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Geology of the Ore Deposits of the Tintic Mining District

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I. Introduction

The geology of the Tintic mining district, fully treated, would occupy an elaborate monograph. This less comprehensive paper is devoted primarily to the occurrence and origin of the orebodies of the district, while space is given to those phases of the general geology only which seem necessary to a proper setting of such a discussion.

The first geological report on the Tintic district to be issued was that by Tower and Smith, published in 1899, in the form of a paper in Part III of the *Nineteenth Annual Report of the U. S. Geological Survey,* and also as *Folio No.* 65, *Geologic Atlas of the United States.* About four years ago a second investigation was begun by Waldemar Lindgren and G. F. Loughlin, of the U. S. Geological Survey. With the exception of a paper on the oxidized zinc ores of the Tintic district by Mr. Loughlin, the results of their work are still unpublished. The writer's acquaintance with the district began in the fall of 1913, and has extended over a period of about two years.

1. *Location*

The Tintic district lies about 65 miles due south of Salt Lake City, and on the west central slope of the Tintic Mountains, a short range, which forms the connecting link between the Oquirrh Mountains on the north and the Canyon Range on the south—the group constituting the first of the Basin ranges to the west of the Wasatch Mountains.

The productive portion of the district embraces an area about 6 miles long and 2 miles wide, which is divided between Juab and Utah Counties. Within this area are the towns of Eureka, Mammoth, Robinson, Silver City, and Knightsville. All these points are tapped by the Denver & Rio Grande and S. P., L. A. & S. L. Railways.

2. *Topography*

As in most of the Basin ranges, topographic relief is strong, dropping rapidly from peaks of 8,100 ft. above sea level to elevations of 5,600 ft. in Tintic Valley on the west and 4,500 ft. in Goshen Valley on the east.

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The regularity of the range is broken by many lateral valleys, one of which has cut well back into the range, forming the low divide above the town of Eureka, through which the D. & R. G. Railway enters the district.

3. *History*

Tintic is among the oldest mining camps in Utah, being antedated only by Bingham, Rush Valley, and Little Cottonwood. Ore was first discovered in the monzonite about 1 mile east of Silver City in December, 1869, and the district was organized in the following spring. The first claim recorded was the Sunbeam, located Dec. 13, 1869, on the first discovery. The second location was made Jan. 3, 1870, on the Black Dragon, a little farther to the north. This was followed in quick succession by locations in the limestone, first on the Mammoth ledge near the middle of the district, and shortly after on the Eureka Hill ledge near its northern end.

Mining operations began at once with the construction of two mills and as many smelters during the first 12 months. Once located, the orebodies have been found to be fairly persistent, with new discoveries from month to month, and today there is good reason to believe that this record can be maintained for some time to come.

4. *Production*

During the early days of the district the production was about equally divided between the deposits in the igneous rocks at the south end of

Total Metal and Gross Values Production of the Tintic Mining District to Jan. 1, 1914.[a]

		1869 to 1879, inclusive	1880 to 1903, inclusive	1904 to 1913, inclusive	Totals to Jan. 1, 1914
Gold:	Ounces	....	....	831,114	....
	Value	$475,451	$11,096,747	$17,180,602	$28,752,800
Silver:	Ounces	1,300,000	50,400,000	51,613,173	103,313,173
	Value	$1,616,130	$38,620,870	$27,343,438	$67,580,438
Copper:	Pounds	1,700,000	37,235,000	89,233,411	128,168,411
	Value	$478,852	$6,081,148	$13,473,378	$20,033,378
Lead:	Pounds	11,000,000	269,000,000	299,176,172	579,176,172
	Value	$631,146	$12,073,854	$13,869,125	$26,574,125
Zinc:	Pounds	....	....	7,306,281	7,306,281
	Value	....	....	$457,378	$457,378
Total value		$3,201,579	$67,872,619	$72,323,921	$143,398,119

[a] Compiled from statistics of G. W. Tower and G. O. Smith, U. S. Geological Survey, V. C. Heikes in reports of 1904 to 1913, inclusive, and other sources.

the district and those in the limestone at the north end. But upon the exhaustion of the oxidized ores in the igneous rocks, due to high water-level, the balance of production was shifted to the deposits in the limestone; and since the closing of the Swansea mines at Silver City, in 1913, the entire production has been from the latter deposits.

II. Areal Geology

The rocks of the Tintic district consist of Paleozoic sediments and a variety of igneous rocks of Tertiary age.

1. *Sedimentary Rocks*

These consist mainly of quartzite and limestone having a total thickness of 12,000 ft. or more. For economic and lithologic reasons they have been subdivided in descending section as follows:

Humbug sandstone Humbug limestone	Constituting the Humbug formation of the U. S. Geological Survey.
Tetro limestone Carbonaceous shale Blue Fossiliferous limestone Chief Consolidated limestone Gemini limestone	Constituting the Godiva limestone of the U. S. Geological Survey.
White-lime-shale Centennial limestone Golden Ray limestone	Constituting the Eureka limestone of the U. S. Geological Survey.
Tintic slate Tintic quartzite	Constituting the Tintic or Robinson quartzite of the U. S. Geological Survey.

At the top of the section is the Humbug sandstone, on the east slope of the Godiva Mountain, which is 224 ft. thick, consists mainly of calcareous sandstone with a few intercalated beds of arenaceous limestone, and is not known to be ore bearing.

The Humbug limestone, 378 ft. thick, consists mainly of nearly pure, coarse-grained, gray limestone with a few intercalated beds of arenaceous limestone of a yellowish buff color. This formation is well exposed on the upper east slope of Godiva Mountain and has carried most of the ore in the Godiva-Sioux Mountain and Iron Blossom ore zones.

The Tetro limestone, 355 ft. thick, consists with little variation of hard, fine-grained, blue, cherty limestone which is not known to be ore bearing.

The Carbonaceous shale, 160 ft. thick, is essentially a thinly bedded, black, shaly limestone, containing bands of black chert, and weathering to a platy or shelly surface. It is most unpromising as an ore-bearing medium and is nowhere known to be mineralized.

The Blue Fossiliferous limestone, 542 ft. thick, consists of 300 ft. of blue, cherty limestone in beds from 1 to 3 ft. thick, resting upon 242 ft.

of blue, highly fossiliferous limestone in thin beds separated by thin partings of impervious clay shale. This formation has been quite extensively prospected, and found to carry no orebodies of importance.

The Chief Consolidated limestone, 615 ft. thick, consists of a series of contrasted horizons which, in descending order, have the following characteristics:

80 ft. of very coarse-grained, massive, dolomitic limestone, on the whole quite favorable to mineralization.

64 ft. of fine-grained, siliceous, hard, brittle, black limestone, which is generally barren, though running the entire length of the ore zone in the Chief Consolidated mine.

38 ft. of medium-grained, fairly pure, blue limestone in thin beds, but with a few black shaly partings which appear to offer some resistance to mineralization.

31 ft. of coarse-grained, pure white to light-gray limestone which appears to be especially favorable to mineralization.

120 ft. of blue, flaky and fairly pure limestone which also appears to be especially favorable to mineralization.

72 ft. of coarse, mottled, light-gray, massive dolomitic limestone, readily susceptible to mineralization.

212 ft. of fine-grained, ashy gray, impure limestone with 14 or more intercalated thin beds of quartzitic sandstone. The horizon lies to the west of the ore zone proper, and its character is such as to discourage exploration for ore within its limits.

The Gemini limestone, 902 ft. thick, consists of 45 or more relatively thin alternating horizons of blue, gray, light-gray, and white limestone of varying texture and hardness, but all generally distinctly bedded. The formation is especially characterized by its purity, *i.e.*, lack of siliceous members, and general susceptibility to mineralization.

The White-lime-shale, 920 ft. thick, consists throughout of fine-grained, bluish gray, thinly bedded, shaly limestone with a few thin conglomeratic beds of the interformational type. It is generally extensively sheeted where folded, and weathers to a yellowish white, whence its name. It is characteristically unfavorable to mineralization, and is not known to be ore bearing.

The Centennial limestone, 798 ft. thick, consists of four relatively thick horizons of massive, dark-blue limestone interspaced by as many relatively thin horizons of thinly bedded, light-gray limestone and one 6-ft. member of thinly laminated, light-green shale. Except for the shale and two 20-ft. impure, sandy horizons, the entire formation is apparently favorable to mineralization.

The Golden Ray limestone, thickness 1,559 ft., consists of five thick horizons of heavily bedded, dark-blue to bluish gray, dolomitic limestone interspaced by five relatively thin horizons of fine-grained, light-gray to white, thinly laminated, impure limestone. While this formation is not known to be ore bearing, a large part of it possesses characteristics which are apparently favorable to ore deposition in other ore-bearing horizons.

The Tintic slate, thickness 358 ft., consists essentially of thinly laminated, green slate with intercalated bands of impure, gray, banded limestone near the top and thin bands of brown, quartzitic slate near the bottom. The formation is highly sheeted due to folding. Its highly siliceous and wholly barren nature does not invite exploration.

The Tintic quartzite, the lowest member in the stratigraphic series, is not fully exposed, but has an estimated thickness of from 5,000 to 7,000 ft. It is for the most part a pure, compact, fine-grained quartzite, white to pink in color. Bedding indistinct and readily confused with a pronounced sheeting due to folding. Occasional interspaced thin beds of pebble-quartz-conglomerate break the general massive nature and lend a clue to the structure.

No special effort has been given to the determination of the age divisions in the above succession. The section affords, however, no evidence of an important stratigraphical break, such as a real erosion unconformity. The thin conglomerates in the White-lime-shale are of the interformational type, and represent only temporary disturbances of the normal state of deposition during a period of shallow-sea conditions. If the chronology as determined by Tower and Smith[1] is to stand, the succession certainly represents continuous deposition from Middle Cambrian well into Pennsylvanian time.

2. *Igneous Rocks*

Packard Rhyolite.—The igneous rocks consist of rhyolite, andesite, tuff and breccia, and monzonite, all of Tertiary age.

The Packard rhyolite, locally referred to as porphyry, occurs as surface flows and intrusive dikes. It occupies a large area in the northern end of the district and, underlying the town of Eureka, extends to the north and east in a range of hills of which Packard's Peak is the most prominent. Its thickness at this point probably exceeds 1,000 ft. The rhyolite varies in color from pink and light purple to light and dark gray. In texture it ranges from glassy to highly granular, with flow banding as a common characteristic.

No metalliferous deposits are known to occur with the Packard rhyolite. Its chief economic interest lies in the numerous springs issuing from the lower slopes, from which the entire water supply of Eureka and the mines in that section of the district is obtained.

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[1] Tower and Smith: Geology and Mining Industry of the Tintic District, Utah, *19th Annual Report, U. S. Geological Survey*, Part III, p. 627.

Andesite, Tuff, and Breccia.—Large areas of andesite with associated tuff and breccia lie to the east and south of the productive portion of the Tintic district. They are, for the most part, older than the metalliferous deposits and, having no genetic relation to the latter, they need not receive further attention here.

Sunbeam Monzonite.—The monzonite is confined to the southern half of the district, where it forms the country rock over an area 4 miles in length, north and south, and 2 miles wide. It is the youngest of the igneous rocks, and occurs in the form of an intrusive stock, cutting and enveloping fragments of all the earlier formations. On the north it lies in an irregular, but nearly vertical, contact with the limestones, which it has metamorphosed through a zone varying from 300 to 500 ft. in width. On the east and south it is in irregular contact with the andesite. Its western boundary is obscured by the overlapping, alluvium-filled valleys, Ruby Hollow and Diamond Gulch, which show it to have been deeply eroded.

In color it is light to dark gray, usually with greenish brown tinge. In texture it is normally evenly granular, but varies from porphyritic on its east and west boundaries to granitic where it is in vertical contact with the limestones.

What is known as the Swansea rhyolite is probably a rhyolitic phase of the monzonite and belongs to the same period of intrusion.

The monzonite is a formation of first importance, since it has been the mineralizing source of all the important orebodies in the Tintic district.

3. *Structure*

Folding.—The sedimentary formations are folded into a simple and fairly symmetrical overturned syncline, the major axis of which strikes north and south and pitches slightly to the north. The axial plane of the fold dips about 60° to the west, resulting in vertical and often overturned dips in the beds of the west limb of the syncline, while the angles of the dip of the beds in the east limb are correspondingly low, rarely exceeding 40°. By reason of its pitch, the syncline becomes wider to the north where the trough is folded into a series of crenulations, forming a wide synclinorium. South of the Ajax fault, which extends from the Mammoth mine east to the Iron Blossom No. 3 mine, no synclinal structure is obtained. While the beds on the north of the fault are steeply inclined, conforming to the normal structure of the syncline, those on the south are relatively flat, lying with gentle dips to the east, in which direction no return dips are observable, because of a thick covering of volcanic rocks.

Faulting.—The folding of the sediments was accompanied by extensive faulting, fracturing, fissuring, and sheeting. The major faults are of the transverse type, striking in a nearly east-west direction across the line of the major fold. These faults show lateral displacements ranging from 500 to 3,000 ft. The direction of throw is usually to the east on the south. Connecting the major faults at various angles are numerous minor faults showing displacements ranging up to 200 ft. Rotary faulting is common, as is shown by marked disparity in the attitude of the beds along the plane of the faults. The major faults are usually accompanied by one or more parallel faults, inclosing a breccia or sheared zone. The occasional occurrence of breccia zones and slickensides parallel to the bedding planes must be interpreted as evidence of some faulting of this type. None of the faults are known to extend into the igneous rocks, which are evidently of later origin. While it is probable that most of the faulting occurred during the period of folding, it is not unlikely that some faulting and fracturing accompanied the intrusion of the monzonite, though none of this origin has been recognized.

Fractures, Fissures, and Sheeting.—Fractures and fissures occur in both the igneous and sedimentary rocks. Sheeting is confined to the latter.

In the Sunbeam monzonite and its porphyritic phase, the Swansea rhyolite, are numerous ore-bearing fissures which have a general north-south direction, but vary from as much as N. 20° W. to N. 45° E. These fissures are of the stretch type, due to shrinkage accompanying the consolidation of the igneous intrusives. For this reason they do not extend into the adjacent sedimentary rocks.

The sediments during the period of their deformation were extensively fractured and sheeted, generally along shearing planes. The fractures, which are usually steeply inclined, are most numerous in the steeply dipping beds and in the vicinity of the major faults. They trend at all angles, those in the northeast and southwest quadrants being the most abundant.

Sheeting has occurred in the quartzite, slate, and more impure shaly limestone beds, where these have been closely folded. It is best developed in the Tintic slate, and the White-lime-shale, along the western limb of the syncline. The Tintic quartzite also is extensively sheeted.

III. Geologic History

The geologic history of the district is, briefly, somewhat as follows:

During Paleozoic time the area was under water, as is evidenced by the 12,000 ft., more or less, of sediments of Paleozoic age. That conditions of sedimentation fluctuated considerably between shallow and deep waters, is confirmed by the alternation of thinly bedded shaly limestone, and shale with relatively pure massive limestones; but there is no evidence that, during this age, any portion of the area was elevated above sea level even for a brief interval.

Early in Mesozoic time extensive earth movements began, which resulted in the elevation and deformation of the Paleozoic sediments into virtually their present highly disturbed condition. Throughout this period of folding and faulting, erosive agents were active in carving the distorted strata into mountain ranges closely approaching the present forms. While folding had probably ceased some time before, the erosion continued right up to the Tertiary.

During Tertiary time, the greater portion of the area was buried beneath extensive flows of rhyolite and andesite, which were interspaced by short periods of erosion. Where the rhyolite flows overlapped the sediments, considerable quantities of iron oxide and ferruginous jasper were formed. These are described under the head of limestone-igneous contact deposits.

Following the extrusion of the Packard rhyolite and andesite, with at least a short period of erosion intervening, came the intrusion of the Sunbeam monzonite and its quartz-porphyry phase, the Swansea rhyolite.

This event brought about the second period of ore deposition, which resulted in the formation of the replacement deposits in limestone and was accompanied or soon followed by the deposition of the fissure-vein ores in the Sunbeam monzonite and Swansea rhyolite. Since the last of the volcanic eruptions and the period of ore deposition, there has been uninterrupted erosion, which has cut deeply into the accumulations of volcanic materials, exposing extensive areas of the sediments and, at a few points, the inclosed orebodies.

The products of this last period of erosion form the alluvium in the valleys and the talus on the upper slopes.

IV. The Ore Deposits

There are three types of ore deposits in the Tintic district: (1) limestone-igneous contact deposits; (2) deposits in igneous rocks; and (3) limestone replacement deposits.

1. *Limestone-Igneous Contact Deposits*

At numerous points along the contact of the limestone and the igneous rocks, particularly the Packard rhyolite, are thin deposits of iron and manganese oxide associated with more or less red and greenish yellow jasperoid and clay-ironstone. The jasperoid has been observed in contact with the limestone of which it is a replacement. The iron-manganese deposits occur both at the contact and filling cavities in the limestone near the contact.

Deposits of this type are widely distributed over the district, particularly its northern end, where, because of the resemblance of the associated jasperoids to certain phases of the quartz in the productive limestone replacement deposits, they have received considerable attention from prospectors.

Locally small quantities of silver and gold have been reported; but, except for the iron ores which have been mined intermittently for fluxing purposes, these deposits have no economic importance.

2. *Deposits in Igneous Rocks*

The ore deposits in the igneous rocks are confined to the southern half of the district, where they occur as veins in well-defined stretch fissures in the Sunbeam monzonite and Swansea rhyolite. The veins are as a rule nearly vertical with frequent croppings at the surface. They have general north-south courses but vary from N. 20° W. to N. 45° E. One, the Sunbeam, has been worked through a length of 2,000 ft. on the strike, but most of them pinched out at a distance of a few hundred feet.

As shown by the old workings, the veins vary in width from a few inches to 10 ft., usually pinching with depth. The average width is about 2 ft. The ore in its unaltered state consisted of silver-lead sulphides and sulpharsenides, occurring in bands and lenses in a gangue of quartz and pyrite. These materials constituted about three-quarters of the mass of the vein. Considerable copper occurred in some of the southern mines, while those in the north have produced lead and silver almost exclusively. Gold occurred sparingly in but few of the deposits. Ground-water level was usually encountered at a depth of from 200 to 700 ft., depending upon the proximity of the sediments. Above water level, the ores assumed the usual oxidized character, with some secondary enrichment. Below ground-water level there was marked decrease in the value and size of the orebodies. This and water troubles usually caused an early cessation of mining, and today all these properties, with one or two exceptions, are indefinitely abandoned. Since the closing of the Swansea mines in 1913 there has been no noteworthy production from deposits of this type.

3. *Replacements in Limestone*

The orebodies of this type are confined to the northern half of the Tintic district, and include all the now productive mines. Mining operations have developed four nearly parallel ore-bearing zones, within which the orebodies appear to be virtually continuous, though at intervals the connections may be mere seams of quartz. These zones have a general north-south direction and may be defined as follows:

1. The Eureka zone, including the Centennial Eureka mine on the south and extending through the Eureka Hill, Bullion Beck, and Gemini mines to the Ridge and Valley mine on the north.

2. The Mammoth zone, beginning at the Black Jack mine on the south and extending through the Lower Mammoth, Phœnix, Gold Chain, Mammoth, Grand Central, Victoria, Eagle, and Blue Bell mines to the Chief Consolidated mine on the north.

3. The Godiva-Sioux Mountain zone, beginning at the North Star mine on the south and extending through the Red Rose, Carisa, Northern Spy, Utah, Uncle Sam, Yankee, May Day, and Apex mines to the Godiva mine on the north.

4. The Iron Blossom zone, beginning at the Dragon Consolidated mine on the south and extending through the Black Dragon, Governor, Iron Blossom Nos. 1 and 3, Sioux Consolidated, Colorado Nos. 1 and 2, and Beck Tunnel No. 1 mines to the Beck Tunnel No. 2 mine on the north.

As might be inferred, these four zones include all the mines that have produced this type of ore. The Eureka zone is the shortest, and at its northern end is divided into two or more channels. At its southern end, it appears to connect with the Mammoth zone, through the Grand Central mine, in which case it is a branch of the Mammoth zone. These two zones lie on the west limb of the syncline, where the beds are nearly vertical and their orebodies have great vertical range.

The other zones are well defined throughout their length of about 2 miles and apparently have no interconnections. They lie near the trough of the syncline and their orebodies are correspondingly shallow.

Occurrence of the Ore.—Like replacement deposits in general, those of Tintic are very irregular in form, but in both shape and size they are governed within certain limits by the associated structures. This explains the dissimilarity in occurrence of the orebodies in the different zones.

In the Eureka and Mammoth zones, which are in the nearly vertical beds of the west limb of the syncline, ore has been mined from the surface to the depth of 1,800 ft.; the orebodies as a rule conforming very closely to the bedding in both strike and dip.

If any one form of orebody can be said to be typical of these zones, it is that of an irregular sheet, pinching and swelling along the line of the beds, and feathering upward into chimneys or pipes.

In an earlier report on the Tintic district[2] reference is frequently made to the north-south fissures, which, it is contended, have governed the course of the ore channels. The writer's investigations have not confirmed the common presence of such north-south fissures within the ore zones, but, on the contrary, have gone to show that practically all the major faulting and fissuring in the district is of the nearly east-west or transverse type.

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[2] Tower and Smith: Geology and Mining Industry of the Tintic District, Utah. 19*th Annual Report, U. S. Geological Survey,* Part III.

Where the ore channel is crossed by faults or zones of fracture, there is usually an enlargement of the orebody along the line of intersection of the faulting and the bedding. This gives rise to another very common type of orebody, characteristic of the western zones, where it is usually the most largely productive form.

At the intersection of the ore channel by a fault, it is not an uncommon occurrence to find that the line of mineralization turns from the plane of the beds and follows the fault for distances up to 100 ft. or more, before again taking the usual course along the beds. Occurrences of this kind probably also account for the occasional division of a single ore channel into two or more parallel ore channels.

In the Godiva-Sioux Mountain zone, the known orebodies have smaller vertical extent but greater lateral variation than do those in either the Eureka or Mammoth zones. This is probably due to the fact that the Godiva-Sioux Mountain zone lies nearer the trough of the syncline where the beds dip at relatively lower angles, seldom exceeding 60° and sometimes as low as 15°.

In the Iron Blossom zone, particularly in its northern half, we find still greater restriction in both vertical and lateral extent of the ore than in any of the other ore zones. This, again, can be attributed to the controlling influence of the structure, since this portion of the zone takes a course directly in the trough of the syncline. The south half of the zone traverses beds dipping at angles up to 30°, and here the orebodies resemble more closely in form those of the Godiva-Sioux Mountain zone.

Influence of Texture and Composition.—Next in importance to structural control is that of the texture and composition of the limestone. Other things being equal, the coarser-grained, softer, and less siliceous limestones are more susceptible to mineralization than are the fine-grained, more siliceous and harder ones, while the associated shales, sandstones, slates, and quartzite are uniformly barren. This principle is well exemplified in all the Tintic replacement deposits, as well as in the replacement deposits of other districts.

Among the several formations described above, there are only four which are known to be ore bearing. These are the Centennial, Gemini, Chief Consolidated, and Humbug limestones. In each case the ore-bearing formation contains several horizons of coarse, soft, and relatively pure limestone, while the remaining formations are more generally fine-grained, hard and siliceous, in that they carry varying proportions of shale and sand.

The influence of magnesia in the limestone is not clearly shown. One dolomitic horizon in the Chief Consolidated formation is quite generally mineralized, while another is only sparingly so. The dolomites are usually coarse grained—a favorable factor, which may offset the disadvantages of difference of solubility.

Zone of Oxidation.—By reason of the folded and broken state of the limestone beds, the ground-water level is extremely low (about 4,765 ft. above sea level), in the sedimentary rocks. This puts it at depths beneath the surface of from 2,300 ft. in the higher properties to 1,500 ft. in those having shafts at relatively lower positions. This condition has led to more or less complete oxidation of the original sulphide ores, with some downward segregation of the ore minerals, and some enrichment due to shrinkage in volume.

V. The Ore

Very little ore has been mined below ground-water level; but developments have demonstrated its continuity into that zone, and something as to its original sulphide character. Above the water table the ore is largely oxidized.

1. *Physical Character*

The oxidized ore is usually massive and granular and quite without structure. A distinct banding, observed locally, is attributed by some to the preservation of an original banding in the replaced limestone. Some soft ocherous material, which usually caps the orebodies, is thinly laminated or stratified—the effect of transportation and redeposition during the process of oxidation. Material of this type is usually found capping the larger bodies of oxidized ore and is encountered more particularly in the higher levels of the oxidized zone.

2. *Mineral Composition*

The ore minerals contain gold, silver, lead, copper, and zinc, in a gangue composed mainly of quartz and some pyrite in the unaltered ore, but with important quantities of calcite and iron and manganese oxides, and smaller amounts of barite and dolomite in the oxidized ore.

Gold is seldom visible, but occurs locally in the native state. Silver occurs native, and where unoxidized as the sulphide (argentite) and the antimonial sulphide (stephanite); but the original compounds are usually altered to the chloride (cerargyrite, or horn silver). Lead occurs originally as the sulphide (galena), but is largely altered to the carbonate (cerussite), with smaller amounts of the sulphate (anglesite), and one or two rarer forms. Copper occurs originally as the sulpharsenide (enargite), but is usually altered to the hydrous silicate (chrysocolla) and the hydrous carbonates (malachite and azurite). Some native copper has been observed which may be in part original. Zinc occurs originally as the sulphide (sphalerite), but is usually altered to the carbonate (smithsonite) or the hydrous silicate (calamine), with small amounts of one or two rarer forms.

3. *Distribution of the Ore Minerals*

From the earliest days an important variation in the north and south distribution of the ore minerals in the several ore zones has been noted. It appears that gold-copper ores predominate at the south end of the zones, gradually giving place to increasing proportions of silver-lead ores to the north, where the latter minerals predominate. As a result, the mines in the vicinity of Mammoth have been chiefly producers of copper and gold, while those in the vicinity of Eureka are chiefly producers of silver and lead. Zinc is found associated with the ore of both ends of the district, probably more frequently in the mines at the north. Vertically the ore zones show no such striking variation in mineral content; but generally the good gold stopes are in the upper levels.

The vertical extent of an ore zone is governed primarily by the accompanying structures. The more nearly vertical are the inclosing beds the greater the vertical range of the orebody. The presence of faults and fissures also favors greater vertical range, irrespective of the angle of the bedding. Their influence is greatest, of course, where the bedding is nearly vertical. The large orebody in the south end of the Chief Consolidated mine, which has a vertical range of 1,000 ft. or more, rakes along the inclined line of intersection of vertical beds and a large cross break.

4. *Origin of the Ore*

The occurrence of the Tintic deposits both within the monzonite and in the immediately adjacent limestones; the character of the mineralization, which is now generally considered to be due to the action of hot solutions; the progressive change in the mineral composition of the ore with increased distance from the monzonite—all point to this rock as the prime factor in the mineralization. In this respect, the deposits of Tintic are like the many others in the southwestern part of the United States, and particularly in western Utah, which are as a rule closely connected in origin with igneous (commonly monzonite) intrusions.

The localization of the deposits within the monzonite was determined by the formation of stretch fissures within the congealing magma, which furnished channels of circulation for the hot solutions that were given off during the period of cooling. These hot solutions chloritized the ferromagnesian minerals, sericitized the feldspars of the wall rocks, and filled the fissures with an aggregate of quartz, pyrite, galena, sphalerite, barite, and some copper, silver, and gold minerals, probably because of a decrease in pressure and temperature as the solutions approached the surface. Alteration above ground-water level has changed these minerals to their oxidized equivalents, with some secondary enrichment.

The localization of the deposits in the limestone was controlled in part by the attitude and character of the beds and in part by the presence of fissures, some of which were probably produced during the period of monzonite intrusion.

Following the fissures caused by the intrusion, the hot mineral-bearing solutions found their way through the fractured and metamorphosed zone into the unaltered limestone, where they naturally took the easiest avenue afforded. This, in the absence of open faults and fissures, was the plane of the bedding.

Where the dip of the beds approached the vertical, the solutions found channels at various elevations, ascending or descending as conditions allowed, but laterally confined to relatively narrow limits. Flat-lying and low-pitching beds, on the other hand, have tended to confine the solutions to a more nearly horizontal course, at the same time permitting greater lateral shift.

At the intersection of faults, the solutions were allowed to spread out both vertically and laterally, producing orebodies of large size and great vertical range.

The process of mineralization has been primarily a replacement of the limestone with quartz and varying proportions of copper, lead, zinc, and silver sulphides, presumably due to decreasing temperature and pressure in the solutions as they run their northerly course.

Soft, coarse-grained, nearly pure limestones have been much more readily replaced by the solutions than the harder, fine grained, and more siliceous beds. Certain horizons of the latter type, even where directly in the course of the mineralized zone, are found to be uniformly barren.

VI. Prospects for the Future

Of the four zones so far developed, not one has been traced to a logically demonstrated terminus; and it is by no means established that similar and equally productive zones do not exist, still undiscovered, in the district.

Since the inception of mining, following the first discovery in 1869, the trend of production in the district has been steadily upward. Great mines have come and gone; but there have been always new ones to take their places. The greatest production in the district's history was attained but two years ago, and that of the coming twelve months promises to exceed it. In view of these facts, and of the tendency to better and more improved methods of mining as our knowledge of the deposits is extended, the conclusion is inevitable that the Tintic district has still to experience the most prosperous period in its history.