G E O L O G Y A N D O R E D E P O S I T S

O F T H E S A N T A Q U I N

M I N I N G D I S T R I C T.

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B Y:-

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Presented in Partial fulfillment of the requirements for the degree of Bachelor of Science in Mining Engineering at the University of Utah.

M A Y - 1 9 1 0

C O N T E N T S

I N T R O D U C T I O N.

GEOGRAPHY:

The Santaquin Mining District lies in the south western part of Utah county, in the north central part of Utah. It is inclosed between meridians 111 46' and 111 47' west, and parallels 139 56' and 139 57' north. The district under consideration is three miles long north and south by two miles wide, on the western face of the Wasatch Mountains, directly east of Santaquin.

The Wasatch range of mountains is the principal range in Utah, extending almost due north and south and is one of the ranges formed by the system of block faulting, which occurred in late Cretaceous times.

The town of Santaquin is the center of a farming community of about 1,000 inhabitants, located at the foot of the mountain on the old Bonneville lake level. It is 67 miles south of Salt Lake City, on the San Pedro railroad.

FIELD WORK AND ACKNOWLEDGEMENTS:

The geological field work upon which the report is based was begun in the latter part of November, 1909, six days having been spent in the field at this time. A second visit of three days was paid to the district in March, 1910, during which the field work was completed.

We take advantage of this opportunity to extend our sincere thanks to Mr. G. L. Bemis, the manager of the Union Chief Mine, and to his foreman, Mr. A. N. Larsen, who assisted us very materially during the field work. In both our field work and sub-

sequent determinations we are greatly indebted to the able assistance of Dr. Fred J. Pack, Deseret Professor of Geology at the University of Utah, and this paper is due largely to his helpful suggestions.

LITERATURE:

To our knowledge there is no literature dealing with the geology of the Santaquin district. The district, however, has been mapped in a general way, both by the Fortieth Parallel Survey and by the United States Topographical Survey.

TOPOGRAPHY:

The mountains in this district are very steep, rugged, and serrated; the top of the divide being about 5,000 feet above the Bonneville lake level. The mountain side is cut by a number of steep ravines running almost east and west, the drainage being towards Utah lake on the west.

"Western face of Wasatch Mountains from Santaquin."

The gullies from north to south are named as follows:

Spring Creek Canyon
Yellow Rock Canyon
McGee's Canyon
Broad Hollow Canyon
Green's Canyon
Jump-off Canyon
Little Man's Canyon
Danish Hollow
Burgeson's Canyon
Paradise Canyon
The Gap
Santaquin Canyon

Of these, the Santaquin canyon is by far the most important, it being the only one having flowing water the year round, and extending far back into the mountains. This is probably due to the fact that the canyon is entirely in limestone and the beds are greatly contorted in this vicinity, giving free access to erosive agencies.

The steepness of the western face of the mountains is due to the great Wasatch fault along this face, it having been preserved by the hard resisting qualities of the rock. Of the rocks, the quartzites stand out in boldest relief, forming prominent cliffs along the mountain side.

On the whole, the topography of this district is mature. This is shown by the serrated nature of the mountains, and the great amount of erosion that is going on.

P A R T I.

S T R A T I G R A P H Y

By

M. O. Packard, Jr.

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DISTRIBUTION AND CHARACTER OF ROCKS:

The accompanying colored aerial map is designed to represent fairly well the distribution of the formations of the Santaquin Mining district. Strict accuracy is not claimed, the elevation being taken from a topographic map, which assisted very materially in locating the principal topographic features.

The Wasatch mountains, east of Santaquin, consist of an anticline plunging 54° almost due east. This anticline faces the west and is greatly eroded. A clear-cut view of the strata is best seen from the distance.

The best section of the sedimentary formation is directly under the axis of the anticline.

The strata comprising the upper part of the anticline consists of quartzite, shale, and limestone. When this formation is projected on a plane they form semi-concentric areas around a core of gneiss. In one place the formation is noticeably faulted as the shale on one side comes in contact with the above limestone; and on the other side with the lower quartzite.

IGNEOUS AND SEDIMENTARY ROCKS:

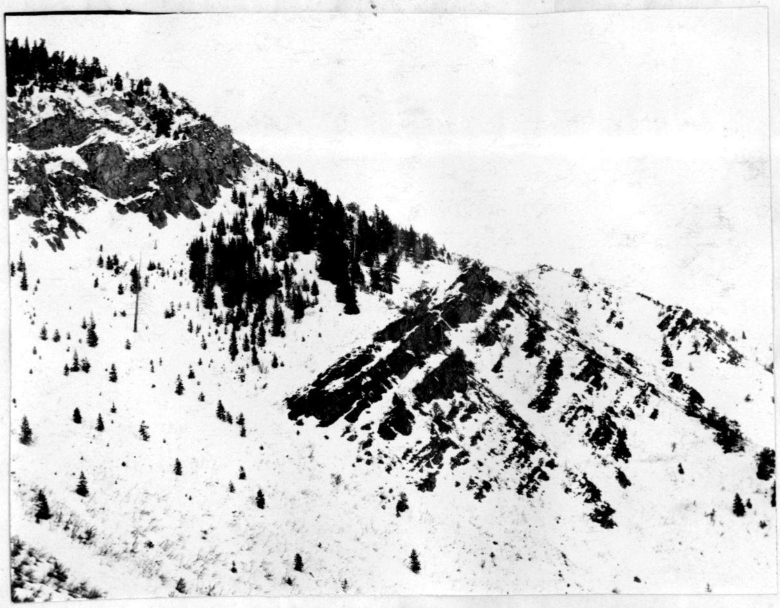
Gneisses and Granites

The gneisses and granites are the lowest formation. The gneisses are of meta-igneous and meta-sedimentary origin. Pink granites are intruded into the gneisses as large irregular masses and sometimes extend up to the overlying quartzite. Near the base of the mountain the granites are coarse grained and in places become almost pegmatites, these being large coarse crystals of quartz, imbeded in a pink or flesh colored ground mass of orthoclase. Higher up near the quartzite they become rather felsitic. In places, the granite appears to be included in the gneiss, and in other places, the gneiss appears to be included in the granite. Just below the top of the big knoll on the north side of Green's Canyon, there is a large dyke of coarse grained granite, extending in a north-westerly and south-easterly direction. This dark granite is included in the pink granite and is undoubtedly yonnger than the pink granite. These gneisses and granites form the core of the anticline.

Quartzite.

Overlying the gneiss and the granites and resting unconformably on them is 400 feet of dark quartzite. Above this is an unconformity, and above which is a conglomerate three to six feet in thickness, that grades into a lighter colored quartzite, 600 feet in thickness. The unconformity and conglomerate are persistant in the anticline; the unconformity represents the so called lost interval. The beds and formation below this unconformity are pre-Cambrian as is seen from conclusions farther on in this paper.

The original bedding planes of the quartzite are very distinct as is seen from the accompanying picture. The quartzite is very hard and rings under the hammer, and is not highly fractured or faulted. Because of its great ability to resist weathering agencies, great masses of it are prominent.



"Picture showing bedding planes of the Quartzite."

Shale

Overlying the quartzite and resting conformably upon it is a bed of shale 50 - 100 feet in thickness. This shale fringes the anticline. Only small portions of it are accessible, most of it being covered by decayed and brecciated material ffom the overlying limestone. This is a finely laminated deposit,and can be taken out in slabs which are easily broken and crushed.

There is another bed of shale in Green's Canyon, just below the unconformity, but is not persistant, and appears to be wholly local.

Limestone

The limestone is the upper portion of the anticline, and is much more extensive than the quartzite or shale. It lies conformably upon the shale and extends to the top of the ridge, and as far east as Payson Canyon, on the east side of the mountain. The limestone is hard and the strata are not well defined, yet they are not exactly similar, there being some strata more siliceous than others. On a whole, however, it is siliceous and rings under the hammer almost the same as quartzite. It weathers in rounded masses.

CORRELATION OF STRATA:

Cambrian

Upon the Wasatch east of Centerville, unconformably overlying the Archean gneisses, is a body of salmon-colored quartzite, containing large gritty grains of pellucid-quartz, and underlaid by a dark heavy bed of purple quartzite. The salmon-colored quartzite is about 600 feet thick, and is overlain by a few calcareous shales which are immediately succeeded by Ute limestone 1,000 feet thick, showing transition from Cambrian to Silurian. (Vol. I. U.S. Geo. Exp. of 40th Parallel, p. 174)

Dioritic gneisses, the prominent feature of the Archaean near the mouth of Ogden Canyon, are unconformably overlain by Cambrian quartzite. Here, are about 1,000 feet of quartzite overlain by 100 feet of siliceous and argillaceous shales, showing an evident transition into the overlying Ute limestone.

The argillaceous shales, which here as elsewhere close the Cambrian series, are exceedingly fine grained, and are prevailing olive and greenish gray in color, and are identical with the beds from the same horizon which underlie the Ute limestone at Quebec Peak, at the forks of the Muddy. (Vol. I. U.S. Geo. Exp. of 40th Parallel, p. 175)

The Cambrian series at the mouth of Big Cottonwood Canyon consist of 800 feet of slates at the bottom; varying salmon-colored and argillaceous beds, containing some mica-bearing zones, 8,000 or 9,000 feet thick; salmon-colored and white quartzite, intercalated with dark schists, 2,500 to 3,000 feet thick;

and a capping of schist 200 feet thick. The contact between the series and the underlying unconformable mass of granite and Archaean schists, is nearly horizontal and extends back six miles at a little below the town of Alta, successively higher members of the Cambrian series rest against the granite until at last the ancient series rise into contact with the Silurian limestone. (Vol. I. U.S. Geo. Exp. of 40th Parallel Sur., p. 167)

The above description shows that the Cambrian of Big Cotton-Wood Canyon is different than at Centerville, and Ogden Canyons.

Pre-Cambrian

Farmington Gneisses

First, we have a coarse grained gneiss which is composed of large crystalline masses of flesh-colored orthoclase, and partially decomposed earthy brown magnesian mica with irregular bodies of pure milky-white quartz. Over these coarse Farmington gneisses is a series of fine grained gneisses in which the feldspar and quartz are both white and the mica muscovite. The gneiss contains minute garnets. A little higher in the series is another gneiss containing a predominance of white mica (muscovite) with a little hornblende, and is rich in garnets. Above this is a heavy group of dark green hornblende-gneisses rich in feldspar and apatite. The hornblende is more or less fibrous, varying from a dark green to black in color. (See 40th Parallel Survey Vol. I.)

AGE OF THE ROCKS:

The pre-Cambrian age is divided by Chamberlain and Salisbury, into Proterozoic and Archaezoic, while Van Hise and Leith use the terms Algonkian and Archaean, objecting to the term "zoic" because the life of the pre-Cambrian is practically unknown.

This paper follows the divisions of the pre-Cambrian as used by Van Hise and Leith, in Bulletin 360 of the U. S. Geo. Survey. This classification is also used by the U. S. Geo. Survey in all its publications.

The Algonkian is characterized by well assorted sediments which give evidence of extensive decomposition of land areas, and of the passing of normal cycles of erosion. Igneous rocks are usually present in abundance but are subordinate to the sediments.

The Archaean rocks are highly folded, contorted, mashed, and metamorphosed. The older rocks have been intruded again and again by igneous rocks on a scale greater than in any of the following ages. Thus the Archaean ages present an intricacy of structure and metamorphiom unsurpassed in any other age, and thus is characterized mainly by igneous rocks with sediments in a very small quantity.

King, (1878) states that in the Archaean outcrops of the 40th parallel, one can not fail to notice the widespread simplicity of petrological forms; the prevalence of the granites, granitoid gneisses, etc. (Bull. 360 U.S. Geo. Survey, p. 73)

At Farmington Canyon, we have practically the same pegmatetic material in the Archaean that we have at Santaquin. Dr. Fred J. Pack, of the University of Utah says, that this pegmatite often occurs in the Archaean. Without a reasonable doubt these gneisses and granites of Santaquin, are Archaean in point of age.

Van Hise and Leith say that the Belt series of Montana in its now known extent constitutes the greatest area of the Algonkian on the continent, and it may be that it should be extended to include Utah, Colorado, and Arizona quartizites. (Bull. 360 U.S. Geo. Survey, p. 41)

The quartzite of the Wasatch mountains of Utah which have previously been assigned to the Algonkian, rests upon the Archaeon with tremendous unconformity. (Bull. 360 U. S. Geo. Survey, p. 39)

For much the larger portion of the continent distinctly recognizably Cambrian rocks rest with profound unconformity upon distinctly recognizable pre-Cambrian rock. (Bull. 360 U. S. Geo. Survey, p. 37)

As stated previously, above the gneisses and granites at Santaquin, there is 400 feet of pink quartzite above which there is a profound unconformity that is traceable throughout the country by means of a conglomerate. This quartzite indicates mature weathering, and from information obtained from Van Hise and Leith, we can conclude reasonably that this quartzite is Algonkian. This quartzite may belong to the great Belt series of Montana.

The strata above this profound unconformity are post-Algonkian. A comparison of these strata with strata of the Cambrian age, as described in this paper of Farmington and Ogden canyons, one can almost conclude that they are of Cambrian age. With information obtained by correlating fossils found in the field, with those of Cambrian age, we conclude that the shale is Middle Cambrian, and that the material down to the unconformity is also Middle Cambrian. The strata above the shale undoubtedly grade into the Upper Cambrian, although no fossils were found above the shale. It is also reasonable to suppose that the Cambrian grades into the Ordivician, and this into the Silurian, although there is no direct evidence proving that such is the case.

FOSSILS:

Cambrian Fossils from the Wasatch Mountains near Santaquin, Utah.

In America the Cambrian age has been divided into three zones. Each zone is represented by a characteristic fauna. The divisions are as follows:

Upper Cambrian - Dikellocephalus Zone

Middle Cambrian - Paradoxides Zone

Lower Cambrian - Olenellus Zone.

In Utah in the Wasatch mountains the Cambrian age appears to be represented by the middle and upper zones.

The fossils procured at Santaquin, were found on the south side of Green's Canyon, on a little ridge which is almost due south of the lower cabin of the Union Chief Mining Company; on the Chief dump, and also on the old Wasatch dump, which is about 200 yards south of the Wasatch tunnel, and about 50 feet higher up the mountain.

The fossils found are correlated with Cambrian fossils as found in Bulletin 30 of the U. S. Geo. Survey, and as found in Dr. Fred J. Pack's paper on the Cambric Fossils from the Pioche Mountains, Nevada.

Description of Species

C r u s t a c e a

T r i l o b i t e s

Genus Bathuriscus, Meek.

Bathyuriscus, Meek, 1873: Sixth Annual Report, U. S. Geo. Survey of the Territories, p. 484.

Bathyuriscus Howelli, Walcott.

(Fig. 4 & 5)

Bathyuriscus Howelli, Walcott, 1886: Bulletin No.30, U.S. Geo. Survey, p. 216, Plate 30.

Emblominus rotunda, Roem, 1887.

Proceedings of the Academy of Natural Science, Philadelphia, 1887, p. 16, Plate I.

Cambric Fossils from the Pioche Mountains, Nevada; Pack, p. 7, Plate II.

This species was not found as one fossil. Cephelons and pygidia were found, but were not well enough preserved to give detailed characteristics.

Bathyuriscus productus, H. & W.

(Fig. 3)

Ogygia productus, Hall & Whitefield, 1887: Geological Exploration of the 40th Parallel, Vol. IV., p. 244, Plate 2.

Bathyuriscus producta, Walcott, 1886: Bulletin No. 30, U. S. Geological Survey, p. 217, Plate 30.

Cambric Fossils from the Pioche Mountains, Pack, p. 8 Plate II.

This is a very characteristic form, and occurs in great abundance. Cephelons and pydidia were found in great numbers One excellently preserved fossil was discovered and appears to differ with figures of Mr. Walcott, and Dr. Pack, in that the axial lobe is well rounded out from the pygidia, and bends in as it comes to a point. This may be a characteristic of this one fossil only.

Brachipoda

Kutorgina pannula, White

(Fig.2)

Tremantis ? pannula, White, 1874: Geographical and Geological Exploration and Survey, West of the 100th Meridan, Preliminary Report "Invertebrate Fossils" p. 6.

Kutorgina pannula, Walcott, 1886: Bulletin No. 30, U. S. Geological Survey, p. 105, Plate VII & VIII.

Cambric Fossils from the Pioche Mountans, Nevada, Pack, P.7 Plate II.

We procured but one good specimen of this species, and it differs with the figure on plate VII in Bulletin 30, U. S. Geological Survey, given by Mr. Walcott, but conforms very well with his figures given on plate VIII of the same Bulletin. Mr. Walcott's description fits this specimen very well, except that there are no pore-like pits, but minute elevations which in a measure take the place of the depressions. This specimen is about nine millimeters wide, and nine millimeters long.

Genus Lingulella, Salter

Linguella, Salter, 1861: Memoirs Geological Survey Great Britain, p. 333.

Lingulella Caelata, Hall (sp.)

(Fig.2)

Orbicula caelata, Hall, 1847: Pal. N. Y., Vol. I, p. 290, pl. LXXIX, figs. 9a-c.

Obolella (O). caelata, Ford, 1871: American Journal Science, 3d, ser., Vol. II, p. 33.

Lingulella caelata, Ford, 1878: American Journal Science, 3d, ser., Vol. XV, p. 127.

Bulletin No. 30, U. S. Geological Survey p.95, Plate VII.

<u>Genus Orthis Dalman</u>

Orthis Dalman, 1827: See Brit. Foss. Brach., Vol I; Genl. Introduction, p. 101.

<u>Orthis ? Highlandesis n. sp.</u>

<u>Orthis? Highlandensis</u>, Walcott, 1886: Bulletin No. 30, U. S. Geological Survey, p. 119, Pl. VIII.

(<u>Fig.</u>6)

The above fossils were usually found in the same stratum. Some time one species is well preserved, and some times another. Many fragments of fossils were found. The brachepods seem less easily destroyed, when the shale is broken while it is damp or wet.

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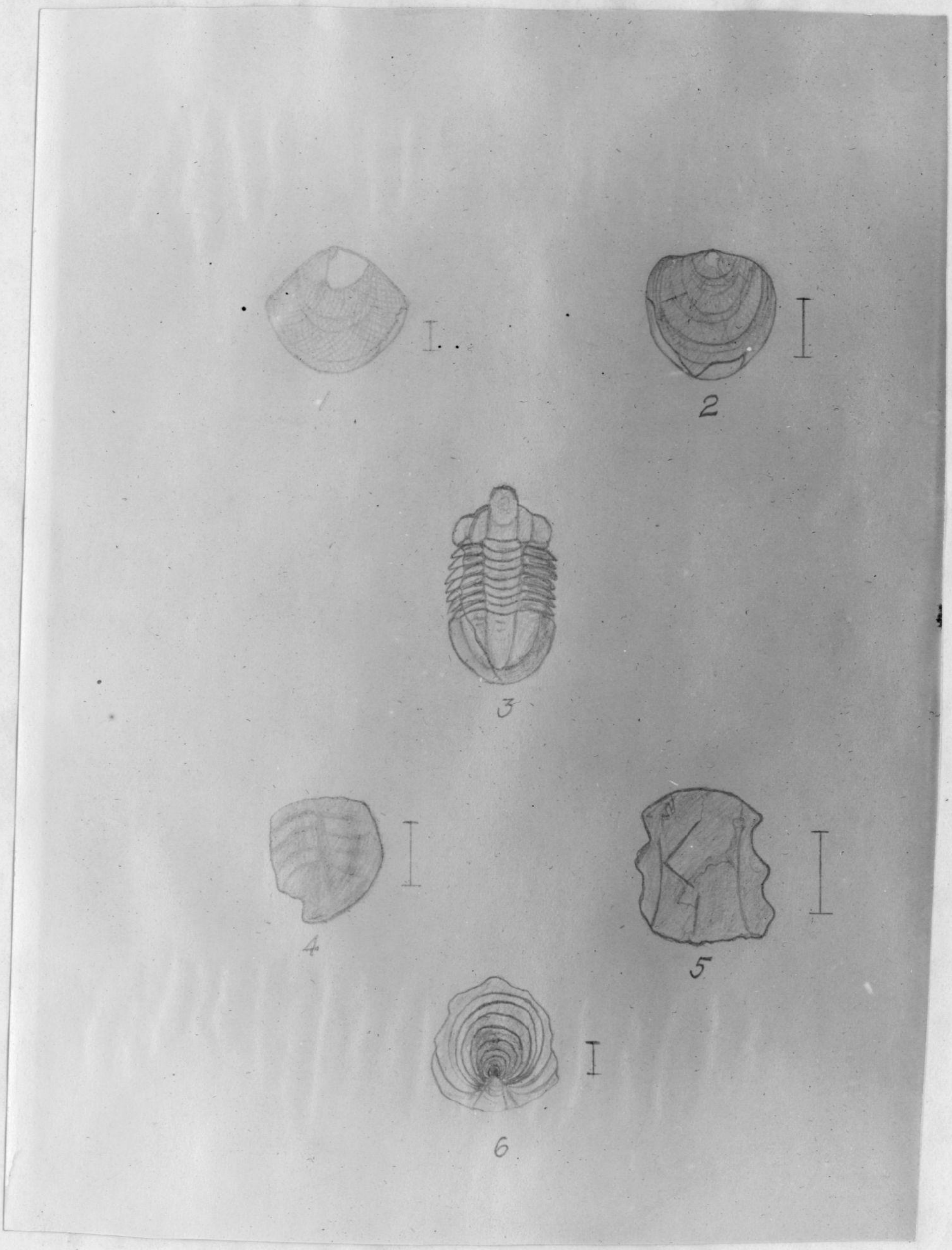


"Cambrian Fossils from the Wasatch Mountains, near Santaquin."

P A R T II.

S T R U C T U R A L G E O L O G Y

By-Fred A. Hale, Jr.,

INTRODUCTORY STATEMENT:

The pre-Cambrian and later rocks of the Santaquin district have been affected both by folding and faulting, while igneous intrusion has played no small part. The readily traceable beds make it comparatively simple to work out the larger structural features of the district, but the scarcity of good exposures in some large areas renders the detail quite difficult. Enough data were obtained, however, for recoganizing the great fold, for tracing most of the great faults, and for making some generalizations in regard to the character of the minor structural features.

The age of the separate faults, folds, and igneous intrustions presents some difficulties. In no place is one fault clearly thrown by another. It is evident, however, that the structural features have been in some degree contemporaneously formed, and the work of the same forces.

In the following pages, devoted to structure, some account of the folding will first be given, the general character of the faults will be described, followed by a discussion of the igneous intrusions.

FOLDING:

The rocks of the Santaquin district have been thrown into one large plunging anticline, resembling a dome. The major axis of this anticline extends almost due east and west, the apex being in the vicinity of Little Man's Canyon, immediately south of Green's Canyon. The anticline plunges sharply to the east, the beds in the vicinity of the Union Chief Mine, dipping about

52° East, and at the top of the divide to the east, which is stratigraphically higher, about 40 East. The southern limb of the anticline is cut off by a large fault in the vicinity of Santaquin Canyon, and the northern limb is gradually lost in the Bonneville sediments of the valley.

The anticline is very well shown on the steep western face of the mountains, a projection of which is given in Plate II-A, while Plate I-A, shows the dip of the beds along the axis of the anticline.

No local folding of any consequence was shown in the district. Immediately south of Santaquin Canyon, however, the rocks, which are of a much later geologic age, have been locally, greatly folded and distorted, showing the presence of local dynamic agencies not present in the older rocks.

FAULTING:

The Great Wasatch Fault.

The steep western face of the mountains in this district is due largely to the presence of the great Wasatch fault, which extends along the base of the mountains, the mountain-side forming the eroded escarpment of the old fault.

The Wasatch fault has been described by King, in the 40th Parallel Survey, as having an accumulated throw of about 40,000 feet, and it is considered one of the largest faults known to geology. The general strike of the fault is north and south, and it may be traced for a distance of about 150 miles from Collinston, in Box Elder County, to the southern part of Utah County. The western block is down-thrown.

This fault belongs to the vast system of block-faulting known to exist between the Wasatch and Sierra mountains, the origin of which dates back to late Cretaceous times. That there have been recent movements along this old fault-plane, is well shown by a 20 foot escarpment, little altered by erosion, which occurs immediately south of Green's Canyon, just above the old Bonneville lake-level.

Local Faulting

Evidences of Faulting.

The existence of a fault in this district is best proved when a formation is found in contact with another, not adjacent to it in the normal stratigraphic sequence. In no places can the planes of the major faults be observed in underground workings, nor was a fault breccia noted in any case.

Although the positive demonstration of faulting depends on the above, the existence of a fault is frequently suggested by certain topographic features. In this district, the fault lines are characterized by gullies in which relatively rapid erosion has taken place along the fractured zone, and by saddles where the faults cross the top of the divide. In places, as in the McGee's Canyon fault, there is an abrupt change of slope along the fault plane, due to differential erosion.

General Character and Direction of Faults.

In this district, it was impossible to determine the dip of the faults, as there were no direct exposures of the fault-plane.

For the same reason it was difficult to determine whether the faults were normal or reversed, but from the character of the outcrops, it would appear that most of the faults in the district are of the normal type, having very steep, almost vertical dips.

Most of the faults abserved had a throw of from 50 to 1,000 feet, thus making them evident, for while multitudes of smaller faults doubtless exist, the conditions do not admit of their being traced.

In direction, most of the faults are nearly east and west. They have a slight radial tendency, striking toward the axis of the anticline, which shows that their origin may be contemporaneous with that of the anticline, as, in the folding, the greatest strain would occur along radial lines from the pole or axis.

Description of Principal Faults.

The dislocation that has the greatest throw will be designated the Santaquin Canyon fault, from its proximity to that canyon. This is a normal fault, with strike nearly due east and west, and with the down-throw on the south. It is distinctly traceable up Santaquin Canyon to the point wherethe gulch, locally termed the "gap", branches off from the main canyon, and thence up this gulch to the top of the divide. The fault here is well shown by erosion, and also by the unlike character of the adjacent beds. The throw must have been at least several hundred feet, as the limestone on thenorth has, to the south, completely disappeared under the lake sediments.

Another fault with a throw of about 100 feet was noted in

Little Man's Canyon, just south of Green's Canyon. This, too, is of the normal type, but with the northern block down-throw. It strikes nearly due east and west. The fault-plane is well shown by an erosion gully, which continues to the top of the divide, and also by the bed of shale, which has been plainly displaced.

The fault which was noted in McGee's Canyon may be called the McGee's Canyon fault. This is of the normal type, with the northern block down-thrown, andstrikes about north 60° east. The throw is in the neighborhood of 1,000 feet. The fault is well shown by erosion, and also by the adjacent beds, as the limestone to the north is found abutting the granite to the south. The fault-plane passes in the neighborhood of the old iron-mine in McGee's Canyon, but is not revealed in any of the underground workings.

MINOR FAULTS AND FRACTURES:

In the vicinity of the Union Chief Mine in Green's Canyon, there has been considerable local faulting and fracturing. There are apparently two distinct sets of fractures, one striking north 40° east, and the other almost due east and west. The dip of these fractures is, in all cases, very steep, being almost perpendicular. Some of these fissures are filled and some open, while some show movements along the planes of fractures, while others do not. In no case has the displacement exceeded a few feet. The movement is well shown by slickensides in the underground workings, both along the fracture-planes and in some instances, along the bedding-planes of the limestone.

The faulting and fracturing in this vicinity is evidently greatly localized, and may be due to the proximity of an igneous intrusion, which has not been uncovered by erosion. Further credence is given to this theory by the presence of porphyry sheets, but a short distance up the mountain.

IGNEOUS INTRUSIONS:

Archaean Macro-Granite Intrusions.

Intimately associated with the pre-Cambrian gneisses are found a series of intrusive sills of an exceedingly coarse grained granite. These sills vary in thickness from a few inches to several feet, and in all cases, apparently follow the bedding planes of the gneiss. The origin and relative age of the Archaean granites have long been open questions with geologists, and as yet are undecided. That the granite is younger than the gneisses is shown by xenoliths of gneiss contained within the granite, while the coarsely crystalline nature of the granite signifies that it was crystallized under great pressure, and consequently at great depths.

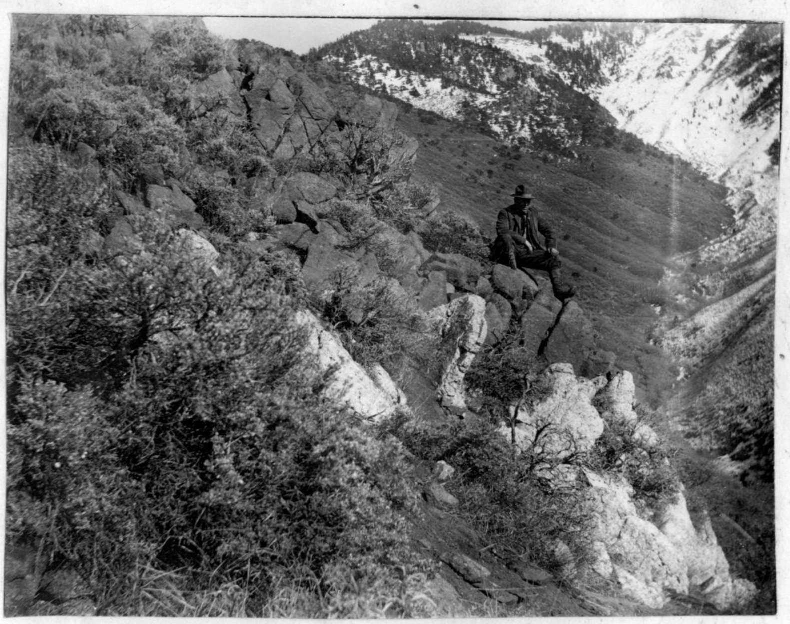
Contact Granite Intrusive Sill.

Along the unconformity between the Archaean gneisses and the Algonkian quartzite, is formed an intrusive sill of a fine-grained pink granite. This sill varies in thickness from 20 to 50 feet and is universally found wherever the contact is exposed. At places, notably in the vicinity of Green's Canyon there are small dykes of the same material, which cut across the bedding-planes of the gneiss, and are evidently tributaries of the main intrusive sill.

No xenoliths of the overlying quartzite were found within the granite, but from the obvious intrusive contact, it is evident that the intrusion occurred after the quartzite was deposited. The crystallization of the granite gives evidence of slow cooling at considerable depth, and it is probable that the intrusion occurred before the folding, and has only been exposed since by erosion.

Dark Granitic Dyke.

In Green's Canyon, immediately west of the intrusive contact between the gneiss, and the pink granite is exposed a dyke of a dark fine-grained granite.



"Contact of Dyke and Archaean Granite, Green's Canyon."

This dyke varies in thickness from 12 to 20 feet, and its walls are evidently almost perpindicular. Its strike is approximately south 10° east. The dyke cuts the gneiss and macro-granite, but disappears in the pink intrusive sill granite, and does not cut the overlying quartzite. This shows that it is either older than the quartzite, or contemporaneous with the other granite. From the fact that the two granites are quite similar in character, it would appear that the latter is the true theory.

Andesite Dyke.

In the Black Balsam tunnel, near the mouth of Green's Canyon, is exposed a small dyke of andesite. The dyke is about 2 feet in width, and strikes north 40° east, with walls practically perpendicular. The dyke was traced on the surface for some distance, out into the quartzite.

The dyke is so small as to be practically unimportant, but it is interesting, in that it is composed of a rock of an entirely different character from the other igneous rocks of the district, and it represents a different period of igneous activity; and one probably of a much later date than the intrusions hitherto described. Again, the rock weathers very easily and consequently is very difficult to observe on the surface, and it is quite possible that there are other intrusions of this nature in this vicinity which have escaped notice.

Porphyry Sills.

Near the top of the divide between Green's Canyon, and Broad

Hollow, and about 1/4 mile east of the Union Chief Mine were noted two sills of a yellowish porphyry. These sills were about 1 to 2 feet in thickness, and apparently followed the bedding planes of the limestone. The rock is so badly weathered that it is difficult to trace the sills for great distances.

This intrusion is the closest to the Union Chief Mine, and the fractured condition existing there, together with numerous iron fissures radiating from these sills would lead one to believe that there may be a larger intrusion of igneous rock in this vicinity. The sills may have been forced between the limestone beds by the intrusion of a much larger body of igneous rock, of which they are only a small part, and the greater mass has not been uncovered by erosion.

HISTORY OF STRUCTURAL DEVELOPMENT:

At this point, it might be well to summarize the chronological events of the structural development of this district, as far as it is possible from the evidence obtained in the field.

Concerning the macro-granitic intrusions, little concerning their age can be determined. It is probable, however, that they occurred in pre-Cambrian times, as the pre-Cambrian rocks are invariably associated with intrusives of a similar character, and igneous forces are known to have been active at that time. The evidence, however, is only inferential at best.

The granitic intrusion, which occurs between the Archaean gneiss, and the Algonkian quartzite, undoubtedly occurred subsequent to the deposition of the quartzite, and prior to the folding. In other words, the intrusion must have occurred between Algonkian and Cretaceous times, but no more definite information could be obtained.

That the folding occurred in late Cretaceous times is answered by the fact that it is well known that the entire Wasatch range of mountains had its birth at this time. The evidence in the field is also rather conclusive that most of the faults were contemporaneous with the folding, so that, they too, had their origin at this time.

Perhaps the most recent event in the structural history was the intrusion of andesite. That it is older than granites is shown by the fact that it cuts the granites, and from its general character, it is evident that it is also older than the folding, which would make it post-Cretaceous. It is not unlikely that this intrusion occurred in Tertiary times, as it is well known that igneous forces were very active in the west at that time.

But, little can be determined concerning the age of the porphyry, other than that it is post-Cambrian. A more detailed study might prove that it was in some way related to the andesite, and that the two were contemporaneous in origin, but, with the present data, such a theory is but inferential.

P E T R O G R A P H Y

By

Fred A. Hale, Jr.

METAMORPHIC ROCKS:

The pre-Cambrian Gneiss.

A gneiss is a metamorphic rock which may be derived from either sedimentary deposits or igneous material. It possesses a characteristic flow-structure, the long axes of the crystals being in a definite direction, and is largely distinguished from the schists by its coarser texture.

This gneiss is of a uniformily dark-green color although at times it takes on a grayish tinge. It possesses the characteristic gneissoid texture and, like all crystalline gneisses. has an imperfect cleavage but megascopically exhibits the characteristic flow-structure.

The microscope shows that the essential constituents are hornblende in an amorphous groundmass of quartz, and feldspar. These form a coarse-grained aggregate, and occasional augite crystals, also appear. See Plate L, figures 1 and 2.

There is considerable evidence to show that the gneisses are derived by metamorphism from coarse-grained sediments although, microscopically, the crystals show very little tendency to parallelism along their major axes. The highly silicious character of the gneiss suggests sedimentary origin. There is no decisive indication of former bedding planes, but the gneiss frequently shows good evidence of having been conglomeritic in nature. We are justified, then, in concluding that at least the greater part of the gneisses are of sedimentary rather than of igneous origin.

The metamorphism of these gneisses, which has been remarkably uniform, may have been due in part to the obvious contact action of intrusive masses, but the process seems to be more nearly a case of regional metamorphism. For this alteration, deep subsidence, and burial under later deposits, intense folding, and time for the completion of slow crystallization and chemical rearrangement, are considered efficient causes.

SEDIMENTARY ROCKS:

The pre-Cambrian Quartzite.

Quartzite is a metamorphosed sand-stone, and consequently implies near-shore deposition. The pre-Cambrian quartzite in this district is a dense , hard, reddish rock, occurring immediately above the gneiss. The microscope shows that it is composed of fine-grained fragments of quartz, cemented by a silicious cement, highly stained by compounds of iron. See Plate I, figure 3.

"Exposure of pre-Cambrian Quartzite in Green's Canyon."

This quartzite has evidently been derived from a fine-grained and rather thin-bedded sandstone, the alteration, as with the gneiss being due to regional metamorphism. As shown in the accompanying photograph; its hard resisting qualities cause it to stand out in bold relief along the mountain-side.

Cambrian Quartzite-Conglomerate.

The Cambrian quartzite-conglomerate is composed of rounded quartzose pebbles, varying in size from 1 to 2 centimeters, cemented by a silicious cement. The pebbles grade insensibly in size into the overlying Cambrian quartzite. The rock does not resist the weathering as well as does the quartzites, and consequently no very good exposures were found.

"Exposure of Cambrian Conglomerate in Green's Canyon."

The pebbles are composed of a perfectly homogeneous quartz and have evidently been derived from the underlying quartzite in the form of sandstone, and subsequently altered to quartzite by regional metamorphism. The size of the pebbles which constitute the conglomerate implies very near-shore deposition.

Cambrian Quartzite.

The Cambrian quartzite is easily distinguished from the pre-Cambrian quartzite by its lighter color, it being of a faint pinkish color, but like the pre-Cambrian quartzite, it is a dense, hard, homogeneous rock possessing no cleavage, but the characteristic quartzitic fracture.

The microscope shows that it is composed of quartz grains of much greater size than the pre-Camorian quartzite, as will be seen by a comparison of the two micro-photographs, figures 3 and 4, Plate L. Like the other quartzite, however, the cementing material is silicious, but only faintly colored by ferruginous compounds.

The origin of this quartzite is similar to that of the pre-Cambrian quartzite, it having been originally a rather coarse-grained sandstone, subsequently altered by regional metamorphism.

Cambrian Shale.

A shale differs from a sandstone or quartzite very largely in texture, it having been derived from fine-grained muds or silts subsequently indurated. It is usually deposited in deeper water than are the sandstones. Its composition is, of course, also somewhat different.

The Cambrian shale in this district occurs in dark thin-bedded layers, gray in color, but having a greenish tinge when seen in mass. The individual beds are very thin, usually being less than 4 inches in thickness. The shale is composed of a fine crystalline aggregate of quartz, containing many glittering scales of sericite, giving it a satin-like sheen.

The shale has been so highly altered by regional metamorphism as to be almost a schist, and in places, notably in the vicinity of the Union Chief Mine, the shale possesses typical schistose structure.

This shale is the only fossiliferous horizon found in this district, but in most cases, the metamorphism has been so intense as to destroy all but the superficial outlines of the original forms.

Cambrian Limestone.

The limestone in this vicinity varies in color from a pure white to almost black. It is prevailingly thin-bedded, the beds ranging in thickness from 1 to 2 feet, and is quite variable in composition, some strata being so silicious as to be almost quartzite. About 200 feet above the quartzite is found a 20 foot stratum of a pure white limestone, a micro-photograph of which is given. (See Plate II., Figure 1.) This limestone appears to have been oolitic in texture, but metamorphism has greatly altered the original texture,

A short distance above this is a stratum of dark-gray limestone containing frequent nodules of chert, and highly silicious, while near the top of the mountain is a reddish stratum of almost pure quartzite. On the whole, with the exception of the one oolitic stratum, the limestones are rather impure, containing varying amounts of silica, up to high percentages. The condition of the limestones shows frequent oscillations of the sea-level during deposition. No fossils were found in this limestone.

IGNEOUS ROCKS:

Granite.

A granite is a holocrystalline rock composed of quartz and orthoclase, with some plagioclase and containing biotite, hornblende or augite as accessory minerals. The term is used loosely to include all coarse-grained igneous rock, but in the technical sense, it refers only to those igneous rocks of granitic texture which contain free quartz , and in which the principal feldspar is orthoclase.

In this district there are two distinct kinds of granite, that occurring in the intercalated series between beds of gneiss and the granite occurring in the dykes.

The first mentioned is an exceedingly coarsely cyrstalline granite, composed essentially of quartz, orthoclase, and biotite. The granite occurs as sills between the beds of gneiss, varying in thickness from a few inches to several feet.

"Exposure of pre-Cambrian Granite in Green's Canyon."

The crystals composing the granite are of considerable size, varying from 1 to 3 inches in length, and the biotite occurring in masses about 1/4 inch thick. The orthoclase is the typical pink variety and the quartz usually occurs as idiomorphic hexagonal crystals. The granite may have contained other accessory minerals such as hornblende, magnetite, etc., which have been subsequently leached out, but no iron stains or other evidence of such was found.

The granite occurring in the dykes and also in the intrusive sill immediately under the pre-Cambrian quartzite is of an entirely different nature from the intercalated macro-granite above described. It is a holocrystalline rock composed essentially of quartz and orthoclase with considerable hornblende and many crystals of magnetite, and in some cases, hematite in the form of specular iron. The granite possesses the typical granitic texture, with crystals ranging in size from 3 to 7 millimeters.

Under the microscope, the quartz and orthoclase show frequent micropegmatitic intergrowths, as shown in the microphotograph. (Plate II., Figure 2.) A crystal of magnetite, surrounded by crystals of quartz and orthoclase is also shown. (Plate II., Figure 3.)

Andesite.

An andesite is a felsitic or porphyritic igneous rock, containing no free quartz, in which the principal feldspar is plagioclase, and the accessory minerals are biotite, augite, and hornblende.

The andesite in this district occurs as a small dyke near the north of Green's Canyon. The rock is greenish gray in color and very fine-grained, although it shows occasional phenocrysts of biotite.

The microscope revels small phenocrysts of labradorite and augite, with numerous needle-crystals of biotite, which occur in a microlitic ground-mass. (See Plate II., Figure 4.) The needle crystals of biotite give the rock a diabasic appearance, but the plagioclase crystals do not appear in the needle form.

Porphyry.

The porphyry, which outcrops in the form of sheets near the top of the mountain is yellowish, and clay-like in appearance. The samples procured were so badly decomposed as to preclude the determination of the original rock form. It is quite silicious, however, and is evidently the decomposition product of a fine-grained acidic igneous rock.

Conclusion.

Concerning the generic relations between the igneous rock found in this district, but little can be said. The two granites, although differing widely in appearance, are in reality very similar, the principal difference being the texture. It can be quite confidently inferred that the two were derived from the same igneous magma. The andesite, of course, differs widely from the granites, and shows no apparent resemblance to them, but it is not impossible that it too was derived from the same source, as well as the porphyry of which but little can be determined.

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P L A T E I.

Figure 1.

Crossed Nicols.

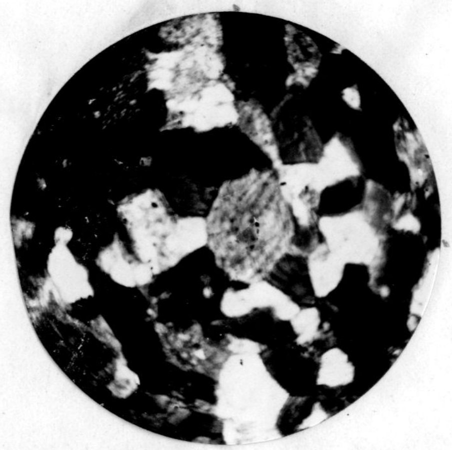

Figure 2.

Plain Polarized Light.

pre-Cambrian Gneiss.

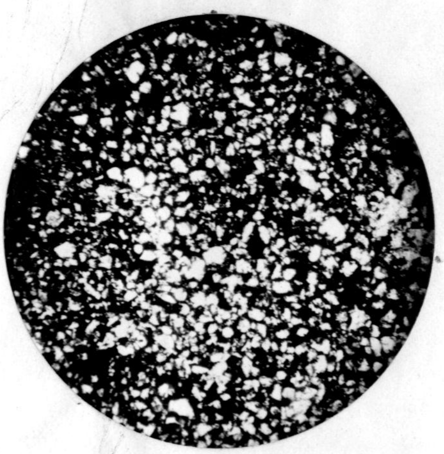

Figure 3.

pre-Cambrian Quartzite.

Figure 4.

Cambrian Quartzite.

P L A T E II.

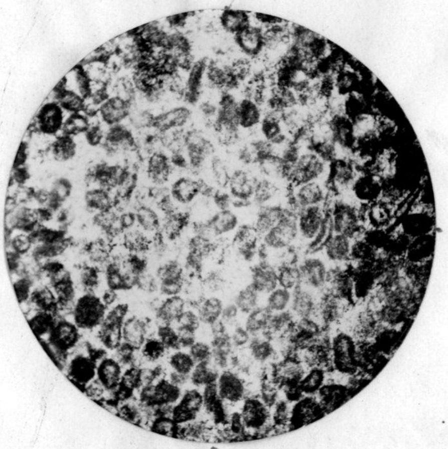

Figure 1.

Cambrian Limestone.

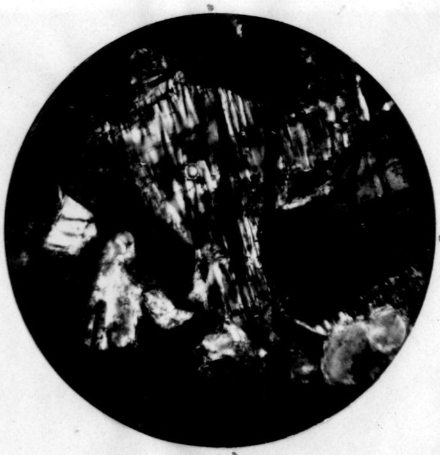

Figure 2.

Granite.

Figure 3.

Granite.

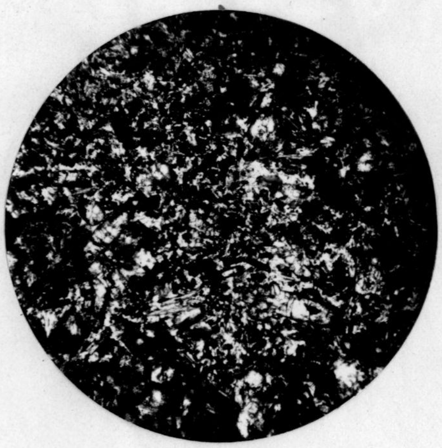

Figure 4.

Andesite.

P A R T III.

E C O N O M I C G E O L O G Y .

By

M. Mansfield.

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GENERAL FEATURES:

The Santaquin Mining District is situated on the western slope of the Wasatch mountains, almost 2 miles east of the town of Santaquin, and just at the southern extremity of the range. The rock series of this district comprise granites, schists, gneisses, and quartzites, all of pre-Cambrian age. The quartzites are the upper member of this division. They are overlain, in turn, by conglomerate, quartzite, shale, and limestone of Cambrian and Post Cambrian age. The chief ore deposits are lead-silver deposits in the limestone. Small bunches of copper minerals were noted in the pre-Cambrian granites where the latter has been cut by a dyke of andesite. Gold and silver values were reported to have been found in the granite at the foot of the mountain.

HISTORY OF MINING DEVELOPMENT:

Some prospecting had been done in the early days, but not until 1899 had any real mining work been started. IT was in this year that work on the Union Chief tunnel in Green's Canyon was commenced by Mr. A. N. Larsen. Small quantities of lead-silver ore were found. Very little was accomplished, however, until Mr. G. L. Bemis came into the field in 1906. Since that time the work of developing this property has gone on steadily. In the same year work was begun on the Wasatch property also, by Mr. Bemis.

In 1900, the Granite Mining Company drove a tunnel into the foot of the mountain. Small quantities of copper ore were found. All the workings are, as yet, in the developmental stage. Those at the base of the mountains are comparatively easy of access, but those situated higher up on the mountain-side are reached only by trails. All supplies have to be carried upon horseback. Practically all of the mines are opened by tunnels. Those worked through inclines or shafts, are operated by windlas or whim. All drilling is done by hand.

THE MINES:

The Granite mine is located at the base of the mountain a short distance south of the mouth of Green's Canyon. A tunnel several hundred feet long has been driven into the Pink granite. Its direction is north 85 east.

The Black Balsam mine is in Green's Canyon, several hundred yards above its mouth. The development consists of a short tunnel driven into the reddish intrusive granite where this granite is cut by a dyke of andesite. Small patches of copper ore were found.

The Union Chief mine is in Green's Canyon, about half way up the mountain top. It is the most extensively developed mine in the district. The workings consist of two cross-cut tunnels in the limestone near its contact with the shale. One tunnel is about 300 feet higher than the other. The lower one is 2,000 feet long in a north-easterly direction, It is connected with the upper one by a raise, and incline. This company's holdings consist of 12 or more claims, 6 of which are patented. The greater part of the field work was dome at this mine, and a fuller description is given later.

The Bullock mine is located at the foot of the mountain, about 100 feet south of the mouth of Broad Hollow. Its developments consist of a 75 foot incline, sunk on a 4 foot vein in the pre-Cambrian granite. The vein material is granite mingled with decomposed schist. Both walls are distinct, and slickensided. Good gold values are said to have been found.

At the mouth of McGee's Canyon, the Iron Prince Mining Company has driven a tunnel several hundred feet long through the limestone into the granite. This is an exceptional condition in which a hill of limestone rests upon pre-Cambrian granite. A body of iron ore carrying small values in gold and silver was found.

Higher up McGee's Canyon are found the workings of the Brownstone Mining Company. They consist of a long tunnel in the quartzite, and of another tunnel in the limestone. The former is barren, while the latter shows almost the same conditions as found at the Union Chief Mine.

The Wasatch Mine is located at the base of the mountain, one quarter of a mile north of the mouth of Yellow Rock Canyon. A tunnel 1,400 feet long is driven into the limestone starting near the limestone-shale contact.

"Wasatch Tunnel from road."

At the time of the last visit, a large vein of ferruginous material comprised principally of hematite and limonite had been encountered. It is a very favorable looking material, and gives promise of becoming ore-bearing when followed up. This is further borne out when it is called to mind, that a fissure higher on the hill, known as the "little Johnny" fissure, carries ore whose gangue is identical with this material.

As before noted, the chief, if not only ore-deposits occur in the Paleozoic limestone, and the principal one is found at the Union Chief Mine. In what follows, this deposit is the one referred to unless the contrary is specifically stated.

P[illegible]ION:

While this district may be said to be in its infancy, some ore has been shipped from it. About 4 carloads were mined from the "Little Johnny" fissure. The Iron Prince has shipped some iron ore to the smelters for fluxing. About 100 tons of first-class ore is stacked on the Union Chief dump, though until the proper facilities are provided, it is almost impossible to ship this ore.

MINERALOGY OF THE ORE-DE[illegible]:

Only those minerals of some importance or interest in connection with the ore deposits are described.

[illegible]lphur is found in the Union Chief Mine, associated with the ores. It occurs in small lumps lying next to the limestone walls of the vein.

Pyrite occurs in insignificant quantities, forming concretions in the limestone. None was observed associated with the ores.

Galena is the most important mineral in the district. It is, in the main, coarsely massive, the cleavage faces indicating crystalline individuals up to 2 inches in diameter. Some of it has a grained appearance, and is called by the miners "horse-flesh galena." Again, this mineral is found in the badly altered portions of the veins in fine grains, not unlike concentrates from a Wilfley table. All is argentiferous; in fact, this is the only mode of occurrence of silver in the district.

Bornite and Chalcopyrite with their alteration minerals, Malachite and Azurite, are found in small patches in the pre-Cambrian granite at the Black Balsam mine. They are associated with a dyke of andesite which cuts through the granite at this property.

Anglesite occurs as incrustations on galena. It is the first stage in the breaking down of the latter mineral.

Barite is not a common mineral, and is not found with the ores. The only occurrence noted was in an east-and-west fissure in the lower tunnel of the Union Chief Mine.

Calcite is the most common mineral. It occurs as a gangue mineral, and as a lining on the walls of cavities, and barren fissures. Large masses of the variety Satin Spar with individual crystals 3 inches in diameter are found.

Cerrusite forms a considerable portion of the ore thus far developed. It occurs as incrustations on the Galena and in a powdery, unconsolidated condition above the Galena.

Hematite is an important gangue mineral, intimately associated with the Galena. Limonite,its alteration product, occurs with the cerrusite.

Specularite and Maguetite occur in the pre-Cambrian granites as segregations.

THE ORES:

Constituents.

The essential constituent of the unoxidized lead-silver ores is a coarse-grained Galena which is always argentiferous. It occurs so pure that it can be sorted and shipped in lumps. There are no associated sulphides. Cerrusite and Anglesite form a considerable portion of the ore, particularly the former. The gangue minerals are hematite, limonite, and calcite. No quartz is present. Obviously, this ore is ideal for metallurgical treatment.

Paragenesis.

By paragenesis is meant the association of the various ore and gangue minerals with special reference to the order and mode of their formation. It the study of the paragenesis of the minerals in a metalliferous deposit, it cannot be safely premised that the various minerals have formed in a simple non-recurrent sequence. More commonly there is a complex and recurrent order of formation. Great length of time and many mechanical and chemical steps are involved in the accumulation of most large ore bodies.

In the Union Chief Mine the hematite and galena appear to have been contemporaneous in origin. A sample from the "Little Johnny" fissure indicated this very strongly. This sample was a mass of hematite and galena very intimately intermixed. That the calcite came in later was conclusively proved by finding specimens in which galena crystals were entirely enclosed in the calcite.

Tenor.

As before noted, the ore is high grade, being remarkably free from any admixture of impurities. The assays given below represent approximately the value of the ore as it could be mined.

Sample No.	Pb.%	Ag. oz. per ton
1	65.85	26.50
2	73.05	18.00
3	78.65	24.50

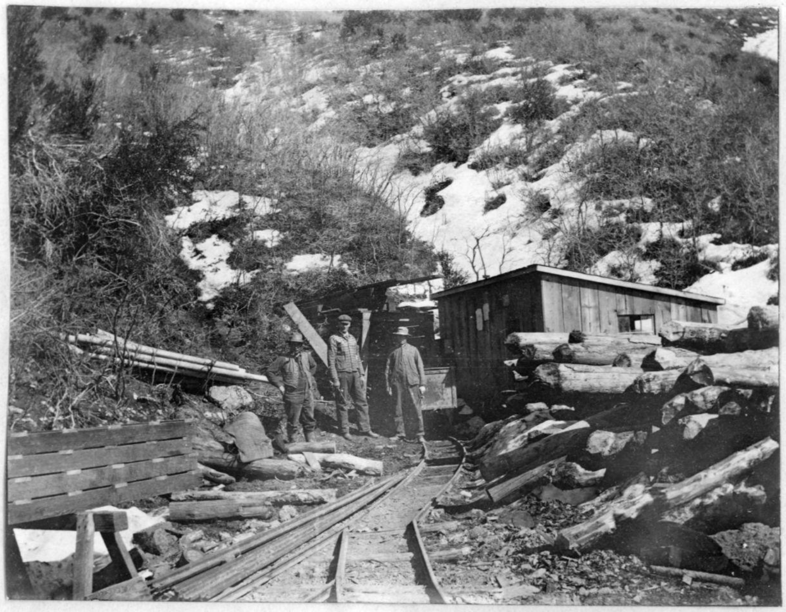
Sample No. 1 was taken from the upper tunnel level. It consisted of cerrusite and hematite with some lime.

Sample No. 2 is from the 85 foot level of the incline. It was composed of cerrusite, with small quantities of galena and gangue mineral.

Sample No. 3 was a lump of galena from a drift at the bottom of the incline. With a possible lead content of 86.6 per cent. it contained 78.6 per cent. The remaining 8 per cent. was principally iron replacing the lead.

FORM AND STRUCTURE OF DEPOSITS:

The ore deposits occur in fissure veins in tabular form. They are formed by the filling of open spaces along nearly vertical planes of fissuring. There are, generally, two sets of parallel fissures which strike north 40° eastand east-and-west, respectively; and dip at angles of 60° to 75° from the horizontal. Pay shoot and fissure zone are practically coextensive. All of the fissures are not productive, nor is any one fissure productive throughout its length. Nice bunches of ore have been found at the intersections of the fissures.



"Mouth of Lower Tunnel, Union Chief Mine."

The pay shoots are from 2 to 3 feet wide, and show a banding of the ore parallel to the walls of the fissure. The galena occurs in rounded masses, varying in size from that of a walnut to boulders 2 feet thick. This rounding, which has the appearance of being due to erosion, is due to alteration. Surrounding the galena is an intimate mixture of cerrusite and hematite. Oftentimes, layers of calcite form 6 inches to 1 foot thick lie either above or below, and in contact with the galena. The limestone walls are invariably intensely brecciated, and shattered and stained red by the hematite.

In as much as the term <u>vein</u> is strictly applicable only to those deposits which fill or accompany a comparatively simple fissure, it is the term to apply to these deposits. The broader term <u>lode</u> would be unsuitable since it applies to zones of fissures rather than to a single fissure. When it is considered that there were but three exposures of ore at the time of our visit, and that all of these were above the lower tunnel level, it is easily seen that there is much room for new evidence regarding the exact nature of these deposits, and this can only be gained by further development work.

THE FISSURES:

In this connection it will be well to further discuss the fissures. It is thought that the fissures were formed about the time the mountains were raised. This happened in post-Cretaceous times. The fissures are not gaping caraks due to tension, but were formed by compression. That compressive forces were active is shown by the selvage found along the bedding planes of the limestone, and by the shattered condition of the fissure walls. Conditions for measuring movement along the fissure planes are unfavorable. That this movement is not structurally important is evidenced by the fact that the rock on each side of the fissure is of the same character. The fissures extend to the surface for the greater part and in several cases are open. This latter condition was very serviceable to the miners for it furnished them with fresh air in what would otherwise have been unventilated portions of the mine.

Where the workings exposed the shale, the fissures were seen to extend into it. They were not found in the quartzite immediately underlying the shale. Just what depth they do attain is conjectural. Owing to the steep dip of the beds into the mountain, there is noreason for thinking that the fissures do not reach considerable depth. This question of depth is a vital one in considering the future of the district.

Relations of Ore Deposits to Surface and Depth.

With the exception of a few bare outcrops of the most resisting rocks, the surface is covered with a mantle of soil which supports a thick growth of vegetation. In a few places the outcrops of the fissures may be traced for short distances. They vary in width from a few inches to 2 or 3 feet, and are filled with ferruginous talcy material. The upper tunnel was started on a north-east fissure. A short distance in, the ore was struck. The workings have a vertical range of about 300 feet, with the lowest exposure of ore about 150 feet below the upper tunnel level, all in the zone of oxidation.

With increasing depth we should expect the ore alteration to become less and less pronounced, resulting in an increasing proportion of sulphides and a decreasing amount of oxides and carbonates; this process culminating in the zone of secondary enrichment in the vicinity of the ground water level. The depth of the ground water level in this district, with its high rugged topography and moderate precipitation should be from 500 to 1,000 feet below the surface. That there is a zone of secondary enrichment at depth is fairly well shown by the condition of the ore exposures, where we have partial oxidation, and partial solution. These solutions in their downward course would precipitate the metals as secondary sulphides some where near the ground water level.

Through the mines as yet developed, would be termed "dry", there is considerable circulation of vadose water. Several pronounced seepages occur in the lower tunnel which are the sole supply of the water required by the miners. In various places cracks in the limestone are filled with crystals of calcite, and barite deposited by these waters. An interesting point in connection with the changes in the ore with depth, is the probable appearance of sphalerite and pyrite particularly the former. It is more easily soluble than the galena, and if present in the primary minerals, it will be found accompanying the galena in the zone of secondary enrichment.

GENESIS OF THE DEPOSITS, (ORES)

In the formation of any ore body, two conditions are of vital importance: Igneous magmas carrying mineralizing solutions and permeable rocks to act as receptacles for the ores. The limestone in this district, with its numerous cracks and fissures and its relative pureness is preeminently fitted to fulfill the latter condition. The source of the ore is a matter of conjecture. A small outcrop of badly decomposed igneous rock was found upon the hill about 1,000 feet north-east of the mine. It appears to lie in a bedding plane in the limestone, and may be an offshoot from a large body of igneous rock intruded into the limestone. While this appears to be the most plausible explanation that can be given, it is not advanced with any degree of certainty for there is no proof that such is the case. As has already been stated, most of the fissures are barren, insofar as they have been prospected, but this is to be expected for but few of them might serve as channels for the ore-bearing solutions.

The evidence at hand seems to show that the ores are later than the fissures, and originated by pneumatolytic action. By pneumatolytic action is meant the action of highly heated watery vapor associated with mineralizing vapors, and metals, under high pressure, originating from an igneous magma, and depositing the materials in the country rock. We may assume that the solutions form the intrusives contained hematite, galena, pyrite, water, barite, and small quantities of argentite, and hydrogen sulphide. The last is named to account for the presence of native sulphur found in the ore. The sulphur may have resulted from a reaction between the limestone, and sulphuretted waters, or it may have been deposited directly as a sublimation or a deposit from or by volcanic gases. That the ores were deposited at great depth is shown by their massive crystallization.

"Union Chief Mine from opposite side of Canyon."

COMPARISONS WITH OTHER DISTRICTS:

At this point it will be interesting to draw a few general comparisons of this district with Park City, the greatest ore-producer in the Wasatch mountains, on one hand, and the Tintic district, just across the Goshen valley, on the other hand. Both the Wasatch and the Tintic mountains came into existence in early Cenozoic times after a long period of Paleozoic and Mesozoic sedimentation.

At Park City the ore deposits are at or near the contact of Upper Carboniferous quartzite and limestone, Those at Tintic occur principally in Carboniferous limestone, while those at Santaquin are found in Cambrian limestone. This is the first great difference--that of age. At Santaquin, the idea was held that this district was a second Park City. This is impossible because a bed of shale lies between the quartzite and limestone. Also, the ore is found up in the limestone.

It is known that the laws governing the deposition of ore bodies in one district will not apply to ore deposition, under similar conditions in another district. Each district has a "habit" of its own, and many serious mistakes have been made by applying to one camp the laws that have been found to hold good in another camp. The last statement is true of the Santaquin district to some extent, at least. Had all that is said above been fully appreciated, considerable dead work would have been saved.

FUTURE OF THE DISTRICT:

To forecast the possibilities of a district so little developed, and contingent upon so many conditions as the Santaqin district, is extremely hazardous. It has long been noticed that be far the greater number of mines become exhausted at comparatively shallow depths; that veins, instead of containing downward uniform in size and composition, like dykes of diabase and porphyry, become smaller and of lower value with depth, and often disappear altogether. It often occurs in regions of high relief and rugged topography that the rate of erosion is greater than the rate at which ores are oxidized, dissolved and reprecipitated at depth; all of which results in the eroding away of the ore, leaving merely a small remnant in place. When the erosion is not so fast, the primary sulphides appear to be oxidized to sulphates, and dissolve. These sulphate solutions percolate downward into the veins or rocks below, along the most open channels, and upon getting below the zone of oxidation are reacted upon by the unoxidized ore. This results in the formation of more and richer sulphides. Since the ores at Santaquin have been partially oxidized and dissolved away, it is only reasonable to suppose that at greater depth larger bodies of ore will be encountered, though just to what extent it would be hard to say. One thing appears to be conclusive, and that is that the limestone is the mineral bearing rock. Also, the fissures in the limestone, and not its contact with the shale or quartzite are the ore bearers.

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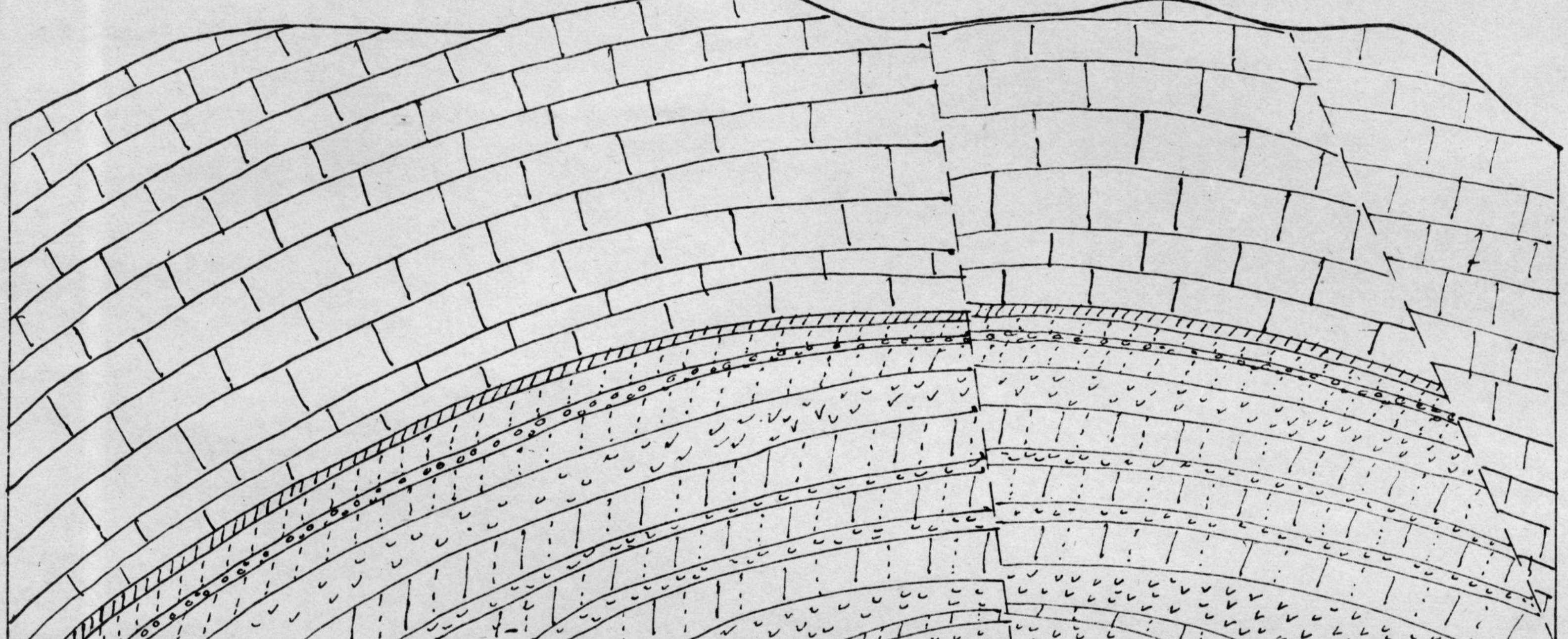
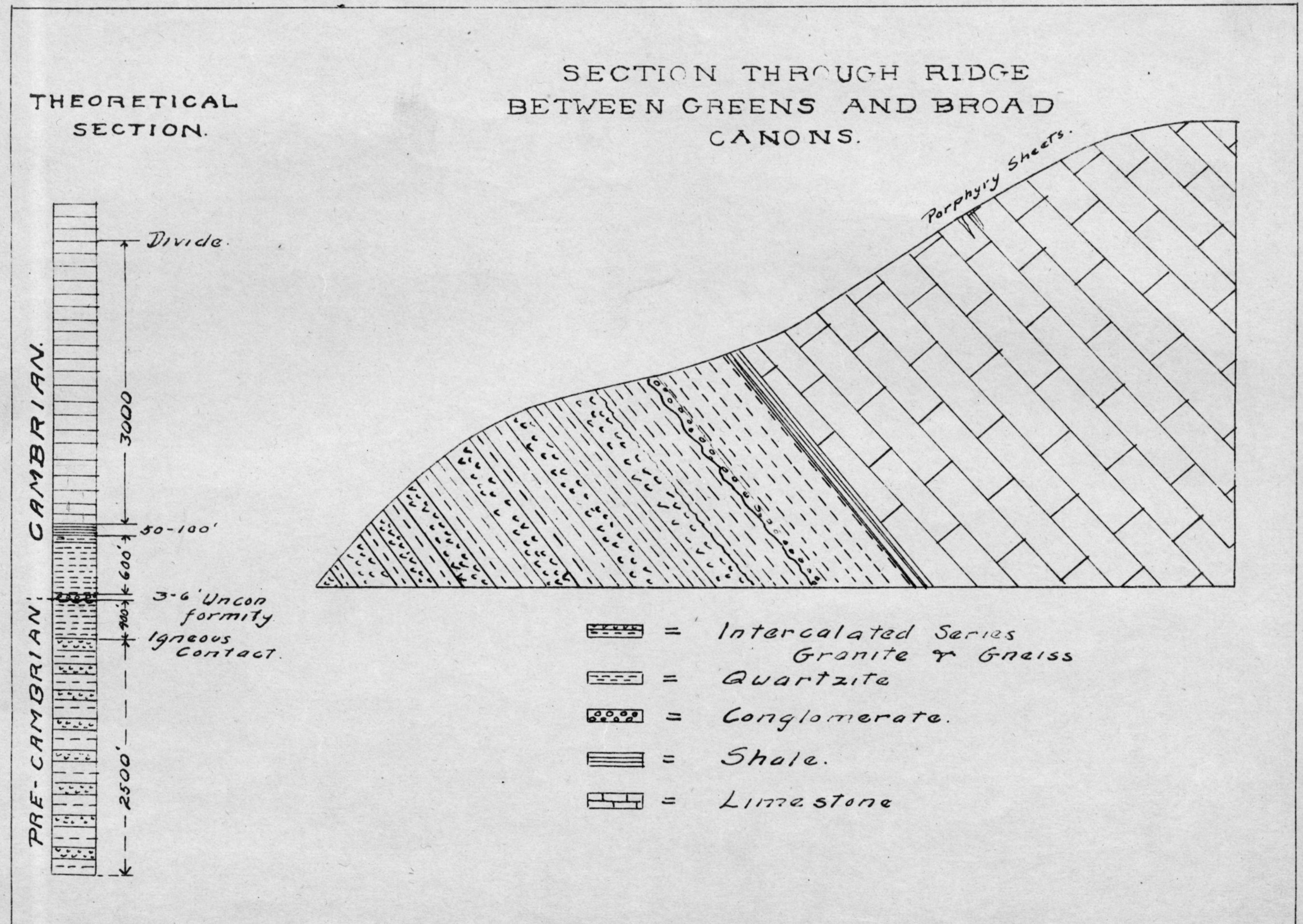
PLATE II-A



PROJECTION ON N & S PLANE.

PLATE I-A


THEORETICAL SECTION.
Divide.
CAMBRIAN.
3000
50-100'
600'
3-6' Uncon formity
Igneous Contact.
PRE-CAMBRIAN.
2500'
SECTION THROUGH RIDGE BETWEEN GREENS AND BROAD CANONS.
Porphyry Sheets.
= Intercalated Series Granite & Gneiss
= Quartzite
= Conglomerate.
= Shale.
= Limestone