THE GEOLOGY AND ORE DEPOSITS OF THE JOHNSON MINING DISTRICT, ARIZONA

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The Geology and Ore Deposits

of the

Johnson Mining District, Arizona,

by

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Contents

Geography.

The Johnson, or Cochise mining district, as it is sometimes known, is in the northwest part of Cochise county, Arizona. This area is at the foot of the eastern slope of the Little Dragoon mountains, which form the summit of the divide between the San Pedro and Sulphur Springs valleys at a latitude of about 50 miles north of the Mexican border and 7 miles northwest of Dragoon Station on the Southern Pacific Railroad. A branch line connected the district with the main line at Dragoon until 1925, when it was removed. At times there is a post-office at the settlement of Johnson in the center of the district. Russelville is another small settlement 3 miles to the south. This is in the Dragoon tungsten producing area.

As used in this report the term "Johnson district" refers to the copper producing area which has the Johnson settlement as the center of a figure approximately two miles square. The district includes a portion of the foothills of the Little Dragoon mountains which rise to the west, and runs approximately to the valley fill on the east. On the opposite side of this vallay and about three miles distant is a low range with a north and south trend known as the Gunnison Hills. The Texas-Arizona group of claims (whose output is included

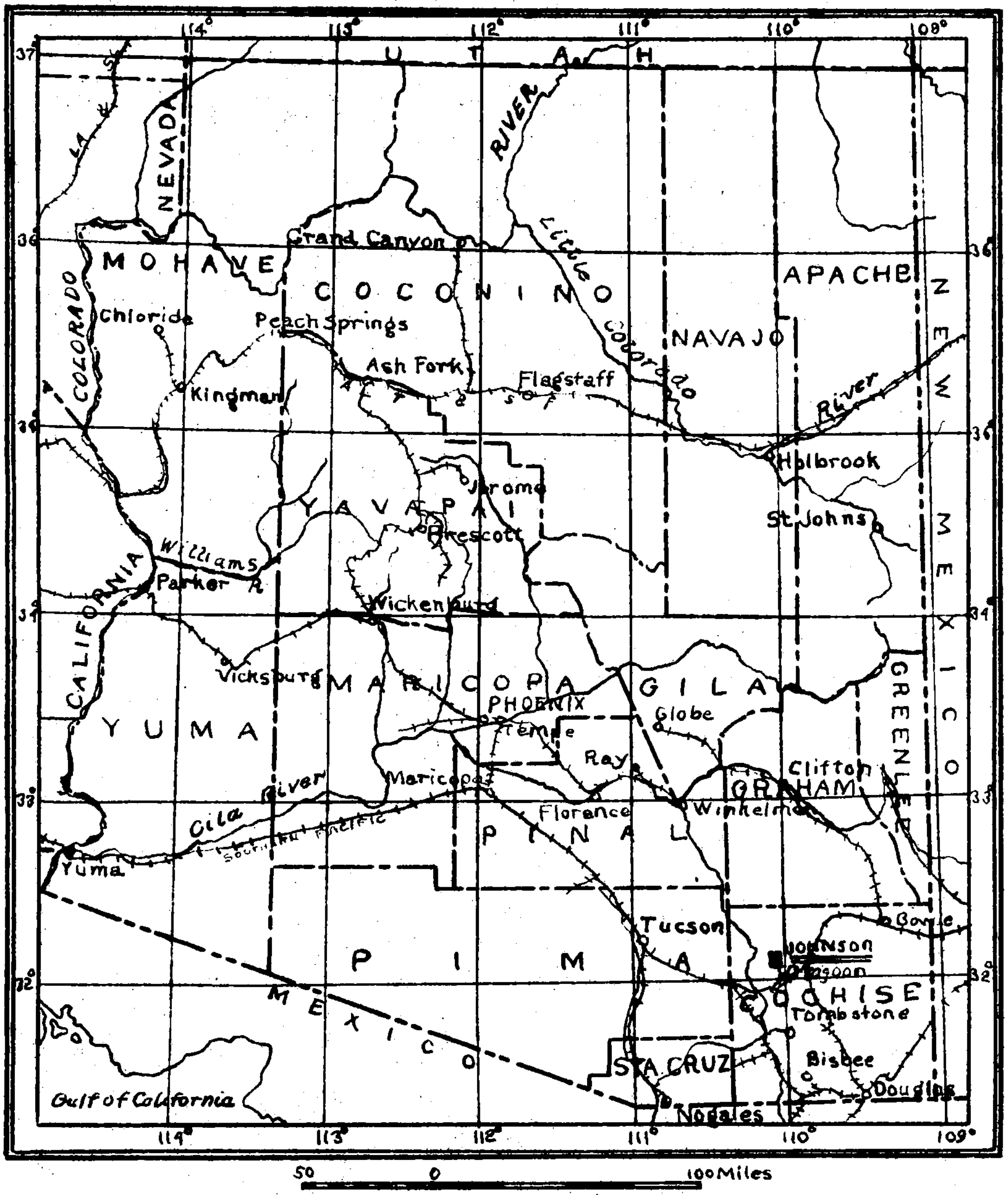


Fig. 1. Index map of Arizona, showing the location of the Johnson mining district.

in the production figures) is located in these hills.

The Little Dragoon mountains occupy an elliptically shaped area of about 8 by ten miles and have a general trend in a north-south direction. The southern portion is granite, while the central and northern parts consist of elevated sedimentary strata which form steep cliffs in the higher reaches of the range. The highest peak, called Lime Mountain by the inhabitants of the region, attains an elevation of approximately 6580 feet above sea level, or 1580 feet above the valley at Johnson. To the west of the Little Dragoons is the San Pedro valley.

The altitude is such that the typical flora of the lower mountain region is supported. This ranges from small cacti such as the prickly pear, ocatilla, and yucca at Johnson, through a growth of scrub oak to manzanita and piñon near the summit.

The climate is typical of the altitude in southern Arizona, hot days with cool nights in the summer ranging to cool days and freezing nights in the winter months. The wind is usually blowing strongly from the northwest, or southwest. In the winter there is considerable rain and snow when the wind is from the Gulf of Lower California. However running water is scarce, there being only one spring on the eastern slope. Water is obtained from wells. The water table is at the 700 level in the Republic mine.

Plate III

General view of the Little Dragoon mountains, including the Johnson mining district at their base.

Cattle feed grows well in favorable years. Consequently this industry, cattle raising, then thrives, being carried on by several local ranchers. In the past five years, dude ranching has gained a foothold. The writer spent many comfortable evenings while in the field at the Seven Dash Ranch on the western slope of the range. Another dude ranch is the Three C at Russellville.

Field Work.

Field work was commenced October 23, 1926, and was continued weekends during the winter, when the weather permitted, until its completion.

Mapping was done with a U.S. Army plane table, Keuffel and Esser open sight alidade, Brunton compass, and Tycos barometer. A second Tycos barometer was used as a check. A small hand level of the Abney type was also used in contouring, and was found to be more accurate than the barometers.

A topographic map covering the property owned by the Mason Copper Company was loaned to the writer. This was reduced photographically to a scale of 1000 feet to the inch and used to establish a base line for the making of the 1000 feet to the inch map.

The method of mapping the topography and geology was a combination of several schemes. Two known points on the small map of the Mason Copper Company were used as ends of the base line and from these two points the position of several flags, sharp hilltops and shafts were located by triangulation. The tracing cloth resection method of location was then used at all set-ups from which three known points were visible. In a few cases, only two points were visible and at these times the board was oriented magnetically and checked by sighting. The altitude of prominent points was determined by barometer at first, but due to the inaccuracy caused by the fluctuations of the instruments, the writer used the

Abney level and vertical angle measurements where the angle was large enough to be accurate in calculation, i.e., 3 or 4 degrees.

The contours of the long central ridge on the Mason property were already located from their map. These were extended from ridge to ridge on either side by use of the Abney level. At every set-up, with the level set at zero degrees, a sight was taken to the known ridge. The point of intersection of the horizontal line of sight with the ridge was noted. This point was sighted at with the alidade and its elevation found quite closely from the map. Therefore the elevation of the point of the set-up would be the same as the point sighted at and was plotted on the map. as such. Each ridge was contoured in turn by sighting at a ridge previously done.

This method was worked out as being fairly rapid and accurate with the advantage of being a one man system. It may be used by one man wherever the topography is such that a prominent hill slope is presented to view. This hill slope must be first accurately contoured by any of the standard methods.

The description of the ore deposits is incomplete because of the suspending of operations by the Mason Copper Company during the winter, with the consequence that the lower workings where the ore is not worked out were flooded and inaccessible.

Acknowledgments

The writer wishes to acknowledge his indebtedness to Dr. F. L. Ransome, Dr. A. A. Stoyanow, Dr. F. N. Guild, and Dr. R. J. Leonard for their valuable suggestions, and to J. B. Tenney, G. W. Wilson, and W. W. Miller for their interest and hospitality.

Bibliography.

The literature on the district is fragmentary. There are several references to the tungsten workings around Russellville. A paper by Kellogg is the best of the published work, but is far from satisfactory.

1883. Hamilton, Patrick, The resources of Arizona: p. 87.
The Peabody mine is mentioned as a copper producer.

1901. Dumble, E. T., Notes on the geology of southeastern Arizona: Trans. A.I.M.E., vol. 31, pp. 696-715.
A sketchy reconnaisance of Cochise County in which the section as observed in the Dragoon Mountains is given.

1904. Rickard, Forbes, Notes on tungsten deposits in Arizona: E. & M. J. vol. 78, pp. 263-265.
A description of the tungsten deposits in the granite to the south of Johnson. Notes the mode of occurrence, the minerals present and the method of working. Also mentions the occurrence of granite porphyry (?) dikes in the main granite intrusion.

1905. Franke, R. P., Geology of the Cochise mining district, Arizona: Min. Rep., vol. 51, p. 503.
A short sketch of the geology (incorrect) and ore deposits. Franke calls the granite pre-Cambrian.

1906. Kellogg, L. O., Sketch of the geology and ore deposits of the Cochise mining district, Cochise County, Arizona; Econ. Geol., vol. 1, No. 7, pp. 651-659.

A short resumè of the general geology with a rough sketch map of the district. Also a description of the ore minerals observed. The map and the interpretation of the structure are erroneous.

1908. Richards, R. W., The Dragoon, Arizona, Tungsten Deposits: Min. Sci., vol. 57, pp. 93-94.

Notes on the occurrence and origin of the hubernite and scheelite ores. The production of tungsten ores and drawbacks to systematic development.

1909. Dinsmore, Chas. A., The Johnson and Dragoon districts, Arizona: Min. World, vol. 31, pp. 833-834.

A short geological resumè and list of properties then operating.

1910. Guild, F. N., The mineralogy of Arizona: pp. 22, 92, Mention is made of the occurrence of molybdenite at Johnson and of the Dragoon tungsten ores.

1916. Taft, H. H., Notes on the tungsten ores of the south west: Min. & Eng. World, vol. 44, pp. 1046-1047.

Mentions the Dragoon tungsten deposits.

1916. Scott, W. A. Mining operations at Johnson, Arizona: Min. & Eng. World, vol. 45, pp. 141-143.
Gives list of properties with short descriptions of their workings.

1917. Hess, F. L., Tungsten minerals and deposits: U. S. Geol. Survey Bull. 652, p. 30.
A colored plate of a specimen of scheelite hubernite ore from a vein north of Dragoon is shown.

1921. Hess, F. L., and Larsen, E. S., Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725, p. 260.
Three fourths of a page mentioning the district and giving a list of minerals observed.

1925. Darton, N. H., A resumè of Arizona geology: Univ. of Arizona Bull. 119, pp. 296-297.
Darton gives an east west section through the district but it is on too small a scale to be of any practical value.

History of Mining.

Mining in the Johnson district dates back to at least 1883, when it is first mentioned in the literature[1]. The Peabody mine, which had been worked up to this time by the Russell Gold and Silver Mining Company, was sold to the Cochise Copper Company. Tenney says[2] that the district was producing in the seventies. The ore was shipped out by ox-team, and finally arrived at Swansea, Wales for smelting.

The amount of work done prior to 1905 was not great. In 1902 and 1903, however, some mining was carried on at the Peabody property by the Dragoon Mining Company. In 1905 development work was carried on at the Copper Chief, Copper King, and Empire claims. From this time until 1914 the development of the camp went on, but production at no time was very large. The Dragoon tungsten deposits were worked intermittently from 1904. The various claims and prospects changed hands at frequent intervals. The producing properties of the district were the Mammoth, Republic, Peabody, Black Prince, Centurian, Empire, Climax, Peacock, Keystone, Princess, Copper Chief, Copper King and Silver King.

Of these properties the Mammoth and Republic were the largest and most consistent producers.

1. U. S. Geol. Survey, Mineral Resources, 1883, p. 284.
2. Personal communication.

They were controlled from 1905 for a period of several years by the Arizona Consolidated Company. In 1909 a small 125 ton smelter was put into operation at the Republic mine by the Arizona United Mining Company. This was not a success due to the lack of a suitable fluxing ore.

During the world war the camp was quite active and the output of copper greatly increased. The Cobriza Mines Development Company controlled by the Goodrich-Lockhart Company of New York, took a lease on the Republic property and shipped 5000 tons of ore a month to the smelter at Douglas. This company also operated the Johnson, Dragoon, and Northern Railroad which connected the district with the main line of the Southern Pacific at Dragoon. The tracks were removed in 1925.

After the war most of the mines closed down with the fall in the price of copper. A few lessees and operators have made small shipments from time to time since. In 1926 the Mason Copper Company attempted to start operations at the Republic and Mammoth mines but did not succeed. At present W. W. Miller controls the Keystone and many of the claims in the district.

The Johnson camp, although one of the oldest in Arizona, has not been a large steady producer. Many companies have operated over varying periods of time, some taking out as much as two million dollars in the case of the Peabody mine. But the fact that the camp is one that may be termed marginal, that is to say, production pays only when the price of copper is high, coupled with the lack of funds put to systematic development work, has been the cause of the ups and downs of the several companies attempting to work in the district.

Production.

The production of the Johnson district prior to 1907 is not obtainable. The mine production from 1907 through 1920 as obtained from the figures of the United States Geological Survey[1] is given in the accompanying table. The total tonnage was 293,506, valued at $5,765,976, or an average value of $21.12 per ton. It should be noted that during the three years that zinc was shipped from the district the average value of the ore was $33.83 per ton, while the average value excluding the years zinc was shipped was $17.31.

1. Heikes, V. C., U.S.Geol. Surv. Mineral Resources of the United States, 1909, 1920, inc.

Production of the Johnson District, Ariz., 1907 - 1920

Year	Mines	Copper	Silver	Gold	Lead	Zinc	Tonnage	Value	Av.Val
		lb.	oz.	$	lb.	lb.	tons	$	$/ton
1907	--	465,880	10,248	--	--	--	--	99,890	--
1908	3	68,024	1,172	--	--	--	449	9,649	21.48
1909	6	210,189	2,691	412	8,421	--	2,809	29,498	10.50
1910	3	271,003	13,406	596	119,778	--	3,836	47,522	12.39
1911	5	19,983	4,884	1,075	101,130	22,423	301	11,992	39.84
1912	8	604,581	22,926	353	121,380	23,800	3,976	121,251	30.49
1913	--	791,971	12,297	80	27,878	21,063	4,393	136,898	31.16
1914	11	2,145,376	32,449	254	103,717	--	20,507	307,578	15.00
1915	10	3,815,538	39,755	80	12,269	--	44,636	688,579	15.43
1916	15	6,204,459	61,430	605	29,212	--	82,133	1,569,339	19.11
1917	19	4,180,646	47,106	691	15,975	--	57,167	1,182,196	20.68
1918	11	4,174,304	36,757	105	4,579	--	44,908	1,068,240	23.79
1919	6	1,332,496	12,091	22	4,976	--	14,565	261,672	17.97
1920	6	1,149,833	14,624	258	48,818	--	13,826	231,672	16.76
		25,434,283	311,336	4,531	598,160	67,286	293,506	5,765,976	21.12

In these production figures are included the output of the Texas-Arizona and Middlemarch properties which are not in the area described in this report.

General Geology.

Introductory Outline.

The oldest rock in the district is a pre-Cambrian schist, which is intruded on the south by a post-Carboniferous granite. Resting unconformably on the schist and dipping to the north and west is a series of sedimentary rocks, consisting of basal conglomerate, quartzite, dolomite limestone, sandstone, and marmorized limestone, which are probably of Cambrian, Devonian, and Carboniferous age.

The beds are faulted, mostly at right angles to the strike. A large monocline is seen in the Little Dragoon Mountains to the northwest, and its southwest extension is shown by the structure of the sedimentary rocks in the Johnson district.

After the formation and partial erosion of the schist, the Paleozoic beds were laid down horizontally. In post-Carboniferous time the intrusion of the granite took place contemporaneously with the folding of the strata. The final stages of magmatic action are evidenced by aplite dikes. The ore deposition probably took place after their intrusion.

Erosion of the folded and raised strata gives rise to the topography of today.

Pre-Cambrian Rocks.

Schist.

The oldest rocks of the district is a schist, probably pre-Cambrian in age. It is well-exposed in the southern part of the district, lying between the granite and the overlying conglomerate and quartzite. It is greatly variable in width due to the intrusion of the granite, there being about 600 feet exposed near the Richmond mine and increasing in width to the west and south to over 4000 feet. The general strike of the schistosity is N. 12° E and the dip is usually nearly vertical.

Like most of the pre-Cambrian schists of Arizona, it is not uniform in character, varying from light green fissile sericite schist to a quartzite with a slightly schistose texture. Even with the great variance in physical appearance, however, it is composed essentially of varying amounts of the same materials, quartz, muscovite or sericite, and green biotite, as shown by the microscope.

Near the granite it is sericitic in character, light green to silvery white in color and very fissile, weathering to a gray powdery micaceous soil. Under the microscope it is seen to be composed mostly of very fine particles of muscovite, or rather sericite, showing general parallel orientation, intergrown with minute grains of quartz.

A small amount of biotite and specks of magnetite are also present.

Immediately at the granite contact there is a phase in which the schist shows round or oval dark green "eyes" or knots between a quarter and a half an inch in size. There are several feet of this following the contact and it is evidently due to contact metamorphic action. The "eyes" are formed by an increase or cryptocrystalline quartz.

At a distance of about 600 feet from the overlying basal conglomerate, or about 350 feet below it stratigraphically, the quartzite facies is found. This varies in thickness from 10 to 30 feet and follows the general dip of the Paleozoic rocks, In places this is true quartzite and forms a distinct ridge running east and west. Ripple marks were found at one point. They were small but well formed. The spot is marked by a monument 2000 feet east of the road to the Hyatt ranch. The rock varies in color from gray to pink and yellow. Where yellow in color it is more sandy in character. Red diffusion bands run through the rock. Small psuedomorphs of limonite after pyrite are found. These average an eighth of an inch in size. Traces of one or more interbedded conglomerates are found in this formation. These conglomerates consist of angular and rounded pebbles of white quartz reaching an inch and a half in diameter, but averaging three quarters of an inch. The matrix varies from quartzite to schist.

Plate IV

Outcrop of schist close to

quartzitic facies.

At first, it was thought that there was an unconformity beneath this quartzitic facies, and such appears to be the case in places, where the gradation between the schist beneath, and the quartzite appears sharp enough to be a contact. It is decidedly gradational, however, both vertically and horizontally down the dip. Lenses of hard quartzite were found in the schist below, and decidedly schistose spots were found in the quartzite. Under the microscope the quartzite is found to consist chiefly of sharp angular grains of quartz about .2 mm. in diameter and smaller, some interlocking, and where not interlocked, the interstices are filled with finer grained quartz and sericite. A small amount of magnetite is present.

In the material showing a more schistose texture, the minerals are the same and occur the same way, but the quartz grains are much smaller. In a thin section of the conglomerate the pebbles are seen to consist of fractured quartz. The matrix is the typical schist of quartz and sericite, plus an excess amount of magnetite, with hematite specks and limonite stain.

Above the quartzite phase the schist again becomes greenish in tint and is somewhat soft and crumbly, rather than exceedingly fissile. It grades into material of a dark color immediately below the overlying basal conglomerate. This dark green material seems to have been a bed averaging about 15 feet in thickness. East of the Richmond mine, dark, hard, round spots of about an eighth of an inch in diameter, give rise to the bed being locally called "birds-eye porphyry". Thim sections show the rock to average equal parts of green biotite in small lath shaped crystals, sericite or muscovite, and fine grained quartz. Some larger flakes of muscovite are present. Intergrowths of the micas are noticed. There is also a large amount of magnetite, enough to noticeably affect the compass needle. A little limonite and chlorite occur as a later alteration. In slide M8, a crystal, appearing in shape like a limonite psuedomorph, has the center composed of chlorite with an exterior border of what may be serpentine. This might be an example of the mixing of amesite and serpentine to form chlorite according to Tschermak.[1]

Derivation.

The writer believes the schist to have been derived from a sedimentary series which varied greatly in character. Dynamic metamorphism produced the sericite in certain beds, while sandstone became quartzite, The upper bed was probably highly ferruginous.

Age.

The age of the schist is given as pre-Cambrian, since it is overlain by quartzite probably corresponding to the Cambrian Bolsa of Bisbee. It is probably the equivalent of the Pinal schist of Globe and Bisbee.

1. Hintze, C., Handbuch der Mineralogie: Zweiter band, pp. 678-688.

Cambrian Rocks.

Basal Conglomerate.

Resting upon the schist is a bed of conglomerate, which varies in thickness, averaging about 6 feet. This bed is fairly persistent throughout the district.

It is composed of rounded pebbles of white quartz and pink or white quartzite. The larger of these take the form of slightly flattened ellipsoids, reaching a length of five inches in the direction of the long axis. The average size of the pebbles is smaller, however, being about two inches. The matrix is composed of pinkish quartzite, of the same character as the overlying quartzite into which the conglomerate grades by virtue of the pebbles becoming fewer and more scattered. Several miles west, near the Seven Dash Ranch, the conglomerate contains some scattered pebbles of red jasper.

Quartzite.

Above the conglomerate is a massive quartzite about 500 to 600 feet in thickness. It is the thickest of the quartzites in the district and forms a prominent ridge. It weathers into steep slopes and small cliffs, similar to the weathered crop slope of a cuesta. Sharp edges are formed by fracturing, which takes place

Plate V

Cambrian quartzite.

Basal conglomerate

at right angles of 90° or less. The color is predominently pink, which , however, may grade into yellow or white. The quartzite is mostly hard and siliceous. In spots, however, a slightly more sandy surface is noted. The fragments of this sandier material weather with more rounded edges. More or less cross bedding is present. Small veinlets of quartz may run through the rock, following no definite direction. Small psuedomorphs of limonite after pyrite are found. These may be up to a quarter of an inch in size. There is also considerable brown and yellow iron staining and red diffusion banding.

Age and Correlation.

From its stratigraphical position and thickness, the conglomerate and quartzite may probably be correlated with the Cambrian Bolsa quartzite and basal conglomerate of Bisbee. E. T. Dumble[1] described and names the Dragoon quartzite in the south pass through the Dragoon mountains. These two quartzites may be the same, but the same trouble experienced by Ransome[2] in attempting to correlate the Dragoon and Bolsa quartzites is also found in this case. That is, the disagreement with the section given by Dumble who has his quartzite underlain by limestone and andesite, and overlain by Devonian limestone.

1. Dumble, E.T., Notes on the geology of southeastern Arizona: Trans. A.I.M.E.,vol. 31,pp. 696-715, 1901.

2. Ransome, F.L., Geology and ore deposits of the Bisbee quadrangle: U.S. Geol Survey, Prof. Paper 21, 9 , 1904.

Dolomitic Limestone.

Conformably overlying the quartzite is 400 to 500 feet of interbedded dolomitic limestone, sandstone and shale. The upper limit of this formation is indefinite, but was taken as a calcareous bed about 3 feet thick. In the extreme western portion of the district, the quartzite is overlain by approximately 100 or more feet of a dark brown and greenish micaceous shale, containing small lenses of crossbedded sandstone and layers of more sandy shale. There are worm trails, ripple marks, and vestiges of what may have been trilobites, found in the shale. In the central and eastern portions of the district this shale is covered by detritus or missing.

The remainder of the formation consists of interbedded sandstone and cherty limestone. None of the individual beds appears more than two feet thick. All contain cherty layers, the sandy facies to a much lesser extent, however, than the limestone. These layers of chert average from a half an inch to an inch in thickness and are separated by an inch to several inches of dolomitic material. This latter substance contains some calcareous matter, but is mostly dolomite, as shown by tests with acid. The weathering is distinctive, as the cherty bands stand out prominently. Many worm trails and casts are found in the more sandy facies.

Plate VI

Typical outcrop of

Abrigo limestone

Metamorphism is extreme in all the rocks of the district east of the immediate vicinity of the mountains. Some formations are altered to a greater extent than others, and there are portions where the original character of the rock may be seen. The rock described in the preceding paragraph has been changed to garnetite in many places. The softer layers between the chert may consist entirely of garnet of the greenish brown variety, grossularite, or they may be epidotized. This also is the country rock for some of the ore deposits and when such is the case, abundant garnet, diopside, vesuvianite, tremolite, actinolite, orthoclase, and calcite is present. The occurrence of these minerals will be more fully described later.

Age and Correlation.

This series is very probably equivalent to the Abrigo limestone of Bisbee and therefore should be Cambrian in age. Its lithological character and stratigraphical position are the same as the Abrigo limestone. In the lower shale facies a remnant has been found, which, although not well enough preserved to be identified with certainty, according to Dr. A. A. Stoyanow[1] is probably a trilobite. The only Cambrian trilobite having a size as large as this specimen is Anoria. If this supposed fossil is Anoria it may assist in showing a correlation between this shale and

1 Personal communication.

the Bright Angel shale of the Grand Canyon, the only other location in the state where Anoria has been found. The metamorphism in the upper portion of the beds makes the search for fossils difficult, but it is the intention of the writer to work further on this problem, and also to search for Ordovician fauna in the upper members. Darton says[1] that the Abrigo, El Paso, and Longfellow limestones are probably equivalent and if such is true, Ordovician fossils might be found.

1. Darton, N. H., A resume of Arizona geology: Univ. of Ariz. Bull. 119, p. 50.

Devonian (?) Rocks.

Interbedded Limestone and Sandstone.

A bed of silicified calcareous limestone three feet thick was taken as the base of the formation that may be Devonian. Lumps of rusty silica and small nodules of epidote are scattered through this rock. This is the same bed mentioned previously as being the upper limit of the dolomitic limestone. There is no unconformity here. Approximately 290 feet of alternating layers of limestone, quartzite, and sandstone follow until the Carboniferous is reached.

Above the 3 foot bed comes 25 feet of sandstone and quartzite. This material and the two other beds of sandstone and quartzite in the Devonian (?) range from siliceous sandstone to quartzite and in a horizontal direction along the strike, rather than vertically. The rock is of a sandy nature near the Mammoth mine and for a thousand feet or more east of that point. Then generally it becomes more quartzitic. These beds are of a yellowish brown sandstone or white quartzite and weather with a rusty stain which penetrates the quartzite to a depth of 1/4 of an inch and the sandstone much deeper. The only time the white color of the quartzite is seen is on a surface of fracture.

Above the first sandstone bed comes

20 feet of more calcareous limestone, which is also silicified. North of the Republic mine, it forms a light green marble whose color is due to epidote. This marble might make good ornamental trim.

The next bed in the series is more sandstone and quartzite and is 80 feet thick.

Following it comes 85 feet of white marble, very similar to the metamorphosed Carboniferous limestone.

The next bed which is the one immediately below the Carboniferous is composed of 75 feet of sandstone and quartzite. This bed is not sandy as the two which precede it, and consists almost entirely of rusty quartzite. Its outcrop is more or less covered with detritus in the district.

Age.

The only basis for calling these rocks Devonian, lies in their stratigraphic position below the Carboniferous and the resemblance of the sandstone to similar sandstone of known Devonian age in the Bisbee district and Peppersauce Canyon in the Santa Catalina Range.

Fossils are present as remnants, but are so badly silicified, that it is impossible to identify them.

Carboniferous Rocks

Limestone and Marble.

The Carboniferous rocks lie conformably on the Devonian (?) and is the thickest formation in the district. A thickness of at least 8000 feet is exposed in the Little Dragoons, but only about 2500 feet can be measured in the Johnson district proper. In this district the limestone is almost all metamorphosed to marble. The marble is mostly pure white in color, but some gray, yellow, and pink is found. The pink variety occurs in a small area north of the O.K. mine. The color is due to manganese, and small dendrites of manganese oxide may be seen in the rock. Not far from this locality, the white marble has been somewhat fractured and the interstices stained yellow by ferruginous solutions. Both of these varieties, as well as the green marble (page 24) might make ornamental stone.

Where the limestone is not metamorphosed it is dark or light gray in color and massive.

Where the limestone is the country rock for ore deposits, it is marmorized, and wollastonite, diopside, and calcite are visible in this sections.

The limestone is cut by granite and traversed by quartz veins near the Dragoon railroad station (about two miles to the northwest), and here is also marmor-

Plate VII

Marmorized Carboniferous limestone,

near the Republic power house.

ized with bands and bunches of radiating crystals of wollastonite. Thin sections show a little quartz, epidote, magnetite, and hematite, also. The bands of wollastonite are composed of radiating crystals, and they occur bordering quartz veins. Where the limestone is in contact with the granite, the radiating structure of the wollastonite is not noticed in hand specimens.

Age.

This limestone was proven to be of Carboniferous age by the occurrence of upper Carboniferous fossils in the gray limestone several thousand feet northeast of the O.K. mine. These were the following:

Seminula mexicana.

Terebratula mexicana. Hall, Emory's Rep't., U.S. and Mex. Boundary Survey, 1857, vol. 1, pl. 20, fig. 2.
Composita mexicana, Girty, The Guadalupian Fauna: U.S.Geol. Survey Prof. Paper 58, 1908, pp. 389-390, pl. XXIV, figs. 11 to 13b.

Spirifer kentuckyensis.

Spiriferina kentuckyensis Meek, Final Rep't U.S. Geol. Survey of Nebraska, 1872, p. 185, pl. 6, fig. 2; pl. 8 fig. 11,--Keyes, Geol. Survey of Missouri, V, 1895, p. 86.

Rhipidomella sp.

Post Carboniferous Rocks.

Major Intrusions.

Texas Canyon Granite.

A small part of the northern portion of the granite is exposed in the southern part of the district. There are at least 25 square miles of granite exposed north of the Southern Pacific tracks. This granite, called the Texas Canyon granite, is intruded into the bordering country rock. It is probably the exposed portion of an underlying batholith. In the Johnson district proper, it cuts the schist. The angle of inclination of the contact varies, but is on the whole, of a low angle.

The results of weathering are striking. Large balanced boulders are left resting on a pedestal a few inches in diameter. Queer and grotesque shapes are common. The weathering starts along and follows fissure planes. (See Plate VIII).

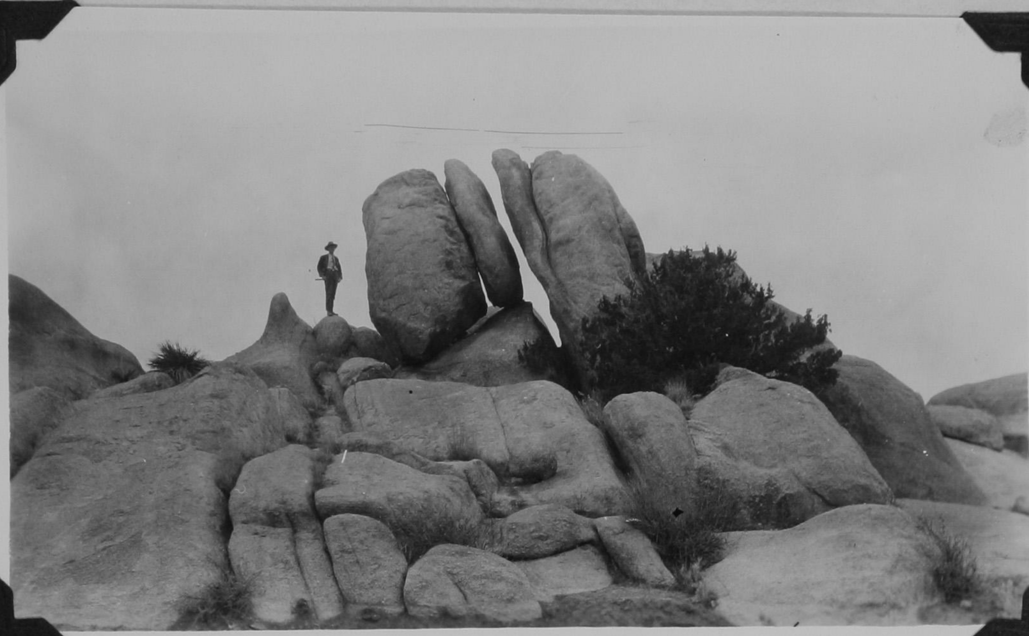
The rock has a porphyritic texture and is remarkable for the large size of the orthoclase phenocrysts, which may reach a length of two inches or more and a width of over an inch. They stand out very prominently on weathered surfaces. These large crystals are untwinned, as far as was observed.

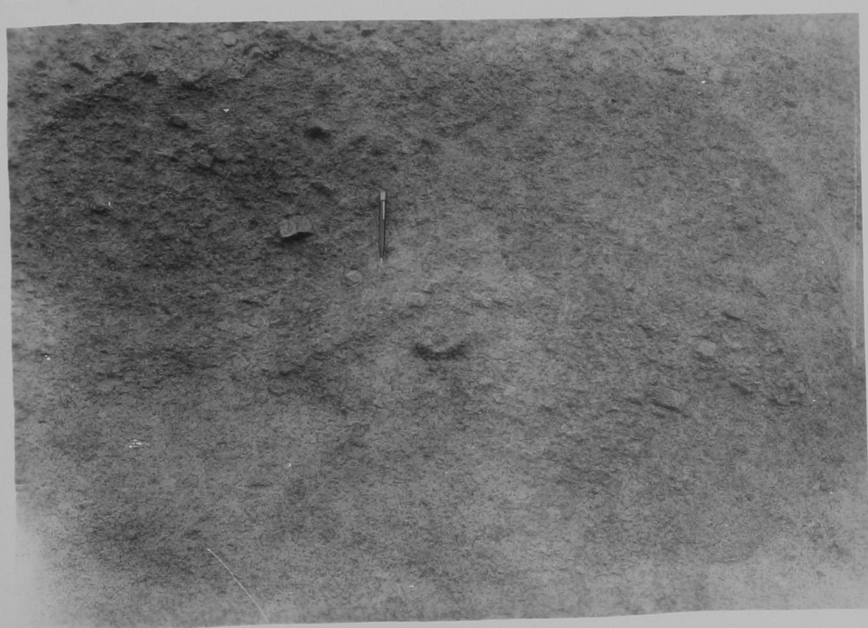
At the margin of the granite is a bor-

Plate VIII

Weathering of granite along fissures, Texas Canyon.

Large orthoclase crystals in the granite.





der phase. The orthoclase crystals become smaller in size and at the contact the texture may be aplitic and hard to distinguish in hand specimens from the aplite of the dikes occurring in the district.

Fairly large grains of quartz are s seen in hand specimens of the granite, as well as large and small crystals of feldspar and small flakes of brown biotite.

Under the microscope, the granite was found to consist of the following minerals: About equal parts of plagioclase and orthoclase. The plagioclase is acid oligoclase. This was determined by the extinction angle, index of refraction and sign. The granite is sodic as shown by the presence of microperthite and microcline. The feldspars are somewhat altered to sericite and paragonite. Some muscovite is also present, but biotite is the predominent mica. Some of the biotite is altered to chlorite. Quartz is present in the large scattered grains noticed in the hand specimens. There is a little apatite in typical rod shaped crystals. A few small grains of a mineral with a higher index than sericite were seen. These may be garnet showing optical anamolies. A little magnetite occurs in small disseminated grains.

This checks fairly well with an analysis of the rock, which follows.

Partial analysis of the Texas Canyon granite.

Dr. R. J. Leonard, analyst.	Corrected analysis.
SiO_2	67.81
Al_2O_3	17.47
Fe_2O_3	1.37
MgO	.55
CaO	2.49
Na_2O	2.42
K_2O	5.41
H_2O^+	.60
H_2O^-	.22
TiO_2	.16
	98.45

The silica is lower than usual for a Granite. Soda is high and the presence of so much plagioclase would tend to show that the rock is between a quartz monzonite and a soda granite. It is quite similar to the Schultze granite of the Ray Miami district.[1]

Contact Metamorphism.

There is considerable contact metamorphism in all the rocks cut by the granite. The altered contact zones in the schist and limestone have been mentioned. (pp. 15 and 26).

1. Ransome, F. L., The copper deposits of Ray and Miami, Arizona: U. S. Geol. Survey Professional Paper 115, pp. 59-61, 1919.

In the granite itself, the quartz content becomes high close to the contact. About 30% was noted in slide M14, taken from a specimen of the granite at the contact with the limestone. The extreme marmorization and garnetization of the limestones of the Johnson district is on such a large scale, that it seems impossible to conceive of it having been caused by the quartz veins which cut these rocks. This metamorphism must then be attributed to the granite. The contact zone is evidently a late stage of metamorphism. The quartz veins may be related to this late action. The same minerals are found bordering the quartz veins in the limestone as at the contact. In the granite itself, bunches of muscovite with iron stain are found along the quartz veins, and in places even along fissures containing no visible quartz.

Age.

Because of the extreme metamorphism found in the Carboniferous rocks, the age of the granite was thought to be post-Carboniferous, although there is no contact of the granite with the Carboniferous rocks, on the surface, in the Johnson district itself, But acting on the suggestion of Mr. Carl Lausen, then of the Arizona Bureau of Mines, who had found wollastonite on one of the tungsten dumps, the writer searched for a contact outside the district proper, and found the granite actually cutting the limestone at a point about two miles northwest of the Dragoon railroad station. A trench was dug across the contact to be sure that no fault was present . The contact metamorphic mineral wollastonite and marmorization show that the rock was cut by the granite was a calcareous limestone of the kind occurring as Carboniferous in the Johnson district.

Minor intrusions.

Aplite dikes.

These are found cutting the granite and schist. They vary in width from a few inches to one of a hundred feet in the granite and schist in the southern part of the district. (Plate IX)

Under the microscope the aplite was seen to consist of small particles of muscovite intergrown with small crystals of orthoclase, microcline, microperthite, and plagioclase. Of these the orthoclase is the most plentiful. No biotite and only a little magnetite were noticed. About 25% of the rock is fine grained quartz.

Plate IX

Contact of granite with Carboniferous limestone. Limestone at right of hammers.

Aplite dike in granite (foreground) and schist (background).

Recent.

Most of the detritus and fill in the district consists of slope wash. There is also considerable stream wash. The material consists of fine sand, gravels, angular and rounded fragments of the rocks of the district. In the stream wash, boulders up to a foot in diameter, are found. They consist of rocks from the Little Dragoons. Much of the material which is underlain by limestone is cemented by caliche.

Structure.

The structure, on the whole is not particularly complicated. The sedimentary rocks dip to the north and west and are cut by cross faults at right angles to the strike.

The structure in the schist is more complex and it is beyond the scope of this paper to state any definite facts concerning this, although several faults in the schist have been plotted on the map.

Throughout most of the district, the strike of the beds is approximately N 45° W, and the dip is 35° to the northeast in the rocks below the lower portion of the Carboniferous. In the Carboniferous rocks the dip increases until it is 53° at the Peabody mine. This tends to show the presence of an eroded monoclinal fold. This monoclinal structure is reflected in the Little Dragoon Mountains. (Plate II). In the southwestern portion of the district the strike changes to a north south direction, and the dip becomes 13° to the west. This change is effected after traversing a series of vertical faults like the spokes of a wheel.

South and west of the granite the rocks dip away from it, so a dome may have covered the granite at one time.

The granite is thoroughly traversed by

Plate X

Dip fault along quartz vein
in Abrigo limestone.

Fissure zone in the granite,
looking northwest.

fissures, showing little or no movement. There is a marked fissure zone in the granite, however, which runs from its northern extension in the Johnson district, through the entire exposure of the granite. Its strike is a little east of south. Muscovité and manganese are noted in the granite along the borders of the fissures, composing this zone.

Almost all of the faults in the district are vertical dip faults, perpendicular to the strike of the beds. Not a great deal of movement has taken place along the faults except in the "wagon wheel" series mentioned earlier, and near the Keystone mine where the Devonian (?) beds are faulted against the Cambrian quartzite with the complete obliteration of the Cambrian limestone.

Erosion, advancing faster in the weaker beds, has caused subsequent valleys to be formed in the central portion of the district. The trend of these valleys follows the strike of the structure. In the northern portion, erosion has been more rapid in the limestone and a flat plain remains, marked by two small hills, which have been preserved because of the more siliceous nature of the rock composing them.

The Little Dragoon mountains, taken as a whole, may be said to be the result of erosion on a series of folded and perhaps block-faulted beds. The folding is visible to the eye, but the block faulting is not so clear. A repetition of the beds in the southern portion of the Gunnison Hills shows a fault to lie between them and the Little Dragoons.

Geologic History.

The recorded history begins in pre-Cambrian time when the sediments were laid down and metamorphosed into schist. There may have been several periods of deposition and metamorphism. The variance in character of the schist gives rise to this supposition.

The basal conglomerate of the Cambrian was then deposited on the surface of the schist. Changing conditions during Cambrian time gave rise to the formation of the sandstone, now quartzite, shale, and magnesian limestone. The Devonian (?) and Carboniferous beds appear to follow perfectly conformably, which gives rise to the question of erosion during Ordovician and Silurian times. The land was evidently very low during these periods and not much erosion took place.

After this came the deposition of the Carboniferous limestone.

The folding of the beds and the intrusion of the granite came in post-Carboniferous times. The metamorphism of the limestones probably came with the intrusion of the granite. Aplite dikes were formed in the granite, apparently as one of the final products. Some of the cross faulting took place at this time and served as passage for the later mineralizating solutions.

The mineralization then probably took

place at a fairly high temperature, as shown by the presence of the contact-metamorphic minerals found in the ore deposits.

Later faulting has also taken place. This is shown by the presence of slickensides along quartz veins. This is seen on the quartz itself.

Finally the erosion of the uplifted rocks has given rise to the topography seen today. The main mass of the Little Dragoons remains, carved into valleys on its slopes, looking out over the low foothills and flat valley, a silent spectator of the irresistible advance of the levelling forces of nature, which will ultimately consume it.

Ore Deposits.

The most important ore deposits are those of copper, Of minor import are the tungsten bearing veins and placers south of the Johnson district, proper. These minor deposits will be discussed first.

Quartz veins and Tungsten Deposits.

The quartz veins occurring at Johnson cut all of the rocks in the district. They vary in width from a fraction of an inch to two feet. Prominent slickensides show that faulting has taken place along some of the veins after the deposition of the quartz.

The quartz is massive and white, of the type known in many localities as "bull quartz". Vugs are lined with quartz crystals, some of which reach a large size. The quartz is stained with limonite. A little copper stain was noticed in the quartz veins cutting the limestones of the district.

In the granite, the quartz veins carry tungsten, and have been worked for their content of scheelite, wolframite and hubernite. These minerals have also been concentrated in placers on the surface of the granite.

Plate XI

An open stope, Mammoth mine.

Tungsten prospect in quartz
vein in the granite.

Copper Deposits.

Occurrence.

Most of the ore mined in the district has come from the Mammoth and Republic mines where is was found in the upper portion of the Abrigo limestone.

The ore from the Peabody mine came from the Carboniferous limestone. This was high grade ore (some of it running 30 to 40% copper), and all came from the oxidized zone. Prospecting to a greater depth might readily lead into a sulphide zone.

The Mammoth and Republic mines have stopes in the sulphide zone. At present the flooding of the lower levels makes it impossible to examine this part of the workings.

In general, the ore follows favorable beds, but is irregular in occurrence, which is usually the case in contact-metamorphic deposits. The ore is also related to fissuring. It is noted there is cross fissuring at every open stope which comes to the surface, and at every mineral bearing prospect hole, and also in the vicinity of every shaft which leads to stopes that have produced in the past, Whether fissures are related to all of the ore bodies in the district is unknown, because of the inaccessibility of the deeper workings.

Plate XII

Shafts and dumps at the Peabody
mine, looking south.

Looking north from the large
headframe, Peabody mine.

Plate XIII

Surface plant, Mammoth mine.

Inclined shaft, Republic mine.

Mineralogy.

Hand specimens of the ore were obtained from the dumps of the Peabody, Mammoth and Republic mines, and polished surfaces and thin sections made from them.

The Peabody ore is oxidized. Malachite, azurite and chrysacolla were found in the samples taken. The gangue, determined by thin sections, is almost entirely composed of small interlocking grains of calcite, with some wollastonite, diopside, sericite and limonite.

In the ores from the Mammoth and Republic mines the following minerals were observed;

Sulphides:

- Bornite
- Chalcocite
- Covellite
- Molybdenite
- Pyrite
- Sphalerite

Oxides:

- Quartz

Carbonates:

- Azurite
- Malachite
- Calcite

Silicates:

- Actinolite
- Biotite
- Chlorite
- Diopside
- Epidote
- Garnet
- Orthoclase
- Tremolite
- Vesuvianite

Bornite:-

Bornite is not plentiful. When present, it occurs intergrown with chalcopyrite and sphalerite.

Chalcocite.-

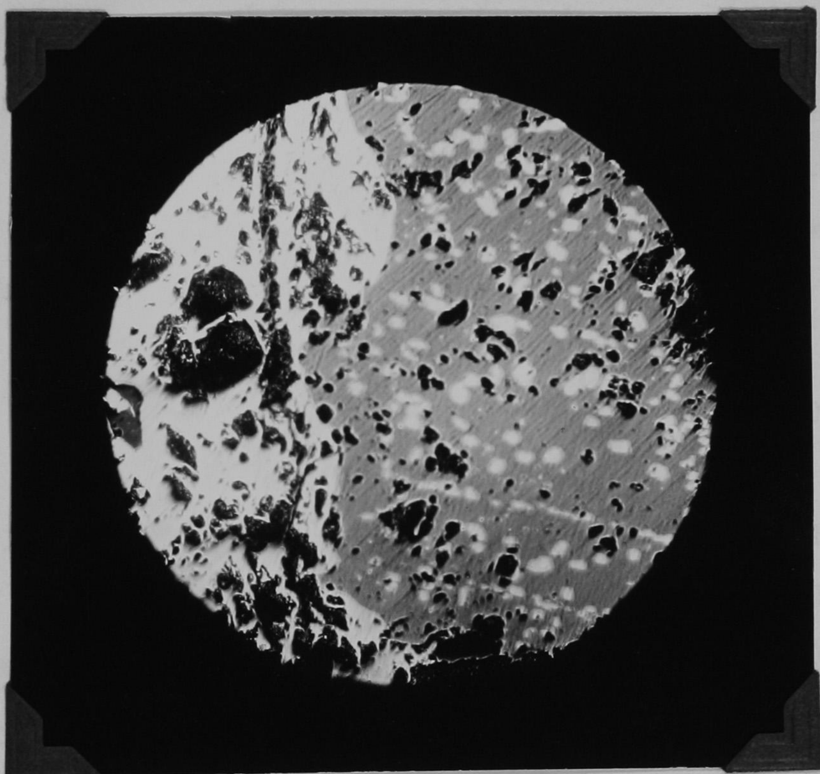
Only a small amount of chalcocite is found. It occurs along cracks and fissures, and as irregular spots in chalcopyrite and sphalerite. When in conjunction with sphalerite, the mineral shows a bluer tinge, in a polished surface, than when it is adjacent to chalcopyrite.

Chalcopyrite.-

Chalcopyrite is the principal ore mineral of copper at Johnson. It occurs in massive form, replacing pyrite and older gangue materials. It is also present as small blebs or specks scattered through the sphalerite. In places these specks appear to follow definite cleavage directions in the sphalerite. (Plate XIV).

Plate XIV

Chalcopyrite and sphalerite,
showing blebs of chalcopyrite
(white) in the sphalerite (gray).
X 190



Covellite .-

Covellite is scarce. It may fill small fissures and cracks in the other copper minerals, chiefly chalcopyrite and chalcocite.

Molybdenite .-

Molybdenite is not sufficiently abundant to be economically important. It occurs in thin flat flakes or scales which are foliated parallel to the basal cleavage. These scales occur disseminated through the other sulphides and gangue, excepting pyrite. The presence of molybdenite is noteworthy as it is a high temperature mineral.

Pyrite .-

The pyrite is present in small crystals showing euhedral edges and as fractured massive aggregates. There is not a large amount of pyrite in comparison with the chalcopyrite and sphalerite in the ore. Pyrite was probably the earliest of the sulphides to be deposited, since euhedral edges of pyrite project into the sphalerite and chalcopyrite. These two latter minerals also fill fissures in the pyrite.

Sphalerite .-

Sphalerite is almost as plentiful as the chalcopyrite and occurs intergrown with it. Sphalerite may also be found in more massive form with little chalcopyrite. With proper milling, separate zinc and copper concentrates might be easily made.

Plate XV

Molybdenite (Mb) surrounded by chalcopyrite (Ch) and sphalerite (Sp).

X 95


Ch
Sp
Ch
Mb

Quartz.-

Quartz occurs as a few small scattered grains and crystals and in the form of late filling in cracks. It is on the whole, not an abundant constituent of the ore.

Azurite.-

Azurite is found with malachite as fissure fillings in oxidized ore.

Malachite.-

Malachite is found in fissures and also more massively in the oxidized zone. Some of it is botryoidal.

Calcite.-

Calcite is ubiquitous and is found massively in crystalline aggregates and also filling cracks in all of the other minerals,

Actinolite.-

Actinolite appears as small bladed aggregates of pale greenish crystals with an extinction angle of 15°. It grades into tremolite.

Biotite.-

Biotite is present in small brown flakes, well disseminated through the gangue.

Chlorite.-

Some chlorite is present, appearing to be an alteration product of the biotite and amphiboles.

Diopside.-

Diopside is rather abundant in small grains or crystals of varying size. Thse show a high berefringence and the largest notices were about .2 mm in width and somewhat longer.

Epidote.-

Epidote is present in small light green grains with a high birefringence.

Garnet.-

Garnet is a very plentiful and makes up the greatest portion of the gangue material. It is mostly pale green to colorless in thin sections, and occurs in aggregates of grains or particles, some of which show the crystal outline. This variety also shows optical anomalies. It is probably grossularite. Some yellowish garnet with minute inclusions was seen in slide M.D. 104. This is probably andradite.

Orthoclase.-

Orthoclase is plentiful in some specimens. It is recognized microscopically only. As far as observed, the orthoclase is entirely anhedral. It may be the variety, adularia, since some of the crystals show a slight schiller structure, which is characteristic of adularia.

Tremolite.-

Tremolite occurs as small bladed aggregates of colorless crystals and grades into actinolite.

Vesuvianite.-

Vesuvianite is present in small pale green isolated crystals. It may be seen very well in some hand specimens using the binocular microscope, and small tetragonal crystals stand out prominently, showing a basal pinacoid and a pyramid.

Classification.

The ore deposits of the Johnson district are of the contact-metamorphic type. This is well shown by the metamorphism, and the occurrence of actinolite, diopside, vesuvianite, and grossularite, which are characteristic of contact deposits.

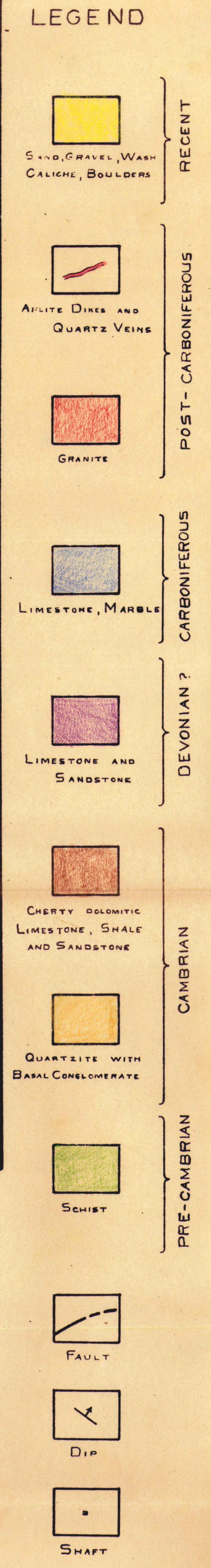
Supergene enrichment.

Supergene enrichment in the district is not prominent. Very little chalcocite and other supergene sulphide minerals were found. The deposits appear to grade from the upper oxide into the primary sulphide zone directly.

Origin.

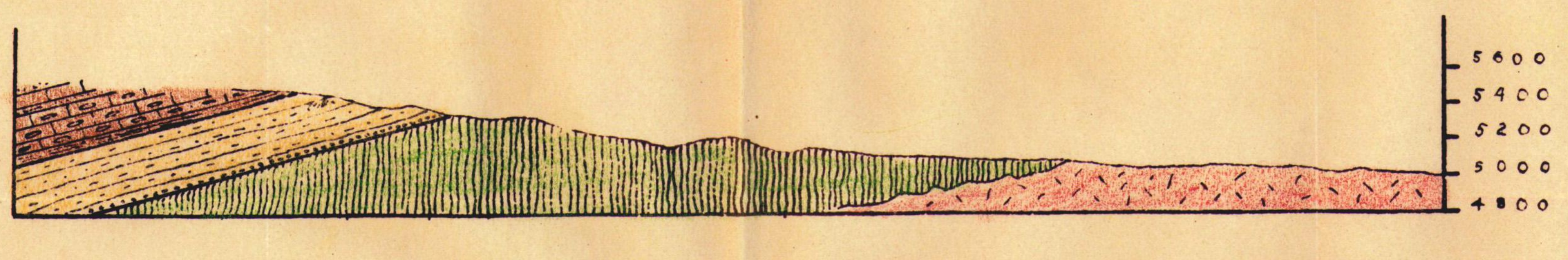
The only intrusion outcropping on the surface which could be related to the ore deposits is the Texas Canyon granite. The Mammoth and Republic deposits are 3000 feet or more from the granite, but the distance may be less in depth. The fault fissures, which probably served as passages for the mineralizing solutions, all have a general trend from the granite toward the ore deposits. The presence of orthoclase in the ore deposits shows that a part of the solutions were potassic. On the whole the evidence points toward a genetic relation of the ore to the granite.

PLATE I

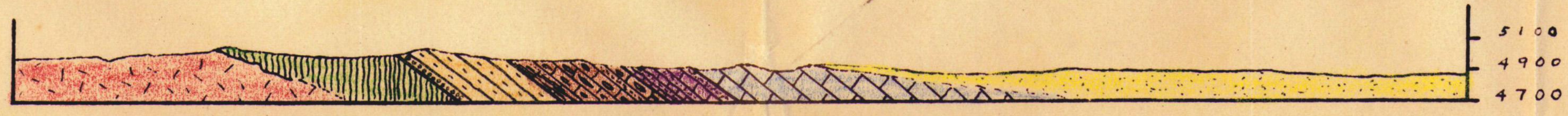


Geology and Topography by R.E.S. Heineman

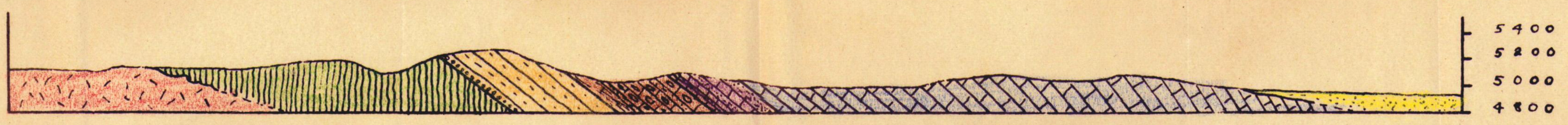
Surveyed in 1926-27



SECTION A-B



SECTION C-D



SECTION E-F

Scale $\frac{1}{12,000}$

1000 0 1000 2000 3000 Feet

Contour Interval
20 Feet

GEOLOGIC MAP AND SECTIONS
OF THE
JOHNSON MINING DISTRICT, ARIZONA.

THE JOHNSON MINING DISTRICT