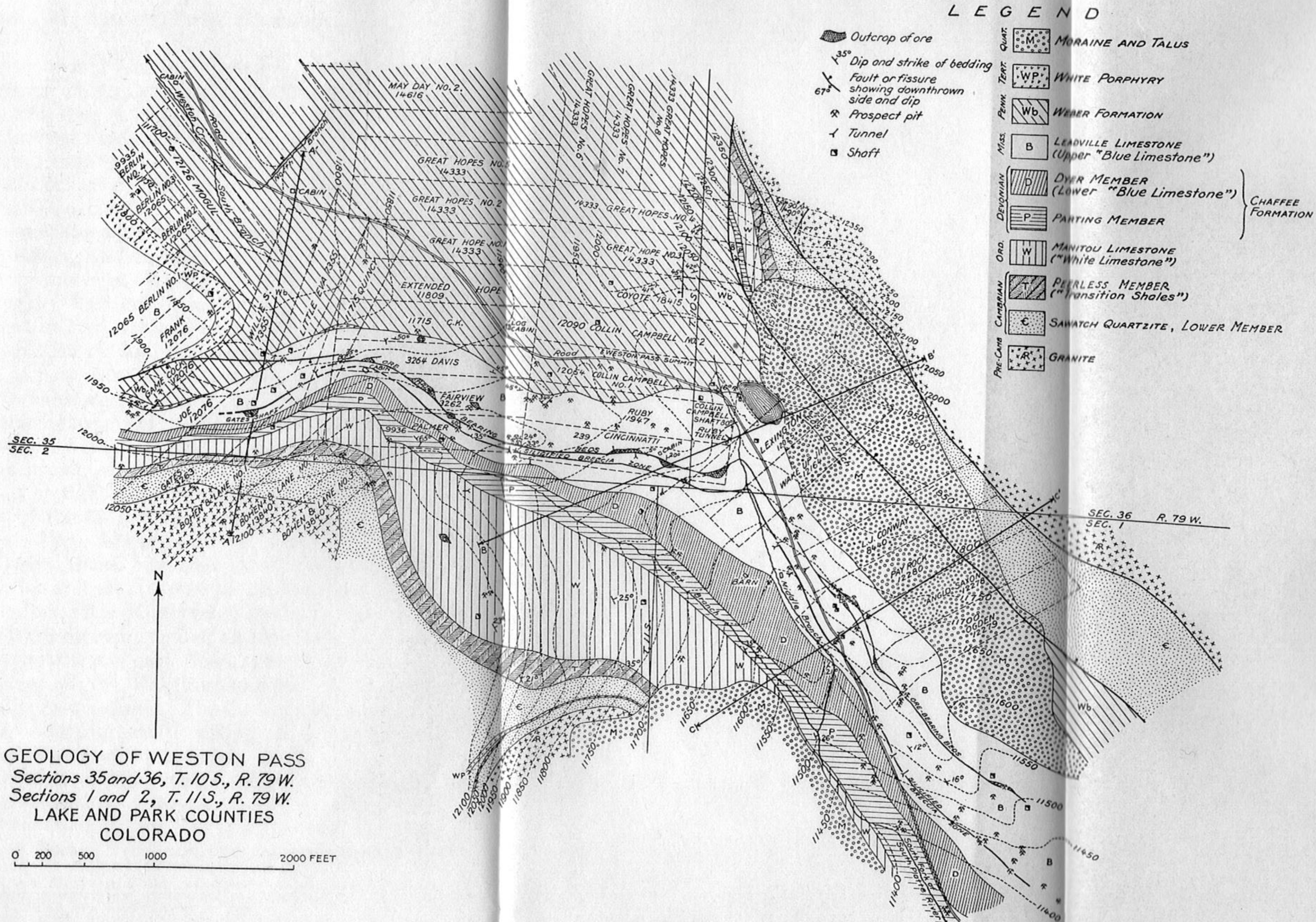
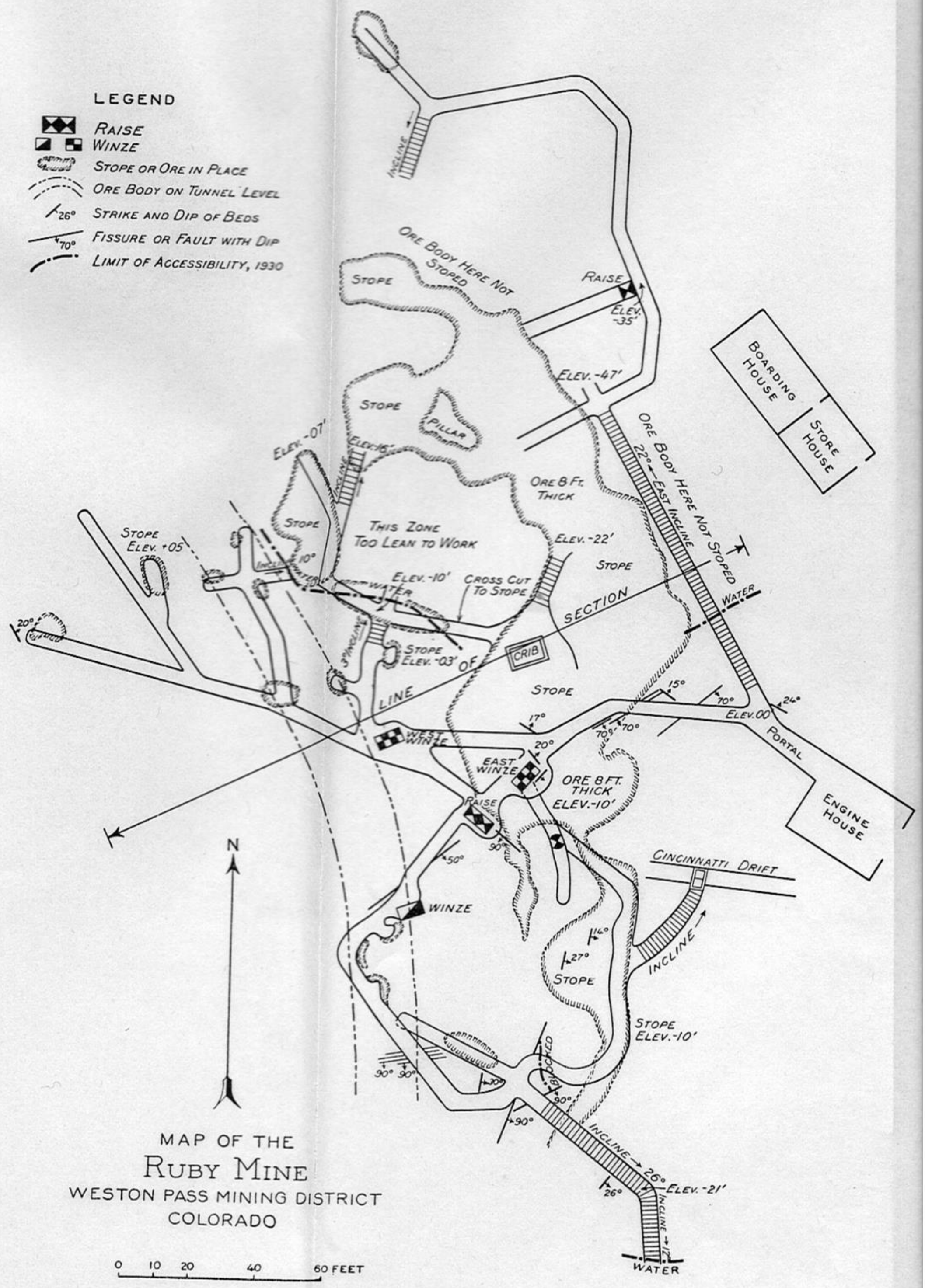
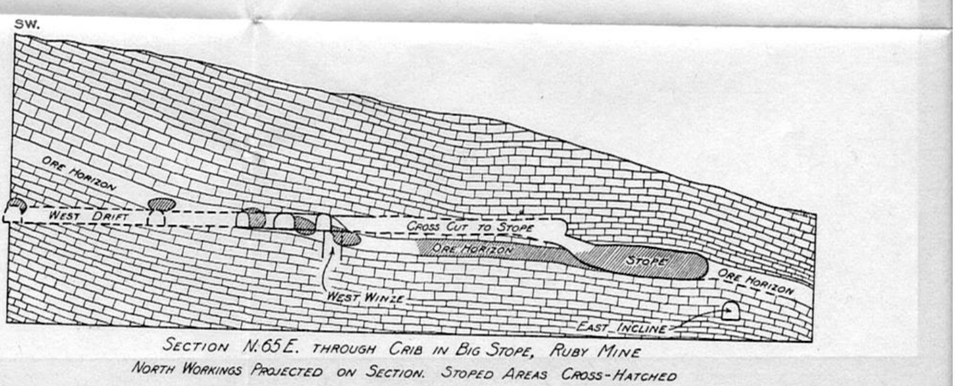

LEGEND
Outcrop of ore
Dip and strike of bedding
Fault or fissure showing downthrown side and dip
Prospect pit
Tunnel
Shaft
QUAT.
MORAINE AND TALUS
TERT.
WHITE PORPHYRY
PENN.
WEBER FORMATION
MISS.
LEADVILLE LIMESTONE (Upper "Blue Limestone")
DEVONIAN
DYER MEMBER (Lower "Blue Limestone")
PARTING MEMBER
CHAFFEE FORMATION
ORD.
MANITOU LIMESTONE ("White Limestone")
CAMBRIAN
PEERLESS MEMBER ("Transition Shales")
SAWATCH QUARTZITE, LOWER MEMBER
PRE-CAMB.
GRANITE
GEOLOGY OF WESTON PASS
Sections 35 and 36, T. 10 S., R. 79 W.
Sections 1 and 2, T. 11 S., R. 79 W.
LAKE AND PARK COUNTIES
COLORADO
0 200 500 1000 2000 FEET
SEC. 35
SEC. 2
SEC. 36
SEC. 1
R. 79 W.
N

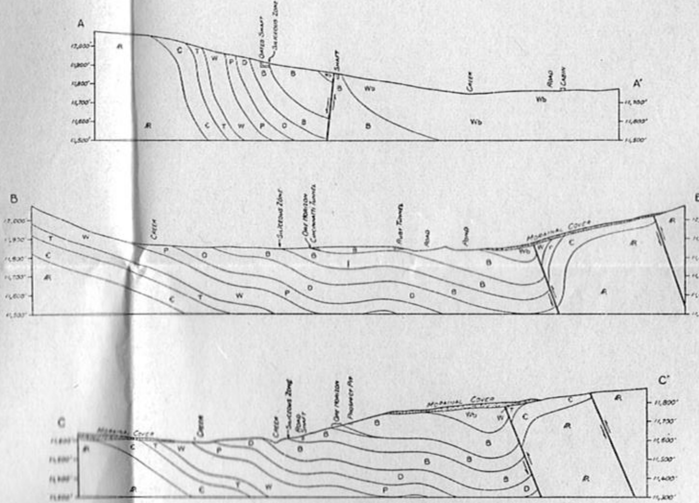
PLATE III





SECTION N. 65 E. THROUGH CRIB IN BIG STOPE, RUBY MINE
NORTH WORKINGS PROJECTED ON SECTION. STOPED AREAS CROSS-HATCHED

PLATE II



STRUCTURE SECTIONS OF WESTON PASS DISTRICT

SCALE

CONVENTIONS AS ON PLATE I.

paper, though the term "White" limestone, in view of its general usage among mining men, will doubtless continue to be used. At Weston Pass it is 100 feet thick. The probable absence of the Harding sandstone and the known lack of the Fremont limestone, both of Ordovician age, above the Manitou, demonstrate conclusively that an erosional unconformity exists above the Ordovician.

Above this unconformity is the newly named Chaffee formation, representing the Devonian in this part of Colorado. Its lower member at Weston Pass is the Parting quartzite (parting or "Parting" of earlier reports), so named after the northwest or Parting[9] spur of Dyer Mountain, which separates Dyer and Evans Amphitheaters, east-southeast of Leadville. This is now definitely recognized as of Devonian age. Its characteristics are like those exhibited elsewhere in the Mosquito Range, except that the shaly beds at the base, suggestions of which were found in the Leadville district[10], are here far more prominent and consist of much dark brick-red shale, overlain by light-green shale, which together make up about 22 feet of the 62 feet of thickness assigned to the Parting quartzite. Some fish plates were found in the lower shaly beds at Weston Pass. In their shaly character and their color these lower beds are similar to the lower parts of both the Elbert formation of Devonian age in the San Juan region[11] and the Harding sandstone of Ordovician age, which is present to the south at Trout Creek Pass. It may be, therefore, that some of the Harding sandstone is here included in the Parting quartzite. The lower shaly beds are overlain by thick bedded quartzite, which comprises the remaining 40 feet of the Parting member.

The upper member of the Chaffee formation consists of 75 feet of light-gray sugary dolomitic limestone, with a few dark-gray and ocher-colored beds. It was formerly included in the Leadville or "Blue" limestone, but fossils collected by

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[9]Recently named by the U. S. Geological Survey committee of geologic names because of the outcrop of parting quartzite.—Colorado Sci. Soc. editors.

[10]U. S. Geol. Survey Prof. Paper 148, p. 30 and fig. 9, 1927.

[11]Burbank, W. S., Revision of the geologic structure and stratigraphy in the Ouray district of Colorado, and its bearing on ore deposition: Colorado Sci. Soc. Proc., vol. 12, p. 158, 1930.

Kirk establish it as Devonian[12]. It is proposed to call this the *Dyer dolomite member,* after its typical exposure on West Dyer and Dyer Mountains, 5 miles east of Leadville.

Above the Dyer dolomite there are sandy layers, 2 feet thick, overlain by an irregularly distributed sedimentary limestone breccia. These beds compose the basal part of the Leadville limestone and represent the beginning of Mississippian sedimentation. The basal sandy beds and the overlying dolomitic limestone have been described in detail in earlier publications[13]. At Weston Pass their total thickness is 370 feet. This thickness is so much greater than that in the Leadville district, to the north, that the possibility of repetition by thrust faults that coincide with the bedding must be admitted. No such faults could be recognized, however, from a study of the outcrops.

The contact between the Leadville limestone and the overlying Weber (?) formation (Pennsylvanian) is concealed by debris and soil, and the sequence in the higher formation is in doubt. The boundary between the two formations is placed at the base of a calcareous and highly carbonaceous shale, which has a dark-gray, almost black color. This is estimated, from observations at the Continental Chief mine and elsewhere near Leadville, to be about 8 feet thick. Immediately above is a bed of black sandstone, 3 feet thick. Still higher in the sequence there are interbedded gray calcareous shales, gray shaly limestones, and noteworthy thicknesses of gray to buff micaceous grits and sandstones. The lower beds appear to be more shaly and limy, and the higher beds to be more gritty, but details are uncertain. In the shaly calcareous beds a small collection of Pennsylvanian fossils included the following forms:[14]

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[12]Kirk, Edwin, written communication, Aug. 11, 1929.

[13]Behre, C. H., Jr., op. cit., p. 40. Singewald, Q. D., and Butler, B. S., op. cit., pp. 301-302.

[14]Johnson, J. H., written communication, July 20, 1931.

Lophophyllum profundum.	Composita subtilita.
L. profundum var. sauridens.	Marginifera ingrata.
Crinoid stems.	Productus cora.
Chonetes geinitzianus.	Spirifer opimus ?
Squamularia sp. ?	Phillipsia major ?
Platyceras sp. ?	

Mr. Johnson reports that these fossils are characteristic of the lower zone of the Weber (?) formation of this section of Colorado.

Tertiary igneous rocks.—Two sills of white porphyry identical with the White porphyry of the Leadville district are present in the area. Their composition is essentially that of a muscovite granite, but their texture is porphyritic, with a dense, stony groundmass. Under the microscope both show extensive sericitization. One, 30 feet thick, occurs in the Sawatch quartzite, about 40 feet above the base of the formation, in the southern part of the area. The other, also about 30 feet thick, lies between the Weber (?) and Leadville formations; it is well exposed above the road about three quarters of a mile from the pass, outside of the area mapped. It grows thinner southeastward and finally disappears completely before the summit of the pass is reached. Only one dike of post-Cambrian age is known in the district. This is also a white porphyry, which under the microscope is seen to be heavily sericitized. It is 15 feet thick and cuts the Cambrian quartzite. It could not be proved to cut the associated white porphyry sill, but the distribution of its float strongly suggests that it does; furthermore, its composition is similar to though not identical with that of the late rhyolite dikes and agglomerate of the Mosquito Range[15]. A somewhat similar rock is exposed on the C. K. claim, near the western edge of the district, but this is thought to be the sheared equivalent of the sill already described that occurs between the Weber (?) and Leadville formations.

Structure.—The general structure of the region is simple. The predominant strikes are northwest, with northeast

[15]Behre, C. H., Jr., op. cit., pp. 42-43, 1929. Singewald, Q. D., and Butler, B. S., op. cit., pp. 304, 307. 1930.

dips averaging about 25°. Hence, eastward from the western edge of the region the formations appear in stratigraphic succession. This regular order, however, is terminated by two large faults which trend northwest and lie about 1,400 feet east of the summit sign at Weston Pass. The aggregate effect of this fault zone is to bring pre-Cambrian rocks on the east against Pennsylvanian (Weber ?) on the west. The minimum stratigraphic displacement would thus be about 765 feet, but the vertical displacement must actually be considerably more, for pre-Cambrian rock occurs east of the fault no less than 300 feet vertically higher than the outcrop of the fault, and the Weber (?) west of the fault must be at least 200 feet thick. The actual throw of the fault zone must thus amount to a minimum of 1,265 feet and is very probably more.

The effect of this major fault zone on the attitude of the beds is marked. Near the western edge of the mapped area the dips are 20°-35° NE.; toward the fault eastward they flatten and the strike changes so as to have an east or northeast trend. Evidently, therefore, the faulting not only raised the east side but carried it northward as well. Finally, at or very near the fault, the beds are so steeply upturned as to be essentially vertical or even slightly overturned; this upward drag of the beds west of the fault is well seen on the south slope of the pass, due north of the lake, where the thin shaly and calcareous strata of the Weber (?) formation are crumpled into a series of steplike folds, rising eastward.

This movement, the results of which are collectively referred to as the Weston fault, was generally not confined to a single plane, where carefully studied, but there appear to be two separate planes along which the movement was distributed. (See Plate I.) Near the north end of the area these two planes unite, and here, northeast of the crest of the pass, the Paleozoic rocks on the east side of the fault have been dragged sharply down, so that the fault plane has the structural effect of a very sharp monoclinal flexure. The general appearance is thus that of a thrust fault produced by compression. The eastward dip of the fault plane, as inferred from the relation of its outcrop to the ground surface, also suggests a thrust, though the dip can not actually be measured.

By analogy with observations in the Leadville district, this fault is thought to have been formed prior to mineralization. The bearing of this fact upon the migration of mineralizing solutions will be referred to below.

There is one other plane of large movement in the region. This is a fault in the western part of the area, which appears to extend approximately eastward through the Frank, Game Cock, Willie S., Little Eva, and Quincy claims. Its presence is shown by its offset of the white porphyry sill that separates the Weber (?) and Leadville formations. It may extend even farther east than the Quincy claim, as relatively steep northerly dips appear anomalously along its eastward projection, but for lack of positive evidence it has not been so mapped.

There are a few noteworthy minor structural features. Thus, in the Ruby mine the dips change from southeast in the south end of the workings to northeast in the north end (see Plate III), indicating an eastward-pitching anticline. Indeed, the regional dips as a whole reproduce this picture on a larger scale. There are also several north or northeast fissures and faults of small displacement, which are shown on the areal map and on the map of the Ruby mine. These are nowhere known to be mineralized.

The most surprising structural feature is the existence of a silicified shattered zone in the Leadville limestone which extends from the southern edge of the area almost to the northern boundary—a distance of about 7,200 feet. This zone occupies a virtually constant stratigraphic position, generally about 90 feet above the base of the formation, or 165 feet above the top of the Parting quartzite. Its thickness varies but is generally about 20 feet. Near the northwestern edge of the area it gradually narrows and is finally no longer distinguishable from the limestone above and below; farther to the northwest its outcrop is concealed by debris, though its presence near the Gates shaft may be inferred with some uncertainty from jasperoid containing lead and zinc minerals seen on the dump. The zone consists of a light-gray, highly silicified, dense jasper rock, evidently silicified Leadville limestone; the silicified rock has been broken into angular fragments that have been recemented by iron-stained silica.

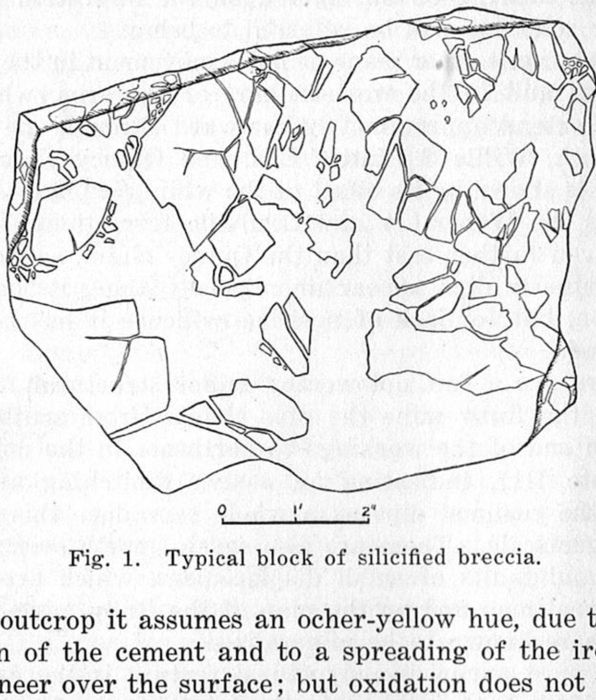

Fig. 1. Typical block of silicified breccia.

At the outcrop it assumes an ocher-yellow hue, due to limonitization of the cement and to a spreading of the iron oxide as a veneer over the surface; but oxidation does not progress deeply into the isolated blocks. This zone, on account of its highly siliceous character, is very resistant to weathering, and blocks of it, still angular, are found far from the outcrop. Above and below it the limestone exhibits no unusual characteristics. The suggestion may be ventured that the zone represents a bed which was shattered by folding; the shattering was probably accompanied by bedding-plane movement, the result being a "bedding slip" fault. Subsequently, on account of the open texture produced by the shattering, siliceous solutions accompanying mineralization found this particular zone the path of easiest progress and hence were most effective there in converting limestone to jasperoid. After partial silicification there may well have been collapse with further brecciation, but the shattering is thought to have chiefly preceded silicification.

It is at least possible that the zone described represents a thrust fault so nearly parallel to bedding as not to be recognizable at any of its few outcrops. This might explain the unusual thickness of Leadville limestone referred to on a preceding page.

Ore Deposits

Mineralogy.—The mineralogy of the ore of this district is very simple. The table below gives the ore and gangue minerals and their common occurrence.

Minerals of the Ore

Hypogene Minerals	
Galena	Common; forms nodules in ore zone.
Sphalerite	Relatively rare in ore; associated with galena.
Pyrite	Rarely with the other sulphides, but commonly disseminated in the limestone near the ore zone.
Dolomite	Common in vugs or bands in limestone.
Witherite (?)	Reported from one small vein.
Quartz	Common in vugs and veinlets; probably in part supergene.
Barite	Rare; associated with ore.
Supergene Minerals	
Cerusite	Moderately common in oxidized ore; as crystals and in dense brown masses.
Anglesite	As thin crusts on galena.
Calamine	Especially common, chiefly in the highly oxidized ore.
Smithsonite	Generally rare, but locally abundant; as films, associated with calamine.
Hydrated iron sulphate	Rare; associated with oxidized ore.
Chalcophanite (?)	Black coatings on smithsonite in rich oxidized ore.
"Limonite"	Very common in massive or earthy form in ore bodies and as cubes after pyrite.
Chalcedony	As siliceous ribbing in and near ore zone; probably in part hypogene.

Little need be added to this table. Sphalerite is rare because of the heavy oxidation of the ore. Pyrite, though seldom seen in the ore mined, leaves traces of its earlier presence in the form of small cubes of limonite scattered in the rock of the ore horizon; some is also seen in carbonaceous nodules at the base of the Weber (?) shale, but this is not genetically related to the ore.

Dolomite is by far the most abundant gangue mineral. It occurs in two ways that are probably mere modifications of the same thing. In one the mineral is coarsely recrystallized and forms areas or a series of subparallel white bands, which give the otherwise gray Leadville formation a striped appearance, so that it is called "zebra rock";[16] this form is not necessarily associated with the ore, though it is as frequently seen in the ore zone as elsewhere. A bed in which "zebra rock" is especially pronounced overlies the ore zone. In the other kind of dolomite the mineral forms larger crystals, as much as a quarter of an inch in diameter, which occupy vugs that were apparently made by solution of the limestone; this type is more commonly associated with the ore and appears to be confined to areas of mineralization. It is probable, from their occasional brownish appearance where weathered, that these dolomite crystals contain small quantities of isomorphous ferrous carbonate and thus approach ankerite in composition.

A surprising feature is the relatively rare occurrence of barite, a mineral generally accompanying ore deposition in the outlying parts of the Leadville district. Though carefully searched for, it was found only on the Gates claim, and there in small quantities; some has also been reported from the Collin Campbell and Ruby workings.

Smithsonite is not widely distributed, but it made up the better part of the high-grade zinc ore formerly mined. Calamine in rosetted crystals or porous, dense masses is a common constituent of the oxidized ore.

The absence of any recognizable silver minerals in the

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[16] Emmons, S. F., Irving, J. D., and Loughlin, G. F., op. cit., pp. 33, 176, 1927.

sulphide ore now in sight, even in polished sections, suggests that the high silver content reported in ore shipped years ago had been concentrated during oxidation.

General characteristics of the deposits.—A striking feature is the fact that almost all of the observed ore occurs at a single stratigraphic horizon. The dump of the Gates shaft shows a good grade of ore which, because of its areal position and its association with a few fragments of jasperoid breccia, is thought to have been developed in the silicified breccia zone. This single, somewhat uncertain observation furnishes the only exception to the statement that the siliceous breccia zone contains no ore. The discontinuous "ore bed" or "blanket deposit" varies in thickness but occupies a constant position, 170 feet above the sandy beds at the base of the Leadville limestone. In its constancy of stratigraphic position it resembles the silicified and brecciated zone already described, and it has been traced an almost equal distance, having a total length of 6,800 feet along the strike. The degree of mineralization through this distance is highly variable, however, and the ore zone can therefore not well be spoken of as a single ore shoot.

The ore is not observed to occur along any well-developed mineralized fissures but impregnates the limestone or occurs in and around small vuggy cavities, which may be massed so closely together as to constitute a larger cellular replacement body in what is otherwise densely crystalline limestone.

Vertically the ore zone was nowhere observed to have a thickness of more than 10 feet, and as a rule it is far less, but some of the stopes are said to have attained a height of 25 feet. It is significant that the thickest and most highly mineralized part of this almost continuous body is at the Ruby mine, situated about midway in the known areal extent of the deposit. It thus appears that the ore spread laterally from this general region.

Tenor of the ore.—Representative analyses of the ore are given below:

ASSAYS FROM WESTON PASS DISTRICT

(Gold and silver in ounces to the ton; other constituents in per cent)

	Gold	Silver	Lead	Zinc	Iron	SiO_2	S
1. Dump, Ruby mine	Tr.	0.5	5.4	4.0	14.8	13.0	?
2. Coarse ore pit, Ruby mine	Tr.	0.8	15.6	4.0	22.4	24.4	0.1
3. Stope, Ruby mine (30-inch cut)	Tr.	4.8	46.2	0.6	?	?	?
4. Southeast stope, Ruby mine	....	0.2	8.9	4.4	?	?	?
5. Boxed ore near southeast stope, Ruby mine	....	0.3	18.3	16.9	?	?	?
6. Tunnel near middle of Cincinnati claim, 42-inch cut	....	Tr.	0.7	....	?	?	?
7. Outcrop of ore at portal of tunnel near middle of Cincinnati claim	....	Tr.	2.8	0.4	?	?	?
8. Loading platform, Collin Campbell shaft	.10	1.4	16.1	2.8	?	?	?
9. Sorted ore from shaft, locality not given	.03	2.0	10.8	28.1	?	?	?
10. Lump Ore, Davis claim	.02	3.2	17.1	7.8	?	?	?
11. Fines from shallow shaft, locality not given	....	....	5.2	14.6	?	?	?
12. Pyritic ore from shallow shaft, locality not given	.02	0.8	....	....	?	?	?

Samples 1, 2, and 8 were obtained by courtesy of E. P. Chapman; samples 3-7 by courtesy of the E. J. Longyear Co.; scamples 9-12 by courtesy of Alfred Tonkin. All the assays except Nos. 3, 9, and 10 are low in silver, and of those three only No. 3 represents moderately deep work. Although all the samples were selected and none may therefore be correctly regarded as typical of the deposit as a whole, yet a study of the outcrop suggests that the ore zone generally, if mined on a large scale, would approximate 3 per cent of lead or slightly less and perhaps 0.5 per cent or more of zinc, with traces of silver; this statement is based on the fact that sample 7 was collected as fairly representing the outcrop. It is altogether possible that the figure for zinc would be appreciably increased below the surface, for there oxidation of the zinc sulphide and its removal in solution would not have taken place. Selective mining on a smaller scale might, also, as in the Ruby mine, yield a richer product.

Much richer ore was shipped from the Ruby mine. It is reported that when zinc was in demand the average ore contained zinc carbonate assaying 30 to 40 per cent of zinc.

Shipments from the northeasternmost incline of the Ruby mine are said to have averaged 15 ounces of silver to the ton and 40 per cent of lead. Smelter returns on ore from the Pay Rock claim are reputed to have shown 35 ounces of silver to the ton and 45 per cent of lead. These were probably all sorted grades, not typical of the average that might be mined under conditions of large-scale production.

Ruby mine.—The major part of the workings and the geology of the Ruby mine are shown on Plate III. The ore occurred as disseminated masses of galena and minor amounts of sphalerite, with cerusite, iron oxide, calamine, and smithsonite, the oxidized minerals clearly forming a casing around the sulphides. The ore lay in more or less continuous masses, following a definite horizon, and mineralization may have been intensified because of the small anticline mentioned in the section on structure.

Much of the mine is now flooded, and the best idea of the ore zone is gained in an old stope near the southeast edge of the workings. Here there appears to have been some movement along the bedding, and the ore is evidently capped in part by the gouge thus developed, in part by a heavily recrystallized but very thin layer of "zebra" limestone, in which there are only a few small pockets of galena. Beneath this horizon the rock is more open and oxidation has progressed so far that only a few small masses of sphalerite remain unaltered, a zone of deep red color surrounding the residual nodules of sulphides. Here and there shaly lenses also cap the thin, discontinuous ore "blanket" and evidently caused the formation of subsidiary "contacts," similar to those of Leadville but far smaller.

Throughout much of the mine there are small gouge-filled fissures striking northeast. These, however, bear no apparent genetic relation to mineralization, nor is there evidence that they were the cause of the offsetting of ore bodies to any appreciable degree.

It is clear that the ore was obtained at essentially one horizon. The stopes have dips consistent with the bedding, and strikes of stopes and bedding are parallel. Indeed, the very form of the main stope (see Plate III) clearly outlines the pitch of the fold in which the ore was developed.

With these facts in mind, the development of the ore is readily followed. The greater part of the work was done in stopes that dipped northeastward and lay a little below the level of the portal and upper workings. Southward the strike of the stopes swings to the southwest, following the south limb of the pitching fold described above. An attempt was made to keep the tunnel workings level, with the result that, as drifting was carried westward, the ore passed into the roof. Where this happened, the ore zone appears to have been so lean that its real structural relations were not recognized, and exploratory drifts were run westward into the footwall, which showed only very irregular and small masses of galena. Here inclined raises should have been put up westward, or equivalent work carried out in order to explore the ore zone.

A phase of the development work was to drive an incline north-northwest from the portal and strike the ore body at depth. To the east of this incline the ore continued to pitch eastward, but water was encountered, and the pumping capacity was not sufficient to handle the flow. This promising line of development therefore had to be abandoned.

Other mines.—None of the openings of the district are now accessible except the Ruby mine. In fact, most of the other underground operations are small and consist mainly of shallow shafts, short tunnels, or small test pits.

The only work of importance on the Collin Campbell claim is a shaft about 300 feet deep. It is said that the ore zone was encountered at a depth of 130 feet, and the silicified breccia zone still lower. On an old map about 140 feet of drifts are shown, together with some stoping said to have yielded three or four carloads. According to some accounts there are connections with the Ruby mine, but these are not shown on maps. Despite the ore shoots (relatively small though they were), the operators evidently failed to recognize the ore horizon of the Ruby and sank 170 feet deeper in the hope of striking another and larger body.

On the Cincinnatti claim a shallow tunnel, now caved, was driven 100 feet northwest, and ore, said to have been valued at about $25,000, was mined. A longer tunnel was dug from a point slightly southeast of the south boundary of this claim; work here amounted to a total of about 300 feet, and some ore was taken out, but the value and quantity are unknown. Later, during the early days of the World War, this claim yielded high-grade oxidized zinc ore.

Several small shafts and tunnels have been opened but are now mainly inaccessible. The largest was on the Pay Rock claim, in the southeastern part of the district. Here a tunnel at shallow depth uncovered ore assaying as much as 35 ounces of silver and $2 in gold to the ton and 65 per cent of lead, and this ore was mined. On the Gates claim, near the western edge of the district, a shallow shaft was put down and a short drift run; the dump shows promising ore, but apparently little has been mined.

Genesis of the ore.—In view of the presence of bedding slips and the absence of any apparent ore-bearing fissure, the writer has inferred that the mineralizing solutions, which probably rose along the Weston fault, penetrated the rock along bedding-plane fractures. These solutions are thought to have selectively replaced a certain bed, probably because of its nearness to the bedding-slip zone.

A possible alternative is the explanation offered by E. P. Chapman and F. M. Stephens[17]—that there is a steeply dipping fault transverse to and intersecting the Weston fault and that the solutions entered the limestone along this transverse fault. No transverse fracture so extensive could be recognized by the writer, but Fred J. McNair[18] has shown one on an early map, and the field work carried on in the studies here reported indicates the presence of a plane of lesser movement crossing the Frank, Quincy, and intervening claims, as stated above.

[17]Oral communication, 1929.
[18]Personal communication.

The evidence for either of these hypotheses is inconclusive. Although it is true that some mineralization has been noted on the Davis claim near the transverse fault, it would seem that if extensive solution movement had taken place along this route, there should be signs of it on the surface along the known or projected trend of the fault. Moreover, the strongest mineralization occurred near the Ruby mine, 600 feet horizontally south of the projected trend of the fissure, and some mineralization is even in evidence in the far southeast corner of the area, 2400 feet from the transverse fault. Finally the constancy of the silicified breccia zone below the ore points to the possibility of appreciable interbed movements, probably thrusting along the bedding planes, and the migration of solutions along the lines thus opened. The close folding near the Weston fault would favor such adjustments between beds, accompanied by shattering. The westward dying out of the ore zone can be accounted for by the reduction of movement away from the Weston fault and by the greater distance which the solutions must have traveled from it.

The writer finds a striking similarity in structure and mineralization between the ore body of the Continental Chief mine, in Iowa Gulch, east of Leadville, and the ore body at Weston Pass. The Continental Chief ore, however, shows much barite whereas the principal gangue mineral at Weston Pass is dolomite, and the ore shoots in the Continental Chief mine are less continuous[19] than those at Weston Pass. Both deposits seem to represent a more distant phase of mineralization than the larger ore masses in the Leadville district, therefore suggesting leaner and more "spotty" ore, and both are near zones of thrust faulting. This comparison may be extended to include the Lyddia, Dyer, Hilltop, Peerless, and other mines in the near Iowa Gulch, some of which have excellent records of production. The relations between the ore bodies of the Weston Pass district and those in and nearer the Leadville district are similar to those between the ores of

[19]Behre, C. H., Jr., op. cit., p. 51 and figs. 4, 6, and 7, 1929.

the North Tintic district and those of the Tintic district in Utah[20].

Production and Future

History of production.—Only a few data regarding quantity and period of production are available. Some of these have already been given above. Evidently no work had been done in this region at the time of Emmon's first visit in 1880, but some of the earlier mining, such as that on the Pay Rock claim, is said by Leadville miners to date back to 1890. Work on the Gates claim is reported to have been carried on about 1900. It is also said that the Ruby mine in its early operations, about 1902, yielded approximately $60,000 from ore containing 40 per cent of lead and 15 ounces of silver to the ton. During the World War the mine was reopened and about 800 tons of oxidized zinc ore containing 35 to 40 per cent of zinc was shipped. The last productive work was done in 1916. The ore shipped from the Cincinnatti claim is estimated to have been valued at $30,000, almost wholly in silver and lead.

On putting together these scattered estimates, none of which are supported by smelter certificates, it seems probable that the value of the total production in this district amounts to not more than $125,000, of which $75,000 came from the Ruby mine, about $30,000 from the Cincinnatti claim, and the remainder from the Collin Campbell and several lesser operations. There has been no actual mining since 1918 at the latest.

Future of the district.—Five factors should be faced before further development of this district can be undertaken intelligently. These are transportation, power, dewatering problems, metal prices, and, above all, reserves. It is safe to say that none of the first three presents insuperable difficulties but that the last two are far more important.

The haul from Weston Pass westward to the Denver & Rio Grande Western Railroad in the Arkansas Valley is about 10 miles over a very poor road, from which some of the

[20]Lindgren, Waldemar, and Loughlin, G. F., Geology and ore deposits of the Tintic mining district, Utah: U. S. Geol. Survey Prof. Paper 107, pp. 267-272, 1919.

steeper grades can probably not be eliminated. That to South Park on the east calls for a longer trip (approximately 16 miles to the nearest connection on the Colorado & Southern Railroad), but the road, which follows a gentler grade along the South Fork of the South Platte River, is in better condition. Possibly aerial tramming as a first relay might be desirable.

Adequate power, probably involving installation of a power line, would be necessary, especially in view of the pumping required for dewatering.

Dewatering represents a difficulty to which some have attributed the discontinuance of operations in both the Ruby and the Collin Campbell mines. The water levels on the two sides of the crest of Weston Pass differ in August by fully 145 feet, rising west of the pass to the collar of a shaft on the Collin Campbell No. 2 claim at 11,940 feet, but standing below tunnel level (11,800 feet) in the Ruby mine. This difference is not clearly explicable. On so narrow a divide and at such high altitudes the chief water sources are probably the slopes of the two adjacent peaks. From Weston Peak some water no doubt drains into fissure channels in and near the Weston fault, but these channels, if not actually tapped, can probably not deliver appreciable quantities into mine workings. If the direction of water flowage is down the dip, following bedding-plane openings, the water level should be lower on the west side of the pass than on the east side; the fact that it is not suggests that the water table on the west slope is supported on the impervious black shale that marks the base of the Weber (?) formation or on dense beds in the upper part of the Leadville limestone and argues once more against the presence of approximately vertical fissures that cut the formations along easterly lines, for these should be channels of drainage if present. On the east side of the pass, on the other hand, natural drainage is not blocked by any rock formations, and the relief is less; furthermore, it is unlikely that further work carried westward from the country east of the pass would draw very much water from the western slope as long as the workings are kept well beneath the top of the Leadville limestone. The amount of water to be handled by a drainage tunnel or pumping would hence not appear to be prohibitive.

Price is a factor whose fluctuations can not be predicted. At present prices (1931) of metals, however, mining in this region, on anything short of very efficient, large-scale operations, could scarcely be contemplated. This is a question which each operator must answer for himself.

Finally, data are not at hand to estimate reserves. A thorough drilling campaign is necessary to determine reserves adequately before any mining enterprise can be contemplated. Such a campaign is favored by two geologic facts. First, the possibility that moderately closely spaced drill holes will miss larger ore bodies is small in view of the continuity of the ore zone as observed at the outcrop. Second, the depths to which test holes need be carried in order to strike the ore zone is not great, probably nowhere exceeding 500 feet. The quantity and tenor of the ore at present in sight at the surface are not encouraging; this visible ore, however, is only the leaner part of the outcrop that was once exposed, the richer part having been removed in early mining operations. Drilling should have as its object the finding of bodies of ore comparable in tenor to that worked in the Ruby mine.