DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 723

GEOLOGY AND ORE DEPOSITS OF THE MANHATTAN DISTRICT NEVADA

BY

HENRY G. FERGUSON

WASHINGTON
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OUTLINE OF THE REPORT.

Gold was discovered in the Manhattan district in 1905, although quartz veins in the vicinity of Manhattan had been worked as early as 1866. The district immediately became one of the "boom camps" of Nevada. The greatest production was reached in 1911, and since that time mining has declined. Placer gold from the deep gravel of the gulch has added to the total output.

Manhattan is in the southern part of the Toquima Range, about 35 miles north of Tonopah. The geology is extremely complex. The southern part of the district is underlain by closely folded Paleozoic rocks. For purposes of mapping these have been divided into five units, to four of which local names have been given. The oldest of these units, probably of Cambrian age, consists dominantly of siliceous mica schist but contains beds and lenses of quartzite and dark sandstone and five beds of crystalline limestone. The total thickness exposed is estimated to be about 5,000 feet. Above this, and provisionally assigned to the Ordovician, is about 800 feet of chloritic schist, altered by thermal metamorphism to "knotted" schist. This unit in turn is followed by 800 feet of gray limestone, partly altered to black jasper, which near the top grades into black slates. The lowest fossiliferous stratum is a thin bed of black slate containing graptolites, which is separated from the underlying limestone by a thin layer of quartzite. The graptolites are of Normanskill (Ordovician) age. Above the graptolite bed is limestone similar in character to that below, followed by a great thickness of chloritic schist, with here and there thin beds of cherty slate and crystalline limestone. The total thickness of this group of beds probably exceeds 4,000 feet in the area mapped.

There are also isolated outcrops of sandstone, in which fossils of probable Permian age have been found.

Granitic rocks intrusive into these sediments and probably of early Cretaceous age occupy a large part of the range to the north and south of Manhattan. Although these granitic rocks crop out over only a small part of the area mapped in detail in connection with this report, the older sediments are everywhere more or less metamorphosed, and siliceous aplite dikes are abundant within them.

Tertiary rocks occupy the northern part of the Manhattan district. Most of them are correlated, chiefly on lithologic grounds, with the Siebert formation of the Divide and Tonopah districts and are therefore inferred to be of upper Miocene age. The oldest member is a breccia made up of fragments of the older rocks and believed to be an ancient cemented talus deposit. This is followed by rhyolite and rhyolite tuff, then by porphyritic rhyolite and a considerable thickness of lake beds, and these in turn by quartz latite. Later came intrusions of rhyolite and andesite porphyry. The youngest of the volcanic rocks is a flow of dacite, probably of Pliocene age, in the northwestern part of the district.

The Paleozoic rocks are closely folded. The principal anticline, which brings the Cambrian (?) rocks to the level of the present surface, is overturned to the north and truncated by a fault that has thrust the lower part of these rocks above those of probable Ordovician age. The latter rocks are themselves compressed into close folds that pass forward into a large overturned syncline. The upper contact of the Cambrian (?) formation is masked by a normal fault.

The granite intrusion appears to have had little effect on the structure, though some of the minor normal faults in the productive part of the district may have been initiated at this time.

The Tertiary rocks show for the most part gentle northerly dips but are cut by several faults. Two periods of Tertiary faulting are represented—one prior to the intrusion of the andesite porphyry and the other later. The many normal faults that cut the older sediments are believed to be almost entirely of late Tertiary age, though it was not possible to trace the faults into the area of Tertiary rocks. Although there may have been some movement in Pleistocene time along the west front of the Toquima Range, this range offers no such topographic evidence of faulting as is presented by the prominent fault scarp that forms the eastern face of the Toyabe Range, a few miles to the west.

The formation of the present Toquima Range dates from late Pliocene or early Pleistocene time. An old erosion surface, of which remnants exist along the crest of the range, is considered to be of late Pliocene or early Pleistocene age.

The history of Manhattan Gulch can be traced in the gravel remnants on the sides of the valley and in the different types of gravel deposits in the gulch itself. The gold-bearing gravels of the gulch contain fossils that are of Pleistocene age, and the succeeding history of the gulch, as interpreted from its deposits, can be roughly correlated with the climatic cycles shown by Lake Lahontan.

The lode deposits of the district belong to two different periods of mineralization, one following the granite intrusion and the other of late Tertiary age. The deposits of the earlier period consist of sulphide-bearing quartz veins and are not industrially important in the Manhattan district. The deposits of the later period include veins in the Tertiary lavas and intrusive rocks and the deposits in the Paleozoic rocks that by their texture and mineral composition indicate formation at shallow depth.

The veins in the lavas consist principally of comby quartz with pyrite and a little free gold and have so far been only slightly productive. To the same type, however, belongs a deposit of silicified tuff, which has been quarried for use as tube-mill pebbles.

The shallow vein deposits of the Cambrian (?) schist have been the most productive of the district. They consist of comby quartz, adularia, and tabular calcite replaced by quartz and adularia, and they carry free gold. In some places they form a network along the bedding and jointing of the schist; elsewhere they form definite lodes.

The ore deposits in the Cambrian (?) limestone are mineralogically both complex and varied. Mineralization of economic character has been largely confined to the third of the five limestone beds. The limestone is cut into small blocks by normal faults. The larger of these faults are of postmineral age, but many of the smaller ones appear to be closely connected with the mineralization. Among the more abundant gangue minerals are coarsely crystalline calcite, fine-grained quartz, fluorite, sericite, leverrierite, and adularia. The metallic minerals include realgar, orpiment, stibnite, pyrite, arsenopyrite, and free gold. It is thought probable that two periods of primary mineralization are represented in these deposits.

The arsenical minerals, which are practically confined to the White Caps mine, offer an interesting problem. The realgar is believed to be of hypogene origin, though it may have been derived from arsenopyrite by later hypogene solutions. The orpiment is clearly a supergene alteration product of the realgar. The gold obtained from the ore in which realgar occurs carries almost no silver, in contrast to that of the other mines, where the fineness of the bullion is about 700.

Downward enrichment appears to have produced much of the extremely rich ore mined in the early days of the camp and is believed to have taken place in certain of the ore bodies in the Cambrian(?) schist, even at considerable depth.

The overthrust fault, though older than the productive mineralization, appears to have been a notable factor in the localization of the ore deposits, for the principal mines all occur on the hanging-wall side and not far from the fault itself. Smaller normal faults of later date appear to have furnished channels for the ore-bearing solutions, and faulting later than the mineralization has added to the complexity of the structure.

The unproductive veins are believed to be of Cretaceous age. The younger deposits, on the other hand, can not be older than late Miocene nor younger than late Pliocene. Apparently in the later part of Miocene time there was considerable metallogenetic activity throughout the Basin Range region.

The limestone ores show several features in common with the vein deposits and are probably of the same age, though the realgar and stibnite may represent a later stage of Tertiary mineralization, and there is some evidence that the formation of the coarse white calcite, the earliest mineral of the deposits, dates back to the time of the granite intrusion.

Placer gold is found in the older gravels, of which remnants exist in places along the sides of the gulch above the present fill; in deeper gravels of the present gulch; and in recent hillside wash. The older gravels have been worked in only a few places. The bulk of the production has come from the gravels that rest on bedrock in the gulch itself, at depths of 40 to more than 100 feet. This gravel, as shown by the fossils found in the mines, has remained undisturbed since Pleistocene time. The gold content is variable; in a few places the pay gravel yielded over $50 to the cubic yard, and in most of the productive mines the yield was over $2 to the yard. The purity of the gold as measured by the bullion returns increases regularly downstream and in the 2 miles of developed ground changes gradually from an average fineness of about 700 to 740. This change is believed to be due to the fact that downstream the gold particles are smaller and present a greater proportionate surface to the action of solvents in the water. As the gold has remained undisturbed for so great a length of time the solvents have had an unusual opportunity for refining the gold.

A little gold has been obtained from the recent hillside wash in the vicinity of the mines in the Cambrian(?) schist.

It is doubtful whether any greatly increased production is to be expected from the lode mines, and the placer mines are clearly approaching exhaustion.

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GEOLOGY AND ORE DEPOSITS OF THE MANHATTAN DISTRICT, NEVADA.

By Henry G. Ferguson.

INTRODUCTION.

FIELD WORK AND ACKNOWLEDGMENTS.

During the field season of 1915 the writer spent four months in the study of the geology and ore deposits of the Manhattan district, Nevada. At that time lode mining had suffered a collapse and little could be seen of the ore deposits. The work was therefore directed chiefly to a study of the complexities of the geologic structure and observations on the placers.[1] The district was revisited in 1919, when the geology of the principal deposits was studied in some detail; another short visit was made in June, 1920. The writer desires to acknowledge the courtesies extended to him by all the mining men of the district. The detailed geologic maps of the surface geology and underground workings of the White Caps mine, made by Messrs. O. McCraney and J. L. Dynan, were of especial value, as were the assistance and helpful suggestions received from the superintendent, Mr. R. L. Taylor. Mr. L. F. Clar assisted greatly in the investigation of the placer deposits and collected much of the information relative to the varying fineness of the gold. Mr. H. G. Clinton has collected valuable fossils from the Pleistocene placer gravels.

Without exception, all with whom the writer came into contact cooperated most cordially and in every way added both to his enjoyment of his field work in the Manhattan district and to the value of the present report. The writer also gratefully acknowledges suggestions and helpful criticisms from his colleagues on the Geological Survey, particularly A. C. Spencer, E. S. Larsen, and R. C. Wells.

[1] Ferguson, H. G., Placer deposits of the Manhattan district, Nev.; U. S. Geol. Survey Bull. 640, pp. 163–193, 1917.

LOCATION AND TOPOGRAPHY.

Manhattan is in the southern part of the Toquima Range, about 35 miles north of Tonopah. (See fig. 1.) The Toquima Range is one of the less prominent of the many narrow, isolated mountain ranges that are such notable features of the Great Basin topography. It trends in a northeasterly to northerly direction and extends from about latitude 38° 25′ N. to about 39° 25′ N. At Manhattan the range is broken by a low pass, and the portion of the range south of this pass is sometimes called the Smoky Mountains. The maximum altitude of this southern portion of the range is about 8,500 feet in the peaks west of Indian Spring. The main range is higher, and Jefferson Peak, east of Round Mountain, has an altitude exceeding 10,000 feet. The crest line is somewhat nearer the eastern than the western border of the range. The range is bordered by desert valleys—Ralston Valley and Monitor Valley on the east and Big Smoky Valley on the west. On both sides, but particularly on the west, the boundary between rock in place and valley fill is irregular, in marked contrast to the sharp lines of demarcation on the eastern front of the Toyabe Range, which borders Big Smoky Valley on the west. At its south end a low, broad pass filled with desert wash separates the Toquina Range from the San Antonio Mountains.

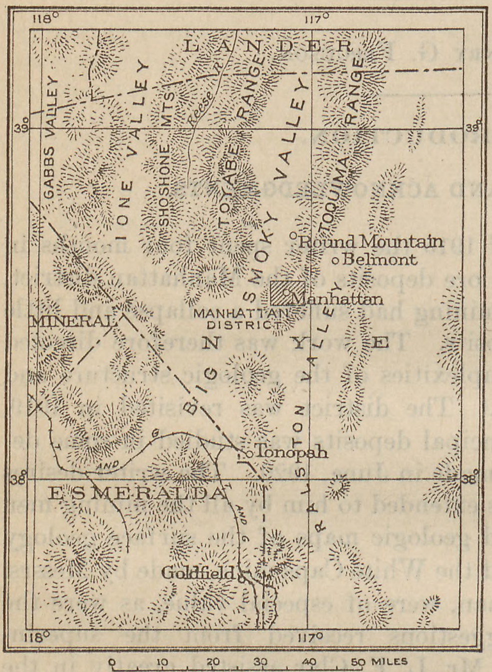

FIGURE 1.—Map of part of central Nevada showing the location of the Manhattan district.

Irregular hills jut out into the bordering valleys in many places. Between the waste-filled portion of the valleys and the foothills of the range there is in most places an irregular strip, at the most 1 mile in width, where the rock surface continues the gentle grade of the valley sides. This is well shown in the northwestern part of the Manhattan area. The border of the range is more clearly defined on the side of Ralston Valley than on the side of Big Smoky Valley, and the hills facing Ralston Valley show steeper slopes, though here, as on the west side of the range, there is a border of rock plain between the hills and the valley. South of Belmont a range of low hills extends southeastward, connecting the Toquima Range with its eastern neighbor, the Monitor Range. A narrow belt along the crest of the range, above 9,000 feet in altitude, shows a marked contrast to the rough topography below. Here there is a belt of rolling upland, which is not flat enough to be called a peneplain but whose gentle relief indicates that it is a relic of mature topography from a previous topographic cycle.

The Toyabe Range is high enough to retain small patches of snow from year to year, and consequently its permanent streams are fairly numerous, but in the lower Toquima Range streams are less common, although numerous small springs exist here and there throughout the range. Northward from the south end of the range as far as Shoshone Creek, a short distance north of Round Mountain, no stream carries sufficient surface water to allow it to overcome evaporation and reach the valley. In several of the dry canyons, however, such as Timber Hill Gulch and Manhattan Gulch, there is a considerable underground flow beneath the gravels. In Manhattan Gulch this underground flow is estimated at about 50,000 gallons a day and is sufficient for placer mining.

The area covered by the detailed geologic map (Pl. I) comprises about 40 square miles and includes a small portion of the southern part of the range eastward from the edge of Big Smoky Valley to a point a short distance east of the divide and northward from Pipe Spring to a point a short distance north of the summit of Bald Mountain. The altitude ranges from slightly less than 6,000 feet on the edge of Big Smoky Valley, in the northwest corner of the area, to 9,274 feet at the summit of Bald Mountain. The northeastern portion of the area is mountainous but slopes off sharply to the south and west. On the west side, beyond a narrow belt of rough ground, the land slopes gently to Big Smoky Valley, the grade of the rock-cut surface uniting with that of the valley fill. South of the mountains is irregular hilly country that contains the productive portion of the mining district.

Manhattan Gulch cuts across the central part of the area with a westerly course and drains the greater part of the district. The land south of the gulch rises to the peaks of the Smoky Mountains, just south of the area mapped, and Timber Hill, a prominent westerly spur that separates Manhattan Gulch from Timber Hill Gulch, to the south. A small portion of the drainage area of North Manhattan Gulch, the next prominent westward-trending gulch on the north, lies within the area covered by the map. In the eastern part of the area a tract of a few square miles is tributary to East Manhattan Gulch, which leads eastward to Ralston Valley.

The nearest railroad point is Tonopah, 42 miles by road from Manhattan, with which it is connected by a daily automobile stage. Automobile stages also connect Manhattan with Round Mountain and Belmont. In the early days of the Manhattan boom a railroad to connect Tonopah with Manhattan, Round Mountain, and Austin was surveyed, but it has never been constructed.

CLIMATE AND VEGETATION.

The Manhattan district has an arid climate, which is mitigated, however, by the presence of the mountains to the north and east. During the winter there is a considerable snowfall, and snow stays on the higher ridges for several months. In the summer short, heavy rains occasionally break the monotony of cloudless skies and at times give rise to destructive floods (Pl. VII).

The precipitation varies greatly from month to month and is very irregularly distributed. Sometimes over half the rainfall for the year may be concentrated in a single storm.

The amount of precipitation in this part of Nevada increases with increase in altitude, and the average temperature is lower at the higher points. Therefore at Manhattan, 1,000 feet higher than Tonopah, the summer heat is less intense and the rainfall greater. The following climatic data from neighboring stations, taken from the publications of the Weather Bureau, give an idea of the general climatic conditions:

Average monthly and annual precipitation, in inches, at stations near Manhattan, Nev.

Station.	Length of record (years).	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Belmont....	14	0.85	1.02	0.96	0.68	0.80	0.43	0.46	0.89	0.50	0.70	0.30	1.09	8.68
Millet.......	9	1.06	.56	.43	.62	.45	.24	.73	.39	.68	.59	.21	.34	6.30
Tonopah....	10	.72	.52	.56	.67	.30	.23	.49	.43	.49	.44	.39	.47	5.71

Average annual temperature, in degrees Fahrenheit, at Millet and Tonopah, 1914–1916.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean annual.
Millet..............	27.1	32.4	41.9	46.4	50.1	58.6	66.8	66.4	56.1	43.1	36.8	25.5	45.9
Tonopah............	29.3	35.5	44.6	48.0	53.6	63.4	71.7	72.0	61.7	51.7	41.6	28.1	50.1

Along the eastern border of Big Smoky Valley there is only the usual assortment of desert bushes. In the hills to the east, however, between altitudes of 7,000 and 9,000 feet, there is a rather sparse growth of single-leaf pine, or piñon (*Pinus monophylla*), and Utah juniper (*Juniperus utahensis*). These are small, the mature pines averaging 35 feet in height and the juniper 12 to 15 feet, but both, particularly the pine, supply a portion of the local requirements for mine timber. Above the timber line the principal vegetation consists of small clumps of mountain mahogany (*Cercocarpus ledifolius*). Shoshone and Jefferson creeks, before they are lost in the desert, are bordered by thickets of willows, which are in pleasant contrast to their parched surroundings. West of the front of the range the scanty desert vegetation becomes more and more sparse until the bare sun-baked playas of the central part of Big Smoky Valley are reached.

HISTORY AND PRODUCTION.

Although the ore deposits of Manhattan were not discovered until 1905, mining had been carried on in other parts of the Toquima Range for at least 40 years previously.

The ore deposits of Belmont, 15 miles northeast of Manhattan, were discovered in 1865 by an Indian,[2] and the camp, under the name Philadelphia district, soon attained considerable importance. In November, 1866, the first stamp mill was erected. This is reported to have had a daily production of a trifle over $1,000, saving about 60 per cent of the silver in the ore.[3] By 1867 a 40-stamp mill had been erected on the property of the Combination Co. and smaller mills on other properties. The town of Belmont had banks, assay offices, and schools, a triweekly stage service, and a weekly newspaper.[4] In 1870 the deepest shaft was 276 feet deep, and the depth to water level was 240 feet.[5] Emmons[6] gives the production of the Combination mine for the first six months of 1868 as $160,297. The acme of the district's production seems to have been reached in 1873. Raymond[7] says: "The town of Belmont has largely increased in population and enterprise and is generally conceded to be second only to Virginia City and Pioche." The reported production of the three larger mines for the year 1873 was $612,523. From this time on Raymond's reports give only short notices of the district, and the next available figures, those of the Tenth Census, show a

[2] Browne, J. R., Mineral resources of the States and Territories west of the Rocky Mountains for 1867, pp. 420–423, 1868.

[3] Browne, J. R., and Taylor, J. W., Reports on the mineral resources of the United States, Washington, 1867.

[4] Raymond, R. W., Mineral resources of the States and Territories west of the Rocky Mountains for 1868, pp. 104–105, 1869.

[5] Raymond, R. W., Mines and mining in the States and Territories west of the Rocky Mountains for 1870, p. 129, 1872.

[6] Emmons, S. F., U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 393–405, 1870.

[7] Raymond, R. W., Mines and mining in the States and Territories west of the Rocky Mountains for 1872, p. 173, 1873.

greatly reduced production. In the year ending May 31, 1880, the district produced 700 tons of ore, which yielded 24,255 ounces of silver, valued at $131,360.[8]

The difficulty of handling increasing amounts of water with the increasing depth and the decline in tenor of the primary ore below the water level caused the abandonment of several mines, and the scanty references in the reports of the Director of the Mint indicate the decreasing importance of the district. In 1881 the Belmont shaft had reached a depth of 600 feet. In 1883 the Belmont produced 1,542 tons of ore, with a gross value of $42,254. The next reference is in the report for 1887, when the Belmont and Highbridge mines together produced 15 tons, yielding $1,534. The Mint reports for the following years make no further reference to the district, but the decreasing totals for Nye County show the waning importance of silver mining. The minimum was reached in 1894, when the production for the entire county is given as $2,000 in gold and $5,000 in silver.

The revival of mining in Nevada that followed the discoveries of the ore deposits of Tonopah and Goldfield had no immediate effect on Belmont, though both of these discoveries are said to have been made by prospectors from that town. Belmont remained inactive until 1914, when the Monitor-Belmont Co. began the erection of a mill with a view to treating the ores by flotation. The mill, which was completed early in 1915, had a capacity of 150 tons and was equipped with ten 1,650-pound stamps, a tube mill, and flotation tanks. Operations were unsuccessful, however, and the camp was again abandoned. In 1917 work was resumed for a short time by the Tonopah Mining Co. and a little rich ore was extracted. Exploration in depth, however, was not encouraging, and the work was not continued. In 1920 Belmont, once one of the principal towns of Nevada, was practically deserted.

At about the time of the discovery of ore at Belmont prospecting was active throughout the region, and during the following years silver mines were worked in the Jefferson, Spanish Belt, San Antonio, and Manhattan districts. These districts, however, never attained the productiveness of the Philadelphia district (Belmont).

The principal mine of the Spanish Belt district, on the east side of the range, between Belmont and Jefferson, was the Barcelona, which seems to have reached its maximum production later than the others, though discovered at about the same date. In 1887 it had a reported production of 764 tons, yielding $57,490, and in 1888 of 708 tons, yielding $19,488.[9] Work was soon afterward abandoned and not regularly resumed until 1918.

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[8] Tenth Census, vol. 13, p. 311, 1885.
[9] Reports of the Director of the Mint.

At about the time of the beginning of mining in the Philadelphia district the San Antonio district, which seems to have included the San Antonio Mountains and the southern part of the Toquima Range, was organized. In 1867 two stamp mills were in operation near Indian Springs. The principal mine was the Liberty, which in 1868 produced 536 tons of ore, yielding 71,694 ounces of crude bullion, valued at $62,649.[10] The mine apparently continued production at least spasmodically until 1888.

The deposits in the Jefferson district, on Jefferson Creek, about 10 miles east of Round Mountain, were discovered in 1866, and work has been carried on there intermittently ever since. The principal mines were the Jefferson and Prussian. In 1875 two 10-stamp mills were in operation, treating ore that carried about $75 a ton in silver.[11] In 1876 the Jefferson and Prussian mines together produced 6,794 tons, yielding silver to the value of $190,694.[12] This probably represents the high-water mark of the camp's prosperity. In 1883 these two mines produced 950 tons of ore, which yielded $20,684; in 1888 the Jefferson mine reported a production of 7 tons of ore, yielding $2,277; and in 1890 the same mine produced 47 tons, which yielded $563. The mines were reopened in 1917, but operations continued for a short time only.

The Manhattan district is mentioned in Raymond's first report[13] as being situated in the "Mootay or Smoky Range (the eastern boundary of Smoky Valley) about 15 miles south of Belmont. The ores are the usual antimonial sulphurets peculiar to eastern Nevada, with their decompositions, such as chloride of silver, etc. The Ophir mine has been opened to a depth of 50 feet and shows some very rich ore. A test working of 2,500 pounds * * * is reported to have yielded by pulp assay $230 per ton." No data are available as to the further operations of this mine. The district was abandoned before 1871.[14] The discovery of the Tonopah deposits in 1900 stimulated prospecting throughout this part of Nevada. The prospectors no longer confined their attention to the prominent quartz veins that had yielded most of the early output, but all promising-looking float was investigated.

In April, 1905, John C. Humphrey discovered ore rich in free gold in the crystalline limestone on April Fool Hill, only about 100

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[10] Raymond, R. W., Mineral resources of the States and Territories west of the Rocky Mountains for 1868, pp. 104–105, 1869.

[11] Raymond, R. W., Mines and mining in the States and Territories west of the Rocky Mountains for 1875, p. 281, 1877.

[12] Raymond, R. W., idem for 1876, p. 138, 1878.

[13] Raymond, R. W., Mineral resources of the States and Territories west of the Rocky Mountains for 1868, p. 111, 1869.

[14] Wheeler, G. M., Preliminary report concerning explorations and surveys, principally in Nevada and Arizona, p. 41, 1872.

feet from the road from Belmont to Cloverdale. The conservatism of the average prospector is shown by the fact that for 40 years "specimen ore" had thus been lying unnoticed close to a well-traveled road. At about the same time silver-bearing lead ore was found near the now abandoned camp of Palo Alto.

In August after the discovery there was a rush of prospectors, but the camp was later deserted, though it filled up again the following winter. In March, 1906, there were 3,000 people in Manhattan and the immediate vicinity.[15]

During 1906 the district was in a state of great excitement, rich discoveries were constantly being reported, and people streamed in from all over the country. Besides Manhattan there were three other towns—East Manhattan, Central, and Palo Alto. To-day only tin cans mark the site of Palo Alto, and two or three shacks are all that is left of Central and East Manhattan.

The showy "specimen ore" found here and there at the surface lent color to the wildest misrepresentations, and a shameful period of "wildcat" promotion ensued. Many people lost their money in fraudulent Manhattan companies, and the bad name thus fastened on the district has since hindered legitimate mining ventures. The winter of 1907–8 was marked by depression following the deflation of the boom, but the hard times that led to the temporary cessation of quartz mining turned the attention of the miners to the placers of Manhattan Gulch and the possibilities of drift mining. Placer mining had been begun in 1906 with the dry washing of rich surface material on the Little Grey and Indian Camp claims, but the prospecting of the gulch itself did not begin until the following year. The placers gave new life to the camp, for the gravel was extraordinarily rich in places and mining was comparatively cheap. The richest placer ground was exhausted by the end of 1912, and since then the placer production has decreased. The lode mines, after passing through the wildcat period, maintained a good production until by 1912 the rich surface ores were largely exhausted. In succeeding years most of the production has come from a very few of the mines and from superficial pockets of rich ore found and worked by lessees.

In 1917 the discovery of rich ore in the lower levels of the White Caps mine led to another boom, which, though short lived, caused a considerable amount of exploratory work throughout the district and an increase in the production. At the present time a small amount of exploration work is being carried on, but only one of the larger mines is in active operation.

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15 Emmons, W. H., and Garrey, G. H., Notes on the Manhattan district: U. S. Geol. Survey Bull. 303, p. 85, 1907.

The accompanying table tells very clearly the story of the rise and decline of the lode and placer mines of the Manhattan district. The figures given for both lode and placer production are probably too low, for " high grading " is known to have been prevalent, and lessees are said to have sometimes concealed their returns to avoid payment of royalty and bullion tax.

Gold and silver produced in the Manhattan district, Nev., 1906–1921.

Year.	Lode mines.							
	Producing mines.	Ore (tons).	Gold.		Silver.		Total value.	Value per ton of ore.
			Fine ounces.	Value.	Fine ounces.	Value.		
1906	5	677	3,874	$80,074	5,697	$3,817	$83,891	$123.92
1907	5	409	1,556	32,175	289	191	33,622	82.21
1908	9	10,769	12,001	248,075	6,093	3,228	251,303	23.30
1909	13	4,198	3,710	76,691	1,937	907	77,598	18.48
1910	31	14,671	12,722	262,958	6,113	3,301	266,259	18.15
1911	35	13,945	20,255	418,683	8,489	4,499	423,182	30.35
1912	20	21,064	15,603	322,534	6,987	4,297	326,831	15.52
1913	31	46,228	13,733	283,854	4,516	2,728	286,582	6.19
1914	24	39,746	6,918	143,002	2,548	1,409	144,411	3.63
1915	19	46,990	7,744	160,064	2,621	1,329	161,393	3.43
1916	11	41,725	5,867	121,261	2,844	1,871	123,132	2.95
1917	19	25,427	5,467	113,008	1,899	1,565	114,573	4.51
1918	12	33,595	13,372	276,397	1,187	1,387	277,784	8.27
1919	10	56,085	13,050	269,750	1,379	1,545	271,295	4.84
1920	11	[a]18,971	....	....	....	....	78,221	4.12
1921	11	782	642	13,276	281	281	13,557	17.34

[a]17,475 tons milled locally, yielding $40,075 in gold and silver bullion, and 1,496 tons which contained 669,392 pounds of arsenic and $38,146 worth of gold shipped to smelter.

Year.	Placer mines.						Total value for lode and placer mines.
	Producing mines.	Gold.		Silver.		Total value.	
		Fine ounces.	Value.	Fine ounces.	Value.		
1906	....	....	....	....	....	....	$83,891
1907	....	60	$1,247	14	$9	$1,256	33,622
1908	7	782	16,157	424	224	16,371	267,674
1909	16	2,266	46,847	965	497	47,344	[b]144,942
1910	29	4,772	98,644	1,958	1,077	99,701	365,960
1911	26	6,582	136,052	2,737	1,451	137,503	560,685
1912	17	8,152	168,512	3,232	1,987	170,499	497,330
1913	34	8,061	166,622	3,104	1,875	168,497	455,079
1914	31	6,307	130,370	2,323	1,247	131,617	276,028
1915	43	6,392	132,132	2,454	1,244	133,376	294,769
1916	25	3,646	75,359	1,384	1,308	76,667	199,566
1917	31	3,129	64,677	1,202	990	65,667	180,240
1918	26	3,110	64,281	1,201	1,201	65,482	342,266
1919	14	1,580	32,663	723	810	33,473	304,765
1920	21	2,121	43,854	886	966	44,820	123,041
1921	....	1,726	35,685	768	768	36,453	50,010

[b]U. S. Geol. Survey Mineral Resources, 1910, p. 526, 1911, states that the production as given in the report for 1909 is $20,000 too low. This amount is therefore added to the total; other figures remain as given in Mineral Resources for 1909.

BIBLIOGRAPHY.

The following publications deal with the geology of this portion of Nevada but do not specifically relate to the Manhattan district:

1870. Emmons, S. F., Geology of the Toyabe Range: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 320–348, 1870. A short description of the general geographic features, stratigraphy, and structure of the central portion of the range, based on a rapid reconnaissance. The geologic map (pl. 13 of the atlas accompanying the volume) covers the portion of the range southward from Austin to Darrough Hot Springs, about 20 miles north-northwest of Manhattan. Abstracts are given in later publications by Spurr (1905), Hill (1915), and Meinzer (1917). Notes on the geology of the Philadelphia district (Belmont) and descriptions of the mines are given in the same volume, pp. 393–405.

1875. Gilbert, G. K., Report on the geology of portions of Nevada, Utah, California, and Arizona, examined in the years 1871 and 1872: U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, 1875. Besides a general study of the geology of the Great Basin, the volume contains notes on the geology of the Toquima Range, including a short sketch of the geology in the vicinity of Belmont, p. 36; a discussion of flow structure in rhyolite, in Meadow Creek canyon, north of Belmont, pp. 143–144; a note on graptolites collected from the slates at Belmont, p. 180; and an analysis of rhyolite from Belmont, p. 649.

1877. Hague, Arnold, and Emmons, S. F., U. S. Geol. Expl. 40th Par. Rept., vol. 2, pp. 618–635, 1877. The Fortieth Parallel Survey covered a region in Nevada for the most part north of latitude 40°. The area mapped west of longitude 117° (Map V), however, extends as far south as 39° 30′, including the camp of Austin. The geology of this region, including the sections on the Shoshone and Toyabe ranges and Carico and Railroad peaks, is described on the pages cited.

1877. White, C. A., U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 4, Paleontology, 1877. Description of fossils collected near Belmont, Nev., pp. 9, 10, and 62–66.

1884. Walcott, C. D., Paleontology of the Eureka district: U. S. Geol. Survey Mon. 8, 1884. A detailed description of fossils from Eureka and the immediate vicinity. A generalized section of the Nevada Paleozoic is given on pp. 284–285. On p. 2 is a note with reference to the graptolites of the Belmont district.

1892. Hague, Arnold, Geology of the Eureka district, Nev.: U. S. Geol. Survey Mon. 20, 1892. Besides a study of the geology and ore deposits of the Eureka district, the volume contains a detailed description of the stratigraphy of the district, the standard Paleozoic section of this part of Nevada, and a study of the lower Paleozoic sections of the adjoining ranges. There is also a report on the microscopic petrology of the igneous rocks by J. P. Iddings.

1900. Spurr, J. E., Quartz-muscovite rock from Belmont, Nev.; the equivalent of the Russian beresite: Am. Jour. Sci., 4th ser., vol. 10, pp. 351–358, 1900. Contains descriptions of the granitic rocks in the vicinity of Belmont, particularly a large dike just east of Belmont, with analysis.

1900. Turner, H. W., The Esmeralda formation: Am. Geologist, vol. 25, pp. 168–170, 1900.

1900. Turner, H. W., Knowlton, F. H., and Lucas, F. A., The Esmeralda formation, a fresh-water lake deposit: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 191–226, 1900. Description by Turner, with sections and map; notes on the fossil plants by Knowlton and fossil fish by Lucas.

1901. Spurr, J. E., Origin and structure of the Basin Ranges: Geol. Soc. America Bull., vol. 12, pp. 217–270, 1901. Largely an argument against the acceptance of Gilbert's fault-block hypothesis. Notes on the structure of the Toquima and Toyabe ranges are given on p. 230.

1902. Turner, H. W., A sketch of the historical geology of Esmeralda County, Nev.: Am. Geologist, vol. 29, pp. 261–272, 1902. A description of the principal rocks in the region, particularly those of the Silver Peak Range. Lower and Upper Cambrian, Ordovician, Carboniferous, and Jurassic formations are described briefly.

1905. Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, 1905. Embodies the results of reconnaissance trips in south-central Nevada made by Spurr and Weeks in 1899 and 1900, together with abstracts of the work of the earlier pioneer surveys, and thus forms a most valuable study of the geology of the region around Manhattan. The Monitor Range is described on p. 89, Toquima Range (principally in the vicinity of Belmont), pp. 90–93; Toyabe Range, pp. 93–97; Reese River Range, pp. 98–99; Pilot Mountains, pp. 103–105; Monte Cristo Mountains, pp. 105–106; Silver Peak Range, pp. 184–186. Abstracts from Spurr's report are given at greater length in the section on stratigraphy in the present volume, pp. 26–36.

1905. Spurr, J. S., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, 1905. The Tonopah mining district lies 34 miles south of Manhattan. The rocks are entirely Tertiary lavas, which are described in detail. The Tertiary rocks of the Manhattan district apparently correspond to the upper part of the Tertiary section in the Tonopah district. The productive ore deposits at Tonopah belong to an earlier period of Tertiary mineralization than the ores of Manhattan. Certain unproductive later veins may, however, be approximately contemporaneous with the Manhattan ores.

1906. Spurr, J. E., The ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, 1906. Describes ore deposits closely related to the alaskitic phases of a large granite intrusion. The granite, which is identical in character with that of Manhattan, is described in detail, and several analyses are given.

1907. Ball, S. H., A geologic reconnaissance of southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, 1907. Contains the results of a reconnaissance survey of the area lying between 36° 30′ and 38° north latitude and 116° 00′ and 117° 30′ west longitude. The work is much more detailed than Spurr's reconnaissance, but the northern boundary of the area covered lies about 40 miles south of Manhattan. The regions nearest Manhattan include the Lone Mountain foothills (pp. 51–55), the northeastern part of the Silver Peak Range (pp. 55–65), the southern Klondike Hills and Ralston Valley (pp. 77–83), and the Monitor Hills (pp. 97–99). More detailed references to Ball's report are given in the section on stratigraphy (pp. 26–36).

1908. Ball, S. H., The post-Jurassic igneous rocks of southwestern Nevada: Jour. Geology, vol. 16, pp. 36–45, 1908. A description of the rocks belonging to " the period of igneous activity beginning in post-Jurassic time and ceasing long prior to the Eocene." The region covered is the same as that described in Bulletin 308 (1907). The granitic rocks are in the main similar to those of the Manhattan district.

1909. Burgess, J. A., The geology of the producing part of the Tonopah mining district: Econ. Geology, vol. 10, pp. 681–712, 1909. A detailed study of the volcanic rocks of the district. Rocks which Spurr (1905) considers as flat-lying intrusives are interpreted by Burgess as flows.

1909. Packard, G. A., Jefferson Canyon, Nev.: Min. and Sci. Press, vol. 99, p. 26, 1909. Short note on the geology and former production.

1909. Ransome, F. L., The geology and ore deposits of Goldfield, Nev.: U. S. Geol. Survey Prof. Paper 66, 1909. The ore deposits of Goldfield, though differing in type, belong to the same general epoch of metallization as those of Manhattan, and the Tertiary rocks inclosing them have certain members in common with those of the Manhattan district.

1909. Turner, H. W., Contribution to the geology of the Silver Peak quadrangle, Nev.: Geol. Soc. America Bull., vol. 20, pp. 223–264. Describes the occurrence, relations, and petrologic characters of pre-Cambrian, Ordovician, and Quaternary deposits and of igneous and volcanic rocks. The portion dealing with Paleozoic stratigraphy is abstracted in part on pages 26–36 of this bulletin.

1912. Locke, Augustus, The geology of the Tonopah mining district: Am. Inst. Min. Eng. Trans., vol. 43, pp. 157–166, 1912. Summarizes the divergent views of Spurr (1905) and Burgess (1909). Locke's views as to the succession of the rocks are closely in harmony with those of Burgess.

1914. Buwalda, J. P., Tertiary mammal beds of Stewart and Ione valleys, in west-central Nevada: California Univ. Dept. Geology Bull., vol. 8, pp. 335–363, 1914. A study of the geology and physiography of a region about 40 miles west of the Manhattan district. The Esmeralda formation (equivalent to the "Siebert" formation) is treated in much detail. On the basis of fossil determinations by J. C. Merriam, the age of the Esmeralda beds is determined as approximately upper Miocene.

1915. Hill, J. M., Some mining districts in northeastern California and northwestern Nevada: U. S. Geol. Survey Bull. 594, 1915. The geology and ore deposits of the Toyabe Range southward from Austin to about latitude 39° 10′ are described on pp. 114–129. A summary of the stratigraphy is given, and the igneous rocks, particularly the intrusive granodiorite, are described.

1915. Louderback, G. D., Basin Range faulting in the northwestern part of the Great Basin: Geol. Soc. America Bull., vol. 26, pp. 138–139, 1915. The evidence indicates that the faulting was essentially normal. The idea of deformation with expansion is accepted as the best interpretation of the northwestern basin region.

1915. Meinzer, O. E., Ground water in Big Smoky Valley, Nev.: U. S. Geol. Survey Water-Supply Paper 375, pp. 85–116, 1915. A preliminary study of the water supply of the valley. Includes notes on the physiography of the region.

1915. Spurr, J. E., Geology and ore deposits at Tonopah, Nev.: Econ. Geology, vol. 10, pp, 713–769, 1915. Presents the results of further detailed work at Tonopah. The conclusions as to the sequence and character of the volcanic rocks are somewhat modified from those of Spurr's earlier report (1905).

1916. Merriam, J. C., Tertiary vertebrate fauna from the Cedar Mountain region of western Nevada: California Univ. Dept. Geology Bull., vol. 9, pp. 161–198, 1916. A paleontologic description of material from the Esmeralda formation collected by C. L. Baker and J. P. Buwalda. The fauna is "probably of upper Miocene age."

1917. Meinzer, O. E., Geology and water resources of the Big Smoky, Clayton, and Alkali Spring valleys, Nevada: U. S. Geol. Survey Water-Supply Paper 423, 1917. The physiography of the region is discussed in detail (pp. 17–50), including the development of the Toquima, Toyabe, and San Antonio ranges, as well as conditions pertaining more directly to Big Smoky Valley itself, such as the existence of Pleistocene lakes. A summary of the pre-Quaternary geology of the region with references to earlier literature is especially complete with respect to the Tertiary rocks (pp. 51–56 and 62–63). The Quaternary valley deposits are described in detail (pp. 57–62 and 64–65).

1918. Bastin, E. S., and Laney, F. B., The genesis of the ores at Tonopah, Nev.: U. S. Geol. Survey Prof. Paper 104, 1918. Chiefly a detailed study of the mineralogy and genesis of the Tonopah ores. The introductory portion, however, contains a review of the geology, and on p. 8 is a table showing the geologic formations according to the interpretations of Spurr (1915) and Burgess (1909).

1921. Ferguson, H. G., The Round Mountain district, Nev.: U. S. Geol. Survey Bull. 725, pp. 383–406, 1921. Gold deposits in rhyolite of upper Miocene or later age, comparable to the intrusive rhyolite of Manhattan, occur in the Round Mountain district, 17 miles north of Manhattan.

1921. Knopf, Adolph, The Divide silver district, Nev.: U. S. Geol. Survey Bull. 715, pp. 147–170, 1921. Description of ore bodies occurring in Tertiary lavas. As at Manhattan, the ore bodies are at least as young as the upper Miocene. The district is 40 miles south of Manhattan, and the succession of lavas is in some respects similar.

The following publications treat on the geology of the Manhattan district:

1907. Garrey, G. H., and Emmons, W. H., Notes on the Manhattan district: U. S. Geol. Survey Bull. 303, pp. 84–93, 1907. A preliminary study of the geology and ore deposits based on a reconnaissance made in March, 1906, soon after the discovery of the district.

1909. Jenney, W. P., Geology of the Manhattan district, Nev.: Eng. and Min. Jour., vol. 88, pp. 82, 83, 1909. Taken from report of April 2, 1909, on the property of the Manhattan Consolidated Gold Mines Co. Contains conclusions on the economic geology of the limestone ores, particularly the Manhattan Consolidated mine, based on the developments up to the beginning of 1909.

1916. Dynan, J. L., The White Caps mine, Manhattan, Nev.: Min. and Sci. Press, vol. 113, pp. 884–885, 1916. A thorough and detailed description of the geology of the mine. Development work at that time included the 310-foot level.

1916. Wherry, E. T., A peculiar intergrowth of phosphate and silicate minerals: Washington Acad. Sci. Jour., vol. 6, pp. 105–108, 1916. A mineralogic study, with analyses, of vashegyite, intergrown with a zeolitic mineral associated with variscite from Manhattan. (See pp. 94–96 of this bulletin.)

1917. Ferguson, H. G., Placer deposits of the Manhattan district, Nev.: U. S. Geol. Survey Bull. 640, pp. 163–193, 1917. A preliminary study of the physiography and placer deposits, repeated and amplified in the corresponding sections of the present bulletin.

1921. Ferguson, H. G., The limestone ores of Manhattan, Nev.: Econ. Geology, vol. 16, pp. 1–36, 1921. A short sketch of the general geology of the district and more detailed study of the ore deposits in the Cambrian (?) limestone.

The following publications on the Manhattan district deal with different phases of the mining industry and contain only incidental references to geology:

1906. Rice, C. T., The Manhattan mining district, Nev.: Eng. and Min. Jour., vol. 82, pp. 581–586, 1906. A description of operations at Manhattan in the early days of the camp.

1907. Packard, G. A., Round Mountain camp, Nev.: Eng. and Min. Jour., vol. 83, p. 151, 1907. Contains a description of early placer operations at Manhattan.

1909. Jones, C. C., Notes on Manhattan placers, Nye County, Nev.: Eng. and Min. Jour., vol. 88, pp. 101–104, 1909. A detailed description of placer-mining operations as conducted in 1909. Gives details of depth of shafts and tenor of pay gravel. A map shows the locations of placer shafts sunk up to the middle of 1909.

1909. Evans, C. R., Manhattan: Am. Min. Cong., 12th Ann. Sess. Proc., pp. 398–400, 1909. A short description of conditions in 1909.

1911. Toll, R. H., Present aspect of the Manhattan district, Nev.: Min. and Eng. World, vol. 35, pp. 539–540, 1911. Notes on the development of the mines.

1915. Quinn, P. J., Treatment at the Big Pine, Manhattan: Min. and Sci. Press, vol. 111, p. 320, 1915. Short article on milling methods.

1915. Nash, Percival, The mines and mills of Manhattan: Tonopah Mines, Aug. 15, 1915; largely reprinted in Min. and Sci. Press, vol. 111, p. 523, 1915. Description of operations and statistics of production.

1917. Kirchen, J. G., Solving the ore-treatment problem at White Caps mine: Eng. and Min. Jour., vol. 104, pp. 905–907, 1917. Describes experiments undertaken to find a satisfactory method of treatment for the White Caps ore, and the process adopted. On p. 906 is an analysis of the ore.

1919. Palmer, W. S., Occurrence of gold in sulphide ore.: Eng. and Min. Jour., vol. 107, pp. 923–924, 1919. Experiments on White Caps ore tending to show that the gold occurs as extremely finely divided native gold, coated with some black mineral, probably sulphide of antimony.

GENERAL GEOLOGY.

SUMMARY.

Although the area covered by the map of Manhattan and vicinity (Pl. I, in pocket) includes only a minute part of one of the smaller ranges of the Great Basin area, yet folded sediments of early Paleozoic age, Mesozoic granitic rocks, Tertiary volcanic and intrusive rocks, and Pleistocene gravels are all represented in it.

The oldest rocks in the area are marine sediments of probable Upper Cambrian age, laid down in shallow water. Sedimentation, probably interrupted by short intervals of emergence, continued during the Ordovician period. Above the Ordovician rocks there is a gap in the record, possibly indicating prolonged emergence of dry land, and the next Paleozoic sediments are marine sandstones of Permian (?) age. Owing to poor exposures the relation of these rocks to the Ordovician sediments is obscure, but there is probably an unconformity of considerable magnitude between them.

Mesozoic sediments, of which there is a considerable thickness at Cedar Mountain, 40 miles to the west,[16] in the Pilot Mountains, 50 miles to the west,[17] and in the Shoshone Range, 30 miles to the northwest,[18] do not occur in the Manhattan district, nor were they encountered in the neighboring parts of the Toquima Range covered by reconnaissance survey (fig. 2).

At some time within the Mesozoic era the older rocks were intensely folded. The folds are closely compressed, and most of them trend a few degrees to the north of west, nearly at right angles to the present mountain range. Many of the folds, particularly in the Ordovician limestones and slates, are overturned toward the north. An overthrust fault that brought the Cambrian (?) rocks above the Ordovician was contemporaneous with this folding.

At a distinctly later date than the folding came the intrusion of great masses of granite and related rocks. The outcrops of these rocks are not well represented in the area studied in detail, but large masses occur close by, both north and south of the Manhattan district, and probably also beneath the Tertiary rocks in the northern part of the area covered by the detailed map (Pl. I). The intrusion of the granite may have caused minor normal faulting in the sediments but apparently little if any doming or crushing. The sediments are intensely altered for a short distance from the granite contact and show over the whole area a greater or less degree of alteration, due to thermal metamorphism. The granite is identical in character with that of the Silver Peak quadrangle, which is essentially contemporaneous with the granitic intrusions of the Sierra Nevada.

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[16] Knopf, Adolph, Ore deposits of Cedar Mountain, Mineral County, Nev.: U. S. Geol. Survey Bull. 725, pp. 363–364, 1921.

[17] Spurr, J. C., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, p. 104, 1905.

[18] Ferguson, H. G., and Cathcart, S. H., Geology and ore deposits of the Tonopah quadrangle, Nev.: U. S. Geol. Survey Bull. — (in preparation).

Tertiary lavas older than the upper Miocene do not appear to be present in the region, and the record of volcanic activity at Manhattan probably began later than at Tonopah. At some time in the Miocene epoch the pre-Tertiary sedimentary rocks of the Manhattan district probably formed part of a small mountain range, which may have had a trend in accordance with the structure, while

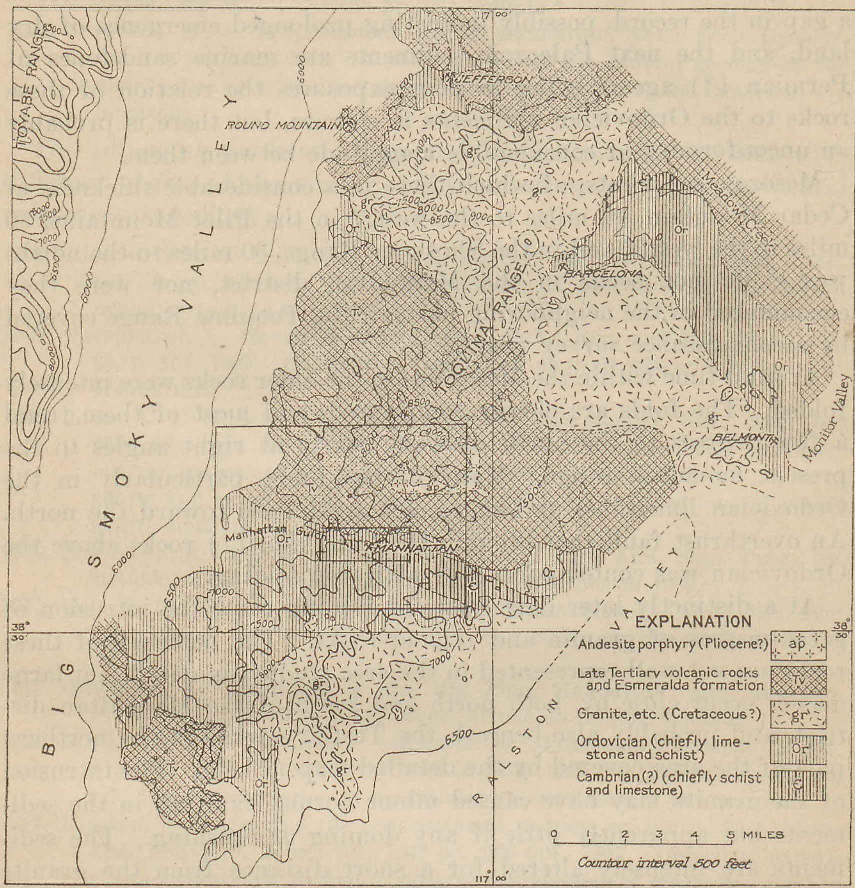


FIGURE 2.—Reconnaissance geologic map of the southern part of the Toquima Range. The larger rectangle indicates the area shown on Plate I; the smaller one the area shown on Plate II.

pinnacle topography characterized the areas of granite exposed. The topography was sufficiently rugged to allow the formation of talus slopes of angular material on the flanks of the hills. This talus is preserved in places and forms the oldest member of the Tertiary succession.

The oldest volcanic rock is rhyolitic breccia, with which are included a few flows of glassy rhyolite and a little bedded material. This rock is believed to be equivalent to the Fraction breccia of the

Tonopah district. The rhyolite breccia and flows buried a part of the older sediments and their talus material and possibly completely buried some earlier flows. A later flow of porphyritic rhyolite is present in the Manhattan district but lacking at Tonopah. This was succeeded by a long period of dominantly lacustrine deposition that produced the Bald Mountain lake beds, equivalent to the Siebert tuff of the Tonopah district and to part of the Esmeralda formation of the Silver Peak region, which are of approximately upper Miocene age. During this period outcrops of older rocks persisted above the level of the lake.

The deposition of the lake beds was followed by a flow of quartz latite, and that in turn by intrusions of glassy rhyolite and andesite porphyry. The rhyolite is found only in small dikes, but the andesite was intruded in larger masses that disturbed the older rocks.

Faulting took place both before and after the andesite intrusion and affected both the Tertiary and the older rocks. The largest normal faults of the area are of later date than the deposition of the lake beds but earlier than the andesite intrusion, and it is probable that many of the normal faults that displace the older sediments in the productive part of the district belong to the same period, though some of the normal faults may be as old as the period in which the sediments were folded.

After a considerable period of erosion came a thick flow of dacite, of which portions remain in the western part of the area.

The development of the present range probably began late in the Pliocene epoch. Manhattan Gulch had already been eroded by early Pleistocene time. Stages in the development of the present topography are represented by small areas of gravel on benches above the present gulf levels and by the deep gravels containing Pleistocene fossils in the gulch itself.

PALEOZOIC ROCKS.

Sedimentary rocks of Paleozoic age, most of them determinable on paleontologic grounds as Ordovician or older, occupy the greater portion of the area covered by the Manhattan map (Pl. I) and inclose all the valuable ore deposits. They have been considerably metamorphosed by igneous intrusion and close folding. Consequently, except in favored situations, they lack fossils, and with one exception it has been necessary to divide them into units on the basis of lithology alone. As no detailed work has been done on the stratigraphy of the neighboring ranges, little aid in defining the formations is available from results obtained in more favorable localities. The use of formation names drawn from the nearest areas of detailed work—the Eureka district, 90 miles to the northeast, or the Silver Peak quadrangle, 75 miles to the southwest—is clearly impossible in the absence of more distinctive fossils than were found at Manhattan. It seems best, therefore, in spite of the disadvantages involved, to give local names to the units employed in mapping. When further work in neighboring areas, where metamorphism is less intense, results in a more satisfactory link between the known areas to the northeast and southwest, these local names may be abandoned and replaced by others more in accord with the faunal evidence. The following subdivisions of the Paleozoic are here recognized, in descending order:

Permian (?) sandstone.
Toquima formation (Ordovician).
Zanzibar limestone (Ordovician?).
Mayflower schist (Ordovician?).
Gold Hill formation (Cambrian?).

CAMBRIAN (?) ROCKS.

Gold Hill formation.—The oldest rocks of the Manhattan district are a series of schistose slate, quartzite, and sandstone which crop out in a wedge-shaped area 1 mile wide at the eastern border of the district and pass under the next higher formation west of Gold Hill, a short distance north of the Tonopah road. No fossils except a few annelid trails were found in these rocks, but as they occur at a stratigraphic horizon considerably lower than rocks that carry fossils of Ordovician age, and as they bear some lithologic resemblance to known Cambrian terranes of other Nevada ranges, they are tentatively regarded as Cambrian.

The base of the formation is not exposed. In the Manhattan district the lowest members are truncated by the overthrust fault that separates this formation from the Ordovician sediments to the north. Nor is the upper limit determinable with certainty, for along at least the greater portion of its southern border a fault separates the upper members of the Gold Hill formation from the knotted schists here named Mayflower schist and referred to the Ordovician.

In the vicinity of the White Caps mine, where the formation was studied in most detail, the lowest members are quartzose schists with subordinate calcitic and lime silicate schists and a few thin beds of quartzite. To the east, where the divergence of strike between the overthrust fault and the beds to the south permits the outcrop of lower beds, there seems to be a greater proportion of quartzite. The outcrops are obscure, however, and the relative preponderance of the resistant quartzite both in outcrop and in talus tends to give a false impression of its abundance. Nowhere was there observed massive quartzite comparable to the Prospect Mountain quartzite of the Eureka section.

A short distance above the lowest member the formation becomes more calcareous and a group of three limestone beds, in places slightly dolomitic, comes in. As many of the ore bodies have been formed by the replacement of limestone, these bodies have been prospected extensively, and in spite of the complex faulting in the productive part of the district they can be traced with certainty as far eastward as the White Caps Extension shaft (Pl. II). Owing to their economic importance these members are here given the local names Pine Nut limestone, Morning Glory limestone, and White Caps limestone. The lowest of the three, the Pine Nut limestone member (named for its exposures on the Pine Nut claim), is about 10 feet thick and is an impure white crystalline limestone, carrying little knots of silicate minerals. The greater resistance of these clusters of silicates gives the weathered surfaces a characteristic knobby appearance. The Morning Glory limestone member (named for its outcrops near the Morning Glory mine) is separated from the Pine Nut by 140 feet of siliceous schist and consists of about 15 feet of white to blue-gray crystalline limestone without mixture of silicates. Between this and the White Caps limestone member (the bed which contains the ore deposits at the White Caps mine) is nearly 200 feet of schist with several thin beds of quartzite. The White Caps limestone is the best-defined lithologic unit of the Gold Hill formation and consists of about 30 feet of pure blue-gray crystalline limestone. The separation from the underlying schists is in most places sharp, but at the top and in places at the base there is a gradation from the pure limestone through calcareous schist to siliceous schist.

Above the White Caps limestone comes a series of siliceous schist, sandstone, and quartzite probably 2,500 feet thick, although closely compressed folds, such as that exposed in the Big Pine glory hole, make estimates doubtful. The schist predominates. In the lower part of the section, as seen in the underground workings of the White Caps and Manhattan Consolidated mines, it is commonly dark gray to purple in color, but it weathers on the outcrop to a rusty brown. As exposed in the Big Pine and Big Four workings the schist to a considerable depth below the surface is brown from the oxidation of pyrite.

Beds of white quartzite at a maximum not exceeding 50 feet thick occur here and there throughout the schist. These beds are of no value as horizon markers, as they thin out within short distances. The thickest and most numerous of the quartzite lenses appear to lie in a zone a short distance above the top of the White Caps limestone.

Several thin beds of dark sandstone are present in the central part of the formation. These show cross-bedding and rarely mud cracks, and though they are thinner and less conspicuous than the quartzite beds, they appear to be more persistent. In a very few places the sandstone grades into a fine-grained quartzose conglomerate.

Above the horizon represented by the schist and quartzite at the Big Pine mine calcareous layers again appear, but most of them are inconspicuous and can not be followed far. Close to the top of the formation, however, are two continuous thin beds of crystalline limestone, altered in places to a rock consisting largely of diopside. Between and above these beds is schist similar in appearance to that below.

The upper boundary of the Gold Hill formation is obscured by a fault that is nearly parallel to the strike and dip of the beds.

The prevailing color of the schist included in the Gold Hill formation is gray where unoxidized and brown on the outcrop or where mineralized in depth, as on Gold Hill; the overlying Mayflower schist is prevailingly dark with commonly a greenish tinge. The Gold Hill schists are dominantly siliceous and consist essentially of quartz and mica, whereas those above are much more aluminous and under the prevailing metamorphism yield the characteristic "knotted" or "spotted" schist. As both base and top of the Gold Hill formation are bounded by faults, the true thickness is unknown. The total thickness of the exposed beds is not over 5,000 feet.

ORDOVICIAN (?) ROCKS.

Between the top of the Gold Hill formation and the lowest fossiliferous bed of the district are sediments which contain no fossils but are tentatively referred to the Ordovician on the basis of their close lithologic similarity to the sediments that occur above the lowest fossiliferous bed. These are divisible into two lithologic units, a lower formation consisting chiefly of schist and schistose slate and here named Mayflower schist and an upper formation that is dominantly calcareous and is here named Zanzibar limestone.

Mayflower schist.—The lower schistose formation, here named Mayflower schist, from its outcrops in Mayflower Gulch, over most of the area has been altered by thermal metamorphism to a "knotted" schist of characteristic appearance. In its typical development this knotted schist shows a rough hummocky surface, due to the presence of closely spaced little lenses of harder siliceous material, around which curve the lamellae of the fine-grained chlorite schist. At a greater distance from the influence of the granite these knots become smaller and fewer, and at a still greater distance they are completely lacking and the rock is a fine-grained dark-green chloritic schist. The knots are also lacking immediately adjacent to the granite contact, where the rock is altered to a coarse friable biotite schist.

For the most part the schist is unaccompanied by other rocks, but in some sections outcrops of a dark-gray limestone, lithologically similar to the overlying Zanzibar limestone, were observed in positions which suggest that thin beds of limestone are interbedded with the schist, although it is conceivable that in these complexly folded rocks the limestone outcrops may represent infolded portions of the Zanzibar limestone. The repetition of schist and limestone on the ridge west of Salisbury Mountain, which has been interpreted as a succession of close folds, might possibly, on the other hand, be due in part to interbedding of the two rocks.

The Mayflower schist is less resistant to erosion than the siliceous slate and quartzite of the Gold Hill formation on one side and the overlying Zanzibar gray limestone and jasperoid on the other, and consequently the general region of its outcrop is marked by a belt of lowland skirting the southern border of the Gold Hill terrane. In a few places, where faulting has brought the overlying limestone against Gold Hill schist, the Mayflower schist is missing. As the contact between the Mayflower schist and the underlying Gold Hill formation lies along a fault, the thickness of the Mayflower is unknown. The exposed thickness is not over 800 feet, and the maximum is probably not much greater.

Zanzibar limestone.—The formation locally known as the Zanzibar limestone, from its prominent development on the Zanzibar claim, about 1½ miles east of Manhattan, consists essentially of blue-gray limestone of varying degrees of crystallinity. In most places dense black jaspilite is interbedded with the limestone. The jaspilite is not confined to any horizon of the limestone, though commonly more plentiful in the lower part. Nor does the proportion increase toward the areas of more intense metamorphism, though the jaspilite is very plentiful in the area of metamorphosed rocks west of Salisbury Mountain.

In many places the limestone grades off at its top and along the strike through dark calcareous slate to a fissile black, very fine-grained slate flecked on the partings with patches of muscovite and limonite. In places these micaceous patches are elongate and show sharp straight edges, suggesting that graptolites were originally present but are now metamorphosed beyond recognition. Except for these patches no trace of fossils was found. In some places this black slate appears to be lacking and the limestone continues up to the base of the Toquima formation.

Recently H. C. Clinton, of Manhattan, has collected a large variety of fossils from limestone of similar lithologic appearance at a point on the east flank of the range about 40 miles northwest of Manhattan. These have been examined by E. O. Ulrich, of the United States Geological Survey, who considers them of equivalent age to those of the Pogonip limestone of the Eureka district.

Close to the granite the limestone is commonly bleached and more coarsely crystalline and may show a considerable development of lime silicate minerals. In immediate contact with the granite there is usually a considerable development of epidote. In the area of metamorphosed sediments west of Salisbury Hill limestone of this type is altered to a dense white rock consisting essentially of quartz and diopside.

The Zanzibar limestone where least contorted, on Black Mammoth Hill, is about 800 feet thick; elsewhere its thickness appears to vary greatly, though for the most part below rather than above this figure.

ORDOVICIAN ROCKS.

Toquima formation.—Under the name Toquima formation is included a great thickness of rocks of varied lithologic character, including the lowest bed in which fossils were found. These rocks occur over a considerable part of the portion of the Toquima Range covered by the reconnaissance. The base of the formation is commonly marked by quartzite, which nowhere exceeds 50 feet in thickness and in places is lacking. Above this is a few feet of dark slate in which are graptolites of Normanskill (Ordovician) age, equivalent to the upper part of the Pogonip limestone of Eureka and the Palmetto formation of Silver Peak. In places a second thin stratum of quartzite is found above the slate. The fossils appear to owe their preservation from effacement by metamorphism to the protection afforded by the quartzite beneath, for no graptolites sufficiently well preserved for identification were found where the underlying quartzite layer is lacking.

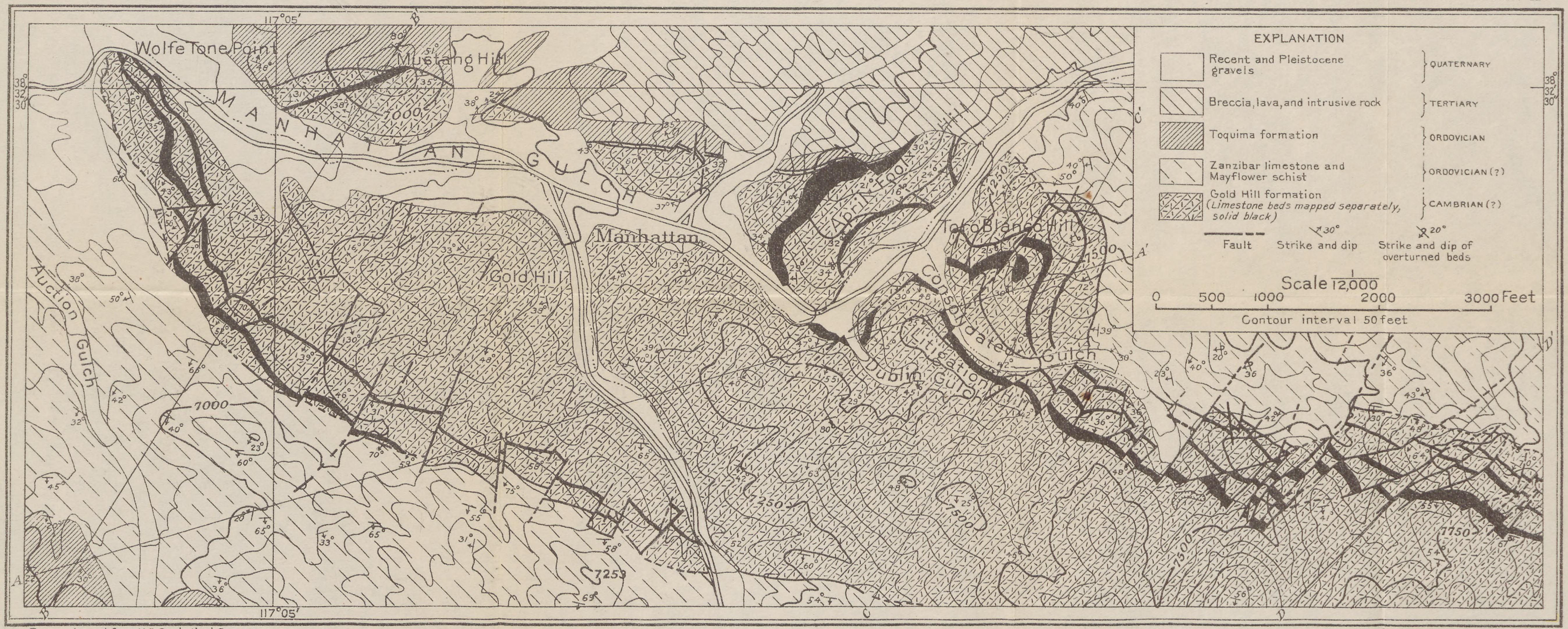
The following fossils from the slate above the basal quartzites were identified by Edwin Kirk, of the United States Geological Survey:

Top of Black Mammoth Hill and westward and southwestward to Manhattan Gulch:

- Dicranograptus sp.
- Diplograptus sp.
- Diplograptus hypniformis White.
- Dicranograptus near D. contortus Ruedemann.
- Climacograptus?.
- Conularia sp.

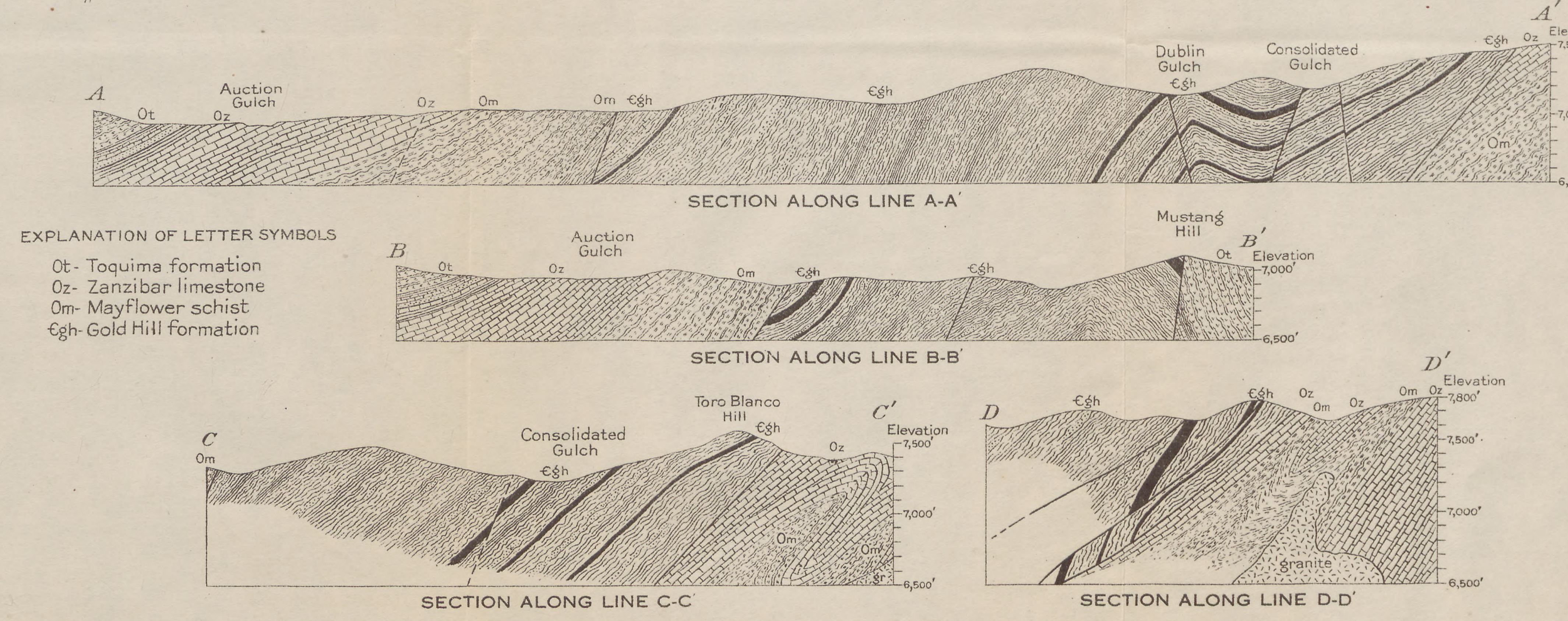
Southeastward from Manhattan Gulch to Auction Gulch, including Mount Moriah:

- Diplograptus angustifolius Hall.
- Climacograptus sp.
- Dicranograptus ramulus White.



Base enlarged from U.S. Geological Survey map of Manhattan and vicinity

Geology by H. G. Ferguson



GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE PRODUCTIVE PORTION OF THE MANHATTAN DISTRICT, NEV.

1923

Diplograptus hypniformis White.
Climacograptus bicornis Hall.
Odontocaulis sp.
Didymograptus sagitticaulis Gurley?.
Dicellograptus sp.
Nemagraptus sp.
Diplograptus sp.
Dicranograptus ramosus Hall.
Glossograptus quadrimucronatus Hall.

Southwestward from Auction Gulch to southern border of the area mapped:
Diplograptus hypniformis White.
Diplograptus sp.

Head of Auction Gulch:
Glossograptus quadrimucronatus Hall.
Dicranograptus?

Salisbury Mountain (including pebbles in fossil talus slopes):
Diplograptus sp.
Diplograptus hypniformis White.
Climacograptus bicornis Hall.
Dicranograptus ramulus White.
Retiolites sp.

Timber Hill Gulch (south of area mapped):
Didymograptus sp.

The graptolites found by the writer in the slates at Belmont appear to occupy the same horizon with reference to the sequence of lithologic formations as at Manhattan. The following species were collected:

Diplograptus angustifolius Hall.
Dicellograptus sp.
Diplograptus hypniformis White.
Lingula sp.

Above the graptolite-bearing slate is gray limestone with black jaspilite, identical in character with the Zanzibar limestone below. This appears to have a maximum thickness of 200 feet. It is perhaps thicker in the section on Salisbury Hill, but there the close folding and intense contact metamorphism make any measurement doubtful. Above this limestone no constant succession of beds could be made out, but the formation consists chiefly of gray-green chloritic schist, similar to the Mayflower schist beneath the Zanzibar limestone, and like it merging into knotted schist in the southern part of the district, where more directly affected by the granite. Interspersed with these schists, however, are numerous beds of dark blocky siliceous slate or chert, much like the black jaspilite in general appearance, and a few beds (nowhere more than 100 feet thick) of brown to gray crystalline limestone which differs from the lower limestone in being free from jasper and massive instead of thin bedded. Slaty chloritic schist, however, forms the bulk of the formation.

On Palo Alto Hill and the ridge to the east there is an apparent repetition of the lithologic units of this series. Gray limestone, similar to that of the Zanzibar formation, underlies slaty schist which on the crest of the ridge is capped by quartzite, with slate carrying graptolites immediately above. On the westward slope of the hill are a succession of thin quartzite beds, each accompanied by its overlying few feet of graptolite slate. How far this repetition of beds may be due to faulting could not be determined. The quartzite is certainly interbedded with the slate, and interfingering of slate and quartzite was observed (fig. 3). The quartzite and

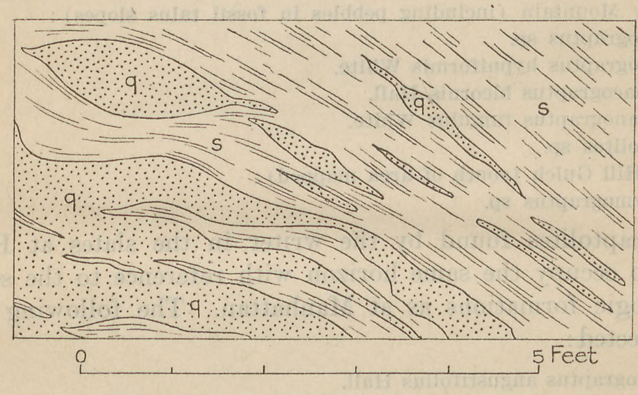


FIGURE 3.—Interbedded quartzite and graptolite slate, Palo Alto Hill.

accompanying slate are best developed near the summit of Palo Alto Hill. Here their apparent thickness is about 100 feet. Along the strike both to north and south there is a marked thinning. To the south the quartzite with accompanying graptolites could be traced across the gulch to a point where it is lost in the flat near the mouth of Old Manhattan Gulch. To the north it appears to die out a short distance south of the border of the Tertiary lavas. It is possible that this gray limestone and the overlying quartzite represent a repetition of the Zanzibar limestone and the lower part of the Toquima formation, due to faulting, but there is no field evidence to support this hypothesis, and the thickness from the base of the gray limestone to the first quartzite bed is greater than that of the Zanzibar limestone elsewhere. It appears more reasonable to conclude that the quartzite is present in lenticular beds at a horizon some 2,000 feet above the base of the formation and that the graptolites of Palo Alto Hill therefore represent a different stratigraphic level from those of Black Mammoth Hill, Mount Moriah, and the hills near Mayflower Gulch.

The following fossils from Palo Alto Hill and vicinity were identified by Mr. Kirk:

Diplograptus hypniformis White.
Dicranograptus ramulus White.
Retiolites sp.
Diplograptus angustifolius Hall.
Dicellograptus sp.
Dicranograptus ramosus Hall.
Climacograptus sp.

Mr. Kirk makes the following comments on the graptolites collected at Manhattan:

The graptolites identified above indicate the Normanskill (Ordovician) age of the containing beds. In the Silver Peak quadrangle, Nev., Turner obtained the same fauna from his Palmetto formation, which undoubtedly is equivalent to the graptolite-bearing series near Belmont and Manhattan. The Palmetto may perhaps be correlated in part with the upper portion of the Pogonip limestone of the Eureka district, or it may be represented wholly or in part by the Eureka quartzite. From published accounts, it appears that the pre-Richmond Ordovician sediments above the true Pogonip in western Nevada consist of a variable amount of limestone, shale, and quartzitic sandstone, the relative amounts of each varying according to the locality.

A small lens of limestone near the north end of Palo Alto Hill yielded the only fossils found in limestone. These were identified as *Salterella* sp. by Mr. Kirk, who states:

I have compared the fossils in this lot with Cambrian species from Nevada and find that they are not the same. The genus *Salterella* ranges up into the Ordovician, so this may well be a new species of Normanskill (Ordovician) age.

The upper contact of the Toquima formation is not shown in the Manhattan district, and its total thickness is unknown. It probably exceeds 4,000 feet in the area mapped and may be much greater, but there may be a greater number of small folds than have been found.

PERMIAN (?) SANDSTONE.

Two or three small isolated outcrops of a coarse sandstone, with lenses of slate, were found at a point about a mile northwest of the village of Manhattan. The rock contains in places poorly preserved fossils, concerning which G. H. Girty reports as follows:

Lot 2054 contains fossils in abundance, but they are compressed and otherwise poorly preserved. Nevertheless, I am satisfied that some of them belong to the genus *Productus*, and apparently the *cora* group, the *semireticulatus* group, and possibly other groups are represented. With less certainty I recognize strophomenoids among the specimens (*Derbya* or *Orthotetes*).

On the whole, I can not doubt that the age of this collection is Carboniferous. Lower Mississippian (Madison) is precluded by the fauna and by the character of the matrix, and it seems rather probable that the age can be limited to Pennsylvanian or Permian.

A single block of similar sandstone included in the tuffaceous rhyolite in the flat a mile west of Salisbury Mountain contains, according to Mr. Girty, "an undetermined *Chonetes* and a *Spirifer* of the *cameratus* group, probably *S. pseudocameratus*. The geologic age is either Pennsylvanian or Permian, and I think it is Permian (*Spiriferina pulchra* zone)."

In the course of a reconnaissance of the Toyabe Range made by the writer and S. H. Cathcart in the summer of 1922 rocks of similar lithologic character carrying fossils identified by Mr. Girty as of Permian age were found to rest unconformably on the Ordovician. There is every probability, therefore, that a considerable unconformity occurs in the Manhattan district. On the basis of the fossils found in the apparently contemporaneous rocks in the Toyabe Range this sandstone in the Manhattan district is herein classified as of Permian (?) age.

Nothing definite could be determined as to the relations of this sandstone to the Ordovician sediments exposed over a large area to the south. No other outcrops of this rock were found in the reconnaissance trips made to other parts of the range. The coarsest sandstone, grading toward a fine-grained conglomerate, contains small pieces of slate resembling that of the Toquima formation to the south. Hence it is presumed that the sandstone rests unconformably on the Ordovician and that the Silurian, Devonian, Mississippian, and Pennsylvanian formations of the Eureka section are absent. On the other hand, as the apparent thickness of the Toquima formation is much greater measured eastward from Black Mammoth Hill than northward toward the outcrop, there may be undetected close folding in the Toquima rocks, or a concealed fault in the area between, or a very considerable erosional unconformity. It is possible that the continuation of the large fault traced eastward across Mustang Hill and not found to the west of Black Mammoth Gulch is displaced to a position between the Ordovician and Permian (?) outcrops by later transverse faulting.

RELATION TO OTHER PALEOZOIC SECTIONS OF SOUTHWESTERN NEVADA.

The Manhattan district stands midway between two areas in which the Paleozoic rocks have been studied in detail. The Eureka district,[19] studied by Hague, Emmons, and Walcott, is 90 miles to the northeast. Less detailed work was done by Turner[20] in the Silver Peak region, about 75 miles to the southwest. Notes on the Paleo-

[19] U. S. Geol. Survey Mon. 8, 1884; Mon. 20, 1892.

[20] Turner, H. W., A sketch of the historical geology of Esmeralda County, Nev.: Am. Geologist, vol. 29, pp. 262–272, 1902.

zoic rocks of other ranges in this part of Nevada are to be found in the reconnaissance reports of Emmons,[21] Spurr,[22] Ball,[23] and Hill.[24]

Fossils are nearly lacking in the Manhattan district, and as lithologic character probably is not constant over large areas, no definite correlation of the Manhattan section with the Paleozoic sections of other ranges can be made. The following notes on the Paleozoic formations exposed in the Nevada ranges within a 100-mile radius of Manhattan may be of value for purposes of comparison.

CAMBRIAN FORMATIONS.

The section at Eureka, 90 miles northeast of Manhattan, shows 7,700 feet of Cambrian sediments. At the base is the Prospect Mountain quartzite, 2,500 feet thick. This consists of brownish-white quartzite, weathering dark brown, ferruginous near the base but white in the upper part. Intercalated with the quartzite are thin layers of arenaceous shale. Above it is the Eldorado limestone (formerly called "Prospect Mountain limestone"), 2,500 feet thick, consisting dominantly of gray compact limestone, with interstratified irregular lenticular beds of shale. Both dolomite and limestone occur in the series. Sandstone layers are rare. Hague[25] says: "It is difficult to define the characteristic features of the group, changes are so frequent in the deposition of the sediments, not only in the vertical but lateral extension." The next unit is the Secret Canyon shale, 1,600 feet thick, consisting of yellow and gray argillaceous shales that pass into shaly limestone. The base of the next formation, the Hamburg limestone, contains transition beds of shaly limestone which pass gradually into the overlying limestone. The Hamburg limestone, 1,600 feet thick, is a dark-gray granular limestone, with only slight traces of bedding, which shows a wide range in silica and magnesia content. Layers of fine sandstone and hard cherty bands occur at irregular intervals.

At the top of the Cambrian at Eureka is 350 feet of the Dunderberg ("Hamburg") shale, a yellow and gray argillaceous shale that contains chert nodules and shows very rapid changes in conditions of deposition, becoming alternately more or less arenaceous or calcareous through its entire thickness as well as laterally.[26] Near the top there are more or less persistent layers of chert and sand, followed by calcareous shale, which passes into the overlying Ordovician Pogonip limestone.

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[21] Emmons, S. F., Geology of the Toyabe Range: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 320–348, 1870.

[22] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, 1903.

[23] Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, 1907.

[24] Hill, J. M., Some mining districts in northeastern California and northwestern Nevada: U. S. Geol. Survey Bull. 594, 1915.

[25] U. S. Geol. Survey Mon. 20, p. 36, 1892.

[26] Idem, p. 41.

Parts of the Toyabe Range have been studied by S. F. Emmons,[27] J. E. Spurr,[28] and J. M. Hill.[29] Cambrian strata were not definitely recognized by Emmons, but below the slate containing Ordovician fossils are sediments considered by Spurr and Hill to be probably of Cambrian age. These consist of compact white quartzite, with some thin beds of white granular limestone, the whole series several thousand feet thick.

Rocks similar in lithologic character to the Gold Hill formation of Manhattan were found beneath the Ordovician of the Toyabe Range south of the thirty-ninth parallel.[30]

In the Quinn Canyon Range, 80 miles east of the Manhattan district, according to Spurr,[31] there are exposures of rusty brown limestone containing Cambrian fossils.

A detailed reconnaissance of the region south of the thirty-eighth parallel has been made by Ball, and the following descriptions are condensed from his report:

In the Specter Range,[32] about 100 miles southeast of Manhattan, 2,000 to 3,000 feet of quartzite and conglomeratic quartzite conformably underlie limestone containing Cambrian fossils. The quartzite is impure and grades through arkose into minor beds of red and green slaty shale. The quartzite is correlated with the Prospect Mountain quartzite of the Eureka district. Overlying the quartzite is 5,000 to 6,000 feet of dark-gray compact fine-grained crystalline limestone. Near the middle of the section are a few layers of black chert and a bed of quartzose sandstone. A few poorly preserved fossils indicate Cambrian age, though Ball considers that the upper portions may belong more properly with the Pogonip limestone (Ordovician).

In the southern Klondike Hills[33] and the Lone Mountain foothills[34] there are limestones which from their similarity to those of the Silver Peak quadrangle are considered to be Cambrian. Those of the southern Klondike Hills are described as follows:

> Cambrian rocks cover a considerable area in the southern part of these hills. They consist of an interbedded series of limestones, jasperoids, and shales, named in the order of their abundance. Neither the top nor the bottom of the series is exposed, but it is many hundreds of feet thick. The limestone, by far the predominant member of the series, is dark gray or blue-black, fine grained, compact, and crystalline. Bedding planes are from 2 to 3 feet apart.

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[27] U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 320–348, 1870.

[28] U. S. Geol. Survey Bull. 208, pp. 94–96, 1905.

[29] U. S. Geol. Survey Bull. 594, pp. 115–116, 1915.

[30] Ferguson, H. G., and Cathcart, S. H., Geologic reconnaissance of the Tonopah and Hawthorne quadrangles, Nev.: U. S. Geol. Survey Bull. — (in preparation).

[31] Op. cit., p. 69.

[32] Ball, S. H., U. S. Geol. Survey Bull. 308, pp. 28, 148–149, 1907.

[33] Idem, pp. 77–78.

[34] Idem, pp. 51–52.

Weathered surfaces are blackish gray in color and smooth in contour, although minor irregularities are produced by the varying hardness of the rock. The limestone grades into a silicified facies, best styled a jasperoid. This is ordinarily a dense banded rock of black and gray color, the laminae of which are in many cases but one-fourth inch in thickness. It breaks with a conchoidal fracture. The slaty shale is rather fine grained and of dark-gray or greenish-gray color. Even minor lenses and thin parting bands of fine-grained sandstone are rather unusual. The sediments form hills of moderate slope with numerous exposures. No fossils were found, but the lithology of the series is similar to that of the Lone Mountain hills, to the west, and in consequence the rocks are almost certainly Cambrian.

The Cambrian rocks of the Silver Peak quadrangle have been described by Turner.[35] Here the earliest rocks are a complex of gneiss, calcareous schist, and granite, of pre-Cambrian (Archean) age, and dolomite, quartzite, and green knotted schist, of probable Algonkian age. The Lower Cambrian (Silver Peak group) in the section north of Clayton Valley shows the following section from the base up: Massive dolomite, massive green quartzite with overlying knotted schist, *Archeocyathus*-bearing limestone, and green *Olenellus*-bearing slate, with dark limestone and some quartzite and thin-bedded slate at the top. In the Barrel Spring section fossils are found at all parts of the section; those nearest the base are large forms of *Olenellus*. The rock forming the lowest *Olenellus* zone is a dark micaceous slate. Higher up are layers of dark limestone with some quartzite. Then comes a second *Olenellus* zone, composed of green slate, again succeeded by fossiliferous limestone. The Upper Cambrian Emigrant formation is unconformable on the Lower Cambrian Silver Peak group and consists of a series of thin-bedded limestone and reddish slate, with some layers of black chert. There appears to be no sharp line of separation between the Emigrant formation and the Palmetto formation (Ordovician).

Cambrian sediments are well developed in the Inyo Range of southeastern California, particularly in the Bishop quadrangle, which lies southwest of the Silver Peak quadrangle. These beds have been studied by Walcott[36] and Kirk.[37] Although this area is outside the 100-mile radius from Manhattan taken for comparison with the Manhattan section, the great completeness of the section exposed there makes a short summary desirable. The Cambrian sediments of the Bishop quadrangle exceed 12,000 feet in thickness and rest unconformably on pre-Cambrian sandstone, dolomite, and limestone. The Lower Cambrian includes two subdivisions—the Campito sandstone, 3,200 feet thick, and the Silver Peak group, about 7,000 feet thick.

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[35] Am. Geologist, vol. 29, pp. 264–265, 1902.

[36] Walcott, C. D., Lower Cambrian rocks in eastern California: Am. Jour. Sci., 3d ser., vol. 49, pp. 141–143, 1875.

[37] Kirk, Edwin, Stratigraphy of the Inyo Range: U. S. Geol. Survey Prof. Paper 110, pp. 19–48, 1918.

The Campito sandstone consists of fine-grained cross-bedded sandstone and is probably to be correlated with the Prospect Mountain quartzite of eastern Nevada. The Silver Peak group consists of fossiliferous calcareous shale, sandstone, and limestone. The limestone is massive and more abundant in the upper part. The sandstone is similar in appearance to that of the Campito and is commonly cross-bedded. Lower Cambrian fossils are abundant. The name Silver Peak was proposed by Turner [38] and used by Walcott [39] for the fossiliferous series of Lower Cambrian sediments in western Nevada and eastern California. The group has the same lithologic and faunal character in the adjoining Silver Peak quadrangle. The Middle Cambrian is represented in the Inyo Range by 50 feet of dense white quartzite overlain by 750 feet of thin-bedded quartzite and calcareous sandstone and 100 feet of granular limestone. The Upper Cambrian includes about 1,000 feet of sediments. The basal third or quarter consists of thin-bedded arenaceous limestone with subordinate amounts of greenish shale. Interbedded with the shale are sandstone and some impure limestone. The series is similar lithologically to the Emigrant formation of the Silver Peak area.

ORDOVICIAN AND SILURIAN FORMATIONS.

In the Eureka district the Ordovician is represented by the Pogonip limestone, 2,700 feet thick; the overlying Eureka quartzite, 500 feet thick; and the Lone Mountain limestone, 1,800 feet thick, which is in part of Upper Ordovician (Richmond) age and in part Silurian. At Eureka [40] the Pogonip limestone rests conformably on the Dunderberg ("Hamburg") shale. The transition is marked by argillite and fine-grained arenaceous beds with interstratified calcareous shale, passing upward into pure fine-grained limestone of bluish-gray color, distinctly bedded and highly fossiliferous. According to Kirk [41] the main mass of the Pogonip exposed in the type area is of Beekmantown age as determined by the faunal content, but the top part carries a Chazy fauna. In earlier work the term has been rather loosely applied to all limestones of Ordovician age throughout central and southern Nevada. The Eureka quartzite is a very prominent feature of the Eureka section. It is a compact vitreous quartzite with indistinct bedding and is a prominent ridge maker. The Lone Mountain limestone contains at the base black gritty beds

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[38] Turner, H. W., A sketch of the historical geology of Esmeralda County, Nev.: Am. Geologist, vol. 29, pp. 264–265, 1902.

[39] Walcott, C. D., Cambrian section of the Cordilleran area: Smithsonian Misc. Coll., vol. 53, p. 185, 1908.

[40] Hague, Arnold, U. S. Geol. Survey Mon. 20, p. 48, 1892.

[41] Kirk, Edwin, Stratigraphy of the Inyo Range: U. S. Geol. Survey Prof. Paper 110, p. 34, 1918.

with Trenton fossils. These pass upward into a light-gray massive siliceous rock.

In the Golden Gate Range, about 100 miles east of the Manhattan district, Spurr[42] found Ordovician and Silurian rocks. At the base of the section is 300 feet of thin-bedded somewhat fetid limestone and limy shale correlated with the Pogonip limestone. Next above comes 250 feet of white vitreous quartzite. Above this is 800 feet of comparatively massive brownish limestone correlated with the Lone Mountain limestone. At a point 150 feet below the quartzite correlated with the Eureka quartzite Ordovician fossils were found in a limestone that probably corresponds to the Pogonip limestone.

In the Quinn Canyon and Grant ranges,[43] about 80 miles east of Manhattan, there is 600 or 800 feet of dark-blue to gray limestone overlain by 300 feet of vitreous quartzite, probably the Eureka quartzite, succeeded in turn by 400 feet of gray-blue massive limestone, the upper part of which is considered by Spurr as probably including part of the Devonian Nevada limestone.

At Hot Creek, in the Hot Creek Range, about 50 miles east of Manhattan, Spurr[44] observed the following section:

Section at Hot Creek.

		Feet.
5. Massive gray coarsely crystalline limestone	[Probably Lone Mountain limestone]	500
4. Shale mixed with thin-bedded limestone		1,000
3. Thin-bedded dark-blue limestone		200
2. Massive white quartzite [probably Eureka quartzite]		400
1. Thin-bedded dark-blue frosty-lustered limestone [probably Pogonip limestone]		400

Ordovician fossils were obtained 200 feet below the quartzite. At a point 3 miles to the west there is about 600 feet of siliceous light-gray limestone below bed No. 1, making in all about 1,000 feet of limestone below the quartzite.

In the Toyabe Range, according to Emmons,[45] there is a series with an estimated thickness of 7,000 feet, consisting of limestone and shale, with siliceous clay slate, locally metamorphosed into schistose rocks. These beds are supposed to be the same as the slates at Belmont and if so must be of Ordovician age. Ordovician fossils have recently been found in places in the southern part of the Toyabe Range, but here the thickness does not appear to exceed 3,500 feet.

For the part of Nevada south of the thirty-eighth parallel Ball[46] gives a generalized section in which he states that the lowest division

[42] Spurr, J. E., U. S. Geol. Survey Bull. 208, p. 57, 1903.
[43] Idem, p. 69.
[44] Idem, p. 85.
[45] U. S. Geol. Expl. 40th Par. Rept., vol. 3, p. 328, 1870.
[46] U. S. Geol. Survey Bull. 308, pp. 28–29, 1907.

of the Ordovician is the Pogonip limestone, 200 to 4,000 feet thick. This limestone seems to succeed the Cambrian limestone without marked lithologic change. It is dark gray, fine to medium grained, and dense and is somewhat lighter in color and more massively bedded than the underlying Cambrian limestone. Near the middle is about 100 feet of white or pinkish quartzite. The transitional rocks from the Pogonip to the overlying Eureka quartzite are an interbedded series of limestone, shale, and quartzite. According to Ball,

> The Eureka quartzite in southwestern Nevada is a typically white or pink, fine to medium grained pure metamorphosed quartzose sediment. Some beds, however, are conglomeratic quartzites, while others are argillaceous and grade into thin interbedded sheets of dark-colored slaty shale.

The quartzite is thicker than at Eureka, reaching 1,200 to 1,500 feet in the Kawich Range, and it is underlain by a transitional series of limestone, shale, and quartzite instead of directly by the Pogonip limestone, as at Eureka.

In the Belted Range,[47] about 100 miles south-southeast of Manhattan, a thickness of 4,000 feet of Ordovician sediments considered the equivalent of the Pogonip limestone is exposed. These rocks consist dominantly of limestone, which is typically fine grained, crystalline, and dark gray or black. Nodules of black chert are present in places, and certain beds of limestone are silicified to a compact black jasperoid, with conchoidal fracture. Quartzite forms a prominent bed near the middle of the limestone. Much of the quartzite is argillaceous and grades into thin-bedded slaty shale.

The Amargosa Range[48] forms the northern border of Death Valley in California just south of the Nevada line. The portion known as the Grapevine Mountains is 110 miles south of Manhattan. Here between 2,000 and 3,000 feet of limestone that yielded Middle Ordovician fossils is exposed. This limestone is correlated with the Pogonip. It is gray to black and is closely laminated but shows heavy bedding. In places areas of coarse white calcite blotch the limestone. A thin bed of white quartzite is interbedded with the limestone in the lower part of the series at Cave Rock Spring. Overlying the Pogonip limestone is about 800 feet of quartzite, the equivalent of the Eureka quartzite. This is a pink, rather fine quartz rock of medium grain, in which conglomeratic bands occur. Thin layers of black fine-grained argillaceous quartzite and of slaty shale are interbedded with the normal quartzite. Above the quartzite is 300 feet of limestone which resembles the Pogonip closely. In this rock were found imperfect silicified fossils of late Silurian age, and consequently the limestone is to be correlated in part with the Lone Mountain limestone of the Eureka section. According to Kirk it

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[47] Ball, S. H., op. cit., pp. 119–120.
[48] Idem., pp. 164–166.

is also to be correlated with the Fusselman limestone of Texas and New Mexico.

At Quartzite Mountain, in the Kawich Range,[49] 40 miles southeast of Manhattan, there is a considerable thickness of rocks of probable Ordovician age, including 400 to 600 feet of interbedded quartzite, slaty shale, and limestone, surmounted by 1,200 to 1,500 feet of quartzite. The Lone Mountain limestone (of Upper Ordovician and Silurian age) is probably also represented in a small area of limestone at what appears to be a horizon stratigraphically above the quartzite.

Dark-gray limestone and fine to medium grained white to red quartzite in the Cactus Range,[50] about 40 miles south-southeast of Manhattan, are considered on lithologic grounds to be the Pogonip limestone and Eureka quartzite respectively.

The Ordovician sediments of the Silver Peak quadrangle have been described by Turner[51] and named by him the Palmetto formation. According to Turner there appears to be no sharp line of separation between the Emigrant formation (Upper Cambrian) and the Palmetto formation (Lower Ordovician). The Palmetto formation consists of dark thin-bedded chert with layers of gray graptolite slate and smaller amounts of reddish slate and an occasional limestone layer. The most abundant and characteristic fossils of this formation are the graptolites found in the gray slate. The graptolites represent two horizons—one of Normanskill age, the other of Beekmantown age—but nearly all of them are of Normanskill age. In the Beekmantown fauna there are two characteristic genera, *Didymograptus* and *Tetragraptus*. In places numerous streaks of light-colored felsitic rock are interbedded with the dark chert of Normanskill age. These streaks may in part represent altered rhyolitic or dacitic tuff and lava.

The Ordovician of the Inyo Range[52] has a total thickness of about 5,000 feet and includes four subdivisions. There is a basal sandstone interstratified with shaly layers, 300 feet thick, followed by 3,500 feet of blue-gray to lead-colored limestone, probably of Beekmantown age. These two subdivisions are correlated with part of the Pogonip limestone of the Eureka district. Above them is 500 feet of bluish to almost black limestone in which shaly beds occur. This series carries fossils of Chazy age and hence is equivalent to the upper part of the Pogonip of the White Pine district. The uppermost subdivision comprises 750 feet of arenaceous shale con-

[49] Ball, S. H., op. cit., p. 100.

[50] Idem, pp. 89–90.

[51] Turner, H. W., A sketch of the historical geology of Esmeralda County, Nev.: Am. Geologist, vol. 29, pp. 262–272, 1902.

[52] Kirk, Edwin, op. cit., pp. 32–36.

taining a fauna of Normanskill age. This formation is predominantly shaly but contains some bands of sandstone. It is correlated with the Palmetto of Turner in the Silver Peak quadrangle.

DEVONIAN FORMATIONS.

Although no rocks of Devonian age were found in the Manhattan district or the portion of the Toquima Range covered by the reconnaissance, Devonian formations occupy a prominent position in some parts of central Nevada, particularly the areas covered by the Fortieth Parallel Survey. In the Eureka district and the White Pine Range there is the Nevada limestone, 6,000 feet thick, a massive gray to bluish-black highly fossiliferous limestone, above which lies 2,000 feet of black argillaceous shale (White Pine shale), originally referred to the Devonian but correlated by Girty [53] with the Caney shale of Arkansas, which he refers to the Mississippian.

Spurr's reconnaissance shows the presence of Devonian rocks in the Golden Gate Range,[54] about 100 miles east-southeast of Manhattan, where 2,000 feet of Devonian beds are exposed—the lower half limestone, largely corals, and the remainder shale and thin-bedded limestone. No certainly identified Devonian is present in the other ranges studied by Spurr [55] in this region. In the Quinn Canyon Range the thickness of limestone above the quartzite that is correlated with the Eureka quartzite is greatly in excess of that of the Lone Mountain limestone at Eureka. It is possible, therefore, that the upper portion of this limestone includes part of the Devonian Nevada limestone. The slate of probable Ordovician age in the northern part of the Toyabe Range is overlain by dark-blue limestone of Carboniferous age. This range has been so little studied, however, that Devonian strata may be present but unrecognized.

In the portion of southern Nevada covered by Ball's reconnaissance the Devonian is thought to be lacking, nor were Devonian formations found by Turner in the Silver Peak quadrangle.

In the Inyo Range, on the other hand, Kirk [56] found Devonian limestone with subordinate shale and sandstone, which are correlated with the Nevada limestone of the Eureka section.

In 1922 Devonian limestone was found by the writer and S. H. Cathcart in the San Antonio Range, 25 miles south of Manhattan. In the central part of the Toyabe Range the Permian rests unconformably on the Ordovician, implying erosion of the Devonian strata in this region.

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[53] Girty, G. H., Relations of some Carboniferous faunas: Washington Acad. Sci. Proc., vol. 7, pp. 11–12, 1905.

[54] Spurr, J. E., U. S. Geol. Survey Bull. 208, p. 57, 1903.

[55] Idem, p. 72.

[56] Kirk, Edwin, U. S. Geol. Survey Prof. Paper 110, p. 36, 1918.

MISSISSIPPIAN FORMATIONS.

The Mississippian of the Eureka section includes the White Pine shale, consisting of 2,000 feet of black argillaceous shales with intercalated sandstones, originally referred to the Devonian, overlain by 3,000 feet of massive quartzite with shale at the top (the Diamond Peak quartzite), of probable Mississippian age.

The Mississippian appears to be lacking in the ranges of central and southern Nevada, within 100 miles of Manhattan, visited by Spurr. Ball's reconnaissance in southern Nevada revealed no rocks of Mississippian age. Wherever well-exposed sections were found the Pennsylvanian rests unconformably on the Lone Mountain limestone.[57] Turner found no Mississippian in the Silver Peak quadrangle.

In the Inyo Range,[58] however, there is at least 1,000 feet of shale with a little sandstone and limestone, with conglomerate at the base, which is correlated with the White Pine shale of eastern Nevada.

PENNSYLVANIAN AND PERMIAN FORMATIONS.

In contrast to the irregular distribution of Devonian and Mississippian formations, the Pennsylvanian appears to be well represented in this portion of Nevada.

In the Eureka district[59] the rocks of known Pennsylvanian age begin with 3,800 feet of heavy-bedded dark limestone with intercalated bands of chert and argillaceous beds near the base (the "Lower Coal Measures" limestone of Hague). This is overlain by 2,000 feet of coarse and fine conglomerates with angular fragments of chert and layers of reddish-yellow sandstone that have been correlated with the Weber conglomerate of Utah. The uppermost formation is the "Upper Coal Measures" limestone, consisting of 500 feet of light-colored blue and drab limestone. This, however, may be of Permian age.[60]

In the White Pine Range, according to Hague[61] and Spurr,[62] the section is similar.

Spurr's reconnaissance disclosed Pennsylvanian formations in different ranges throughout central Nevada, but less well developed than in the region of the fortieth parallel.

Several ranges in the extreme southern part of the State, southward and southeastward from the Pahranagat Range, show a considerable thickness of Carboniferous limestone.

In the Toyabe Range Emmons[63] found a considerable thickness of Carboniferous limestone overlying the Ordovician (?) slate.

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57 Ball, S. H., U. S. Geol. Survey Bull. 308, fig. 3, 1907.

58 Kirk, Edwin, U. S. Geol. Survey Prof. Paper 110, pp. 38–39, 1918.

59 Hague, Arnold, U. S. Geol. Survey Mon. 20, p. 84, 1892.

60 Kirk, Edwin, Stratigraphy of the Inyo Range: U. S. Geol. Survey Prof. Paper 110, p. 44, 1918.

61 Hague, Arnold, op. cit. (Mon. 20), p. 191; U. S. Geol. Expl. 40th Par. Rept., vol. 2, pp. 542–547, 1875.

62 Spurr, J. E., U. S. Geol. Survey Bull. 208, p. 62, 1905.

63 Emmons, S. F., U. S. Geol. Expl. 40th Par. Rept., vol. 3, p. 323, 1870. Spurr, J. E., op. cit., p. 95.

Ball[64] correlated the oldest Pennsylvanian in southern Nevada with the so-called Weber conglomerate of the Eureka section, the two lower formations of the series apparently being absent. Above this is a considerable thickness of limestone.

In the Belted Range[65] the lower formation, which has been considered the equivalent of the Weber conglomerate, consists of 800 to 1,000 feet of sandstone with conglomeratic bands, which appear to contain pebbles derived from Cambrian strata, and an overlying shale 300 to 500 feet thick. The overlying Pennsylvanian limestone is approximately 2,500 feet thick.

In the Cactus Range a conglomerate containing pebbles probably derived from Cambrian, Ordovician, and Silurian rocks is also correlated with the Weber conglomerate.

The conglomerate was not found in the Panamint Range,[66] where the Pennsylvanian limestone, of which some 1,500 feet is exposed, is in fault contact with the Pogonip (Ordovician).

In the Reveille Range[67] a massive white quartzite that underlies the Pennsylvanian limestone is correlated with the Weber conglomerate, although lithologically more closely resembling the older quartzites of the Eureka section. Above this is massive limestone of Pennsylvanian age.

Pennsylvanian limestone similar to that of the Belted Range also occurs on Shoshone Mountain.[68]

According to Turner,[69] sandstone and slate with cherty layers containing fossils referred to the upper Carboniferous were found southeast of Candelaria. No study was made of the formation.

The Pennsylvanian of the Inyo Range[70] contains a basal limestone, between 500 and 1,000 feet thick. This is not present in the south-central Nevada sections. Unconformably overlying it is the Diamond Peak quartzite, at least 3,000 feet thick. The "Lower Coal Measures" limestone of the Eureka section is represented by calcareous shale and impure limestone, with a thickness of about 3,000 feet. The probable stratigraphic equivalent of the so-called Weber conglomerate is the Reward conglomerate, 250 feet thick, which is clearly a nonmarine deposit. Above this is the Owenyo limestone, 125 feet thick, containing a fauna similar to that of the "Upper Coal Measures" limestone of the Eureka section and assigned by Girty to the Permian.[71]

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64 Ball, S. H., U. S. Geol. Survey Bull. 308, p. 30, 1907.
65 Idem, pp. 120–122.
66 Idem, pp. 203–204.
67 Idem, pp. 115–116.
68 Idem, p. 143.
69 Turner, H. W., op. cit., p. 266.
70 Kirk, Edwin, op. cit., pp. 40–45.
71 Idem, p. 45.

COMPARISON WITH THE MANHATTAN SECTION.

The foregoing summary shows the impossibility of making definite correlations on lithologic grounds between the rocks of the Manhattan section and the Paleozoic formations of the neighboring ranges. The Gold Hill formation of Manhattan is perhaps equivalent to the Dunderberg ("Hamburg") shale of the Eureka district, but there is no close similarity. The upper part of the Cambrian of the Toyabe Range, on the other hand, is much more like the Gold Hill formation. Farther south the dark Cambrian limestones with black chert and jasperoid described by Ball bear a closer lithologic resemblance to the Zanzibar limestone, of supposed Ordovician age, than to the rocks mapped as probable Cambrian at Manhattan. The Emigrant formation of Turner, however, consists of alternations of shale and sandstone and limestone similar to the Gold Hill formation of Manhattan.

The Mayflower schist does not closely correspond in lithologic character or stratigraphic position with any of the Ordovician sediments of the neighboring ranges that have been described.

The Zanzibar limestone, including the black slate below the first graptolite horizon, is probably the equivalent of the lower part of the Pogonip limestone described by Ball. The quartzite in the Manhattan district taken as the base of the Toquima formation is overlain by limestone similar to the Zanzibar and may represent the quartzite described by Ball as nearly everywhere present in the middle of the Pogonip limestone. If it does, the Pogonip limestone in the sense in which the term was used by Ball includes also the lower 100 or 200 feet of the Toquima formation. The Palmetto formation as described by Turner appears to be lithologically as well as paleontologically similar to the Toquima formation.

Silurian, Devonian, and Mississippian strata are present in the Eureka section, to the northeast, and Devonian and Mississippian in the Inyo Range, to the southwest, as well as in some of the ranges farther east, but at Manhattan all three are lacking and the possible equivalent of the so-called Weber conglomerate rests unconformably on the Ordovician slate. It is likely that the same condition is present in the Toyabe Range. In Nevada south of the thirty-eighth parallel Ball found a thin stratum of Silurian limestone but no Devonian or Mississippian. No rocks of Silurian, Devonian, or Mississippian age are recorded by Turner from the Silver Peak quadrangle, but Devonian and Mississippian rocks are present a short distance to the west and southwest, in the Inyo Range. It is inferred that a land mass was persistent in this portion of southwestern Nevada during much of the time from the Silurian to the Pennsylvanian.

The outcrops of sandstone and conglomerate of Permian (?) age in the Manhattan district are too obscure and cover too small an area to justify any correlation with formations of similar age except in the Toyabe Range, where the Permian rests unconformably on the Ordovician. Possibly they represent the equivalent of the so-called Weber conglomerate of the Eureka district.

GRANITIC ROCKS (CRETACEOUS?).

Granitic rocks intrusive into the Paleozoic sediments occupy much of the Toquima Range, and it is probable that a considerable mass of such rocks is buried under the Tertiary rocks near Bald Mountain and the valley fill of Ralston Valley near Spanish Springs and Belmont.

As the stage from Tonopah approaches the Toquima Range from the south the visitor to Manhattan readily perceives that much of the flat valley on the southeast side of the range is covered with only a thin veneer of detrital material, and that here and there the underlying granite is visible. Nearer the range the road passes between granite hummocks of fantastic shapes. Beyond Spanish Springs the hills are higher and the topography more rugged, and just north of a short canyon cut in the granite the contact with the Paleozoic sediments is reached at Pipe Springs. To the west the northern border of the granite area reaches as far as the prominent peak forming the summit of the southern part of the range, and to the east it reaches Ralston Valley, a short distance south of the mouth of East Manhattan Gulch. It is probable that the granite extends northward under the fill of Ralston Valley and that the southern mass is connected with the northern granite area west of Belmont. A small area of granite, separated from the larger mass by a narrow belt of metamorphosed sediments, occupies the head of Old Manhattan Gulch, near Mustang Spring.

The largest area of granite exposed in the explored portion of the Toquima Range extends northwestward from Belmont and crosses the range in a broad, irregular belt. The contact of the granite with the Cambrian (?) and Ordovician sediments is exposed along its northern border between Belmont and Barcelona and thence northward toward the headwaters of Meadow Creek. Beyond this point it is buried under later lavas except for a short stretch between Jefferson and Round Mountain. On the south side the contact of the granite with the Ordovician sediments is exposed on a part of the western flank of the range, but along the greater part of its southern border the granite passes beneath Tertiary lavas, which, it is believed, cover a southward extension of this granite area nearly as large as that now remaining exposed. At three points in the Manhattan district there are small outcrops of granite surrounded by Tertiary rocks. These represent summits of granite peaks formerly buried beneath the lavas and tuffs. One of these outcrops near the northeast corner of the area, at an altitude of 8,300 feet, is surrounded by the Bald Mountain lake beds and must have persisted as an island throughout the lacustrine period. The other two, a short distance north of Salisbury Peak, protrude through Round Rock rhyolite.

The granite varies in mineral composition in different parts of the mass, though no evidence of intrusion at different times was found. Most of the thin sections examined are microcline granite, but the rock grades in places into quartz monzonite or granodiorite. Commonly the granite is porphyritic and carries large feldspar phenocrysts, which may be as much as 5 or 6 centimeters in length. These may be microcline or orthclase, and many of them are perthitically intergrown with albite. The remainder of the rock is of coarse-grained granitic texture. Quartz is prominent and in some specimens equals or exceeds the feldspars in volume. The feldspars consist of orthoclase, microcline, albite, and oligoclase in varying proportions. In none of the sections examined was either orthoclase or plagioclase entirely lacking. Biotite is present except near the contact, where its place may be taken by muscovite. Muscovite is not common in the inner portions of the large masses but occurs abundantly near the contacts. Other accessory minerals are magnetite, ilmenite, titanite, garnet, zircon, monazite, and tourmaline, which are present in small amounts only.

The granite of the Toquima Range undoubtedly forms a part of the same batholith as the granite of identical mineral composition and appearance studied by Spurr and Turner in the Silver Peak region. The following partial analyses of granites from the Silver Peak quadrangle, made by George Steiger, are quoted from Spurr's report.[72]

Partial analyses of granitic rocks from southern part of Silver Peak quadrangle.

	1	2	3	4	5
Silica (SiO_2)	68.50	69.23	71.14	73.22	76.04
Lime (CaO)	.60	3.38	2.56	1.52	.46
Soda (Na_2O)	4.05	3.75	3.65	2.79	7.58
Potash (K_2O)	4.83	4.75	3.37	5.35	.07

These analyses indicate a considerable range in composition, the rocks varying from a basic phase having the composition of a quartz monzonite or granodiorite through the ordinary granite type to alaskite (No. 5).

[72] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, p. 23, 1906.

The silicic phases of magmatic differentiation are represented by alaskites varying in texture from aplites to pegmatites. Narrow dikes or sills of very fine-grained alaskite aplite are extremely common throughout the district. In many places they are intruded parallel to the bedding of the inclosing sediments and from their fine-grained and siliceous aspect might readily be mistaken for thin beds of white quartzite. They consist essentially of an aggregate of quartz, feldspar, and muscovite, in which the individual grains do not commonly exceed 0.03 millimeter in diameter. Quartz is the predominant mineral and in most places forms more than half the rock. The feldspars present include orthoclase, microcline, and albite; the albite usually occurs in comparatively small amount. Muscovite is present in two forms—in individual crystals contemporaneous with the other rock minerals and commonly containing numerous quartz inclusions, and in little spherulite-like clusters and radiating groups replacing the felspar. As Spurr[73] has shown, the formation of the second type of muscovite probably followed the solidification of the dike.

An alaskite dike in the vicinity of Belmont has been described in detail by Spurr,[74] and the following analysis of the rock was made by George Steiger, of the United States Geological Survey:

Analysis of alaskite near Belmont, Nev.

SiO_2	84.15	H_2O-	0.21
Al_2O_3	9.67	H_2O+	.74
Fe_2O_3	.51	TiO_2	Trace.
FeO	.07	SO_2	Trace.
MgO	.53		
Na_2O	2.65		100.12
K_2O	1.57		

In a few places in these dikes quartz greatly predominates and the rock approaches a quartz vein in constitution. Rarely small crystals of pyrite, apparently original, are present. The gradation between alaskite aplite and vein quartz is less noticeable than in the Silver Peak region, however, nor do the alaskites contain appreciable amounts of valuable minerals.

Basic rocks are rare. An outcrop of serpentine was found in the Ordovician sediments of the southern part of the range near Baxter Springs. A small mass of gabbro cuts the older sediments near the Belmont road, between the Maris mine and the mouth of East Manhattan Gulch. Within the area mapped on Plate I a small mass of diorite is the only basic rock associated with the granitic intrusions.

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[73] Spurr, J. E., Quartz-muscovite rock from Belmont, Nev.: Am. Jour. Sci., 4th ser., vol. 10, pp. 351–358, 1900; Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, p. 43, 1906.

[74] Quartz-muscovite rock from Belmont, Nev.: Am. Jour. Sci., 4th ser., pp. 351–358, 1900.

This rock crops out on the east bank of Mayflower Gulch near the southern border of the area.

The evidence of age yielded by the rocks of the Toquima Range shows only that the granite is post-Permian and pre-Miocene. The following summary by Spurr[75] of the evidence as to the age of the granites in the Silver Peak quadrangle applies equally well to the extension of that granite mass in the Toquima Range:

In the Pilot and the Excelsior ranges, a short distance north of the Silver Peak quadrangle, there are granitic rocks similar to those at Silver Peak. Here they are probably intrusive in Triassic and Jurassic strata. Still farther north, in the Ellsworth Range, similar granitic intrusives penetrate formations which the writer has provisionally referred to the Triassic. Some of these intrusive rocks are characterized by unusually large orthoclase phenocrysts like the type above referred to in the southern part of the Silver Peak quadrangle. North of this area, in the Star Peak Range, are granitic rocks (accompanied by alaskite dikes) which are intrusive into Triassic and probably Jurassic strata. Similar granitic rocks occur also in neighboring mountain ranges and are in many cases known to be intrusive into Paleozoic strata. At Belmont dikes intrusive into Silurian strata consist in part of coarse granite porphyry, with very large feldspar phenocrysts, identical in appearance with the coarse porphyritic phases in the Ellsworth and Silver Peak ranges.

The work of Mr. H. W. Turner has shown that the granitic rocks in the southern part of the Silver Peak Range cross Fish Lake Valley, which lies west of the range, and are represented in the White Mountain Range. Granitic rocks are well represented in this range (even more than in the Silver Peak Range) and in portions at least are known to cut Cambrian strata. The White Mountain Range is separated from the Sierra Nevada by Owens Valley. This adjacent portion of the Sierra Nevada is made up almost wholly of granitic rocks, and the similar granitic masses of the two ranges are separated only by patches of Tertiary volcanics or by the detritus flooring the intervening valley. In the Sierra Nevada these rocks consist mainly of granodiorite and granite, and the date of their intrusion has been fixed by studying the age of the intruded strata as in the epoch which included the close of the Jurassic and the beginning of the Cretaceous periods.

In the various granitic areas outside of the Silver Peak quadrangle, which the writer has enumerated above, aplitic rocks, chiefly of alaskite composition, are abundant as a later phase of the consolidation of the magma.

It appears probable, therefore, that the granitic rocks of the Silver Peak quadrangle and of various other ranges of western Nevada are similar in general nature and origin to the granitic rocks of the Sierra Nevada and, like them, are of late Jurassic or early Cretaceous age.

Ball's study of the part of the State south of the thirty-eighth parallel[76] showed widely separated areas of granitic rocks ranging in mineral composition from alaskite through biotite granite to quartz monzonite. These he considers "to have been contemporaneous in a broad way" and of post-Jurassic or very early Cretaceous age. Similarly, Louderback[77] assigns a post-Jurassic age to the granite

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[75] Spurr, J. E., op. cit. (Prof. Paper 55), pp. 25–26.

[76] Ball, S. H., The post-Jurassic igneous rocks of southwestern Nevada: Jour. Geology, vol. 16, pp. 36–45, 1908.

[77] Louderback, G. D., Basin Range structure of the Humboldt region: Geol. Soc. America Bull., vol. 15, p. 319, 1904.

of the Star Peak Range, in west-central Nevada. Farther east, in Utah, Butler[78] found that the principal period of granitic intrusion was the early part of the Eocene.

It appears most likely that, as Lindgren[79] suggests, the batholithic intrusions of the Pacific coast gradually spread eastward and that the intrusive rocks in central and western Nevada and eastern California are but little younger than the great California batholith. Hence, in the writer's opinion, it is probable that the granitic intrusions of the Toquima Range are of early Cretaceous age. If the folding of the Paleozoic rocks took place at the end of Jurassic time the intrusion of the granite to its present position must have been slightly later, for the granite masses truncate the folds.

TERTIARY ROCKS.

SUMMARY.

In the northern part of the area covered by the geologic map (Pl. I) the older rocks are deeply covered by a series of Tertiary lavas and sediments having a maximum thickness of about 3,000 feet. These beds have been divided for purposes of mapping into several lithologic units, but between several of these units the boundaries are not distinct and it is difficult to draw definite lines of separation. Each of the units shown on the map in places contains facies so closely allied to those above and below as to suggest that the period of their deposition was comparatively short and that only a small part of the later Tertiary history of central Nevada is here recorded.

Sedimentary, pyroclastic, and igneous rocks compose the Tertiary succession. A comparison of the igneous rocks of Tonopah and Divide with those of Manhattan strongly suggests that the whole series of lavas and tuffs at Manhattan, except the dacite and the intrusive rocks, is equivalent in age to the Siebert formation in the broad sense defined by Ransome[80] and Knopf[81]—that is, including both the Fraction breccia and the Siebert tuff as described by Spurr[82] for the Tonopah district. Recent geologic mapping of the Tonopah quadrangle has shown the identity of the "Siebert" formation in this broad sense with the Esmeralda formation, previously

[78] Butler, B. S., The ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, p. 99, 1920.

[79] Lindgren, Waldemar, Igneous geology of the Cordilleras: Problems of American Geology, pp. 260, 262, 1915.

[80] Ransome, F. L., Geology and ore deposits of the Goldfield district, Nev.: U. S. Geol. Survey Prof. Paper 66, pp. 66–68, 1909.

[81] Knopf, Adolph, The Divide silver district, Nev.: U. S. Geol. Survey Bull. 715, pp. 150–154, 1921.

[82] Spurr, J. E., U. S. Geol. Survey Prof. Paper 42, pp. 39–40, 51–54, 71, 1906.

described by Turner,[83] hence the latter name is used in this report, and "Siebert" formation in this broad sense is abandoned for Esmeralda formation, the older name.

For purposes of geologic mapping the Tertiary rocks of Manhattan have been divided as follows, beginning with the youngest:

Dacite, a thick flow in the northwestern part of the area, probably of much more recent age than any of the other Tertiary rocks.

Andesite porphyry, a coarsely porphyritic intrusive. Occurs in large masses and dikes, cutting the earlier formations. Probably of about the same age as the Divide andesite of the Divide district.

Maris rhyolite, a glassy intrusive which cuts older flows, particularly the Round Rock member. Suggestive of the Oddie rhyolite of Tonopah.

Esmeralda formation:

- Quartz latite member, containing breccia and quartz latite flows and except for the comparative paucity of foreign inclosures closely similar in appearance to the underlying Round Rock member.
- Bald Mountain lake beds member, a series of conglomerate, tuffaceous sandstone, and shale, apparently the same as the Siebert tuff of Tonopah.
- Diamond King member, a porphyritic rhyolite rich in quartz. The lower portion is a massive even-grained flow, and the upper is a bedded tuff consisting exclusively of material derived from the underlying lava and with difficulty distinguishable from it.
- Round Rock member, consisting chiefly of rhyolite breccia with large numbers of foreign inclusions, minor amounts of tuff, and a few lenses of sandstone. In the lower portion there is at least one flow of glassy rhyolite and probably more. Is believed equivalent to Fraction breccia of Tonopah.
- Hedwig breccia member, composed of angular fragments of the underlying Paleozoic rocks and believed to constitute fossil talus slopes.

ESMERALDA FORMATION.

The Esmeralda formation in the Manhattan district is divided into the members named in the preceding table and described on the following pages.

HEDWIG BRECCIA MEMBER.

The oldest of the Tertiary rocks, the Hedwig breccia member of the Esmeralda formation (so named from its outcrops in the vicinity of the Hedwig claim), contains no volcanic material. In general it consists of a well-cemented breccia composed of small angular fragments of the various Paleozoic rocks (Pl. III, *B*). Where the base can be

[83] Turner, H. W., The Esmeralda formation, a fresh-water lake deposit: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 197–208, 1900.

observed the underlying rock is nearly everywhere the same as that forming the breccia, and in places it is difficult to determine exactly where the breccia begins. Very little of the breccia consists of mixed materials, but in the neighborhood of the quartzite lenses fragments of the quartzite are found mixed with other material at some distance from their source. Many outcrops show pebbles of Ordovician limestone well cemented in a calcareous matrix, but all the pre-Tertiary rocks—schist, quartzite, and granite—have furnished material in one place or another. Water-laid material is rare. At one point in the eastern part of the area a small stream channel filled with a conglomerate consisting of rounded granite pebbles, evidently the fossil remnant of a stream draining the granite area to the north, crosses an outcrop of breccia consisting of fragments of slate and limestone. Small patches of water-laid material also occur in the southern part of the area.

As a rule the individual fragments composing the breccia are not over an inch or two across. Exceptionally they may consist of large angular blocks, especially where quartzite predominates.

The breccia fringes the northern border of the Paleozoic sediments from East Manhattan to Mustang Hill and is found in the region to the north and northwest of Black Mammoth Hill, in small areas surrounded by Round Rock rhyolite. Material of the same type occurs at the base of the lavas in Timber Hill Gulch, south of the area covered by the detailed geologic map.

The nature of the material forming the breccia, its angular character, and its close relation to the underlying bedrock show that it is a remnant of the old talus slopes formed under conditions approaching aridity in a region of some relief. The angularity and general lack of bedding show that stream deposition was a factor of minor importance in its formation. The presence of much limestone in small sharp fragments is perhaps additional evidence of aridity. The lack of any general mixing of material from different formations is evidence that the slopes were on the whole gentle, though the quartzite beds seem to have formed ridges of some prominence, and the total range of deposition, from an altitude of 8,000 feet on Salisbury Hill to 6,700 feet northwest of Black Mammoth Hill, implies a fair amount of relief.

The irregular distribution of the breccia and the lack of good exposures make estimates of its thickness uncertain. It is doubtful, however, whether it anywhere exceeds 100 feet in thickness.

ROUND ROCK MEMBER.

The oldest lavas found in the Manhattan district are a series consisting of pumiceous rhyolite and rhyolitic breccia and tuff, which form a single lithologic unit called the Round Rock member, from exposures in the vicinity of Round Rock, about a mile north of Manhattan (Pl. III, *A*). The rock is commonly buff to light gray and is spotted with numerous inclusions, which comprise representatives of all the older rocks of the region and also pebbles of spherulitic rhyolite and hornblende andesite derived from older flows not exposed in the Manhattan district. These inclusions are in places so numerous as to exceed in volume the inclosing rhyolite, and they range in size from huge boulders down to minute specks visible only under the microscope. Near the base the inclusions are naturally most numerous. In places where the contact with the underlying Hedwig breccia is exposed the angular slate fragments form nearly the whole of the rock, with only a cement of igneous material. Elsewhere little dikes of the rhyolite penetrate the underlying breccia irregularly.

The general appearance of most of the material suggests a breccia rather than a lava flow, and there is no doubt that much of it is of pyroclastic origin, but here and there in the lower part of the member are sheets that have a matrix of dark glass, and many specimens which in the field suggested a pyroclastic breccia show under the microscope a glassy flow-banded base. It was impossible to reach a definite conclusion as to the origin of several of the specimens examined.

The effusive portions show sparsely scattered small phenocrysts of quartz and feldspar and less commonly biotite. The larger phenocrysts are mostly broken and rarely present complete crystal outlines. Magmatic embayments are common in the quartz. The feldspars include both orthoclase and oligoclase, but their relative amount varies greatly in the different specimens examined. More commonly orthoclase is greatly predominant; but some specimens contain so much plagioclase that they might be classed as quartz latite.

Flows of rhyolite, which are in part glassy, appear to be most common near the base. The middle part of the member contains the greater proportion of pyroclastic material, including rhyolitic tuff and breccia and a little sandstone and water-laid tuff. Above this is a coarse breccia made up of angular fragments of the older rocks, with little or no volcanic material, which strongly suggests a deposit formed from a talus slope or fan cone. This breccia occurs between fine-grained sedimentary beds. Flow-banded rhyolites are again prominent near the top of the member. These upper flows commonly carry more biotite than those near the base.

The Round Rock member is in places overlain by thin-bedded quartzose sandstone probably nowhere over 80 feet thick, which for convenience of mapping has been included with it. This sandstone is well exposed on the hill west of Slaughterhouse Gulch but elsewhere is found only in a few spots, being either lacking or hidden by talus from the overlying Diamond King member. In places a conglomerate containing pebbles of pre-Tertiary rocks and rhyolite occurs with the sandstone.

The rocks of this member, particularly the pyroclastic and sedimentary members, are soft and friable and are more easily worn down than any others in the district. Consequently the Round Rock member occupies a belt of lowland between the Paleozoic sediments on the south and the more resistant later Tertiary rocks on the north. The lowland belt is broken by irregular hills that owe their origin to later intrusions, to local induration of the breccias, or to the presence here and there of exceptionally resistant rocks. (See Pl. III, *B*.) The maximum thickness of the Round Rock member in the Manhattan district is about 800 feet.

Similar rocks occur outside the Manhattan district at the base of the volcanic series in the southern part of the range, between Willow Spring and Baxter Spring, and along the western front of the range a few miles northeast of Round Mountain. A few small isolated patches of Round Rock rhyolite breccia are found here and there in the Paleozoic area. A dike of rhyolitic tuff, similar in character to the tuffaceous phase of this member, has been intruded along the fault between the Cambrian (?) and Ordovician sediments on Mustang and April Fool hills.

DIAMOND KING MEMBER.

Above the Round Rock member lies the Diamond King member, named from its prominence on Diamond King Hill. The lower part consists of a thick flow or series of flows of porphyritic rhyolite. The wide distribution of this rock, the absence of any contact metamorphism in the sediments above and below it, and the transition to water-laid sediments of like mineral composition at its top indicate that it is effusive and not an intruded sheet. In the upper portion this rhyolite grades into bedded tuff of the same composition and general appearance and evidently derived from it. The tuff in places consists of boulders of the quartz-rich rhyolite in a matrix of quartz and feldspar grains, and except where the distinction between boulders and matrix has been accentuated by weathering the rock can not be distinguished from the underlying rhyolite. Elsewhere faint banding due to a slight concentration of the quartz grains, which for the most part are sharp dihexagonal pyramids and show little or no rounding, indicates the sedimentary nature of the rock. The sediments directly overlying the Diamond King member are composed exclusively of material derived from this lava, without any admixture of foreign material; therefore the streams that deposited them must have been confined to the area covered by the rhyolitic eruption. Possibly to some extent these sediments are the result of wave action, where the lava flow entered the lake. The presence of sandstone directly below the Diamond King rhyolite and of water-laid beds at places in the Round Rock tuffs shows that the period of sedimentation began some time earlier. Logically these sediments should have been included with the overlying Bald Mountain beds, but the impossibility of making any good separation in the field rendered it advisable to include them in the Diamond King member. Moreover, in the central part of the area there appears to be an upper sheet of very similar rhyolite at a higher horizon in the lake beds.

The rhyolite and rhyolite-like tuff together have a maximum thickness of about 800 feet on the southern slopes of Diamond King Hill. Farther west, however, the thickness is less, and only about 100 feet of the sedimentary phase alone is present in the northwest corner of the Manhattan area, in the hill facing Big Smoky Valley. In the northern part of the Toquima Range and in the Toyabe Range rocks similar in character to the Diamond King rhyolite and in apparently the same stratigraphic position have a much greater thickness.

The surface on which the Diamond King rocks were laid down appears to have been rather irregular, owing possibly to erosion of the Round Rock member before they were deposited or to faulting prior to the deposition of the Bald Mountain lake beds. The present altitude of the base of the member ranges from 6,900 feet on the west to about 8,000 feet in the central part of the area. This difference can be only in part due to tilting, as the dips are mostly to the north.

The rock is pink or white and is everywhere notably porphyritic, the thick studding of little quartz crystals, 2 or 3 millimeters in diameter, being a characteristic feature. These phenocrysts are commonly in the form of dihexagonal pyramids, but as in the fresh rock the crystals tend to break even with the matrix, the crystal form is most apparent in the derived sediments. Feldspar phenocrysts are also prominent. In all the thin sections examined both orthoclase and oligoclase were found, with orthoclase greatly in excess. Ferromagnesian minerals are almost entirely lacking; only a few small plates of biotite were observed. The groundmass commonly consists of a microcrystalline aggregate of minute interlocking grains, apparently quartz and orthoclase with small specks of magnetite. Only rarely is any flow structure observable. Glass is likewise very rare. In one specimen showing flow structure small areas of a minutely crystalline pale-green substance elongate parallel to the flow lines are believed to represent original inclusions of clayey matter, smeared out during the viscous flow of the inclosing rhyolite. In places other foreign inclusions, principally small slate pebbles, are present. The tuffaceous and sedimentary phases of the series closely resemble the rhyolite, and in many places discrimination is doubtful, even with the aid of the microscope.

The rhyolite and to a less degree the sediments directly derived from it resist erosion and commonly form prominent hills with steep slopes. As a rule the lower contact is masked by talus slopes of huge blocks of rhyolite.

BALD MOUNTAIN LAKE BEDS MEMBER.

The upper part of Bald Mountain, to an altitude within about 400 feet of the top, is composed dominantly of fine-grained sediments closely similar in lithologic character to the Siebert tuff, of the Tonopah district, described by Spurr.[84] Fine-grained material predominates. Here and there ripple marks and faint cross-bedding can be observed in the sandstone. In a few places mud cracks are discernible in the fine-grained beds. The shale includes alternate thin bands of very fine and slightly coarser material, which suggest seasonal deposition.

The line between the bedded tuff included in the Diamond King member and the Bald Mountain sediments is in places very indefinite. As a convenient distinction for field mapping the level at which the thin-bedded sediments become dominant has been taken as the base of the Bald Mountain member. In a few places a fine-grained conglomerate containing pebbles of Diamond King rhyolite, together with a smaller number derived from the pre-Tertiary rocks, marks the base of the member. Elsewhere the fine-grained sandstone and shale rests directly on the massive rhyolite tuff.

The sequence of sediments appears to have been twice broken by volcanic activity. In the lower third of the member, in the region south of Bald Mountain, there appears in places a rhyolitic tuff closely resembling the tuffaceous rocks of the Round Rock member. Small outcrops and boulder groups of a rock identical in appearance with the Diamond King rhyolite were encountered on the gentle western slopes of the mountain at an average altitude of 200 feet above the base of the Bald Mountain beds. The exposures were not sufficiently good in either locality to determine the thickness, but it is probable that neither the tuff nor the flow exceeds 50 feet.

Although fine-grained sandstone and shale predominate in the beds at Manhattan, comparatively coarse material is much more

[84] Spurr, J. E., Geology and ore deposits of the Tonopah district, Nev.: U. S. Geol. Survey Prof. Paper 42, pp. 51–54, 1905.

abundant than at Tonopah, and the diatomaceous beds present at Tonopah and Goldfield are lacking at Manhattan.

No fossils were found in these beds within the area mapped in detail, but about 4½ miles northeast of Manhattan small shells were encountered in fine-grained material forming the matrix of a granitic conglomerate. William H. Dall examined these shells and reported as follows:

The matrix is a combination of waterworn quartz grains completely rounded, with a profusion of unworn sharp particles of quartz sand, cemented by a limy infiltration. The only organic remains revealed by careful scrutiny are a few fragments of a species of *Limnaea* resembling *L. palustris* Müller, which give no clue to its age. It is obviously a fresh-water deposit.

A short distance from the Belmont road, near the Maris mine, fragmentary blades of vegetable material resembling coarse grass were found embedded in the finer-grained shale.

The evidence of the presence of standing fresh water implies a certain degree of humidity but not necessarily a climate much less arid than the present. At the top of the Bald Mountain beds a few feet of coarse fan conglomerate, containing large angular and partly rounded fragments of the Paleozoic sediments and granitic rocks, together with finer-grained material derived either directly from the earlier rhyolites or indirectly through prior deposition in the lake beds, show a change from lacustrine to terrestial deposition. Similar fan conglomerates were encountered by Buwalda in his study of the Esmeralda formation.[85] A small outcrop of granite near the top of the lake beds in the northeast corner of the Manhattan area (Pl. I) represents an island buried by the deposition of the lake beds. Probably in prelacustrine time the granite had been eroded to a group of sharp pinnacles such as are now common in the region between Barcelona and Ralston Valley.

The higher parts of the range both north and south of Manhattan were probably never completely under water during the lacustrine period, as both the fan conglomerate at the top and those near the base of the series contain material from the pre-Tertiary rocks. It is thought likely that the basin in which the beds at Manhattan were deposited was but a small arm of the great Esmeralda Lake, which in the stage represented by the fan conglomerate at the top had become a desert valley that was partly filled by the accumulations from the hills on either side.

The maximum thickness of the Bald Mountain beds, as measured on the southwest slope of Bald Mountain, is about 500 feet. The thickness, however, varies greatly from place to place, for the surface of the Diamond King member, on which it was laid down, is notably

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[85] Buwalda, J. P., Tertiary mammal beds of Stewart and Ione valleys in west-central Nevada: California Univ. Dept. Geology Bull., vol. 8, pp. 335–363, 1914.

irregular, owing probably both to inequalities of original deposition and to erosion and possibly to previous faulting, as at Tonopah.[86]

QUARTZ LATITE MEMBER.

The period of sedimentation was again succeeded by the outpouring of silicic lava, now dominantly pumiceous, rather than massive and porphyritic like the Diamond King flows. This rock resembles very closely the Round Rock rhyolite, at the base of the volcanic series. The only readily noticeable difference is that whereas the Round Rock rhyolite carries a great number of good-sized pebbles of slate, schist, and granite, the quartz latite flows only rarely carry slate pebbles of any size but contain numerous minute inclusions of uncertain composition, probably originally mud or soft shale, and small dark specks that represent the greatly comminuted Paleozoic slate. As in the Round Rock rhyolite, thin flows of obsidian are present, particularly in the hills east of Bald Mountain, and the workings of the Buckeye prospect indicate that the series of flows is broken by small amounts of bedded tuff. In the Manhattan district this member has a maximum thickness of more than 700 feet, and an unknown amount has been lost by erosion. It may be thicker beyond the limits of the Manhattan area, but its northward extension was not explored. No rock that could be correlated with the quartz latite was found elsewhere in the range.

The rock carries comparatively few phenocrysts, and they consist of very small grains of quartz and feldspar. Plagioclase, commonly oligoclase, is dominant, and orthoclase rather rare. Small grains of magnetite are thickly though irregularly disseminated through the groundmass, and rarely small flakes of biotite can be seen, but the rock is deficient in dark minerals. The groundmass ranges from a dark glass to a minutely polarizing aggregate that apparently consists chiefly of quartz and plagioclase.

MARIS RHYOLITE.

Small dikes and irregular masses of brecciated rhyolite cut the Round Rock lava and tuff of the Manhattan district. These rocks crop out in a belt about a mile wide extending northwestward from the north side of Salisbury Peak to the edge of Big Smoky Valley, at the point where the Round Mountain road enters the valley. At the Maris mine rock of identical appearance and mineral composition is intrusive into the Bald Mountain lake beds, and in the same series of lake beds on the slopes of Bald Mountain indications of similar intrusives were found. The rhyolite intrusion at Round

[86] Spurr, J. E., op. cit., p. 53.

Mountain, which also cuts lake beds of similar appearance,[87] has the same general mineral composition. The Maris rhyolite is more resistant than the friable Round Rock rhyolite and tuff into which it is intruded and usually forms small irregular hills. The rock is fine grained and pale pink to purple. It carries numerous minute rounded or subangular fragments of rhyolite of the same character as the matrix. It is probable that this feature is due to autobrecciation and is the result of cooling sufficient to permit partial solidification, followed, before cooling had proceeded very far, by renewed movement and intrusion into the tuffaceous rhyolite.

Many inclusions of the earlier rocks are present in the Maris rhyolite, though these are less abundant than in the Round Rock member. Most of them are small fragments of slate and limestone, but at one place large boulders of granite have been brought up.

Small specks of quartz and feldspar are the only visible minerals in the rhyolite. As in the Round Rock rhyolite, both orthoclase and oligoclase are present. The relative proportions vary greatly, but in most of the specimens examined orthoclase predominates. The groundmass may be either glassy or composed of an intimate mixture of minute crystals of quartz and feldspar or it may consist of a minutely crystalline or spherulitic mass, broken and cemented by glass. In one place tridymite was observed in a small cavity in the glassy rhyolite. Ferromagnesian minerals seem to be completely lacking, though a few small dikes of biotite-bearing rhyolite were found in the district. In one place, however, a dike of the biotite-rich rhyolite cuts the Maris rhyolite.

ANDESITE PORPHYRY.

At some time later than the eruption of the quartz latite, and probably also later than the intrusion of the Maris rhyolite, came the intrusion of large masses of andesite porphyry. The rock is coarsely porphyritic and was classed as diorite porphyry by Emmons and Garrey.[88] As it is associated entirely with surficial rocks, the equivalent term andesite porphyry is considered more applicable here. The principal occurrence of the rock in the Manhattan district is in a large mass that forms the line of sharp hills west of Slaughterhouse Gulch and north of the Belmont road (Pl. IV). This mass has a width of over 1,000 feet and a length of more than 2 miles. Besides this single mass there are in the immediate neighborhood several smaller masses and great numbers of small sills and dikes. The andesite porphyry is found principally in the vicinity of Bald Mountain and the hills to the north, but a few small dikes, finer

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[87] Ferguson, H. G., The Round Mountain district, Nev.: U. S. Geol. Survey Bull. 725, p. 388, 1921.

[88] Emmons, W. H., and Garrey, G. H., U. S. Geol. Survey Bull. 303, p. 87, 1907.

grained than the larger masses, occur here and there throughout the area.

In the central parts of the large masses the andesite porphyry commonly shows well-developed columnar structure. Near the contacts it is in places amygdaloidal, the vesicles having been filled with chlorite and calcite. The rock minerals show greater alteration than in the more silicic rocks; the more calcic feldspars have yielded calcite, and the augites both calcite and chlorite. The rock is markedly porphyritic and shows abundant phenocrysts of white feldspar against a dark groundmass. Altered augite crystals are also present but are less conspicuous. Plagioclase is the only feldspar present and is more calcic than in the effusive rocks, consisting of andesine, which in some specimens is close to labradorite in composition. The groundmass shows a diabasic texture and consists of small rods of andesine feldspar with interstitial areas of what is probably chloritized augite.

The andesite porphyry bears a close resemblance to the Divide andesite of the Divide district, 40 miles to the south, described by Knopf.[89]

HORNBLENDE AND BIOTITE ANDESITE PORPHYRY.

Numerous small dikes of hornblende and biotite andesite porphry occur in the region north and northwest of Black Mammoth Hill. They cut the Round Rock member and apparently also the Maris rhyolite, though no clear proof of this could be found. None of these dikes were found in the area occupied by the upper members of the volcanic series, but on the other hand pebbles from these dikes were not found in the conglomerates of the Bald Mountain lake beds. These dikes are, however, clearly older than the dacite, next to be described.

These rocks are porhyritic, though finer grained than the andesite porphyry of Slaughterhouse Gulch and its vicinity. Feldspar is everywhere prominent and is commonly a rather sodic andesine in composition. In some of the dikes small phenocrysts of hornblende occur; in others biotite; in one or two both minerals are present. The groundmass consists principally of minute feldspar laths of approximately the same composition as the phenocrysts. In some of the specimens examined a small amount of quartz in the groundmass indicates a rock approaching dacite.

It seems reasonable to assume that all types of intrusive rocks represented in the area were essentially of the same age. Thus as the Bald Mountain lake beds are without doubt equivalent to the

[89] Knopf, Adolph, The Divide silver district, Nev.: U. S. Geol. Survey Bull. 715, pp. 147–170, 1921.

Siebert tuff and to part of the Esmeralda formation, the andesitic intrusive rocks must be at least as young as the upper Miocene.

DACITE.

The plateau-like hill on the northern border of the Manhattan area, facing Big Smoky Valley, is composed of massive dacitic lava, probably a single flow. A short distance to the west are two small hills composed of rock of the same type. These, however, may represent intrusive masses. The dacite rests unconformably on the tilted tuffs of the Diamond King member, on the Round Rock member, and on small dikes of Maris rhyolite and the biotite andesite porphyry described above.

It is clearly much the youngest of the volcanic rocks of the district, for a considerable period of erosion must have intervened after the intrusion of the andesite and rhyolite dikes before the dacite was poured out. The flow may even be later than the formation of Big Smoky Valley, for its position on the eastern flank of the range indicates that the present topographic features may have already been outlined.

The rock is porphyritic, with numerous but very small crystals of feldspar, biotite, and minor quartz in a porcelain-like groundmass showing various shades of gray, green, and purple. The steep cliffs facing the south exhibit well-marked columnar structure and consist largely of black obsidian, studded with small crystals of feldspar. Obsidian also predominates in the upper part of the mesa. The feldspars range in composition between oligoclase and andesine. Orthoclase appears to be lacking. Biotite is present in small regular flakes, usually a little less numerous than the feldspars. Quartz in small corroded phenocrysts is about equal in amount to the biotite. The groundmass is glassy and contains numerous rodlike microlites. Rarely a peculiar mottled polarization is observable.

The dacite appears to extend only a short distance northward beyond the area covered by the Manhattan map (Pl. I), as it was not found at North Manhattan Gulch, 3 miles north of this area.

AGE AND CORRELATION OF THE TERTIARY ROCKS.

The Esmeralda rocks of the Manhattan district from the Hedwig breccia to the quartz latite strongly suggest deposition within a comparatively brief period of time. The eruption of the lower flows of Round Rock rhyolite must have followed closely upon the deposition of the loose hillside material that now forms the Hedwig breccia. The sequence of rhyolite flows and pyroclastic rocks forming the Round Rock member is broken by sediments of the same type as occur in the Bald Mountain beds above. In particular, the sandstone between the Round Rock rhyolite and the overlying Diamond King rhyolite exactly resembles the Bald Mountain beds.

The Diamond King rhyolite probably represents remnants of a thick lenticular flow of viscous material, as it occupies only a small area and is variable in thickness. Although there is no direct evidence, it is thought likely that this flow may have been poured out beneath the waters of the lake. If it was, the fact that the lower sedimentary beds resting upon it (and included with it on the geologic map) consist entirely of material derived from the rhyolite, bouldery at the base and finer grained above, may be due to reworking of the upper part of the flow by the waters of the lake.

The Bald Mountain beds represent lacustrine deposition, probably almost entirely in shallow water, but at the top they contain a bed indicative of surface deposition in an arid climate.

The last of the Esmeralda succession, the quartz latite, may mark either the end of lacustrine deposition or an interval in which lavas were again erupted.

The close similarity of the Bald Mountain beds to the Siebert tuff of Tonopah has already been pointed out. Beds of this same type extend southward from Tonopah over a great part of the area covered by Ball's reconnaissance,[90] and to the west and southwest the Esmeralda formation as mapped by Turner[91] and Buwalda[92] covers a large area. Ransome[93] and Buwalda have shown that there is no reason to doubt the identity of the two. As the formation is so widespread, it is reasonable to correlate the lacustrine beds of the Manhattan area with the Siebert tuff of Tonopah and the Esmeralda formation of the Silver Peak and Cedar ranges. These formations, as Merriam[94] has shown, are probably of upper Miocene age.

If the correlation of the Bald Mountain lake beds with the Siebert tuff is valid, it is but a short step to extend the argument and correlate the Round Rock member with the lithologically similar Fraction breccia of Tonopah and Divide. The Diamond King member is lacking at Tonopah. The older series of flows present in the Tonopah district are, on the other hand, lacking at Manhattan or buried beneath the flows of Round Rock rhyolite.

The correlation of the later intrusive rocks with those of the Tonopah district is less definite. The Maris rhyolite, however, is strikingly

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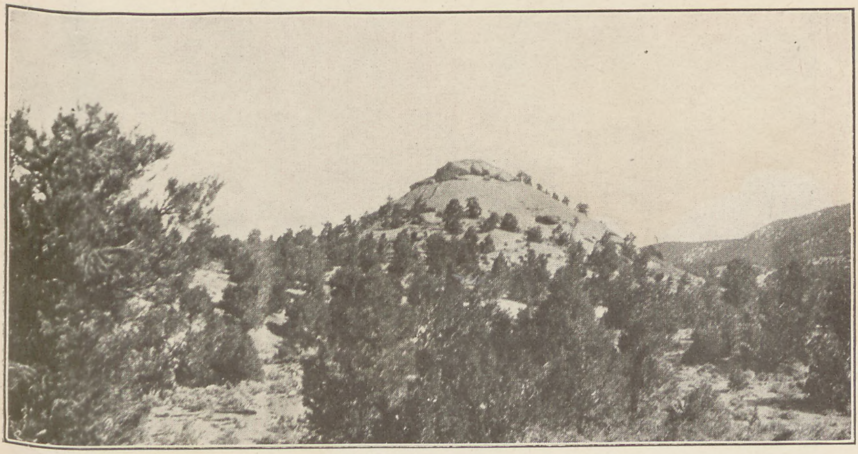
[90] Ball, S. H., A geologic reconnaissance of southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, 1907.

[91] Turner, H. W., The Esmeralda formation, a fresh-water lake deposit: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 191–226, 1900.

[92] Buwalda, J. P., Tertiary mammal beds of Stewart and Ione valleys in west-central Nevada: California Univ. Dept. Geology Bull., vol. 8, pp. 335–363, 1914.

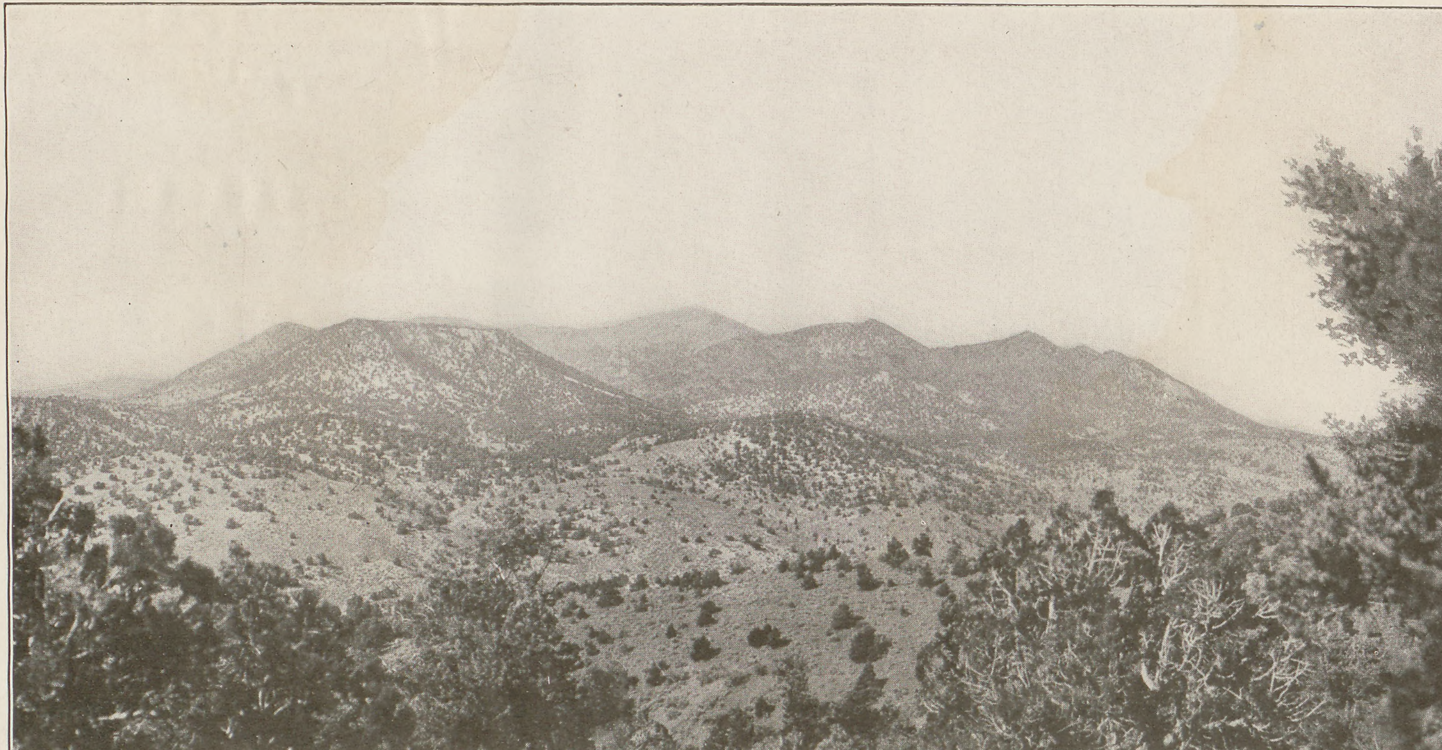
[93] Ransome, F. L., Geology and ore deposits of Goldfield, Nev.: U. S. Geol. Survey Prof. Paper 66, p. 98, 1909.

[94] Merriam, J. C., Tertiary vertebrate fauna from the Cedar Mountain region of western Nevada: California Univ. Dept. Geology Bull., vol. 9, pp. 161–198, 1916.

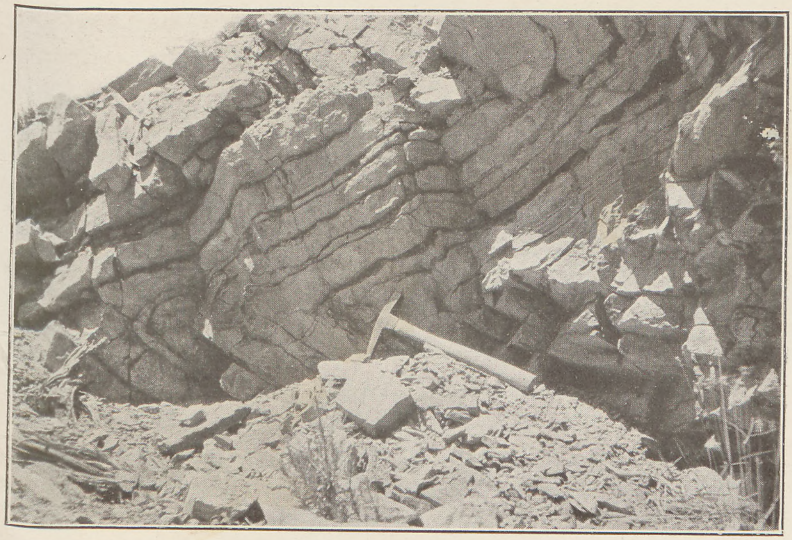


A. ROUND ROCK, A TYPICAL EROSION FORM OF THE ROUND ROCK BRECCIA.

B. HEDWIG BRECCIA RESTING ON CONTORTED SLATES OF THE TOQUIMA FORMATION NORTH OF MUSTANG HILL.



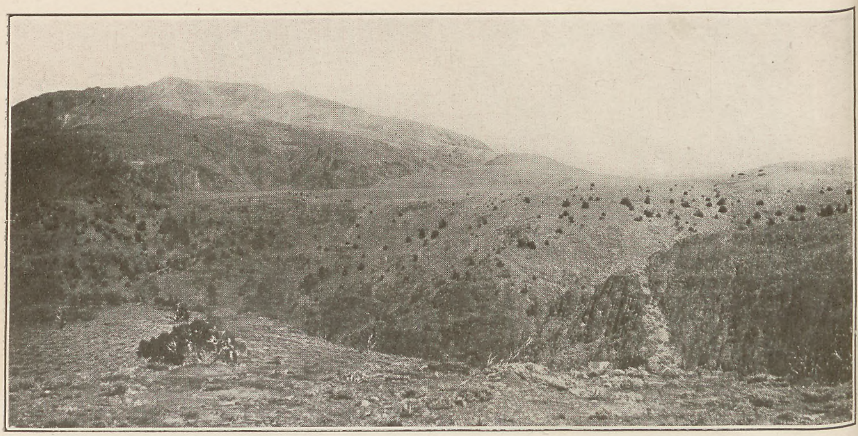
HILLS OF VOLCANIC ROCKS NORTH OF BELMONT ROAD.



A. FOLDS IN ZANZIBAR LIMESTONE NEAR TONOPAH ROAD.

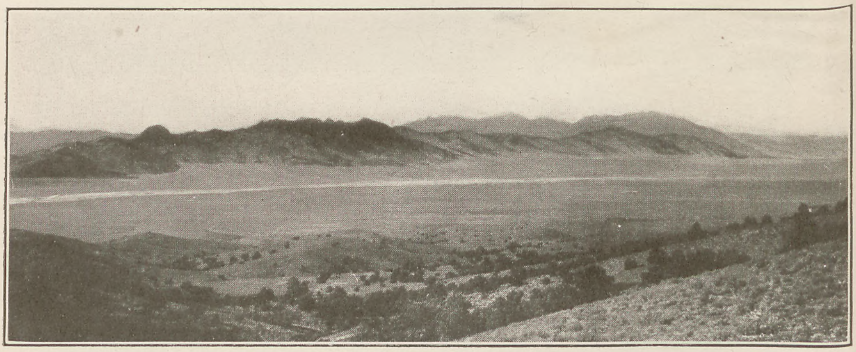
B. OLD STOPE OF LITTLE GREY MINE.

Showing the older Pleistocene gravel resting on the Cambrian (?) schists.



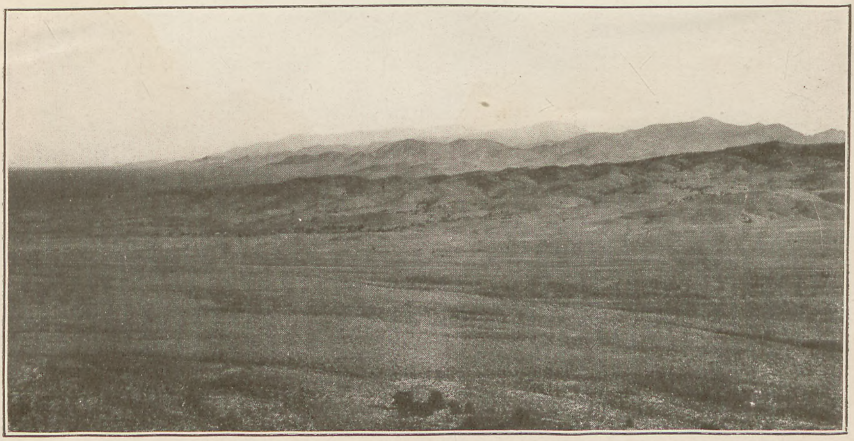
A. CENTRAL PART OF TOQUIMA RANGE, NEAR THE HEAD OF MEADOW CREEK.

Showing older mature topography.



B. FRONT OF TOYABE RANGE FROM TOQUIMA RANGE

Showing fault-scarp topography.



C. FRONT OF TOQUIMA RANGE.

Looking north from western part of Manhattan district.

similar to the Oddie rhyolite of Tonopah,[95] and the andesite porphyry to the Divide andesite of Divide.[96] The small hornblende andesite dikes in the western part of the area presumably belong to the same intrusive epoch, as they appear to cut the Maris rhyolite.

As the outcrops of the andesite porphyry extend to an altitude only slightly below the erosion surface on the crest of the range, it is probable that the intrusion took place prior to this period of erosion. This older topography apparently corresponds with a similar erosion surface in the southern ranges of Nevada, which is tentatively assigned by Ball [97] to the late Pliocene. Hence the time of intrusion of both the andesite porphyry and the rhyolite must have been about the end of the Miocene or the early part of the Pliocene. The dacite, which owing to its topographic position may be later than the development of Big Smoky Valley, is therefore probably of very late Pliocene or early Pleistocene age.

These inferences as to age rest on two assumptions—first, the identity of the Bald Mountain lake beds with the Siebert tuff of Tonopah and of the Siebert with the Esmeralda formation, of upper Miocene age; and, second, the identity of the upland erosion surface with that in the southern ranges described by Ball and the validity of Ball's determination of the age of this surface as late Pliocene.

STRUCTURE.

The structural history of the region begins with a period of intense folding, during which the Paleozoic rocks were compressed into a series of close folds, in part overturned (Pl. V, *A*), and a large overthrust fault was developed. The trend of the axes of the folds is commonly a few degrees north of west, normal to the present trend of the Toquima Range. Possibly the normal fault along the southern border of the Gold Hill formation also dates from this time. The older sediments may have suffered some deformation before this final folding, but if so all trace of it has been obliterated. This folding was complete before the granite reached its present level, and the intrusion of the granite caused little if any doming of the sediments, though it may have caused minor normal faulting. The Tertiary rocks show gentle dips, generally to the north except in the immediate vicinity of the andesite intrusions, but they are broken by several large normal faults, most of which appear to be older than the andesite intrusion, although there was some faulting later. Faults of presumed late Tertiary age also displaced the pre-Tertiary rocks.

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[95] Spurr, J. E., op. cit., pp. 49–50.
[96] Knopf, Adolph, op. cit., pp. 155–156.
[97] Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, pp. 15–17, 1907.

The axes of the folds in the Paleozoic sediments trend a few degrees north of west, nearly at right angles to the present trend of the range. The anticlines tend to be steeper or even overturned along their northern limbs. The principal anticline brings the Gold Hill rocks to the surface and occupies an irregular line of hills extending diagonally from the southeastern part of the district mapped through Black Mammoth and Palo Alto hills to Big Smoky Valley.

The northern area of Ordovician sediments, on the ridge of which Salisbury Peak is the highest point, has been interpreted as a series of close folds of the Zanzibar limestone overturned to the north, culminating on Salisbury Peak in a great overturned synclinal fold that brings in the upper division of the Ordovician, the Toquima formation, apparently dipping beneath the stratigraphically lower Zanzibar limestone.

Many of the mines of the district occur within the limestone beds of the Gold Hill formation. Three of these limestone beds near the base of this formation and two near its top have been so well exposed by prospect pits that the structure can be determined with certainty in spite of the complications caused by faulting. Throughout most of the area, particularly in the eastern part, the Gold Hill strata dip to the south and southwest. The dips are variable but generally not steep, and minor overturned folds are less common than in the Ordovician rocks. A sharp fold in the limestone beds at the east end of Manhattan, southeast of April Fool Hill, is mapped on Plate II, and a smaller closely compressed fold may be seen in the Big Pine glory hole. West of the town both limbs of the anticline are developed. The crest follows about the line of the gulch, slightly north of west, from April Fool Hill. Between the eastern edge of the area mapped and the Belmont road the northern limb of the anticline is lacking and the Gold Hill rocks are thrust over the closely folded Mayflower schist and Zanzibar limestone. The plane of the overthrust where observed in the Zanzibar tunnel and the 800-foot level of the White Caps mine has a southerly dip of about 36°, slightly flatter than the dip of the overlying Gold Hill beds. No data on the dip of the fault could be obtained between the White Caps mine and April Fool Hill. The fault plane appears to strike in a northwesterly direction across Toro Blanco Hill. On the eastern slope of April Fool Hill the northern contact of the Gold Hill formation is masked by the Hedwig breccia, but west of the summit prospect workings show a southerly dip of 75°–80° to the fault plane between the Gold Hill and the Toquima formation to the north. The same steep dips characterize the exposures on the small hill west of April Fool Hill and on Mustang Hill. The fault plane must therefore be notably undulatory, or perhaps the steeply dipping fault on April Fool and Mustang hills is a different fault, branching off from the overthrust, and the flatter fault is lost under the breccia and lavas to the north. The fault on Mustang Hill can not be traced westward, but presumably it turns northward under the waste-filled valley of Black Mammoth Gulch and is lost under the lavas. As the top of the Gold Hill formation is likewise concealed by a fault the amount of displacement along the overthrust is indeterminable, but it is probably a few thousand feet.

The southern border of the Gold Hill formation, at least in the vicinity of Manhattan, is likewise a fault plane. This part of the district has not been as well prospected as the region to the north, and therefore the position and inclination of the fault can not be well determined. The strike follows approximately that of the Gold Hill sediments and is northwesterly on the ridge south of Black Mammoth Hill and westerly in the central and eastern parts of the area. The dip appears to be also closely accordant with that of the Gold Hill beds. The few observations made show dips of 60°–75° SW. and S. This fault can not be traced north of Manhattan Gulch and, like the reverse fault on Mustang Hill, must continue along the bed of Black Mammoth Gulch, displacing or joining the Mustang Hill fault. As this fault so closely follows the strike and dip of the Gold Hill strata and is displaced by the later faults, which appear to be, in part at least, connected with the granite intrusion, it is inferred that this fault resulted from the same movement that produced the overthrust fault to the north and the major folding in the sediments.

The Ordovician sediments north of the overthrust and south of Salisbury Peak are compressed into a series of close folds that strike a little north of west and are overturned to the north. The crest of the ridge, including Salisbury Peak, is occupied by a syncline in which the lower portion of the Toquima formation is preserved. The strata on the southern limb are overturned and dip to the south and southwest. Just north of the crest of the hill the dips are nearly vertical, and on the northern slope they are nearly horizontal. Contact metamorphism due to the buried mass of granite to the north obscures the relations to some extent, and it is not certain how far the major structure is complicated by smaller folds. To the northeast the dips are steep, but here also the relations are blurred by contact metamorphism. The lowest member of the Toquima formation, the graptolite-bearing schist, is not present on the northeast limb of this syncline, but at one point north of the sedimentary series on the eastern border of the area mapped an outcrop of the Hedwig breccia contains angular fragments of graptolite-bearing slate.

Rocks belonging to the Toquima formation occupy the area north of the northern fault between Mustang and April Fool hills. The exposures are not good, and all that can be inferred from the irregular dips is extremely close folding. The structural relations of the isolated Permian (?) outcrops to the north are unknown.

The rocks of the Toquima formation south of the area of the Gold Hill formation lie in a rather flat syncline, complicated by minor folds that are in places overturned to the north. South of this a smaller anticline brings the Zanzibar limestone to the surface near the heads of Mayflower and Old Manhattan gulches. No graptolites were found above the Zanzibar limestone in the small area along Old Manhattan Gulch, but the rock exposed resembles the Zanzibar limestone and the inferred structure is in accord with the observed dips.

The structure of the southwestern part of the area could not be worked out in detail. Several minor closely compressed folds were found, and undoubtedly others are present also. The section drawn through this region shows an apparently great thickness of rocks belonging to the Toquima formation. This, however, is probably in part due to folds which were not discovered owing to the lack of definite beds that could be traced and the paucity of good outcrops over a part of this region.

No evidence that would assist in dating this period of folding is obtainable in the Manhattan district or the neighboring portions of the Toquima Range. However, as the movements that produced similar folding in the Sierra Nevada probably took place at the end of the Jurassic period, it is reasonable to assume an equivalent age for the principal folding at Manhattan. This assumption does not exclude the probability of minor movements in Paleozoic time, for if, as appears to be the case, the Permian (?) sandstone here rests unconformably on the Ordovician there may have been a certain amount of uplift and tilting prior to its deposition.

Although the granitic intrusion in the vicinity of Manhattan caused widespread changes in the chemical and mineral composition of the invaded sediments, it effected little change in the preexisting structure, for the intrusive mass cuts sharply across the folds without any apparent doming or distortion of the beds. The reconnaissance of the Toquima Range as far as Belmont (fig. 2) likewise gave no evidence of any doming by the intrusion. The freedom of the granite from schistosity or even notable shearing is evidence that the intense folding of the sediments had been completed before its intrusion. Certain normal faults in the productive part of the Manhattan district appear, however, to have been initiated by the granite intrusion. The evidence for faulting at this period is of a mineralogic nature and is presented in the descriptions of the ore deposits (pp. 82–85, 113). Such faulting as may have taken place in connection with the granite intrusion appears to have been of a very minor nature and had no effect on the major structural relations of the rocks of the Manhattan district.

The bedded Tertiary rocks show for the most part very gentle northerly dips. Here and there close to the intrusive masses or near the major faults the dips are steep and vary in direction, but on the whole a slight northerly dip prevails throughout the area covered by the Tertiary rocks.

The normal faults throughout the area, with the exceptions described above, seem to be all of late Tertiary age. Two periods are represented—one, in which the movements were probably the more pronounced, prior to the intrusion of the andesite porphyry but involving all the members of the Esmeralda formation, and the other later than the intrusion of the porphyry. Three prominent faults cut the Tertiary rocks on the hill southwest of Bald Mountain. They are roughly parallel and strike about north-northwest, and the downthrow in each case is on the southwest side. The total maximum vertical displacement exceeds 400 feet. Although these faults are traceable to points within a mile of the older sediments to the south, their continuation can not be found in the older rocks. A fourth fault in the Tertiary rocks follows the line of Slaughterhouse Gulch northward across the saddle west of Bald Mountain. This fault seems to be clearly older than the andesite porphyry, for small masses of the intrusive rock cross the strike of the fault plane. This fault is less well defined than the other three, and the position of the fault plane is for the most part concealed by talus on the steep slopes. The fault seems to have a maximum displacement of about 400 feet, with a downthrow on the west, but like the others it can not be traced southward into the sediments.

A group of three east-west faults are still more obscure but are indicated by the different levels of the contacts of the upper members of the Esmeralda formation in the vicinity of Bald Mountain. The northernmost of these faults appears to cross the summit just west of Bald Mountain, where the lower contact of the quartz latite is dropped down about 300 feet on the south side. It does not cross the Slaughterhouse Gulch fault, for the same contact on Bald Mountain is not displaced, nor does it appear to reach the northwesterly fault on the west. As a small mass of andesite porphyry occupies the position of the fault plane to the west this fault probably had its inception prior to the andesite intrusion, but the workings of the Buckeye prospect show that there was also faulting in the same general direction which has involved the intrusive rock. A second parallel fault crosses the saddle south of Bald Mountain. This lies east of the Slaughterhouse Gulch fault and can not be traced beyond it. A short distance to the east a mass of andesite porphyry crosses the projected strike of the fault. The downthrow is to the south and on the saddle can not exceed 200 feet, though possibly it is greater farther east. The presence of a third fault in the same general direction is implied by the repetition of the contact of the Round Rock and Diamond King members of the Esmeralda formation north of the main mass of andesite porphyry on the high ridge a mile south of Bald Mountain. This fault seems to have been the principal site of the andesite intrusion, and the difference in altitude of the upper contact of the Round Rock tuffs implies that it had a downthrow to the south of about 200 feet.

The different levels of the upper contact of the Round Rock tuffs in the northwestern part of the area north of Black Mammoth Hill suggested the possibility of a northeasterly fault with a considerable downthrow to the southwest. No direct evidence of faulting or shearing could be obtained, however, although the Round Rock tuffs are well exposed in the gulch to the south along the supposed line of faulting. It was therefore considered more likely that the discordance in the contact represents an irregularity in the topography prior to the outflow of the Diamond King rhyolite. If such a fault exists it must be older than the intrusive Maris rhyolite, for the contact of Maris rhyolite and Round Rock tuffs, only a short distance to the south, is not displaced.

In a few places the contact between the Paleozoic sediments and the Tertiary rocks to the north may be a fault plane. Garrey and Emmons[98] mention one such contact, and here and there in the district others were found by the writer. Such faulting can not have been very marked, however, for over most of the distance the contact is irregular in detail, and even where it is approximately straight, as in the stretch northwestward from Black Mammoth Hill, the presence of the Hedwig breccia on the north implies that the faulting can not have been of any great magnitude.

The older sedimentary rocks are everywhere cut by normal faults of comparatively small throw. In almost every prospect pit and tunnel throughout the area there is some evidence of faulting. Only such of these faults as displace mapped contacts to a notable extent are shown on the larger geologic map. On the smaller map of the productive part of the district an attempt has been made to show the faults in more detail, but even here it is impossible to map them accurately, as will be seen by the detailed map of the White Caps property on page 83 and the underground maps on pages 85, 86, and 91. Although it was impossible to trace more than one of these faults in the Tertiary rocks to the north, they are, with the exception of the

[98] U. S. Geol. Survey Bull. 303, p. 88, 1907.

very minor displacements of possibly earlier date, regarded as of late Tertiary age—either contemporaneous with the larger preandesitic faults described above or representatives of the later period of minor postandesitic faulting. The evidence for this conclusion is largely indirect. Although only one fault was traced directly from the older sediments into the volcanic rocks, numerous prospect pits in the volcanic rocks show shear zones and faults that follow the trend of the faults in the sediments to the south, and as the contacts north of the region of intense faulting are largely concealed by talus from the ridge to the south it is quite likely that undiscovered displacements of the contacts exist. These faults cut sharply across the folds of the older rocks and displace the older faults as well, and hence they are clearly later than the period of folding and overthrusting. Mineralogic evidence connected with the ore deposition likewise points to a Tertiary age for these faults.

In the eastern part of the area, eastward from Gold Hill, the dominant trend of these small faults is northeasterly, though subordinate faults of varying strike are present. In the western part northwesterly faults prevail. The faults appear to be much more closely spaced in the productive part of the district, particularly along Litigation Hill eastward to the White Caps mine. This closer spacing probably exists, but it is necessarily exaggerated on the map, for the numerous surface workings greatly facilitated the geologic mapping in this part of the district.

The straight east front of the Toyabe Range indicates a recent fault of considerable magnitude along the west side of Big Smoky Valley. On the Toquima Range there is no comparable scarp.

DEVELOPMENT OF THE PRESENT TOPOGRAPHY.

The Quaternary history of the region, leading to the development of the present topography, has a direct bearing on the economic geology of the Manhattan district, with reference not only to the formation of the placer deposits but also to problems concerning the oxidation and redeposition of certain minerals of the lode deposits.

OLD EROSION SURFACE.

The recent lavas found elsewhere in the Great Basin are not prominent in the Toquima Range, and except for the comparatively minor dacite flow there appears to have been no volcanic activity since late Miocene or early Pliocene time.

In probably late Pliocene time a postmature topography was characteristic of a large portion of the Basin Range province. The old surface of this time is not preserved in the Manhattan district, though the high ridge that includes Bald Mountain and Buckeye

Hill reaches nearly to its level, but it may be seen in the higher part of the range on the divide between Jefferson and Meadow creeks, 15 miles to the northeast (Pl. VI, *A*). Here the crest of the range shows rolling upland country surmounted in places by granite peaks. Ball[99] mentions the existence of similar old topographic forms on the Kawich, Belted, Amargosa, and Panamint ranges, to the south. Meinzer[1] found a similar mature topography on the Toyabe Range. Buwalda[2] found an early old-age topography on Cedar Mountain. As this older erosion surface extends over so large an area and occurs at different altitudes on different ranges it follows that the present mountain ranges must be of later date. Ball considers this mature surface to be of late Pliocene age, as it is later than the early Pliocene "later rhyolite" and older than the later tuffs and older alluvium that mark the transition from Pliocene to Pleistocene. If his inference is correct, at least the major part of the mountain-building movements that produced the present ranges must have been confined to the end of the Pliocene and the early part of the Pleistocene, for at the period marked by the Pleistocene lakes a topography approaching that of the present day had been attained.

BLOCK FAULTING.

The east face of the Toyabe Range, on the opposite side of Big Smoky Valley, presents a well-marked fault scarp. Long spurs, which slope gently down from the crest, are sharply truncated and present steep triangular facets toward the valley. The headwaters and upper reaches of the streams are wide and open, whereas at the mouths the streams flow through steep, narrow canyons. The front of the range follows a broadly sinuous rather than a straight line, but in the 30 miles shown on the topographic map of the Tonopah quadrangle it varies less than a mile to either side of a north-south line. Faulting has continued until recent time, for Meinzer[3] reports that fault scarps cut the alluvial fans at the mouths of the canyons.

The Toquima Range, however, presents a different appearance. On the west side of the range the rock shelf that borders the mountains deepens gradually westward beneath the valley wash. Moreover, the boundary between gravel and rock outcrop is irregular, and the gravel at the edges is clearly only a thin veneer resting on a planed-off rock surface. Eastward from the valley, toward the mountains, however, this rock surface ends rather abruptly against

[99] Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, pp. 16–17, 110, 161, 202, 1907.

[1] Meinzer, O. E., Ground water in Big Smoky Valley, Nev.: U. S. Geol. Survey Water-Supply Paper 375, p. 90, 1915.

[2] Buwalda, J. P., Tertiary mammal beds in west-central Nevada: California Univ. Dept. Geology Bull., vol. 8, pp. 358–359, 1914.

[3] Meinzer, O. E., op. cit., p. 91.

irregular ridges, the outliers of the main mountain mass. There is a notable lack of gradation between the gently sloping rock bench and the hills. Here and there the bench cut in rock is lacking, and prominent hills, such as Round Mountain, rise directly from the valley fill. The larger stream valleys are filled with gravel in their lower courses, but the streams are still eroding their headwaters and eating back into the small area along the crest of the range that still preserves the postmature surface of the earlier cycle.

Certain physiographic features, however, suggest the possibility of some recent movement of the mountain mass relative to the valleys bordering its sides. The eastern flank of the range was not studied in detail, but it is here that the evidence of movement seems to be the clearest. Although the divide follows nearly the median line of the range the canyons of the eastern streams are distinctly narrower than those on the west. Meadow Creek rises in the mature upland south of Mount Jefferson and flows southeastward through a gradually narrowing valley until at its mouth it is inclosed in vertical walls of rhyolitic agglomerate. There is no flaring of the valley at the mouth, and the stream enters Monitor Valley over a broad, flat alluvial fan directly from the canyon. Apparently no difference in resistance to erosion of the rocks can explain this abnormality, for in its upper reaches the country rock is a dense rhyolite, whereas in the canyon it is largely a coarse rhyolitic agglomerate, which should be the more easily eroded of the two. East Manhattan Gulch also trends southeastward from the low divide east of Manhattan to Ralston Valley, and, though without permanent surface flow, it exhibits the same inversion of normal conditions which characterizes the Meadow Creek valley. Near East Manhattan there is a wide gravel-filled valley cut mainly in Round Rock tuff and the underlying Hedwig breccia but in part in the harder quartzite and schist of the older sediments. Toward the southeast the valley sides steepen until for a mile above its mouth the gulch is a deep, narrow canyon with walls of schist and jaspery limestone. No trace of any fault scarp remains, although for a few miles north of Belmont a line of rhyolite cliffs, broken by Meadow Creek canyon, faces the valley. Southeastward from Belmont, however, a branch range connects the Toquima Range with its eastern neighbor, the Monitor Range, separating Monitor and Ralston valleys. It is not known whether the eastern face of the Monitor Range shows a recent fault scarp.

The evidence as to the west flank of the Toquima Range is less clear, though there are certain features that seem to imply some relative downward movement of Big Smoky Valley in the vicinity of Manhattan Gulch, presumably by faulting. The western limit of exposed rock, although less sharply defined than in the Toyabe Range, nevertheless follows a fairly straight line. Had the development of the range been entirely the result of erosion the boundary between rock and valley fill should be far more irregular, and where a belt of easily eroded rock, such as the Round Rock tuff north of Manhattan Gulch, crosses the range a much deeper reentrant of valley fill would be expected than is actually present.

The buried canyon of Manhattan Gulch is likewise deeper where it passes beneath the valley fill than near its head, and, so far as can be determined, the walls are as steep.

MANHATTAN GULCH DRAINAGE AREA.

The present drainage area of Manhattan Gulch extends westward from a point on the Belmont road three-quarters of a mile west of East Manhattan to Big Smoky Valley, a distance of about 6 miles. The drainage area is asymmetric, and in the western part the divide is much nearer the gulch on the north than on the south side. The divide forming the eastern boundary follows a nearly straight line from Bald Mountain south to Summit Hill. The divide on the north side is about 2 miles north of the gulch in the extreme eastern part, but it turns sharply southward, crosses the belt of soft rhyolite tuff near the head of Black Mammoth Gulch, and for the remainder of the distance parallels the course of Manhattan Gulch at a distance of half to three-quarters of a mile to the north. On the south side Timber Hill, a high ridge composed of metamorphic slate and a little granite, forms the divide, which follows a nearly straight westerly course about 2 miles south of Manhattan Gulch. It seems probable that the diversion of a part of the former drainage on the north side of the gulch westward to Big Smoky Valley has been effected through the gradual disintegration of the belt of soft rhyolite tuff that crosses the head of Black Mammoth Gulch and the transportation of the disintegrated material by occasional floods, rather than through normal stream erosion. Less evaporation on the north side of the hills to the south of the gulch than on the southward-facing hills to the north may also have been a factor. It is likewise possible that the drainage area of the gulch also once extended farther eastward and has been reduced by the headward erosion of East Manhattan Gulch.

In the southeastern part of the area covered by the detailed map a portion of the stream that once flowed in the comparatively broad valley cut in the Mayflower schist along the Tonopah road may have been captured by the stream that now flows southward through the granite-walled canyon south of Pipe Spring.

The deeper gravel of Manhattan Gulch shows near bedrock more pebbles derived from the sediments than from the lavas, a relation which is reversed nearer the surface, and this change in the character of the gravel, together with the presence of numerous well-rounded granite pebbles in the lower gravel, lends probability to the hypothesis that the stream formerly had a greater extension in the region covered by the granite and older sediments.

The course of Manhattan Gulch is inherited from an earlier physiographic cycle, for it is completely independent of the structure of the rocks across which it is cut, although most of the tributary gulches are more or less adjusted to the structure. The easily eroded rhyolitic tuff forms a lowland belt extending from east to northwest across the area but is nowhere occupied by a stream valley, whereas Manhattan Gulch over the greater part of its course is inclosed in walls of metamorphic sediments whose strike is transverse to the gulch. Presumably at its inception Manhattan Gulch was cut in these tuffs, which then extended farther southward. Its course may have been determined by the southern limit of these tuffs, for, as has been shown in a previous section, the overlying Bald Mountain beds did not completely cover the Paleozoic sediments.

The depth of gravel filling varies in the northern and southern tributaries of Manhattan Gulch. On the north side the gulch receives two important tributaries—Slaughterhouse Gulch, which enters near the north end, and Black Mammoth Gulch, which enters between Black Mammoth and Mustang hills. Both gulches drain territory covered by volcanic rocks, and in both prospect shafts show a deep filling of gravel. On the south side several gulches, of which the largest are Consolidated, Dublin, Big Pine, Auction, and Old Manhattan gulches and an unnamed gulch in the extreme west, drain into the main valley. These gulches for the most part have a north-
th the strike of the sedim .
None of them contain nearly as much gravel as the northern tributaries, although all except the two westernmost are filled with gravel for a short distance back from their mouths.

It is conceivable that this difference may be to some extent due to recent northward tilt. That such tilting has taken place since later Miocene time is shown in the northward dips that are common in the Bald Mountain beds. On the other hand, the southward-flowing streams, in the period when erosion was at its height, easily cut their valleys down to grade across the belt of soft rhyolitic tuff, whereas those on the south, which flowed across rocks of more equal resistance, maintained a generally more even grade throughout. If any tilting occurred it must have been prior to the formation of the Pleistocene lakes or confined to the immediate vicinity, for, according to Meinzer,[4] the old shore lines of Lake Toyabe, 15 miles to the north, are still horizontal.

[4] Meinzer, O. E., op. cit., p. 30.

PLEISTOCENE GRAVELS AND CANYON CUTTING.

Manhattan Gulch shows traces of several different stages of erosion. The oldest stream deposits occur only in the patches of older gravel here and there along the valley sides. This gravel is coarse. Most of the pebbles are rounded to subangular and about 4 to 8 inches in greatest diameter, though there are a few boulders of larger size. Fine clay and sandy material serves as a cement, but only in one place was a distinct bed of sand or fine gravel seen. The best exposures were found in the upper part of the gulch, particularly in the north face of Gold Hill, the upper level of the Little Grey mine (Pl. V, *B*), and the ridge back of the transformer house, 800 feet southeast of the Manhattan Ore & Milling Co.'s mill. At the last-named locality the gravel consists of 2 to 3 feet of hard cemented material, containing many boulders, particularly of the resistant Diamond King rhyolite. Between this hard material and bedrock is 10 to 15 feet of loose sand and fine gravel. The coarse gravel is so well cemented as to require the use of a pick in mining, but the underlying sand is unconsolidated. A small area of coarse rounded gravel near the eastern edge of the area mapped on Plate I probably does not belong to the Manhattan Gulch drainage.

The deep gravel of the gulch has been explored by placer mining, which is carried on from shafts sunk to bedrock. The depth of the old channel and the character of the material resting on bedrock are therefore easily ascertained. The upper part of the material that fills the gulch could not be so well studied, as nearly all the shafts are of necessity closely timbered. The deepest channel lies at depths of 40 to more than 100 feet below the present surface of the gulch. Several benches at higher altitudes represent stages in the erosion of the canyon, but the outer walls are everywhere steep. The old Wolfe Tone shaft, for instance, reaches bedrock at a depth of 70 feet not more than 50 feet from the rock outcrops on the end of Wolfe Tone Point, and at the "Narrows," below the Happy Day claim, the slope to the deep channel appears to be even steeper. It is believed that the average angle of rock slope toward the bottom of the gulch is at least 45°. In some places the rock benches are sharply defined, but elsewhere they grade into one another and into the deep channel. The grade between bench and deep channel is not as steep as that from the canyon wall to the bench and probably does not exceed 30°. The benches are not continuous. In places two well-defined sets are present; elsewhere they appear to be lacking. The accompanying sketch map and sections (fig. 4) show the relation of the deep channels and benches at a mine in the lower part of the gulch.

The average grade of the present surface of the gulch, between the town of Manhattan and the Japan claim, is 3½ per cent, but the grade is slightly steeper in the eastern and flatter in the western part. The average grade of the bedrock channel is slightly greater, as is shown by the fact that the westernmost shafts are the deepest.

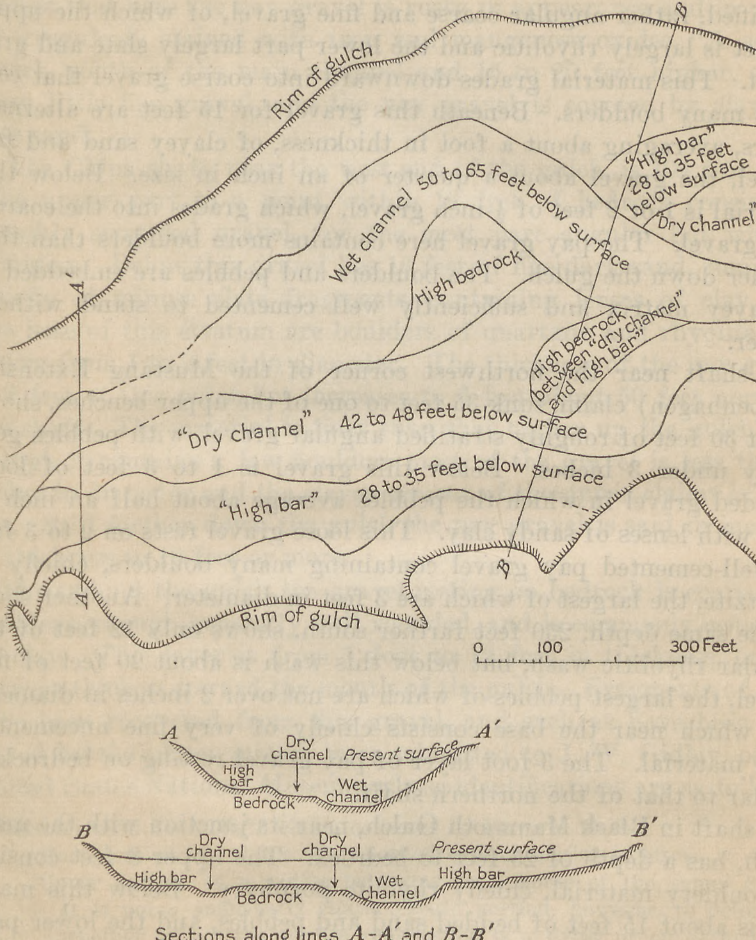


FIGURE 4.—Sketch map and sections of parts of Arlington No. 3 and Amboy claims, showing benches and deep channel.

The grade of the bedrock channel is far less regular than that of the present surface. There are stretches where the softer rocks have been worn down, separated by steeper stretches where the stream crossed the more resistant beds of the sedimentary series in rapids.

In the gulch the pay gravel is covered by finer gravel and sand, and this in turn by a roughly stratified deposit of more angular material. Complete sections were difficult to obtain, as most of the shafts that are not closely timbered are caved. The following sections, however, taken at intervals down the gulch, show the general character of the deposit.

A shaft near the southwest corner of the Mustang claim (Pl. XVIII, p. 124) shows in its upper portion about 45 feet of roughly stratified, rather angular coarse and fine gravel, of which the upper 10 feet is largely rhyolitic and the lower part largely slate and gray schist. This material grades downward into coarse gravel that contains many boulders. Beneath this gravel for 15 feet are alternate layers, averaging about a foot in thickness, of clayey sand and fine gravel, the gravel about a quarter of an inch in size. Below this material is 1 or 2 feet of ½-inch gravel, which grades into the coarser pay gravel. The pay gravel here contains more boulders than that farther down the gulch. The boulders and pebbles are embedded in a clayey matrix and sufficiently well cemented to stand without timber.

A shaft near the northwest corner of the Mustang Extension (Copenhagen) claim, sunk 35 feet to one of the upper benches, shows about 30 feet of roughly stratified angular gravel, with pebbles generally under 3 inches. Below this gravel is 1 to 3 feet of loose rounded gravel in which the pebbles average about half an inch in size, with lenses of sandy clay. This loose gravel rests on 2 to 3 feet of well-cemented pay gravel containing many boulders, chiefly of quartzite, the largest of which are 3 feet in diameter. Another shaft of the same depth, 250 feet farther south, shows only 12 feet of the angular rhyolitic wash, but below this wash is about 20 feet of fine gravel, the largest pebbles of which are not over 2 inches in diameter and which near the base consists chiefly of very fine uncemented slaty material. The 3-foot layer of pay gravel resting on bedrock is similar to that of the northern shaft.

A shaft in Black Mammoth Gulch, near its junction with the main gulch, has a depth of 25 feet to bedrock. The upper 3 feet consists of bouldery material, chiefly rhyolite porphyry. Below this material is about 15 feet of bedded sand and pebbles, and the lower part consists of coarse gravels and angular boulders, the largest of which are about 1 foot in diameter.

On the African claim a 65-foot shaft on the southern branch of the channel shows 10 feet of very roughly stratified material, chiefly fragments of rhyolite. Below this comes 40 feet of evenly bedded fine gravel and sand, the gravel layers averaging about 1 foot in thickness and the sand layers 3 feet. From this level to the top of the pay gravel is uncemented very fine slaty gravel, the "chicken feed" of the placer miners. This fine gravel contains a few sandy lenses, but most of it shows only very imperfect sorting. In the shaft the contact between the upper sand series and the fine slaty gravel dips 45° N., which is evidence of shifting stream channels. The pay gravel rests on a bedrock of dark crumpled slate. The pay gravel on the Last Chance claim is 1 to 6 feet thick and is covered with fine slaty gravel of the same type. A bench 4 feet above the main channel and 50 feet to the north shows similar conditions, except that here the pay gravel is rusty in appearance and in places is irregularly stained with iron and manganese oxides. A second bench, south of the main channel and 15 to 20 feet higher, shows very little fine gravel, and the pay gravel is covered by clay and fine sand.

The China shaft, near the west end of the gulch, is 105 feet deep. The upper part to a point within 12 feet of bedrock consists of roughly stratified gravel, for the most part angular but without boulders. Below this gravel lies 10 feet of fine dark sand, composed chiefly of minute slate fragments, containing lenses of clay. At the base of this stratum are boulders of quartzite and rhyolite porphyry from 1 to 2 feet in diameter. The thickness of the pay gravel is 2 feet at this point but increases to 6 feet about 50 feet north of the shaft. The material is finer than that higher up the gulch, and though it contains a few boulders most of the gravel is less than 2 inches in diameter and the clayey cement of the upper claims is lacking. Still farther down the gulch the pay gravel is said to increase in thickness to 10 feet or more.

Throughout the gulch the gravel resting on bedrock is coarse and bouldery, though generally well rounded, and is commonly cemented by clay. This layer is from 1 foot to 12 feet in thickness, on the average thickest toward the mouth of the gulch. Fragments of bone have been recovered from this gravel, and such as have been preserved by the placer miners were submitted to J. W. Gidley, of the United States National Museum, whose identifications are as follows:

Material from Searchlight claim, collected by Percival Nash:

Horn core of one of the short-horned extinct species of bison.

Upper portion of a radius belonging to a horse of the genus *Equus*. It is not a sufficiently characteristic portion, however, to determine whether or not the species represented is a living or an extinct one. The character of the fracture suggests that the bone may be of Pleistocene age.

Fragment of a proboscidian tusk. It may be either mastodon or mammoth, probably the latter. It indicates a deposit of Pleistocene age.

Material from mines near Central, collected by L. F. Clar:

Elephas sp.; tusk, very badly broken. *Equus* sp.; distal end of tibia, metatarsus, and other fragments.

Cervid cf. *Rangifer* sp., parts of tibia and metatarsal. Both are probably Pleistocene.

Equus sp., upper molar. Probably Pleistocene.

Material from Bulldog group (Edna claim?), at the mouth of the gulch, collected by H. G. Clinton:

> Portions of a right lower jaw of an extinct species of *Bison*, possibly new, and several teeth and a bone of the fore leg represent an extinct species of horse belonging to the living genus *Equus*. Both these animals indicate that the gravels in which they were found are of Pleistocene age. Personally I am inclined to consider the beds as rather early Pleistocene on the evidence of the horse material, which seems to indicate a species closely related to or perhaps identical with *E. occidentalis* Leidy, but I would not care to say so definitely without having more material from the locality to examine.

The bones were found scattered and are broken, but they were probably deposited during the deep-channel period of erosion and not in the older gravels; otherwise they would hardly have survived, even in their present fragmentary state.

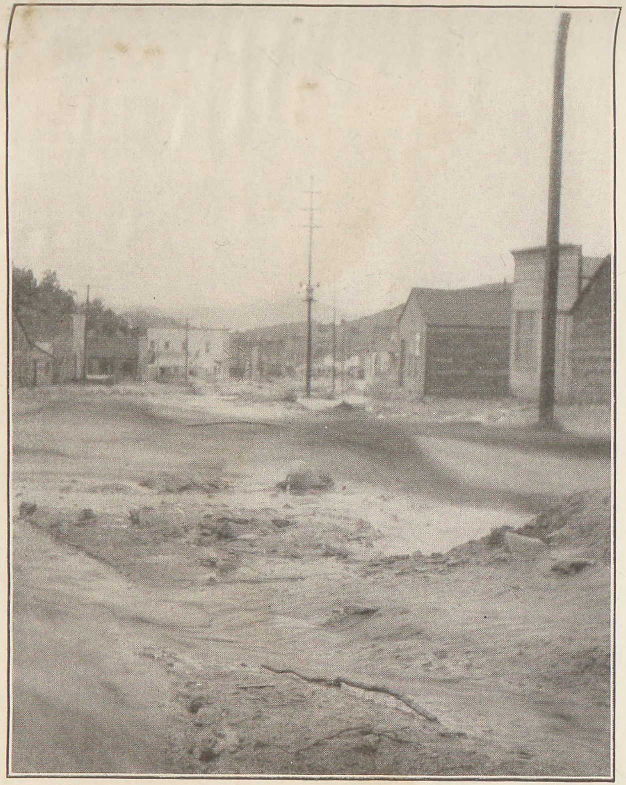
The fine material above the coarse pay gravel contains imperfect plant remains and fragments of partly carbonized wood, but none were sufficiently characteristic to admit of determination.

QUATERNARY HISTORY.

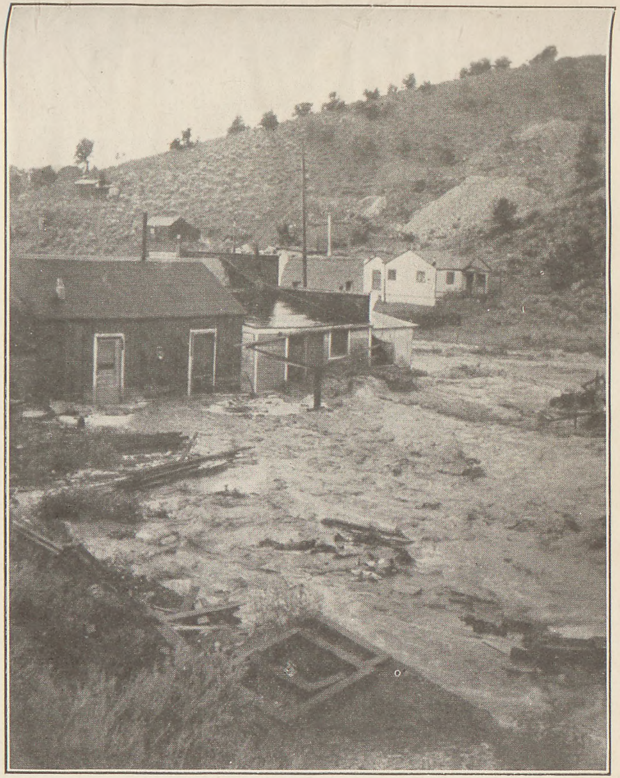
It is possible from the evidence at hand to reconstruct the history of the gulch. The older gravels found on the edges of the valley represent one or more stages in the early erosion of the gulch, presumably by a perennial stream. The present course of the stream was determined during this period, and as it now flows transverse to the rock structure, presumably its original course was determined by the existence of a belt of the easily eroded Round Rock tuff. Probably most of the valley erosion was accomplished during this period, for the tributary gulches have adjusted their courses to accord roughly with the rock structure, but most of them have not cut their channels to accord with the depth of the buried canyon. Consolidated Gulch, which runs transverse to the rock structure, perhaps represents a remnant of the original master stream, now become insignificant through capture of its headwaters and greater development of more favorably situated tributary gulches.

The period of time represented by the erosion that occurred between the formation of the old erosion surface of probable late Pliocene age and the stage of the stream represented by the older gravels mentioned above must have been enormously greater than the time necessary for the succeeding stages, yet if the fossils of the deep gravels are of early Pleistocene age, this erosion must have taken place during the early part of the Pleistocene. After this early erosion the stream began to cut a sharp canyon in the older broad valley, and the older gravels were largely removed.

The buried bench gravels represent stages in the process of canyon cutting. As many as three benches are preserved in different parts



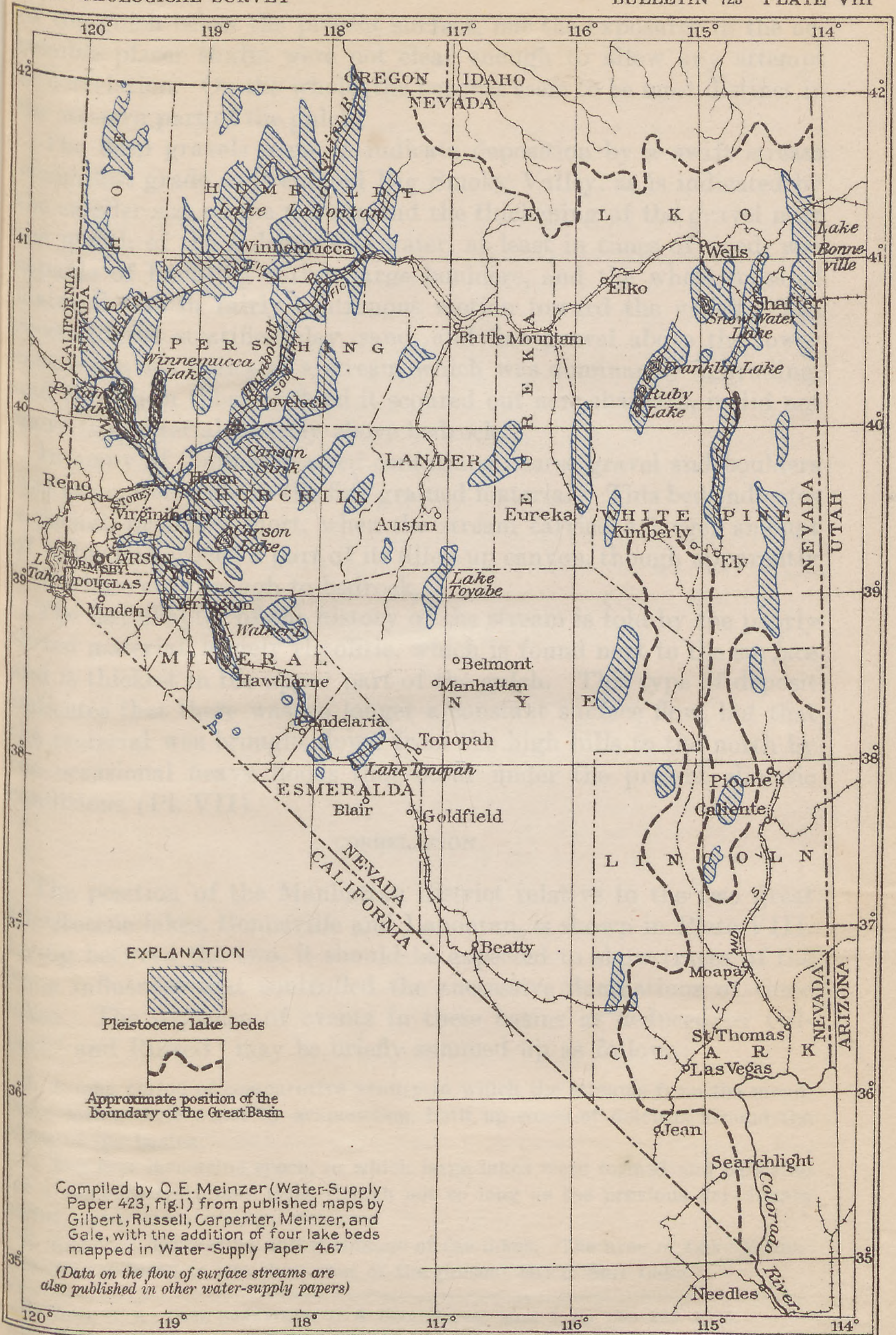
A.



B.

FLOOD OF AUGUST, 1914, AT MANHATTAN.

Photographs by R. F. Steele, U. S. Forest Service.



MAP OF NEVADA SHOWING PLEISTOCENE LAKE BEDS

1923

of the gulch below the present surface, but the exposures in the accessible placer shafts were not clear enough to allow any attempt at correlation. On the whole, the benches seem to be most distinct in the western part of the gulch.

The deep gravels seem to indicate deposition by a swift stream which lost grade as it entered Big Smoky Valley, as is indicated by the smaller size of the pebbles and the thickening of the gravel near the mouth of the gulch. The water, at least in times of flood, was capable of handling rather large boulders, and the whole mass of material was in fairly continuous motion toward the valley. The succession of stratified clay, sand, and fine gravel above the lower coarse gravels indicates a stream which was dominantly aggrading, and though in times of flood it scoured out new channels, it did not move the material directly above bedrock.

In many of the shafts a bed containing coarse gravel and boulders was encountered above the fine-grained material. This bed indicates a period, probably short, when the stream carried a larger amount of water and eroded a part of its filled-up canyon, though apparently it nowhere cut through to bedrock.

The last chapter of the history of the stream is told by the poorly sorted material, largely rhyolitic, which is found next to the surface and is thickest in the upper part of the gulch. This type of deposit indicates that there was no longer a constant surface flow, but that the material was brought down from the high hills to the north by the occasional heavy floods that occur under the present climatic conditions (Pl. VII).

CORRELATION.

The position of the Manhattan district relative to the two great Pleistocene lakes, Bonneville and Lahontan, is shown in Plate VIII. Lying between the two, it should be expected to show traces of the same influences that controlled the successive fluctuations of these lakes. The sequence of events in these basins as deduced by Gilbert [5] and Russell [6] may be briefly summed up as follows:

1. A long period of comparative aridity in which the streams from the mountains, losing their water by evaporation, built up cones of detritus around the edges of the basins.

2. The first lacustrine epoch, in which large lakes were formed and persisted for a comparatively long time, though not so long as the previous dry-climate period.

3. Renewed desiccation and shrinkage of the lakes. The area of Lake Bonneville was reduced to less than that of the present Great Salt Lake.

[5] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, pp. 259–262, 1890.

[6] Russell, I. C., Geological history of Lake Lahontan: U. S. Geol. Survey Mon. 11, pp. 250–268, 1885.

4. A comparatively short lacustrine epoch in which the lake waters rose to a point above their previous high level, resulting in overflow from Lake Bonneville, but not from Lake Lahontan. Although the waters rose to higher levels, this lacustrine epoch was far shorter than the earlier one.

5. Shrinkage of the lakes to the present remnants. The time involved in this stage is far shorter than the interlacustrine epoch.

The two lacustrine epochs are naturally correlated with intervals of moister or colder climate during Pleistocene or glacial time. As Gale[7] has shown, the increase in humidity was probably slight, for the large lakes were favorably situated to receive the waters of streams flowing from the higher summits—from the Sierra Nevada to Lake Lahontan and from the Wasatch Mountains to Lake Bonneville. In several of the inclosed basins of the intervening area lakes did not form, although most of the northern basins contained lakes. Gale says: "Desert conditions, possibly with slight modifications, such as greater frequency of periodic storms, may logically be assumed never to have suffered the establishment of a full, continuous flow in the typically desert-basin drainage areas." A comparatively slight decrease in temperature would probably result in refilling of the old lake basins.

Meinzer[8] sums up the Quaternary history of Big Smoky Valley as follows:

At the beginning of the Quaternary period the basin of Big Smoky Valley had essentially its present dimensions and the mountain ranges occupied approximately their present positions. Slight disturbances, however, took place during the period, resulting in fault scarps on the valley sides. The characteristic process of the period has been the erosion of the mountains and the deposition of the resulting detritus in the valley. The climate was probably arid during most of the period, but in late Pleistocene time there was at least one relatively humid interval when large lakes were formed. There was also a time, apparently contemporaneous with the lake epoch, when deposition on the upper and middle parts of the alluvial fans generally ceased and valleys of considerable depths and width were cut.

Wind work, chiefly the handling of sandy sediments of the valley fill, was probably in progress throughout the period and is now going on, the present dunes having been deposited chiefly since the desiccation of the lakes. The great extent of postlacustrine wind work is indicated by the fact that dunes of very different ages occur on the lake bed in the lower valley. Considerable erosion of the tuff formations and a small amount of erosion on the flats has been accomplished by the wind, but except for the building of the dunes the wind has not been an important factor in the molding of the topography of the basin.

The existence of the two large lakes, exposing at their maximum stages respectively 85 and 225 square miles of water surface to continuous evaporation, indicates distinctly less aridity than exists at the present time, when there are no permanent lakes, when the surface waters that occasionally spread

[7] Gale, H. S., Notes on the Quaternary lakes of the Great Basin, with special reference to the deposition of potash and other salines: U. S. Geol. Survey Bull. 540, pp. 402–403, 1914.

[8] U. S. Geol. Survey Water-Supply Paper 423, pp. 64, 65, 1917.

over the interior depressions are quickly disposed of by evaporation, and when the areas over which the slow evaporation of ground water takes place are considerably smaller than the ancient lake beds. On the other hand, these lakes do not indicate any great degree of humidity but only the moderate differences in precipitation and evaporation exhibited by the somewhat better watered and cooler basins that contain salt lakes at the present time. Both lakes show great fluctuations in water level in response to numerous climatic variations within the epoch of relative humidity. Even in the most humid times, however, Lake Toyabe occupied only about 18 per cent and Lake Tonopah about 4 per cent of their respective drainage basins. At no time did either lake overflow its basin, nor did Lake Toyabe ever discharge into the lower valley.[9]

In proportion to the size of their respective drainage basins Lake Toyabe was more than four times as extensive as Lake Tonopah. This difference was due to the higher altitude and consequently greater run-off of the northern than the southern mountains, to the lower altitude and latitude and consequently greater evaporation in the lower than the upper valley, to the relatively small contributions of water made by remotely connected areas tributary to the lower valley, such as Ione Valley and the basin discharging at Crow Spring, and perhaps also to the greater amount of underground leakage from the lower than from the upper valley.

If the maximum extent of Lake Toyabe was contemporaneous with either lacustrine period of Lake Lahontan, it clearly should be correlated with the most recent, for

The shore features have not been much changed since the ancient lakes disappeared. In many places the gravelly ridges seem to be almost without modification. In only a few places have the shore features been cut by gullies. The principal changes have been produced by aggradation on the large fans, where the shore features have been, to a great extent, buried under sediments deposited by the streams. Small beaches at both ends of Lake Toyabe and at the northeast end of Lake Tonopah have no doubt been thus buried, and the lower parts of even some of the large ridges may be buried beneath considerable recently deposited material.[10]

The first expansion of the two great lakes apparently did not have its counterpart in Big Smoky Valley. The absence of evidence of an older lake may be due to one of three causes:

1. There may have been drainage of the valley either to the north or south. Geologic and physiographic studies of the region are not sufficiently detailed to disprove this absolutely, but such work as has been done points to the conclusion that the Big Smoky basin has not been a part of a large drainage system since the time of the development of the great lakes.

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[9] Lake Tonopah was in the southern part of the valley, west of Tonopah, between Millers and Blair Junction, and Lake Toyabe occupied a portion of Big Smoky Valley between the Toquima and Toyabe ranges. The southern limit of Lake Toyabe was 15 miles north of the mouth of Manhattan Gulch. According to Meinzer (op. cit., p. 30), its length at its time of maximum extension was about 40 miles, its width 9 miles, and greatest depth 170 feet.—H. G. F.

[10] Meinzer, O. E., op. cit., p. 41.

2. Climatic conditions, though permitting the existence of perennial streams in the mountains to a greater extent than to-day, did not allow the formation of large permanent water bodies in the valley. This would mean that in Big Smoky Valley the second higher stage of Lake Lahontan was accompanied by the formation of a lake, while the first, though longer continued, was not.

3. An older lake may have existed, all traces of which have been obliterated by more recent deposits.

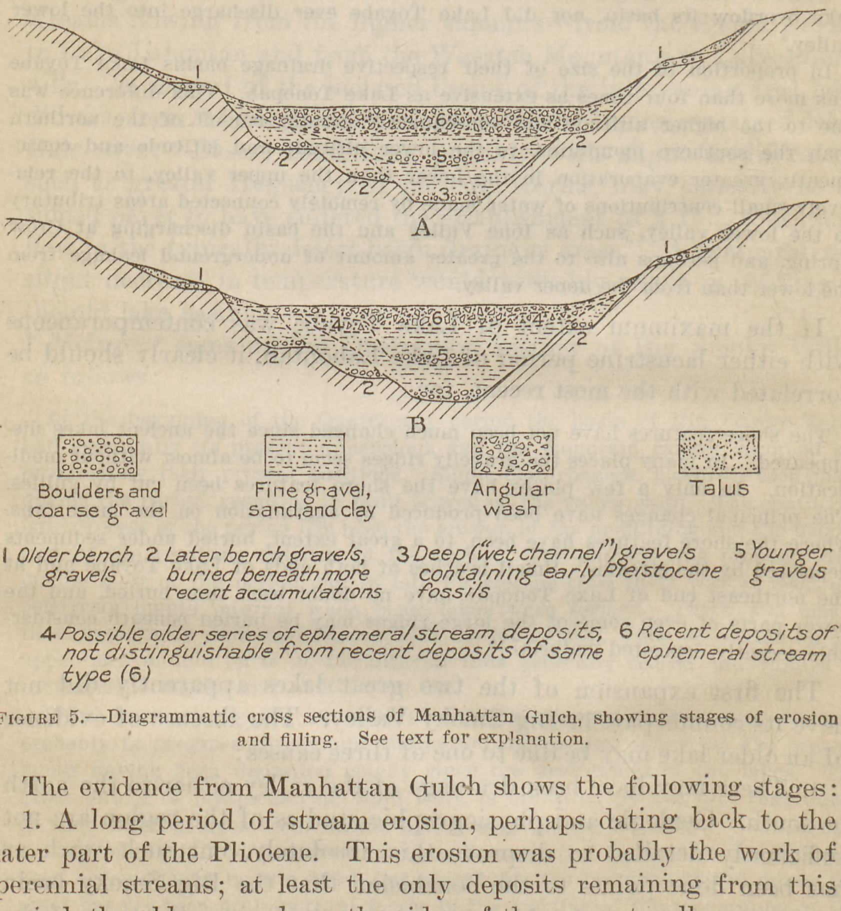

FIGURE 5.—Diagrammatic cross sections of Manhattan Gulch, showing stages of erosion and filling. See text for explanation.

The evidence from Manhattan Gulch shows the following stages:

1. A long period of stream erosion, perhaps dating back to the later part of the Pliocene. This erosion was probably the work of perennial streams; at least the only deposits remaining from this period, the older gravels on the sides of the present valleys, appear to represent the work of such streams (No. 1, fig. 5).

2. A period of greatly stimulated erosion resulting in the cutting of a rock-walled canyon from 40 to 100 feet in depth in the bottom of the old valley. This is divisible into several stages, marked by the presence of benches cut in the canyon walls (No. 2, fig. 5). The gravel laid down at this period contains fossils of Pleistocene age. The canyon, as shown by placer-mining developments, extended

beyond the present limit of exposed rock and turned sharply to the north at the mouth of the present gulch.

3. Decrease in the carrying power of the stream and deposition of a considerable thickness of fine-grained material (No. 3, fig. 5). It is possible that a part of the poorly bedded angular material found in the upper portion of the shafts may have been deposited at this time (No. 4, fig. 5, B), but there is no clear evidence of this.

4. Rejuvenation of the stream and erosion of a part of the material laid down in the previous stage (No. 5, fig. 5).

5. Filling of the gulch to its present level by material brought down by occasional floods—much the condition that exists to-day, though apparently floods of the present day do not carry coarse material as far down the gulch as formerly (No. 6, fig. 5).

The work carried on during these stages is shown diagrammatically in Figure 5. These diagrams are not drawn to scale and are intended only to present graphically the substance of the preceding paragraphs. The only essential difference between the two is that in Figure 5, B, it is assumed that a part of the angular ephemeral stream deposit belongs to an earlier stage.

The stages shown at Manhattan can not be definitely correlated with the Bonneville and Lahontan stages, but certain parallels in the Quaternary history of the three regions are suggested.

The cutting of the now buried rock-walled canyon was probably contemporaneous with the earlier and longer lacustrine epoch, during which a lake may have existed in Big Smoky Valley, but all traces of its existence have been obliterated. In Manhattan Gulch, however, the revival of erosion may have been in part due to faulting in the valley, for the canyon is narrowest and deepest near its mouth and shows no flaring, as would be expected had the renewal of erosion been due simply to a change in climatic conditions, and as has been shown above (p. 63) there is some slight evidence for assuming the presence of a fault parallel to the west front of the Toquima Range. The evidence afforded by the canyon cutting is not conclusive, for a period of revived erosion with a permanent stream flowing toward a lake in Big Smoky Valley would produce the same result.

The bedded deposits of clay, sand, and fine gravel overlying the coarse bouldery gravel of the deep channel indicate a change in the character of the stream, which now began to fill up with fine material the canyon cut during the previous stage. A probable explanation is found in altered climatic conditions, resulting in decreased stream volume, as no change appears to have taken place in the grade of the channel or in the topography of the drainage basin. As suggested above, a portion of the coarse angular débris considered due to floods during a period of dry climate may belong to this stage. This stage therefore, marked by a perennial stream of decreased volume, which possibly faded into an ephemeral stream, may represent the arid period that intervened between the two principal lacustrine stages. It is likely that the solution channels in limestone found in the Manhattan Consolidated mine, below the present water level, may have been formed at this time.

The last period in which a perennial stream able to erode its channel flowed down the gulch must have been of comparatively recent date and short duration and probably was contemporaneous with the formation of the shore lines of Lake Toyabe now in existence and the second expansion of Lakes Bonneville and Lahontan. There is no evidence, however, that the stream flowing down Manhattan Gulch ever entered Lake Toyabe for any long period, if at all. In all probability the increased humidity, or what would give the same result—lower temperature with consequent decrease in evaporation—was only sufficient to carry the waters to the edge of the valley, much as those of the perennial Jefferson and Shoshone creeks are carried to-day.

ECONOMIC GEOLOGY.

LODE DEPOSITS.

The ore deposits of the Toquima Range belong to two periods of metallization, differing both in the character of the deposits and in geologic age. The deposits of the first period, which are not economically important in the Manhattan district, were formed after the intrusion of the granitic batholith and its accompanying silicic dikes. To this class belong the tungsten deposits of Round Mountain and Spanish Springs, the gold-bearing veins allied to aplite dikes, of the type mined in the Silver Peak region, and the quartz veins of Belmont, in which the valuable minerals contain chiefly silver, lead, and copper, with minor amounts of gold. This period of metallization was completed before the beginning of Tertiary volcanic activity. As the deposits are closely associated with the granite, the date of ore deposition may be placed as early Cretaceous. Later ore deposition is represented by ore deposits within the lavas, as in Round Mountain and Jefferson and the northern part of the Manhattan district. The most valuable deposits of the Manhattan district are within the older rocks, but they show by their texture and mineral composition that they were formed at comparatively shallow depths. It is possible that the more recent deposits represent more than one period of ore deposition. The productive deposits are confined to a small area, which has been mapped on a larger scale (Pl. II).

DEPOSITS OF DEEP-SEATED ORIGIN.

Ore deposits that show characteristics of origin under conditions of comparatively high temperature and pressure are found throughout that portion of the range in which erosion has uncovered the granite batholith and surrounding metamorphosed sediments. These deposits include tungsten-bearing veins, which occur within the granite area; auriferous quartz veins closely allied with the aplitic phase of the granite, such as those in the Silver Peak region described by Spurr;[11] and quartz veins carrying silver-bearing sulphides, such as those mined at Belmont, a few miles northwest of Manhattan.

Quartz veins, carrying small amounts of the manganese tungstate, huebnerite, have been prospected in the granite area in the vicinity of Spanish Springs, a few miles south of the Manhattan district. These veins were not visited, but from the descriptions received they appear to be of the same type as those of Round Mountain, described in a recent publication.[12] No tungsten-bearing veins have been encountered within the Manhattan district. Hess and Larsen[13] have found that scheelite is present in many of the areas of metamorphosed rocks surrounding the granitic intrusions in Nevada and California, but so far as known no scheelite occurs in the contact zones of the Manhattan district, though no special search has been made for it.

Specimens of metamorphosed slate containing small yellowish scales of the rare vanadium-bearing mineral calci-vorbothite, a vanadate of copper and lime, and a greenish coating which is probably a copper sulphate like dihydrite (pseudomalachite), as well as secondary copper minerals such as malachite, azurite, and chrysocolla, have been obtained from the region of contact metamorphism bordering the granite mass south of the Manhattan district. No information is available as to the size and nature of these deposits, but they presumably belong to this period of metallization.

In the Manhattan district the sulphide-bearing veins of the older group commonly do not occur within the granite areas but in the surrounding sediments, usually outside the zone of most intense contact metamorphism. So far as known, deposits of the contact-metamorphic type have not been mined in the Toquima Range.

No veins of this period of ore deposition have been profitably worked in this district. Such of the older veins as have been prospected in the vicinity of Manhattan are narrow and of no great con-

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[11] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, p. 20, 1906.

[12] Ferguson, H. G., The Round Mountain district, Nev.: U. S. Geol. Survey Bull. 725, pp. 388–390, 1921.

[13] Hess, F. L., and Larsen, E. S., Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725, pp. 245, 246, 1921.

tinuity. They are commonly made up of white glassy quartz with minor amounts of calcite and here and there contain coarsely crystalline sulphides, including pyrite, galena, tetrahedrite, bornite, and chalcopyrite. The tenor in precious metals is low, and the silver content is commonly greater than the gold. Tourmaline occurs as a minor gangue mineral in a few veins of this type. In one vein orthoclase feldspar is present, and the vein closely resembles quartzose segregations of the aplite dikes.

Quartz veins carrying principally chalcopyrite and tetrahedrite with small quantities of both gold and silver are rare and of no economic importance. Veins of this type have been unsuccessfully prospected in the slate area east of Round Mountain and south of Jefferson Creek. In the Manhattan district a few of the abandoned prospects, such as the Nugurock, in the slates north of Central, belong to this class. A small vein carrying a little bornite in a gangue of quartz and orthoclase was cut in the lowest level of the Earl mine.

Changing composition of the ore-bearing solutions is indicated in the ore of the Nemo prospect, near Central. Here galena is the principal sulphide, though chalcopyrite is present in small amounts; of the precious metals present silver is usually more abundant than gold. The Nemo is the only deposit of this class that has been developed to any extent. Here the dark schists of the Toquima formation are intruded by small aplite sills and contain quartz lenses parallel to the schistosity. The ore minerals consist of galena, chalcopyrite, and pyrite, which are present in small lenticular masses of quartz.

DEPOSITS OF THE SHALLOW VEIN TYPE.

DEPOSITS IN THE TERTIARY ROCKS.

The volcanic rocks, including the andesite porphyry and the Maris rhyolite, which are of post-Esmeralda age, contain small veins, apparently not continuous over long distances, most of which follow joint cracks or minor faults.

The veins in the lavas have been prospected chiefly near Bald Mountain but have so far yielded little or no return. The ore consists of minute veins of comby iron-stained quartz, with minor amounts of tabular calcite, largely replaced by quartz, and rarely fluorite and adularia. Pyrite has been present but, so far as the workings have been extended, is completely oxidized to limonite, though most of it retains the original shapes of the pyrite crystals. Here and there minute specks of free gold can be seen on the surface of the grains of oxidized pyrite.

Deposits of this type have been prospected principally in the Bald Mountain, Buckeye, and Desmond prospects on Bald Mountain. Work has not proceeded far enough to determine the possible size and extent of the veins, but so far as could be seen the veins are small and not continuous over long distances. Apparently some of them follow faults and others occur in small fissures without marked displacement. There is also some faulting of later date than the mineralization.

The Wall mine, in the extreme southern part of the district, belongs to the same class. It differs from the prospects on Bald Mountain in that there are no distinct veins, the ore minerals apparently filling open spaces in the fossil talus deposit of Tertiary age. The deposit is also the only one of this type in which a silver-bearing mineral is found, for near the surface cerargyrite occurs abundantly in places. There is also a larger proportion of fluorite than is found in the Bald Mountain prospects.

A deposit of silicified tuff occurs on the east side of the Toquima Range, close to the Belmont road, about 8 miles from Manhattan. This rock is quarried and, after rough rounding in a tube mill, shipped to Manhattan, Tonopah, and Goldfield for use in tube mills. The material has been found to be as satisfactory as the Danish pebbles ordinarily used, but owing to the isolated position of the deposit the high cost of transportation prevents its widespread use. The quarry is known as the Maris "pebble mine." The country rock consists of some of the finer-grained members of the Bald Mountain lake beds. They are here tilted at low angles to the north and are cut by irregular dikes of Maris rhyolite. The silicification of the shaly lake beds appears to be largely confined to certain favorable beds, which have been more or less brecciated. In thin sections of the best grade of material the minutely brecciated structure can be seen, the little fragments lying at all angles and almost completely replaced by minutely crystalline quartz in a matrix of finely banded quartz and chalcedony. This brecciation aids in giving the requisite toughness to the material, for unbrecciated tuff, even though silicified, tends to split along the bedding planes. Certain beds that are rejected in quarrying contain small cavities parallel to the bedding lined with drusy quartz and in places a little calcite. Elsewhere small veinlets containing quartz pseudomorphic after tabular calcite were seen. According to Mr. Maris the material as mined has a small gold content, not over $2 a ton.

DEPOSITS IN THE OLDER ROCKS.

The mines of Gold Hill, southwest of Manhattan, have yielded the largest production in the Manhattan district. The deposits, although almost identical mineralogically, include ore bodies of two types. One type is exemplified by the large bodies of low-grade ore without well-marked walls worked in the mines on the summit and eastern flank of Gold Hill. To the other type belong the deposits on the western slope of the hill that follow definite lodes, whose position is determined by preexisting faults. In some of the mines, such as the Jumping Jack and Big Four, the two types tend to coalesce, but as a whole they are fairly distinct.

The ore bodies of the first type occur in a broad zone about 100 by 800 feet, extending from the Big Four southward to the Reilly Fraction and including parts of the Big Pine, Mayflower, and Jumping Jack properties. The country rock consists of quartz-mica schist, with several beds of white quartzite and dark-green sandstone, which in a few places grades into a fine-grained conglomerate. The strike is northwesterly and the dip 38°–78° SW. The most prominent series of joint planes strikes about N. 30° E. and is about vertical or dips steeply to the southeast. In the Big Four workings a minor system strikes N. 5° E. and dips 68° W. The ore consists of innumerable little veinlets which follow the jointing and to a less extent the bedding (Pl. IX, *A*). Few of these veinlets are as much as an inch in width, but they are spaced closely enough to permit the mining of the whole mass of schist, particularly because near the surface the more friable vein material tends to break free from the inclosing rock, thus permitting concentration by crushing and screening.

The veinlets consist principally of comby quartz, but the larger ones contain quartz pseudomorphic after tabular calcite. Adularia also occurs plentifully in places, both with the quartz replacing the original tabular calcite (Pl. IX, *B*) and in small crystals resting on the plates of quartz that retain the form of the original calcite. Small patches of manganese oxide occur here and there in the veins but are not common. The veins originally contained a small amount of pyrite, but this is oxidized even in the deepest workings and is now represented by irregular iron staining of the quartz near the surface and by small specks of limonite that in places preserve the form of the original pyrite crystals. The schist, on the other hand, though heavily stained with iron oxide near the surface, preserves the unaltered pyrite at shallower depth, either as minute disseminated crystals or small threadlike veinlets. The pyrite in the schist is said to be practically barren, and the only value of the ore is in its content of free gold.

Gold in particles large enough to be visible in the hand specimen is rare, but concentrates in the pan show finely divided pale-yellow gold. Several of the thin sections of the ore show, under the microscope, small crystals of gold, commonly resting on the quartz or adularia crystals or embedded in the adularia. So far as could be determined, the gold is not closely associated with the oxidized pyrite, nor is the presence of manganese oxide here indicative of rich ore. Although a few very rich streaks were encountered, the tenor of the ore mined was probably less than $5 a ton. At the Big Pine mine in 1915 rejection of oversize material brought the grade of the ore milled up to about $10 a ton.

Ore of this type has been mined to a maximum depth of about 300 feet below the surface, but most of the gold produced has come from depths of less than 100 feet. At greater depths not only was the tenor somewhat lower but as the veinlets would not split easily from the inclosing schist, it was necessary to mill all the material mined, thus increasing the cost.

The group of mines west of the summit of Gold Hill shows the same type of mineralization, but here the lodes are better defined and follow faults, most of which are of small throw but continue for considerable distances. The three most valuable deposits of this group are those of the Jumping Jack, Union No. 9, and Little Grey mines.

The primary ore consists of irregular veins in crushed schist throughout zones of crushing that range in width from a foot or two to a maximum of 20 feet. The ore is similar to that of the schist ore body on the top of the hill, but the veinlets are more closely spaced and commonly wider, forming a far larger proportion of the lode material. The mineralization was not confined to the principal zone of crushing, but in many places little veinlets of the same type extend into the country rock. Few of these veinlets. however, are spaced closely enough to give workable ore.

Quartz both in comb structure and pseudomorphic after tabular calcite is the principal gangue mineral, adularia is plentiful, and a little calcite was found in ore from the Little Grey mine.

The ore is in most places stained with iron or manganese oxide, and commonly the best ore is highly manganiferous. Pyrite occurs in the veins in the lower levels of the Little Grey mine and is disseminated in the schist at less depth than in the veins. There has been later movement along many of the lodes and also along planes intersecting the lodes at small angles. Where this has occurred, gold of supergene origin is found in association with crushed vein material and gougy manganese oxide.

In the Jumping Jack workings ore of this type follows a definite fault plane that strikes about N. 30° E. and dips 70° NW., approximately parallel to the major joint system in the schist ores just to the east. This fault continues northward into the Big Four workings, but there it becomes less definite and the ore more closely resembles that of the Big Pine. In the Jumping Jack ground the lode consists of a crushed zone 2 to 10 feet wide between walls marked by gouge and slickensides. The vein has been developed to a depth of nearly 200 feet vertically below the outcrop. So far as can be inferred from the old stopes the ore bodies were small and irregular.

The Union No. 9 vein, a short distance to the east, strikes N. 10° E. and dips 60° W. The lode is narrower than some of the others, but it is well defined, and the old stopes show a width of 3 to 6 feet. It has been explored to a depth of 600 feet on the dip of the vein, but nearly all the gold produced was found above the 300-foot level. A smaller parallel vein, 30 feet to the east, has also yielded ore. The ore is similar to that of the other mines of this type.

The Little Grey lode crops out at a lower altitude at the western edge of Gold Hill. The ore-bearing fault, which strikes N. 20° W. and dips 60° W., has been productive to a depth of 200 to 300 feet down the dip.

Other fault lodes of the same type have been mined to some extent on Gold Hill and in the immediate vicinity but have been productive only at shallow depth.

DEPOSITS IN LIMESTONE.

The ore deposits in the limestone beds of the Gold Hill formation show most complex mineralization and a great variety of minerals. The ore is confined almost entirely to a single limestone bed, the upper of the three lower limestones, locally known as the White Caps limestone. This bed has been traced from a point about a mile east of the White Caps mine through Litigation Hill to the summit of April Fool Hill, where it is cut off against the overthrust fault. Throughout its course it is broken by closely spaced normal faults, mostly of small throw. This faulting appears to be most intense and complicated in the region between the White Caps and Manhattan Consolidated shafts. A detailed study of this region was made by Messrs. McCraney and Dynan, of the White Caps Mining Co., in connection with the White Caps-Morning Glory litigation in 1917, and through the courtesy of the officials of the White Caps Mining Co., their map, with slight changes by the writer, is here reproduced (fig. 6). The region west of the Consolidated shaft was mapped by the writer on a much smaller scale, which admits of showing only the more extensive faults (Pl. II).

Most of the faults are of small throw and strike a few degrees east of north. Faults of this type show steep dips, commonly to the east. They are cut by a few later faults of flatter dip, which strike in a general northeasterly direction and on which the displacement is much greater than on the earlier series. Both series cut the overthrust fault, and the larger faults are probably later than the Tertiary lavas to the north.

Besides these faults there are some obscure faults of another type. Repetition of the limestone bed on the 600-foot level of the Union Amalgamated, on the 300-foot level of the Manhattan Consolidated, and between the surface and the 310-foot level of the western part of the White Caps mine is apparently due to faulting, possibly contemporaneous with the overthrust, which closely parallels the sediments in strike and dip.

The White Caps mine appears to mark the eastern limit of profitable mineralization of the limestone. In the Zanzibar, White Caps Extension, and Red Caps prospects the limestone bed has been ex-

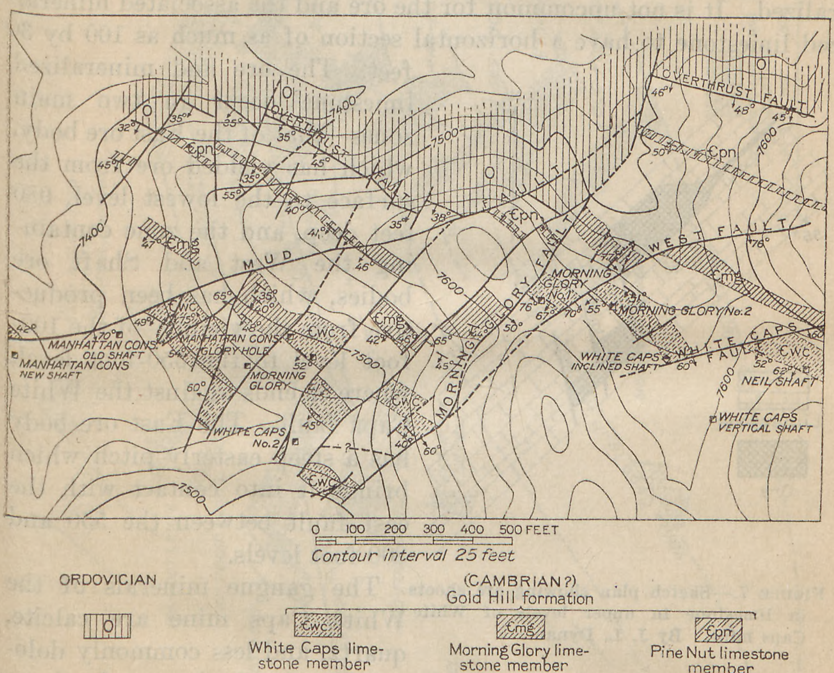


FIGURE 6.—Geologic map of the area between the White Caps and Manhattan Consolidated mines. By O. McCraney and J. L. Dynan, with minor modifications by H. G. Ferguson.

plored farther east, but so far without success, although some mineralized limestone has been encountered.

The limestone is cut by three major faults known as the East fault, White Caps fault, and West fault, which strike northeast and dip southeast (fig. 8). There are also a number of small northerly faults which are earlier than the larger faults and preceded and apparently, to a large extent, controlled ore deposition. These are cemented by ore and almost lose their identity in the ore bodies. The three main faults cut the earlier series and contain rounded fragments of ore.

The accompanying sketch by Dynan[14] (fig. 7) shows the relation of the ore bodies in the upper part of the mine to the earlier faulting. The map of the 310, 565, and 800 foot levels (Pl. X) and the sections (figs. 9 and 10) show the distribution of the ore bodies in the limestone. Figure 8 shows the limestone blocks as exposed at the surface and developed on the different levels.

The ore occurs in large bodies replacing the limestone. Mineralization does not, as a rule, extend completely across the bed but usually follows one wall, more commonly the footwall. The rock in which the small faults are most numerous appears to be most highly mineralized. It is not uncommon for the ore and the associated mineralized limestone to have a horizontal section of as much as 100 by 30 feet. The ore and mineralized limestone occur in two main zones—that of the East ore body, which has yielded ore from the surface to the lowest level, 980 feet deep, and the zone containing the West and Shaft ore bodies, which has been productive from the vicinity of the 100-foot level to the 550-foot level, where it ends against the White Caps fault. The East ore body has a steep easterly pitch which brings it into contact with the east fault between the 550 and 800 foot levels.

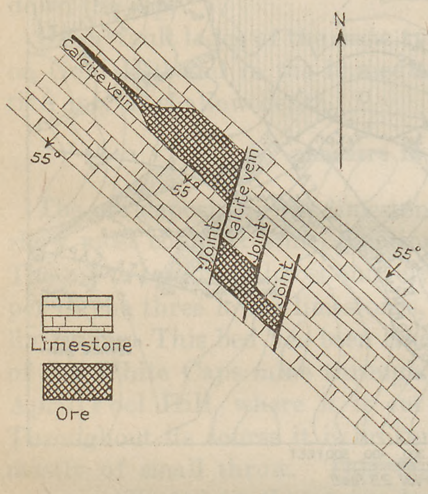


FIGURE 7.—Sketch plan showing ore shoots in limestone in upper levels of White Caps mine. By J. L. Dynan.

The gangue minerals of the White Caps mine are calcite, quartz, and less commonly dolomite, fluorite, and sericite or leverrierite, a hydrous aluminum silicate.[15] The principal sulphides are pyrite, stibnite, realgar (AsS), orpiment (As_2S_3), and probably arsenopyrite. Cinnabar is reported to have been present in the ore found above the 200-foot level[16] and has recently (1923) been found in appreciable amount on the 980-foot level. Pyrite occurs throughout the deposit but in less amount than the other sulphides. The realgar and orpiment are auriferous, but visible gold is completely lacking even in the oxidized ore. The stibnite is practically barren. Accord-

[14] Dynan, J. L., The White Caps mine, Manhattan, Nev.: Min. and Sci. Press, vol. 113, pp. 884–885, Dec. 16, 1916.

[15] Larsen, E. S., and Wherry, E. T., Leverrierite from Colorado: Washington Acad. Sci. Jour., vol. 7, pp. 208–217, 1917.

[16] Dynan, J. L., op. cit., p. 885.

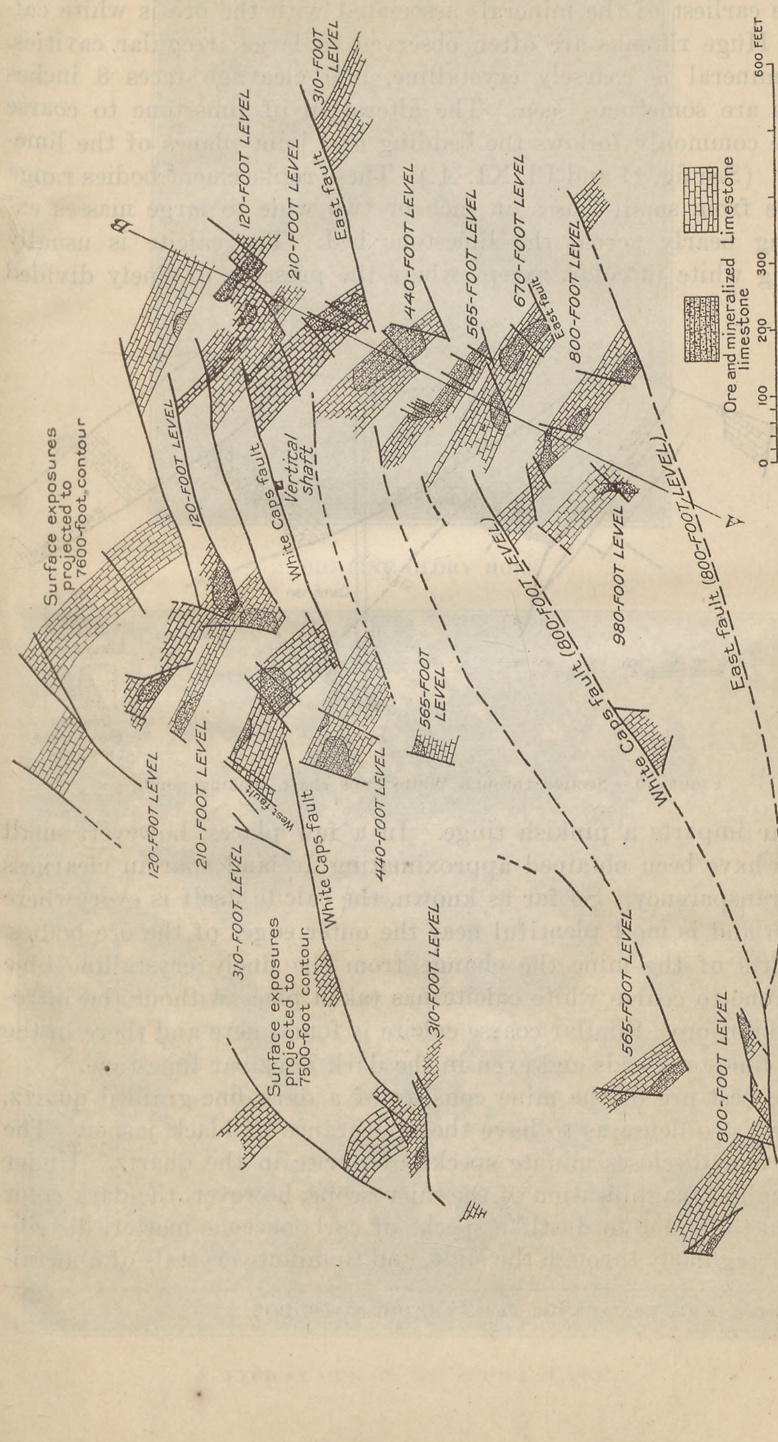


FIGURE 8.—Composite plan showing limestone blocks in White Caps mine. *A–B*, Line of section, Figure 10.

ing to Kirchen[17] many tests show that the gold content of the stibnite ranges from a trace to $2 a ton. It is not known whether the cinnabar is auriferous.

The earliest of the minerals associated with the ore is white calcite. Huge rhombs are often observed in large irregular cavities. The mineral is coarsely crystalline, and cleavage faces 8 inches across are sometimes seen. The alteration of limestone to coarse calcite commonly follows the bedding and joint planes of the limestone. (See fig. 11 and Pl. XI, *A*.) These replacement bodies range in size from small lenses an inch or two wide to large masses extending nearly across the limestone bed. The calcite is usually glaring white in color, except where the presence of finely divided

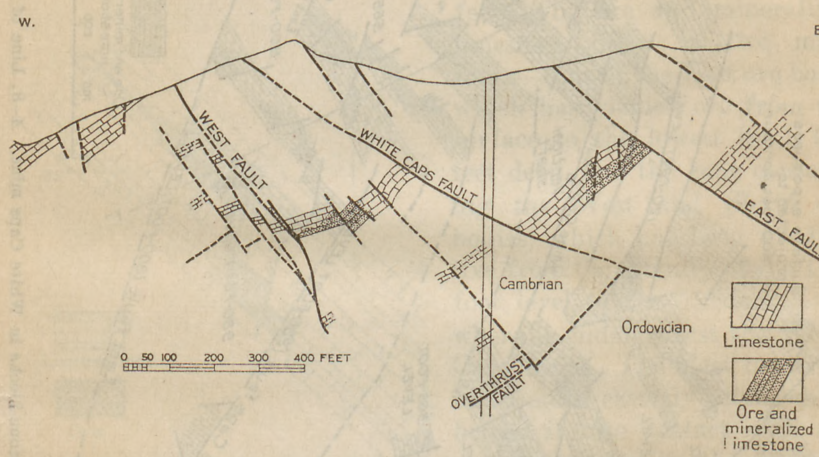
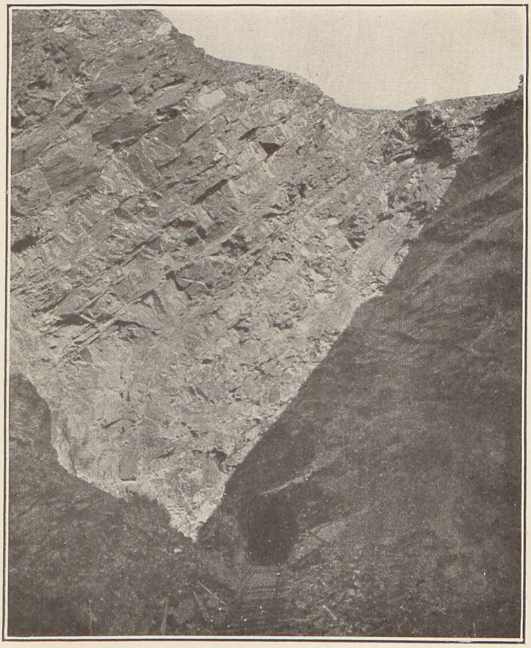


FIGURE 9.—Section through White Caps shaft, looking north.

realgar imparts a pinkish tinge. In a few places, however, small pieces have been obtained approximating Iceland spar in clearness and transparency. So far as known, the calcite itself is everywhere barren and is most plentiful near the outer edges of the ore bodies. In parts of the mine the change from the finely crystalline blue limestone to coarse white calcite has taken place without the introduction of ore. Similar coarse calcite is found here and there in the other limestone beds and even in the dark Zanzibar limestone.

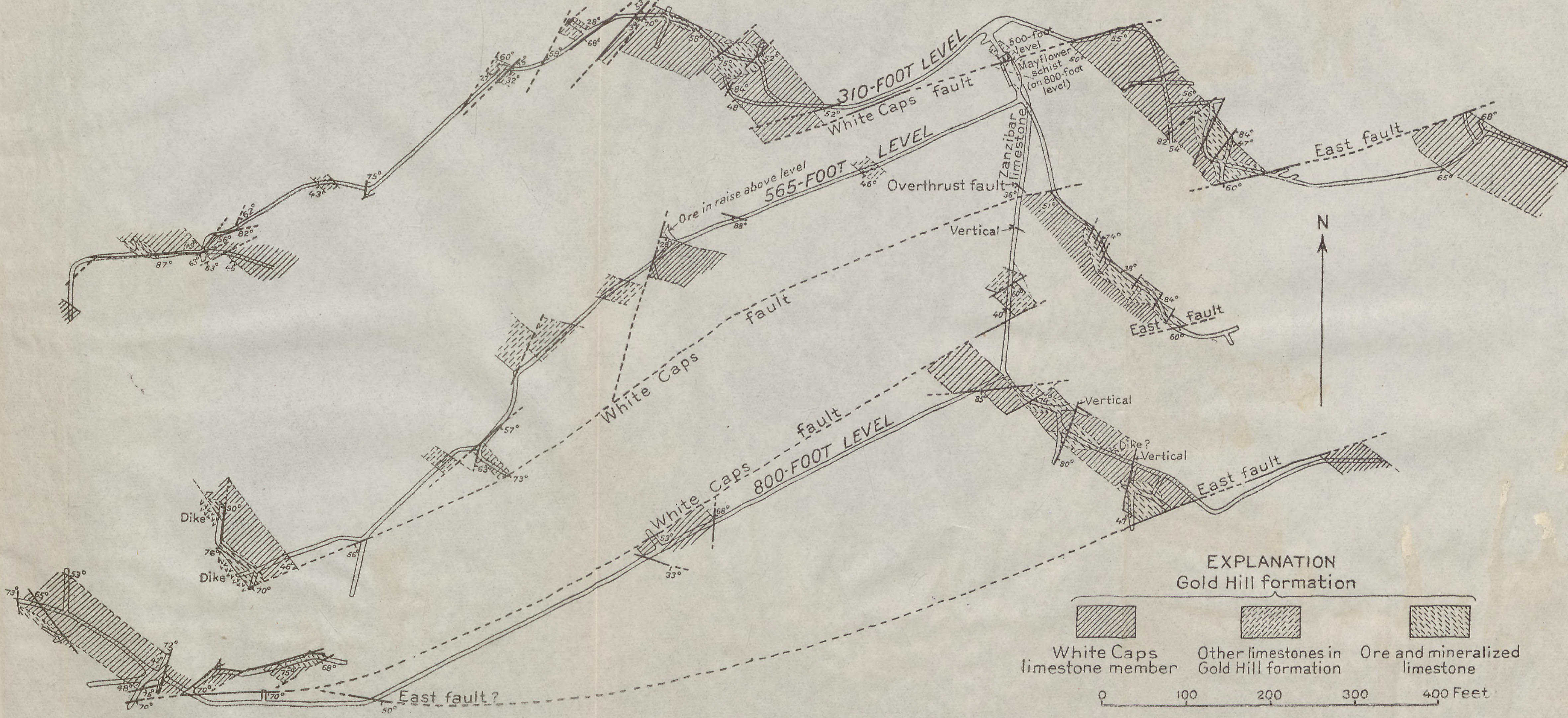
The best ore of the mine consists of a dark fine-grained quartz, in places so dense as to have the appearance of black jasper. The hand lens discloses minute specks of pyrite in the quartz. Under the highest magnification of the microscope, however, the dark color is seen to be due to dustlike specks of carbonaceous matter, distributed irregularly through the slide, and to minute crystals of a metal-

[17] Kirchen, J. G., Eng. and Min. Jour., vol. 104, p. 906, 1917.



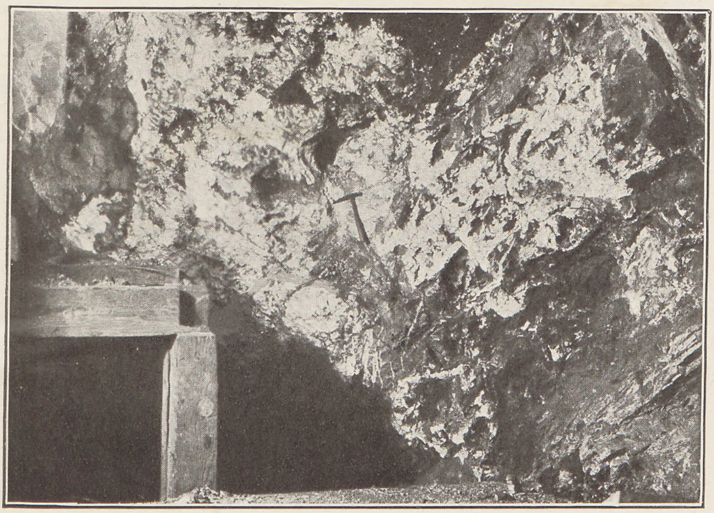
A. BIG PINE GLORY HOLE.

B. TYPICAL ORE OF THE SCHIST MINES.

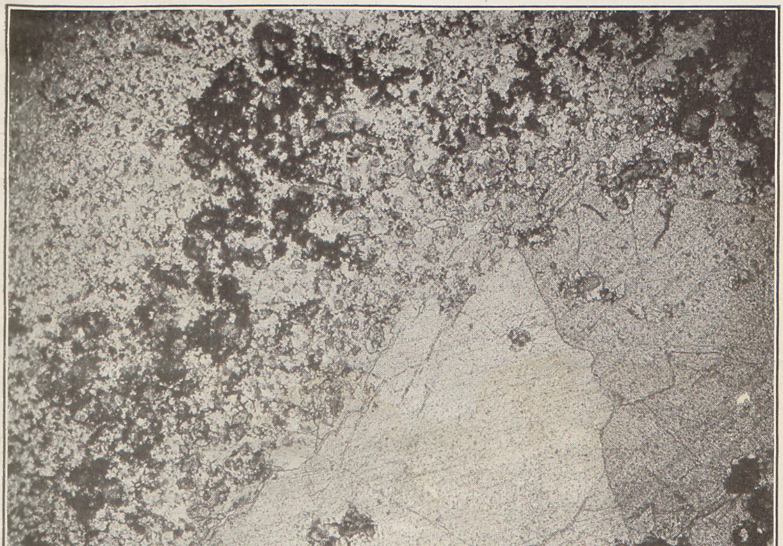


GEOLOGIC MAP OF THE 310, 565, AND 800 FOOT LEVELS, WHITE CAPS MINE.

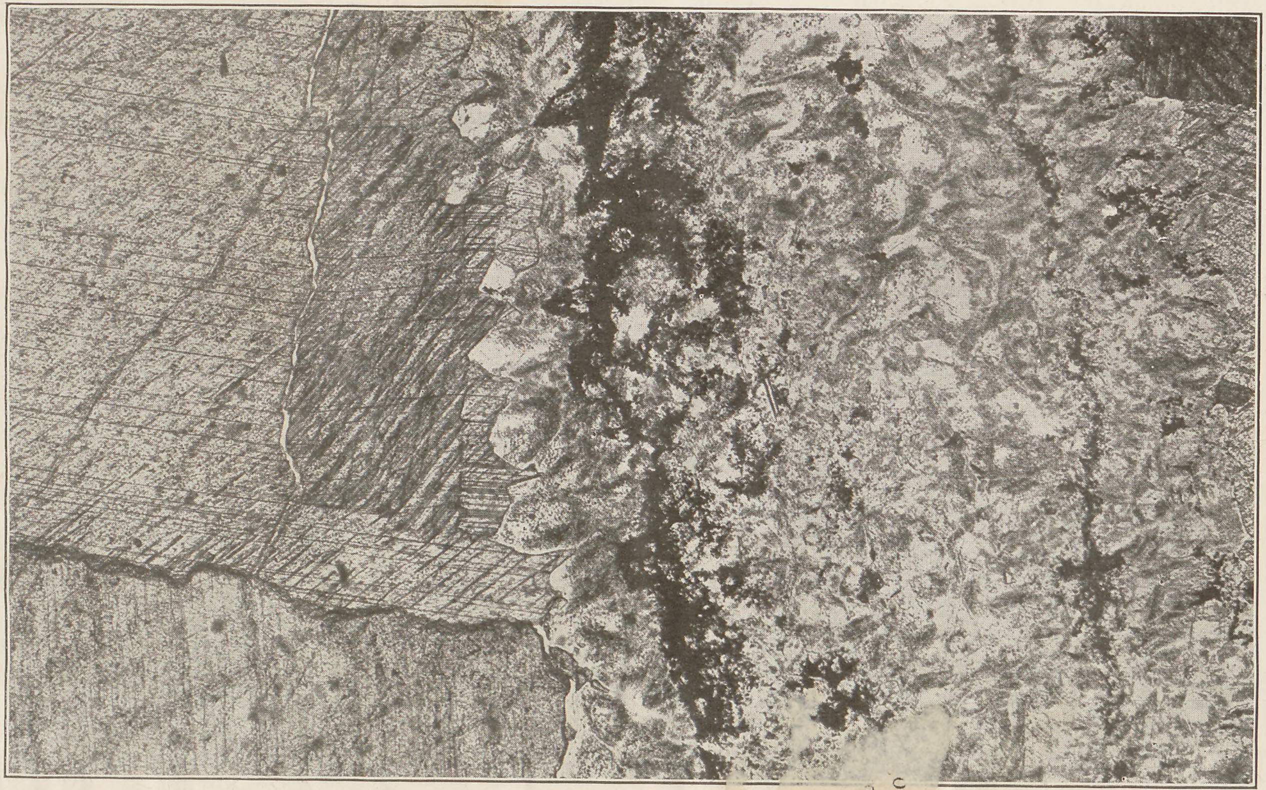
Derived in part from maps by J. L. Dynan, O. McCraney, and R. L. Taylor.



A. LIMESTONE PARTLY REPLACED BY COARSELY CRYSTALLINE WHITE CALCITE, 310-FOOT LEVEL, WHITE CAPS MINE.



B. COARSE CALCITE PARTLY REPLACED BY QUARTZ WITH DISSEMINATED PYRITE AND ARSENOPYRITE AND A LITTLE CARBONACEOUS MATTER.



ORE FROM DUMP OF MANHATTAN CO[illegible]

From 300-foot level, East ore body. Fine-grained quartz with disseminated [illegible] ...cite. Enlarged 50 diameters.

lic mineral which may be in part arsenopyrite. Qualitative tests of this material, however, indicate that antimony is present in much greater amount than arsenic; hence it is probable that most of the minute metallic crystals are stibnite rather than arsenopyrite, as was at first supposed. The quartz has replaced the limestone and, to a less extent, the coarse calcite (Pl. XI, *B*). It is closely confined to the ore bodies and does not show the wide distribution characteristic of the barren calcite. The replacement of limestone by

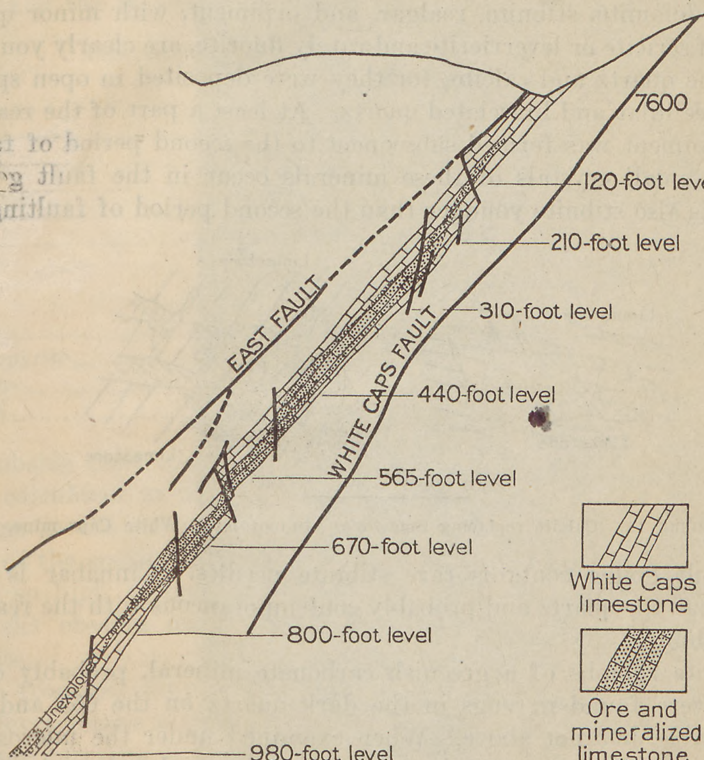


FIGURE 10.—Section in White Caps mine along line *A–B*, Figure 8.

quartz has involved a considerable loss of volume, indicated by numerous drusy cavities, usually elongate with the bedding of the limestone. In these cavities minerals of later age—dolomite, stibnite, realgar, and orpiment—have been deposited. In places this reduction of volume, possibly assisted by the abstraction of sulphides by later solutions, has been sufficient to permit collapse and local brecciation of the quartz, following later movement along the major faults.

A little muscovite was observed in some of the thin sections of the dark quartz. It is apparently contemporaneous with the inclosing

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quartz, although rare muscovite was found in thin sections of the limestone from specimens taken close to the walls.

The calcite and dark quartz are younger than the first period of faulting, as both quartz and calcite, but especially the quartz, recement the shattered zones where the minor faults enter the limestone. On the other hand, they are clearly older than the last movement on the larger faults, for along these faults are rounded fragments of the quartz.

The dolomite, stibnite, realgar, and orpiment, with minor quantities of sericite or leverrierite and rarely fluorite, are clearly younger than the quartz and calcite, for they were deposited in open spaces of the cellular and brecciated quartz. At least a part of the realgar and orpiment was formed subsequent to the second period of faulting, as small crystals of these minerals occur in the fault gouge. There is also stibnite younger than the second period of faulting, as

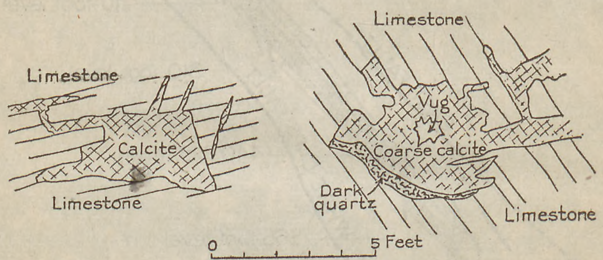

FIGURE 11.—Calcite replacing limestone, 440-foot level, White Caps mine.

the fault gouge contains rare stibnite needles. Cinnabar is also later than the quartz and probably contemporaneous with the realgar and stibnite.

Minute rhombs of a greenish carbonate mineral, probably dolomite, were found in vugs in the dark quartz on the 665 and 800 foot levels, but not above. When examined under the microscope these were found to contain very minute crystals of an isotropic mineral of high refractive index, but it was not possible to make a definite determination.

Later pyrite is found, particularly in the upper levels. Like the stibnite and realgar, it occurs in drusy open spaces in the dark quartz or more rarely in flat rosettes along the cleavage faces of the white calcite. It is small in amount compared to the stibnite and realgar. Marcasite is probably also present, but its existence could not be definitely proved.

Among the later minerals of the deposits are minor amounts of quartz and calcite of a second generation and rarely sericite or leverrierite. Small crystals of fluorite on projecting quartz crystals of one of the druses in the fine-grained quartz were observed on the 200-foot level east of the shaft.

No free gold has been found in the White Caps mine. The bullion obtained by the cyanide process contains almost no silver, having a value of about $20 an ounce. The ratio of gold to silver is said to be about 17 to 1.

Dynan[18] gives the following analysis of ore from the 310-foot level and the mineral composition as calculated from the analysis:

Analysis of ore from 310-foot level, White Caps mine.

SiO_2	55.8	As	1.5
Al_2O_3	1.8	MgO	3.2
CaO	7.2	H_2O	8.0
Fe	8.9	CO_2	9.2
S	8.2		
Sb	.7		97.3

Mineral composition.

Pyrite	13.8	Quartz	7.4
Arsenopyrite	3.3		
Stibnite	1.0		97.1
Calcite	19.6		

Probably most of the arsenic shown in the analysis should have been calculated as realgar, for that mineral is nearly everywhere present in the arsenical ores, especially in the upper levels, and none of the specimens examined microscopically by the writer indicated so high a content of arsenopyrite, even on the assumption that the obscure metallic particles are arsenopyrite rather than stibnite.

Ore from the lower levels of the East ore body, except the 800-foot level, shows a much higher percentage of arsenic, and at one time ore carrying 30 per cent of arsenic was shipped to the smelter. Other analyses of ore from the upper levels are given in the description of the White Caps mine on page 150.

The Manhattan Consolidated has been developed by five levels to a depth of 500 feet. The 100-foot and 500-foot levels were not accessible at the time of the writer's visit. The shaft cuts the overthrust fault below the 400-foot level. A normal fault of large throw, known as the Mud fault, from its wide zone of gouge, cuts the mineralized limestone. It has a northeasterly strike and dips to the southeast.

The limestone bed is repeated on the 300-foot level, apparently by a fault nearly parallel to the bed in dip and strike. Small faults of nearly northerly strike and small displacement are numerous.

[18] Dynan, J. L., op. cit., p. 884.

These are older than the faults of the northeast series, such as the Mud fault. Movement parallel to the bedding is shown in gouge streaks along the top of the limestone. As no underground maps were available at the time of visit, the geology could not be accurately mapped, but the accompanying sketch map (fig. 12), based on a hasty compass and pacing survey, is believed to represent the general relations of the limestone blocks as developed in the mine.

The ore east of the fault is similar to that in the western part of the White Caps mine. The ore body is formed by the replacement of limestone on both sides of a small northerly fault. Coarse white calcite is prominent, particularly near the edges of the mineralized area. The best ore is a dark quartz much like that of the White Caps, containing perhaps a little microscopic arsenopyrite and much pyrite. (See Pl. XII.) Stibnite is present in small amount in drusy cavities in the dark quartz and in the limestone and calcite. Realgar is only occasionally found. Small realgar crystals occur in the gouge along the Mud fault, particularly near the surface.

The ore also differs from that of the White Caps mine in that a considerable proportion of silver is associated with the gold. Bullion from the East ore body is said to have a fineness of about 0.620.

The ore west of the Mud fault differs markedly from that of the East ore body. Instead of being a large replacement body, the ore occurs in small fault fissures forming the so-called vein deposits. Four of these "veins" have been exploited: two follow northeasterly faults of small throw; another, which is less well defined, follows a fault nearly parallel to the strike of the limestone; and the fourth follows a rather irregular zone of mineralization along the top of the limestone. The alteration of the limestone does not extend for more than a few feet from the controlling fissures, and the ore shoots are small and irregular. Both coarse calcite and fine-grained quartz are present. These occur as replacement deposits along the bedding of the limestone, thinning out away from the fissure. The quartz resembles that of the White Caps mine in texture but is lighter in color, being bluish gray rather than black.

Irregular solution channels, in places following the dip of the limestone for 300 feet or more, are common in the limestone near the fissures. These do not carry water but contain deposits of muddy material, apparently chiefly limonite and manganese oxide, in which wire gold occurs.

Fluorite in colorless, amber, and green crystals is plentiful in the ore west of the fault in the larger cavities in the fine-grained quartz, but nowhere is it associated with the coarse calcite. Stibnite is rare, and realgar is absent in the western part of the mine.

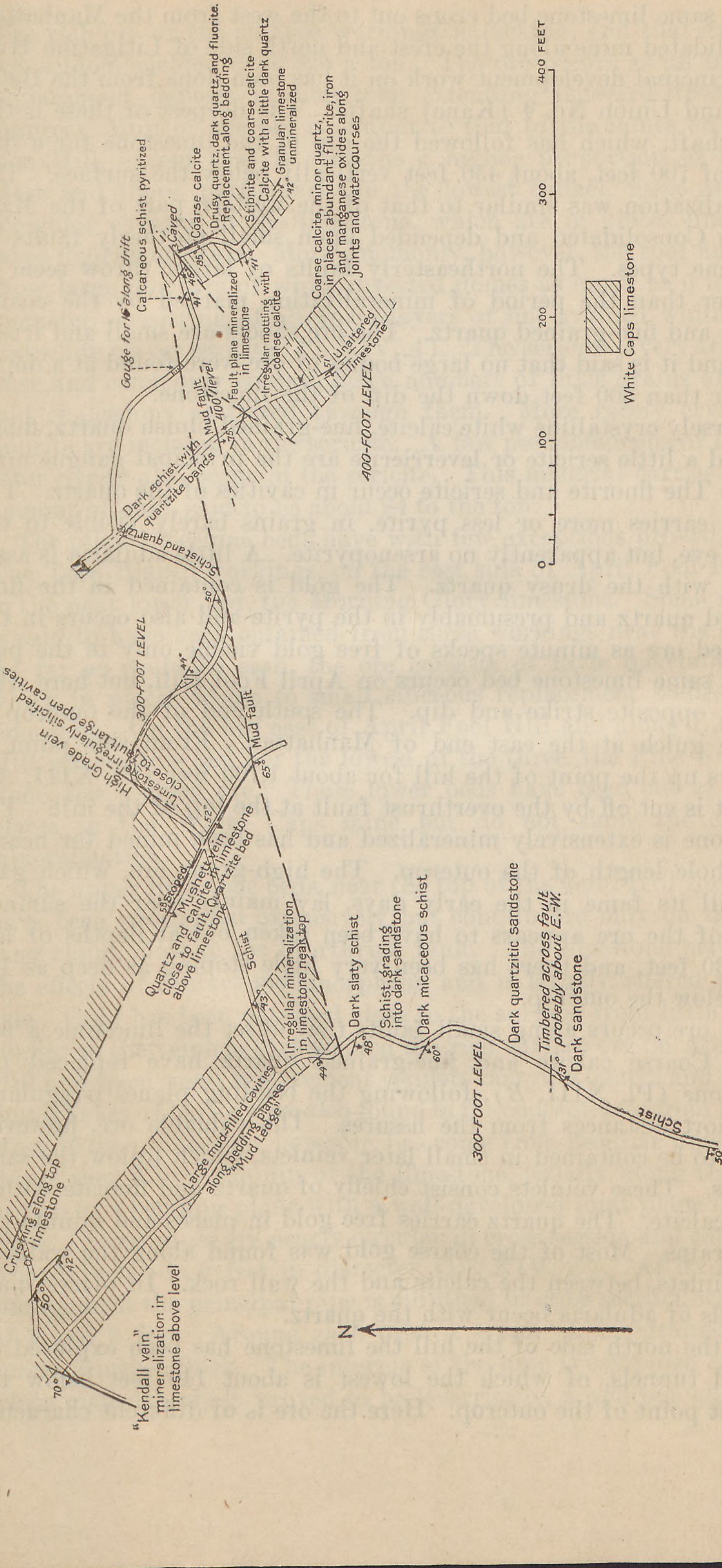

FIGURE 12.—Sketch map of the 300-foot and 400-foot levels, Manhattan Consolidated mine.

The same limestone bed crops out to the west from the Manhattan Consolidated mine along the crest and north side of Litigation Hill. The principal development work on it has been done from the Bath, Earl, and Union No. 4 (Kane) shafts. The deepest of these is the Earl shaft, which has followed the dip of the limestone for a distance of 700 feet, about 450 feet vertically below the surface. The mineralization was similar to that of the western part of the Manhattan Consolidated and depended upon small northerly faults of the same types. The northeasterly faults of larger throw seem to be later than the period of mineralization marked by the coarse calcite and fine-grained quartz. The ore shoots are small and irregular, and it is said that no large bodies of ore were found at a depth greater than 300 feet down the dip of the limestone.

Coarsely crystalline white calcite, fine-grained bluish quartz, fluorite, and a little sericite or leverrierite are the principal gangue minerals. The fluorite and sericite occur in cavities of the quartz. The quartz carries more or less pyrite, in grains barely visible to the naked eye, but apparently no arsenopyrite. A little adularia is associated with the drusy quartz. The gold is contained in the fine-grained quartz and presumably in the pyrite and also occurs in the oxidized ore as minute specks of free gold visible only in the pan.

The same limestone bed occurs on April Fool Hill, but here with nearly opposite strike and dip. The south end of the outcrop is in the gulch at the east end of Manhattan. From this point it follows up the point of the hill for about 1,700 feet (Pl. XIII, *A*), until it is cut off by the overthrust fault at the top of the hill. The limestone is extensively mineralized and has been mined for nearly the whole length of the outcrop. The high-grade ore, which gave the hill its fame in the early days, lay mainly near the surface. Most of the ore appears to have been taken out at depths of less than 30 feet, and there has been very little stoping as deep as 100 feet below the outcrop.

The ore occurs along small faults that offset the limestone a few feet. Coarse calcite and fine-grained quartz have replaced the limestone (Pl. XIII, *B*), following the bedding planes irregularly for short distances from the fissures. The valuable ore, however, seems to be contained in small later veinlets, which follow the same fissures. These veinlets consist chiefly of quartz and fluorite with a little calcite. The quartz carries free gold in places and minute pyrite grains. Most of the coarse gold was found along the walls of the veinlets, between the calcite and the wall rock. In places small crystals of adularia occur with the quartz.

On the north side of the hill the limestone has been explored by several tunnels, of which the lowest is about 140 feet below the highest point of the outcrop. Here the ore is of different character.

The rich ore of the surface workings is lacking, and that extracted has seldom yielded over $20 a ton. The ore occurs as an irregular replacement deposit in limestone extending outward from small fissures. Most of the ore is similar to that of the mines on Litigation Hill, except that it contains a higher proportion of fluorite. Here and there, particularly in the lowest tunnel, there are large irregular caverns in the limestone, which are in places lined with large fluorite crystals. More commonly, however, the roof and walls show large numbers of white inverted domes as much as 6 inches in diameter, consisting of alternate layers of fine-grained white quartz and white clayey sericite (Pl. XIV, *A*). The sericite layers are rarely pure and commonly contain large numbers of little grains of quartz and chalcedony scattered through them. More rarely crystals of fluorite are inclosed in the sericite. A few pseudomorphs of limonite after pyrite also occur in the sericite. This material carries a small amount of gold, said to be about $4 to the ton.

The other limestone beds have with few exceptions proved barren. The Toro Blanco workings, on the east side of April Fool Hill, are in the next lower bed, the Morning Glory limestone. Some rich ore is said to have been obtained from these workings near the surface. As far as could be seen, the ore consists of little quartz veinlets, which in places widen to small siliceous replacement bodies in the limestone. On the hill east of April Fool Hill and along Litigation Hill neither this bed nor the lowest of the three, the Pine Nut limestone, has yielded ore. These lower beds have been cut at several places in the White Caps mine but do not show the slightest mineralization.

The upper limestone beds, near the top of the Gold Hill formation, have been prospected extensively but contain ore only on the Mustang claim, close to the overthrust fault. The limestone here shows the effects of contact metamorphism and is largely altered to diopside. Gold has been obtained close to the surface from little fissures similar to the veinlets that yielded the rich surface ore on April Fool Hill and from small replacement veinlets carrying quartz and fluorite. Small flakes of barite were also found in the concentrates from this ore. Most of the production, however, has come from peculiar pipelike ore shoots that follow the dip of the limestone, usually along the intersection of a bedding plane with a well-developed joint plane or small fault. These pipes are nearly circular in cross section and commonly from 8 inches to 2 feet in diameter (Pl. XIV, *B*). At its greatest enlargement the principal pipe is elliptical in cross section, with axes of 5 and 2 feet. Around each pipe is a rim of fine-grained white quartz 2 inches thick. The interior of the pipe is composed of a soft white material which proved to be leverrierite, a hydrous aluminum silicate, with the formula $Al_2O_3.2SiO_2.2\frac{1}{2}H_2O$.[19] Specks of limonite scattered irregularly through the pipe represent original pyrite. Free gold occurs throughout the leverrierite, in sufficient amount to have yielded over $40,000 in a distance of about 100 feet along the pipe. The gold is mostly very fine, but a little of it occurs as round pellets that look like small shot. So far as could be determined from microscopic examination, the gold is everywhere surrounded by the leverrierite and has apparently no close association either with the oxidized pyrite or with disseminated quartz.

The principal pipe has been followed down the dip of the limestone for about 100 feet. Several smaller pipes branching upward from the main pipe were encountered but not developed. The richest spots were said to have been found at the intersections of the main pipe with its branches. The lower workings were not accessible at the time of the writer's visit, but it is said that with increasing depth the pipes became less well defined and were difficult to follow.

The Sunset prospect is on what is probably the same limestone bed, about 3,000 feet southwest of the White Caps mine. No workable ore has been encountered here, but the limestone has been irregularly replaced by barite, which contains clusters of large stibnite needles, partly oxidized to valentinite (Pl. XVI, *B*). These are nearly barren of gold.

The dark Ordovician limestones have not proved productive. In places, as at the Black Mammoth and Oso prospects, there is some coarse white calcite, similar to that of the mines in the Gold Hill formation but without the accompanying dark quartz. Here and there coarse feathery gold has been found, either in small cracks in the limestone and quartzite or along the walls of small calcite stringers, in a few places penetrating along the cleavage planes of the calcite.

PHOSPHATE MINERALIZATION.

The Train prospect, just north of Black Mammoth Hill, contains minerals that are not known elsewhere in the district and though probably of no economic importance merits brief description. Percy Train in 1910 discovered small veinlets of a peculiar glassy green mineral delicately laminated with white bands, occurring with variscite in small veins that traversed irregularly the slates of the Toquima formation, a short distance south of the contact with the Tertiary lavas. According to Mr. Train, the mineral occurred in a small pocket surrounded by variscite, and small stringers of dull brown and brownish-green variscite cut the slates in the vicinity. A small amount was sold as a semiprecious gem stone under the

[19] Larsen, E. S., and Wherry, E. T., Leverrierite from Colorado: Washington Acad. Sci. Jour., vol. 7, pp. 208–217, 1917.

name "trainite," but though it was of pleasing appearance its softness and brittleness rendered it unsuitable for gems. A sample sent to the United States National Museum was identified by E. T. Wherry [20] as vashegyite. Wherry gives the following description:

The material presents the form of a "sulphate" green, glassy mass, traversed by numerous subparallel wavy white lamellae, varying from 1 millimeter down to 0.05 millimeter in thickness, but at the latter size becoming too translucent to be distinguished, so that the variation may well continue to still thinner dimensions. Both minerals are practically amorphous, showing between crossed nicols only traces of weakly doubly refracting material.

A small sample of the purest green material which could be separated by hand picking was submitted to J. E. Whitfield for analysis; it was free from visible lamellae, although it may have contained indistinguishable ones. Its composition proved to be: CaO 6.30, CuO 1.25, MgO 0.80, Al_2O_3 25.90, Fe_2O_3 2.14, P_2O_5 24.76, SiO_2 7.32, H_2O below 100° 21.90, above 100° 9.20, sum 99.57. These figures lead to no simple formula, but as it seemed probable that the silica might be due to lamellae which are present but unrecognizable because of their thinness, an attempt was made to determine the composition of the white lamellar mineral. It proved impracticable to separate the lamellae from the green groundmass with any degree of completeness, but a very small sample, containing perhaps one-third of the latter, was analyzed by the writer with the following results: CaO+CuO 9.0, MgO 0.5, Al_2O_3+Fe_2O_3 23.3, P_2O_5 12.1, SiO_2 30.0, H_2O below 100° 10.4, above 100° 14.8, sum 100.1.

The following properties of the green mineral were determined by Wherry: Color, pale green; luster, vitreous; hardness, 3.5; specific gravity, 1.98; structure, amorphous, glasslike; index of refraction, 1.48 to 1.50; double refraction, absent; ratio, Al_2O_3: P_2O_5: H_2O, about 3:2:18; impurities, considerable, including copper oxide, which gives the green color. These properties agree very closely with those of the hydrous aluminum phosphate described by Zimányi [21] as vashegyite.

The nature of the white lamellar mineral can not be definitely made out from the data at hand. Of the constituents found in the second analysis, all of the P_2O_5 and part of the Al_2O_3 and H_2O are undoubtedly due to the admixed green material; if this amounted to one-third of the whole, then the approximate composition of the white mineral would be CaO 17, Al_2O_3 17, SiO_2 47, and H_2O 19, corresponding roughly to the ratios of these four constituents, respectively, 2:1:5:7. No amorphous mineral of this composition appears to be on record, although the crystalline zeolite laubanite differs only in having slightly less water. However, the mean index of laubanite as determined by Dr. Larsen [22] is 1.475, while that of the present mineral is higher, varying from 1.53 to 1.54; so the two must be entirely distinct. It may be noted that the mineral fuses with intumescence before the blowpipe, so that it evidently belongs to the zeolite group, but under the circumstances it would be unsafe to assign a name to it.

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[20] Wherry, E. T., A peculiar intergrowth of phosphate and silicate minerals: Washington Acad. Sci. Jour., vol. 6, pp. 105–108, 1916.

[21] Math. term. Ertesitö, vol. 27, p. 64, 1909; Zeitschr. Kryst. Min., vol. 47, p. 53, 1909.

[22] Private communication.

Although in many aluminum phosphates siliceous inpurities have been found to be present, no definite intergrowth relations have heretofore been reported to exist between the two. The structure here shown is not difficult to explain, however, when the colloidal character of the materials is considered. The lamellae have the aspect of forms produced by rhythmic precipitation in gels, such as obtained in many of the experiments described by Liesegang [23] and others. In this case if, while the phosphate gel was still soft, a solution containing calcium and silica flowed over it, reaction might readily have occurred, with removal of part of the phosphoric acid and formation of a calcium-aluminum silicate with the liberated alumina.

The material studied is regarded, then, as a colloidal vashegyite traversed by rhythmically precipitated laminae of a calcium-aluminum silicate of probably zeolitic nature.

At the time of visit a small cut in the hillside with a maximum depth of about 10 feet showed dark crumpled slate cut by irregular veinlets of variscite. The interbanded vashegyite and zeolitic mineral were not seen in place by the writer and, according to Mr. Train, were encountered only close to the surface. Recently the rare phosphate mineral barrandite $(Fe,Al)_2O_3.P_2O_5.4H_2O$ has been identified in specimens from the Manhattan district.[23a]

Although the deposit is within the older rocks, the type of mineralization and the proximity to the lavas suggest that it is probably of Tertiary age. No similar minerals were found elsewhere in the district, however.

MINERALOGY.

DEPOSITS OF DEEP-SEATED ORIGIN.

The mineralogy of the different types of deep-seated deposits present in the Manhattan district implies deposition under changing conditions of temperature and pressure. Huebnerite occurs only in veins in the granite. Molybdenite was found at one place, sparingly developed in the silicated limestone. The vanadium minerals are also confined to the area of rather intense metamorphism surrounding the granite. Pyrite occurs both as an apparently primary mineral in the siliceous aplite dikes and in the quartz veins with other sulphides. Tetrahedrite, chalcopyrite, galena, and sphalerite were found only in the veins in the sediments at some distance from the granite.

Coarsely crystalline quartz is the predominant gangue mineral. In a few veins small crystals of tourmaline are intergrown with the quartz. Other gangue minerals observed are muscovite, chlorite, orthoclase, and calcite.

Various oxidation products of the sulphides are present in small amount.

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[23] Geologische Diffusionen, Dresden and Leipzig, 1913.

[23a] Shannon, E. V., Barrandite from Manhattan, Nev.: Am. Mineralogist, vol. 8, pp. 182–184, 1923.

SHALLOW VEIN DEPOSITS.

The shallow vein deposits, both in the Tertiary rocks and in the Gold Hill schists, present the usual characteristics of deposits of this type. The principal gangue minerals are quartz, adularia, and tabular calcite, but most of the original calcite has been replaced by quartz and adularia. Fluorite appears to be absent from the Gold Hill schist ore but is present in the prospects on Bald Mountain and in the Wall prospect, in the southern part of the district. Apparently the only sulphide mineral is pyrite, for the most part oxidized to limonite. Manganese oxide is present in considerable amount in a few of the Gold Hill deposits. Free gold occurs in all deposits of this type—in some as a primary mineral, in others as a secondary mineral derived from the auriferous pyrite. No silver-bearing minerals were observed except in the Wall prospect, where cerargyrite occurs in the surface ores.

DEPOSITS IN LIMESTONE.

The mineralogy of the limestone ores is extremely complex and presents several problems of sufficient interest to justify a somewhat lengthy discussion.

DISTRIBUTION.

As set forth in the preceding description of the limestone deposits, although the productive zone is less than 2 miles in length, the individual deposits show a wide variation in the mineralogic character of their ores. The following table illustrates the principal variations encountered in crossing the district from east to west. For comparison, the ores of the Gold Hill schists and of the Tertiary rocks have been included.

Principal minerals present in the limestone ores of the Manhattan district.

[+ and parentheses indicate relative abundance or scarcity, respectively.]

	Native gold.	Arsenopyrite.	Pyrite.	Stibnite.	Realgar and orpiment.	Fluorite.	Quartz.	Quartz after tabular calcite.	Chalcedony.	Calcite.	Sericite or leverrierite.	Adularia.	Barite.
White Caps:													
Eastern part	......	(×)	(×)	(×)	+	......	+	......	......	+	......	......	......
Western part	......	(×)	(×)	+	(×)	(×)	+	......	......	+	(×)	......	......
Manhattan Consolidated:													
Eastern part	......	(×?)	×	×	(×)	×	+	......	......	×	(×)	......	......
Western part	×	......	×	(×)	......	+	+	......	......	×	×	......	......
Litigation Hill	×	......	×	......	......	+	×	......	......	×	×	(×)	......
April Fool Hill	×	......	×	......	......	+	×	(×)	(×)	×	+	(×)	......
Mustang	×	......	(×)	......	......	×	×	......	......	(×)	+	(×)	(×)
Sunset prospect	......	......	×	+	......	......	×	......	......	(×)	......	......	×
Schist ores	×	......	×	......	......	......	+	+	......	(×)	......	+	......
Ores of Tertiary rocks	(×)	......	×	......	......	×	+	×	......	(×)	......	×	......

The ores show great variations in character along the same bed of limestone. Sericite is abundant on April Fool Hill and leverrierite in the higher limestone on Mustang Hill, and neither is abundant at the east end of Litigation Hill; fluorite also decreases toward the east, though it is found in the Manhattan Consolidated and very sparsely in the White Caps. The fine-grained quartz, on the other hand, is more abundant in the eastern mines. Arsenopyrite is largely confined to the White Caps, though it may be present in small amount in the dark quartz of the Manhattan Consolidated. Pyrite is persistent throughout but is far less noticeable in the White Caps than in the other mines. The coarse calcite occurs throughout and indeed is not confined to the vicinity of the ores but seems to occur sporadically in all the limestones, particularly where they are fissured.

The difference in the ores within so short a distance may be due in large measure to changing character of the solutions along the strike. It may also be due in part to differences in original vertical position, at least with respect to the principal mineralization prior to the most recent faulting. The larger faults have their downthrow sides on the east; hence at the time of the deposition of the first series of minerals the White Caps stood highest, followed by the eastern part of the Manhattan Consolidated and Litigation Hill mines, and lastly April Fool Hill, which was much lower than the White Caps at the time of the ore deposition, though there is no way of determining how much of the displacement is due to postmineral faulting.

PARAGENESIS.

The paragenesis of the principal minerals of the limestone mines appears to be as follows: (1) Coarsely crystalline white calcite. (2) Fine-grained quartz containing arsenopyrite and perhaps stibnite in the White Caps mine and pyrite elsewhere. In some deposits a little adularia appears to have crystallized contemporaneously with the quartz. Nearly contemporaneous, though on the whole a little younger, are fluorite, sericite, leverrierite, and rare adularia, found chiefly in the eastern deposits. In places quartz is closely intergrown with one or another of the micaceous minerals. (3) Stibnite of distinctly later date, together with later pyrite, quartz, and calcite. Realgar and cinnabar also belong to this group, though realgar appears to be slightly later than the stibnite. All the minerals of the second group, though younger than the first period of faulting, are older than the most recent movement along the major faults. The realgar and possibly the stibnite were introduced subsequently to the second period of faulting. It appears, therefore, that in the White Caps mine and the eastern part of the Manhattan Consolidated mine, at least, the ores were formed during two or more periods of mineralization, succeeding faulting of different ages.

ARSENICAL MINERALS.

Arsenical minerals (arsenopyrite, realgar, and orpiment) are confined to the White Caps and the East ore body of the Manhattan Consolidated and occur in quantity only in the eastern part of the White Caps mine. Recent mineralogical work by W. T. Schaller, however, shows minute amounts of iron and arsenic, probably in the form of scorodite, present in ore from April Fool Hill, so it is possible that small amounts of arsenical minerals may be more widespread than has been supposed. The dark jasper-like quartz that forms the best ore of the White Caps contains besides the disseminated carbonaceous matter minute crystals of a metallic mineral. These range from the lower limit of visibility to a maximum of 0.05 millimeter, but most of them are less than 0.02 millimeter in diameter. Many of these little crystals are so twinned as to resemble minute jackstones. The shape of the particles and the fact that qualitative tests show the presence of arsenic in ore of this type indicate that at least a portion of this disseminated metallic mineral may be arsenopyrite. On the other hand, examination of polished sections under the highest magnification failed to distinguish clearly the presence of arsenopyrite, although disseminated pyrite is abundant. It seems likely that a little finely divided arsenopyrite is present but that it is a comparatively rare mineral.

Assays exceeding $200 to the ton have been obtained from ore of this type, but no gold can be seen in it under the microscope, and none is obtainable from it by amalgamation. Palmer,[24] however, found that this dark ore, concentrated by panning and treated with nitric acid, yielded minute specks of free gold. Palmer suggests that this gold is in close association with antimony sulphide, but it is also possible that the gold may be present in the disseminated pyrite and arsenopyrite or perhaps closely associated with the diffused carbonaceous matter.

Realgar occurs in large amounts in the East ore body but only sparingly in the western part of the mine. It was present in the East ore body between the 665 and 400 foot levels in amounts so large that it was shipped to the smelter as an ore of arsenic. Its mode of occurrence is very similar to that of the stibnite. It replaces the coarse calcite, in crystalline masses whose boundaries follow the cleavage planes of the calcite (Pl. XV, *A*) in narrow streaks fol-

[24] Palmer, W. S., Occurrence of gold in sulphide ore: Eng. and Min. Jour., vol. 107, pp. 923–924, May 24, 1919.

lowing the cleavage; it is also common as a filling of the numerous cavities in the dark quartz. A stope above the 665-foot level shows realgar and dark quartz in irregular bands as much as several inches across. In places blocks of practically pure realgar 2 feet in diameter have been obtained. The realgar is gold bearing, though so far as the writer is aware it does not yield as high assays as are sometimes obtained from the dark quartz. Smelter shipments of 30 per cent arsenic carried $20 to the ton in gold.

In the vicinity of the ore, but outside the ore bodies, realgar is more widely distributed than the other minerals. It is the only ore mineral found outside the limestone and occurs in the footwall and hanging-wall slate in small veinlets and impregnates the slate for distances of a few feet from the limestone. Realgar, in small scattered crystals and replacing the gouge itself, is found in places in the gouge of the faults of the most recent series, particularly the White Caps fault (Pl. XV, *B*). In general the realgar shows the same associations and mode of occurrence as the stibnite, and the two minerals are often found closely intergrown. In a few specimens realgar was found in clusters of little radiating rods, replacing stibnite.

Realgar occurs in greatest quantity throughout the East ore body from the 300-foot level to the 665-foot level. Below the 665-foot level the ore consists of very cavernous dark quartz, brecciated and crumbly in places, with scattered patches and crystals of realgar. Recently (1922), however, development work on the 980-foot level revealed ore rich in realgar.

The origin of the realgar is the most interesting mineralogic problem offered in the study of the ore deposits. It may be, as Dynan [25] has suggested, a secondary mineral derived from arsenopyrite. On the other hand, there seems to be evidence that it was deposited by hypogene solutions, though possibly resulting from the alteration of the disseminated arsenopyrite by such solutions. Normally, under the action of oxidizing waters, scorodite or pharmacosiderite should be the end point of oxidation of arsenopyrite.[26] There appear to be numerous deposits, however, in which realgar is a secondary sulphide,[27] and Lindgren[28] even says:

> Realgar and orpiment are probably always supergene sulphides, but they are not found in the secondary zones of copper deposits. They are rather more characteristic of the oxidized zone and often are derived from arsenopyrite. The chemistry of their deposition is uncertain.

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[25] Dynan, J. L., op. cit., p. 885.

[26] Lindgren, Waldemar, Mineral deposits, p. 898, New York, 1919.

[27] Emmons, W. H., The enrichment of ore deposits: U. S. Geol. Survey Bull. 625, p. 466, 1917.

[28] Op. cit., p. 899.

It is possible that the method of formation of supergene realgar from arsenopyrite is analogous to the formation of sulphur in the first stages of the oxidation of pyrite. Stokes[29] gives the following equation:

$$FeS_2+Fe_2(SO_4)_3=3FeSO_4+2S.$$

The equivalent reaction in the case of arsenopyrite would be

$$FeAsS+Fe_2(SO_4)_3=3FeSO_4+AsS.$$

Stokes, however did not obtain arsenic sulphide when arsenopyrite was treated with ferric solutions.[30]

The formation of sulphur in the manner indicated above is considered by Stokes[31] the first stage in the oxidation of pyrite, for the sulphur thus formed normally reacts with ferric sulphate to give more ferrous sulphate and sulphuric acid.

Native sulphur formed from the alteration of sulphides has been mentioned by numerous observers.[32] The sulphur occurs in the zone of oxidation, commonly associated with other oxide minerals. Presumably the formation of a considerable amount of sulphur implies a deficiency in available oxygen to complete the process as outlined by Stokes.

The realgar at Manhattan occurs to a depth of at least 600 feet below the present water level and is not associated with other oxide minerals, although scorodite may be present at least to depths below the 565-foot level, and iron oxides are now being deposited from the water in the deeper part of the mine. The evidence from the physiographic history of the district and the presence of solution channels in the limestone to as great depths as the 565-foot level of the White Caps and the 400-foot level of the Manhattan Consolidated imply a period of aridity in which the water level may have been depressed below its present position but hardly to the depth required for so large an amount of oxidation.

On the other hand, there is no inherent reason why realgar should not be found as a primary mineral in ore deposits formed at shallow depth. In the microscopic examination of the White Caps ore the writer has not been able to find any evidence of alteration in place of arsenopyrite to realgar. The large amount of realgar found between the 400 and 660 foot levels would require the alteration of an enormous amount of arsenopyrite, but there is no evidence of any marked leaching of the arsenopyrite in the upper levels and it is doubtful whether any considerable amount of arsenopyrite is present in the primary ore. There is a little later pyrite, apparently

[29] Stokes, H. N., On pyrite and marcasite: U. S. Geol. Survey Bull. 186, p. 15, 1901.
[30] Idem, p. 33.
[31] Idem, p. 15.
[32] Emmons, W. H., op. cit., p. 486.

contemporaneous with the realgar and stibnite but not at all comparable in volume to the realgar. It may be, however, that an iron-rich gossan has been eroded.

Realgar has been found in deposits formed from hot springs at the surface, as in the Yellowstone National Park[33] and at Steamboat Springs, Nev.,[34] and it is present as an apparently primary mineral in other deposits.

In the Camp Floyd (Mercur) district, Utah,[35] the ore has replaced cherty limestone and carries silver in the lower part of the series and gold at a stratigraphically higher horizon. Spurr considers that the silver deposits are distinctly older than the gold deposits and that there is no intimate relation between the two. Butler is inclined to consider all the deposits of essentially the same age. The gold deposits are thus described by Butler:[36]

> Many of the limestone beds are silicified to a cherty quartz with small amounts of a mineral resembling sericite. The shaly beds appear to have suffered less alteration, though they have probably gained silica and possibly some potassium, which have formed sericite. The potassium, however, may have been originally present in the shale. Most of the ore contains also considerable barite and secondary calcite. The principal metallic minerals are pyrite, realgar with some orpiment, and cinnabar.

According to Spurr, the realgar is in large part of hypogene origin, but a small amount of supergene realgar is also present. No arsenopyrite is mentioned in any of the descriptions except that of Jackling,[37] who says that the base ores contain "large quantities of base-metal sulphides. Arsenic is the chief of these, occurring as realgar, orpiment, and mispickel [arsenopyrite] in quantities sometimes as high as 50 per cent but averaging not to exceed 2 per cent. Realgar is by far the most plentiful of the arsenic-bearing minerals, fully three-fourths of the arsenic appearing in this way."

Realgar occurs in small amount in the Philipsburg district, Mont.,[38] where it appears to be, at least in part, a primary mineral, for it occurs at depths where enrichment of silver is ineffective.[39]

The ores of the Monte Cristo district, Wash., contain realgar.[40] Spurr considers that this is derived from the arsenopyrite. At one

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[33] Weed, W. H., and Pirsson, L. V., Am. Jour. Sci., 3d ser., vol. 42, p. 401, 1891.

[34] Becker, G. F., U. S. Geol. Survey Mon. 13, p. 344, 1888.

[35] Hills, R. C., Ore deposits of the Camp Floyd mining district, Tooele County, Utah: Colorado Sci. Soc. Proc., Aug. 6, 1894. Jackling, D. C., Director of Mint Rept. for 1899, pp. 181–182, 1900. Spurr, J. E., Economic geology of the Mercur mining district, Utah: U. S. Geol. Survey Sixteenth Ann. Rept., pt. 2, pp. 395–455, 1895. Butler, B. S., Ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, pp. 382–395, 1920.

[36] Op. cit., p. 393.

[37] Op. cit., p. 182.

[38] Emmons, W. H., and Calkins, F. C., Geology and ore deposits of the Philipsburg quadrangle, Mont.: U. S. Geol. Survey Prof. Paper 78, p. 153, 1913.

[39] Emmons, W. H., The enrichment of ore deposits: U. S. Geol. Survey Bull. 625, p. 406, 1917.

[40] Spurr, J. E., The ore deposits of Monte Cristo, Wash.: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 2, pp. 777–865, 1901.

A. SOUTH END OF APRIL FOOL HILL.

Showing workings in the White Caps limestone. The outcrop of the folded limestone is outlined by the position of the shallow shafts.

B. TYPICAL QUARTZOSE ORE WITH SMALL REMNANTS OF UNREPLACED CALCITE FROM UPPER WORKINGS OF APRIL FOOL MINE.

Enlarged 40 diameters.

A. INTERBANDING OF QUARTZ AND CHALCEDONY WITH SERICITE IN LOWER TUNNEL OF APRIL FOOL MINE.

Enlarged 21 diameters.

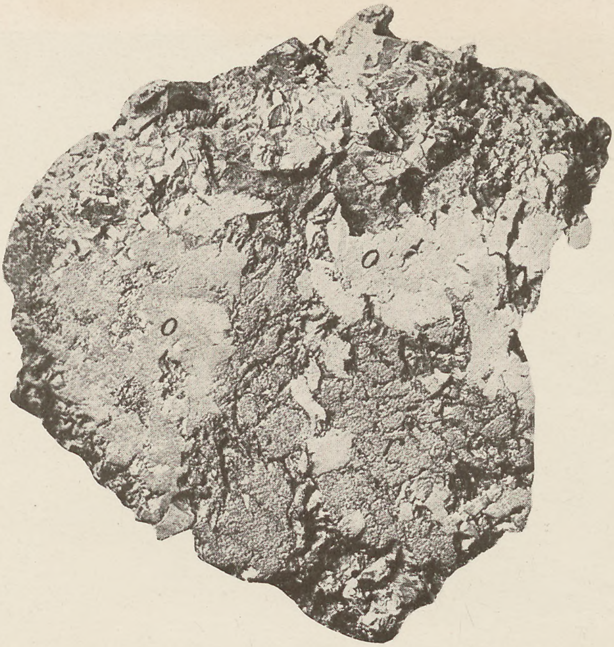
B. "PIPE WORKINGS" ON UPPER PART OF MUSTANG CLAIM (TRAIN & CHASE LEASE).

A. COARSE CALCITE REPLACED BY REALGAR, WHITE CAPS MINE.

Enlarged 21 diameters.

B. FAULT BRECCIA IMPREGNATED BY REALGAR, 665-FOOT LEVEL, WHITE CAPS MINE.

Enlarged 40 diameters.



A. ARSENICAL ORE SHOWING ALTERATION OF REALGAR TO ORPIMENT (*o*), 310-FOOT LEVEL, WHITE CAPS MINE.

Twice natural size.

B. STIBNITE IN GANGUE OF BARITE AND QUARTZ, SUNSET PROSPECT.

Enlarged 21 diameters.

place realgar seems even to have formed since the drifts were opened. It should be noted, however, that in some places in that district realgar is older than chalcopyrite and stibnite.

Deposits of orpiment and realgar of sufficient size to be of commercial importance are rather rare, and few good descriptions are available. Deposits at Luceran and Duranus, in the Maritime Alps, France, have been described by Orcel.[41] In the Luceran deposit orpiment occurs in lamellar masses associated with calcite and lamellar barite in Cretaceous marl. Blocks of pure orpiment weighing as much as 50 kilograms were formerly obtained. Crystals of orpiment occur in veins of barite crossing the marl. In places the orpiment incloses specks of realgar. In the Duranus deposit realgar occurs in veins of "spathic" calcite in marly limestone, commonly in large masses in the limestone, more rarely in long crystals in the calcite veins. No orpiment is present. Orcel offers no hypothesis as to the genesis of these deposits, nor any reason for the preponderance of orpiment in one and of realgar in the other.

In recent work on the ores of the Round Mountain district[42] it was found that small crystals of realgar are present in the auriferous quartz veins, which are of late Tertiary age. As no arsenopyrite occurs in these veins, so far as known, the realgar was presumed to be primary. Its presence as a probable primary mineral in a deposit of similar age in the vicinity of the Manhattan district lends weight to the possibility of its being a primary mineral at Manhattan.

It is evident from the descriptions quoted above that the occurrence of primary realgar is by no means unknown. The direct evidence of its occurrence in the Manhattan district, however, is not perfectly conclusive. Realgar is found only in the White Caps mine, the only mine in which the quartz contains the finely divided metallic mineral that is probably in part arsenopyrite. Moreover, it was one of the last minerals to be formed, as it replaces stibnite and is found in the gouge of the later faults. On the other hand, the process that presumably led to the formation of realgar from arsenopyrite was oxidation and is hardly likely to have taken place at so great a depth below water level, especially as the realgar is not accompanied by other minerals characteristic of oxidation, nor is there any evidence that the water level was ever depressed much below the level to which the orpiment, an undoubted oxidation product of realgar, extends.

The proportion of arsenopyrite present in the unaltered ore is so small that it is difficult to imagine the derivation of the large amount

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[41] Soc. franç. min. Bull., vol. 41, pp. 176–180, 1918.

[42] Ferguson, H. G., The Round Mountain district, Nev.: U. S. Geol. Survey Bull. 725, p. 392, 1921.

of realgar from material of this type, without the formation of an extensive gossan, of which there is now no trace. The close association and same general habit of occurrence of the realgar, stibnite, and cinnabar suggest that the three are essentially contemporaneous. It is, of course, perfectly possible that here, as in the Mercur deposits, both hypogene and supergene realgar occur, but no criteria were discovered that would distinguish between these two types, if they are present. It is possible, for instance, that the small realgar crystals found in the latest fault gouge are of supergene origin, being derived from earlier-formed realgar, but other than their position there is nothing to indicate that they are.

The similar mode of occurrence of the realgar and stibnite suggests another possible explanation. If the stibnite is distinctly later than the quartz and arsenopyrite, as it appears to be, the later hypogene solutions, which deposited the stibnite, may also have attacked the arsenopyrite. The fact that in the Sunset prospect stibnite is intergrown with barite shows that the stibnite was here deposited within the range of temperature and pressure in which sulphates could be deposited from the hpyogene solution.[43] Under such conditions the alteration of arsenopyrite to realgar might take place somewhat after the manner postulated on page 101. The arsenic thus dissolved might be deposited as realgar in the zone where the ascending waters began to mingle with the bicarbonate of the supergene waters of the limestone.

The fact that the stibnite is barren and the realgar carries gold perhaps points to the secondary but not necessarily supergene origin of the realgar. For if the realgar were derived from arsenopyrite the gold present in the arsenopyrite might be expected to migrate with the arsenic to the realgar, whereas if both stibnite and realgar were of hypogene origin and contemporaneous, the gold would probably be present in both minerals instead of only one. Moreover, the realgar is not confined to the zone in which oxides occur but is found to the lowest depth yet explored.

The total amount of arsenopyrite in the primary ore is so small that it seems improbable that alteration of ore of this type could have yielded the large amount of realgar present in the east ore body of the White Caps. On the whole the evidence favors the hypothesis that the realgar is a hypogene mineral but was deposited at a later date than the principal minerals of the ore bodies.

Orpiment is found in the upper 400 feet of the East ore body and is clearly derived from realgar, presumably through the action of

[43] Butler, B. S., Ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, pp. 190–195, 1919.

oxidizing waters. Specimens can be collected which show all stages of alteration (Pl. XVI, *A*) from threads of orpiment along little cracks in the realgar through cores of realgar surrounded by orpiment to pure orpiment. It is difficult to understand why the change from realgar should yield a mineral with higher sulphur content (AsS to As_2S_3), without the formation of oxidized arsenical minerals at the same time. In the lower levels of the mine, however, below the zone in which the orpiment occurs, the mine waters flowing from fissures near the ore are depositing a limonitic sludge on the walls of the drifts. Tests of this material made by W. T. Schaller show the presence of about 10 per cent of arsenic, equivalent to 16 per cent of As_2O_5. Apparently orpiment is the stable sulphide under surface conditions, and the alteration takes place through oxidation of a part of the arsenic of the realgar rather than of the sulphur. This is soon redeposited in association with iron oxide, probably as an arsenate. An analogous reaction is that by which chalcocite changes by oxidation to covellite and cuprite.[44]

The alteration of the realgar to orpiment takes place with comparative rapidity in the sunlight. Fragments of realgar left on the mine dump soon lose their bright-red color, owing to the formation of a thin coating of orpiment. A small amount of pure realgar was placed under glass in the sunlight. Incipient alteration was noticed within a few days, and in a few weeks the transformation to orpiment was well advanced, but powdered realgar in a corked bottle altered only very slowly. No recognizable arsenic oxides were found, though according to Dana[45] realgar alters in the light to orpiment and arsenolite.

The following experiments were made by W. T. Schaller in order to test the probability of the alteration of realgar to orpiment through the action of oxidizing waters:

Realgar (powdered) heated in flask on steam bath with water gave no reaction.

Realgar (powdered) treated similarly with H_2SO_4 (dilute) gave no reaction.

Realgar (powdered) treated similarly with ferric sulphate and dilute H_2SO_4 reacted, forming orpiment and claudetite (which formed in the neck of the flask); no arsenolite could be identified; ferrous sulphate was abundantly formed. The following is probably the reaction that occurs:

$$6AsS+3Fe'''_2(SO_4)_3.3H_2O=2As_2S_3+As_2O_3+6Fe''SO_4+3H_2SO_4.$$

GOLD OF THE ARSENICAL ORES.

The White Caps mine alone of the mines of the Manhattan district has yielded no free gold. The rich ores are those which contain arsenical minerals, for the stibnite is barren or nearly so. The

[44] Lindgren, Waldemar, Mineral deposits, p. 859, New York, 1919.
[45] System of mineralogy, p. 34, 1895.

bullion is remarkably free from silver, having a ratio of about 17 parts of gold to 1 of silver, in contrast to the usual ratio of about 2 or 2½ to 1 in the other mines. It is believed that this anomaly is due to the prevalence of arsenical minerals, for all the arsenical ores, arsenopyrite, realgar, and orpiment, tend to precipitate gold rather than silver from solutions.[46] If the gold was deposited contemporaneously with the arsenical minerals, as it seems to have been, the presence of preponderating arsenic in the sulphide solutions may have had the same effect. No explanation can be offered, however, for the occurrence of arsenopyrite and plentiful realgar in one mine and their absence from neighboring deposits whose ores are of the same type and of the same age.

It seems significant that the only known ore deposits at all closely resembling that of the White Caps—the Gold Reef ores of the Camp Floyd (Mercur) district—show the same absence of free gold and the same lack of silver in the bullion. According to Jackling,[47] "Silver is very sparsely distributed in all classes of ore, rarely exceeding 1 ounce of silver to 10 ounces of gold." According to Heikes,[48] the silver content of the gold ore was so small that the bullion carried only 1 ounce of silver to 111 ounces of gold.

So far as the writer is aware, in other deposits whose gold is of unusual fineness the gold occurs free, close to the outcrop, and is presumed either to have been enriched in place through the solution of silver or to have been precipitated from solutions of surficial origin.

It is at least a tenable hypothesis that hypogene solutions that are rich in arsenic and free from lead, zinc, and copper tend to precipitate gold without any important mixture of silver.

STIBNITE.

Stibnite is found throughout the White Caps deposits, most abundantly in the western part of the mine, and also in the East ore body of the Manhattan Consolidated. Small crystals are common in the vugs of the dark quartz. Its most usual mode of occurrence is in roughly radiate crystalline masses, some of them several inches in diameter, which replace the limestone or coarse calcite and to a less extent the dark quartz. In places small "sunbursts" of stibnite crystals occur along cleavage planes of the coarse calcite, and small needles were found in the fault gouge of the later faults. In all these positions, particularly in the East ore body, stibnite may be closely intergrown with realgar. A rare form of stibnite con-

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[46] Grout, F. F., Econ. Geology, vol. 8, p. 417, 1913.

[47] Op. cit., p. 182.

[48] Heikes, V. C., Gold, silver, copper, lead, and zinc in Utah in 1913: U. S. Geol. Survey Mineral Resources, 1913, pt. 1, p. 409, 1914.

sists of delicate hairlike crystals found in cavities in the calcite and sparsely in the quartz. Orpiment occurs in this same habit and association, but not realgar. Although the stibnite is practically barren of gold it is confined to the ore bodies. Only rarely do small clusters of stibnite crystals occur outside of the mineralized areas.

Stibnite partly oxidized to valentinite occurs in one of the higher Gold Hill limestones at the Sunset prospect. Here the mineral forms radiate masses in the limestone but is accompanied by rather coarsely crystalline barite, with which it is apparently contemporaneous.

Stibnite occurs only in the limestone and, except at the Sunset prospect, only in the White Caps bed. That stibnite should be confined to the limestone and nowhere present in the neighboring schist is probably due to the influence of the country rock, as the waters passing through the limestone would contain bicarbonate, which would precipitate stibnite from an alkaline solution.

SERICITE AND LEVERRIERITE.

Leverrierite ($Al_2O_3.2SiO_2.2\frac{1}{2}H_2O$) occurs in the limestone on Mustang Hill, and sericite in the similar deposits in the limestone on April Fool Hill. In the limestone deposits to the east, particularly along Litigation Hill, are small amounts of a mineral that may be either sericite or leverrierite. In the White Caps and Manhattan Consolidated this mineral is rare and is found only in small inconspicuous white blebs, in the vugs of the quartz. It is minutely crystalline and has a silky luster. Its optical properties and its peculiar property of slaking in water suggest leverrierite, but as similar material occurring in greater amount on April Fool Hill proved to be sericite it is regarded as more probably sericite. Toward the east along Litigation Hill the amount of sericite increases, apparently proportionately with the fluorite, and in the lower tunnels on April Fool Hill it forms a conspicuous part of the ore (Pl. XIV, *A*). Here the roofs of large solution cavities in the limestone present a mammillary appearance, with closely spaced hemispherical protuberances consisting of alternating layers of quartz and sericite. The sericite layers contain quartz, chalcedony, fluorite, and rarely pyrite. This mineral was first identified as leverrierite on the basis of its physical and optical properties, but water determinations made by W. T. Schaller showed only 3.81 per cent below 100 and 5.11 per cent above 100°. Qualitative tests also indicated the presence of considerable potash. Similar sericite was noted by Knopf[49] in the Divide district.

The pipes of Mustang Hill (Pl. XIV, *B*) consist largely of leverrierite, which here contains quartz in disseminated grains and little

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[49] Knopf, Adolph, The Divide silver district, Nev.: U. S. Geol. Survey Bull. 715, p. 159, 1921.

nests of crystals; pyrite, now oxidized to limonite; and free gold. The quartz is so intimately mixed with the inclosing leverrierite that it was difficult to procure enough pure material for an analysis. The following partial analysis made by R. K. Bailey, of the United States Geological Survey, served to confirm the optical determination of leverrierite: H_2O-, 4.56 per cent; H_2O+, 16.15 per cent; K_2O, 0.3 per cent.

The close association of the leverrierite with quartz, fluorite, pyrite, and gold indicates that it is a primary mineral in the limestone deposits. It is one of the latest formed minerals of the first group and probably older than the stibnite and realgar, though definite evidence on this point is lacking.

The mineral has not been commonly reported in ore deposits, but owing to its inconspicuous appearance and close resemblance to sericite it may have been often overlooked. It was found by Larsen and Wherry[50] in quartz veins with manganese oxide. Racewinite from the Highland Boy mine of Bingham, Utah, described by Winchell,[51] appears to be identical with leverrierite.[52] Here it occurs in ores associated with intrusive monzonite porphyry.

BARITE.

Barite was not found in the deep-seated veins nor in the shallow vein deposits of the schists or Tertiary rocks, and it is comparatively rare in the limestone deposits. It was found in small distinct crystals in concentrates from the open-cut workings on the Mustang claim and in larger crystalline masses in the Sunset prospect, where it occurs with quartz and stibnite (Pl. XVI, *B*). On the other hand, abundant barite is present in the concentrates from the placer gravels of the gulch. Here it is so plentiful as to be about equal to the magnetite in volume, and pebbles as much as an inch in length are not uncommon. The abundance of barite in the placer points either to the presence of baritic deposits as yet undiscovered or, what is more likely, to the former presence, probably in the limestone deposits, of an upper zone, now almost completely eroded, which contained barite. If the second suggestion is correct, the occurrences at the Mustang and Sunset represent uneroded remnants of such an upper zone.

OXIDATION AND ENRICHMENT.

There is no doubt that, except in the White Caps mine, the ores mined close to the outcrop, in both the schists and the limestones, were

[50] Larsen, E. S., and Wherry, E. T., Leverrierite from Colorado: Washington Acad. Sci. Jour., vol. 7, pp. 208–217, 1917.

[51] Winchell, A. N., Racewinite, a peculiar mineral from ore deposits in Utah: Econ. Geology, vol. 13, pp. 611–615, 1918.

[52] Butler, B. S., Ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, p. 113, 1920.

on the average much richer than those at comparatively shallow depths. The accompanying curve (fig. 13), derived from data given in Mineral Resources, shows the relation of total production to average value of bullion obtained per ton milled. During the early years of the camp, from 1908 to 1912, when few of the shafts exceeded 100 feet in depth, the output was 64,647 tons of ore, which yielded $1,345,173, an average recovery of $20.81 a ton. In 1913 to 1919, when very few surface discoveries were made and most of the mining was done at greater depths, 289,796 tons of ore was mined, which yielded

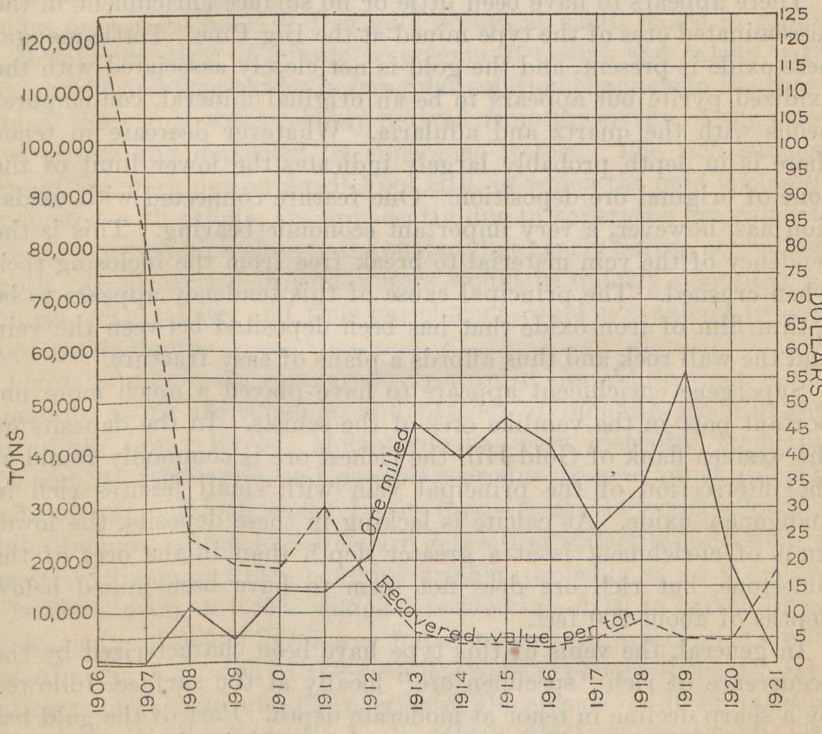


FIGURE 13.—Curve showing tonnage of ore milled in the Manhattan district, 1906–1921, and average value per ton of bullion obtained.

$1,379,170, or $4.75 a ton. This difference is of course due in large part to the mining of large quantities of low-grade ore from the Big Pine mine in the second period, but it also brings out the sharp decrease in tenor of the ores of the district after the rich surface ores above water level had been largely exhausted.

It was found difficult to obtain accurate data on the depth to water level. The height of the water table is dependent on the underground stream flowing along bedrock in Manhattan Gulch. At the Big Four mine the water stood 380 feet below the collar of the shaft, or more than 100 feet below the bottom of Manhattan Gulch, 1,000 feet to the north, but at this point the water table was undoubtedly depressed to some extent by pumping from the neighboring mines. In the White Caps mine the water level was reached between the 100 and 210 foot levels. As Pleistocene fossils are found in Manhattan Gulch it is probable that the same general water level has been maintained since early Pleistocene time, with depressions during periods of greater aridity. The "watercourses" in the limestone, which are found to a depth of at least 500 feet below the surface, are evidence of such a depression.

There appears to have been little or no surface enrichment in the disseminated ores of the type mined at the Big Pine. Little manganese oxide is present, and the gold is not closely associated with the oxidized pyrite but appears to be an original mineral, contemporaneous with the quartz and adularia. Whatever decrease in tenor there is in depth probably largely indicates the lower limit of the zone of original ore deposition. One feature connected with oxidation has, however, a very important economic bearing. This is the tendency of the vein material to break free from the inclosing rock when crushed. The principal cause of this tendency appears to be a thin film of iron oxide that has been deposited between the vein and the wall rock and thus affords a plane of easy fracture.

Supergene enrichment appears to have played a much more important part in the veinlike ores of the schists. In the deposits on the western flank of Gold Hill the richest ore is commonly found at the intersection of the principal vein with small fissures rich in manganese oxide. As calcite is lacking in these deposits, the lower limit of enrichment is at a greater depth than in the ores of the limestone, but rich ore does not seem to have been mined below depths of about 200 feet.

In general, the veins of this type have been characterized by the occurrence of rich "specimen ore" locally at the surface, followed by a sharp decline in tenor at moderate depth. Part of the gold has apparently been taken into solution and redeposited a short distance below the outcrop. During a part of Pleistocene time erosion was more rapid than the process of enrichment, and gold from the enriched zone has been carried down into the gulch.

At least a part of the free gold in the rich surface ores of the limestone mines is due to deposition from supergene solutions. No free gold has been found in the White Caps or the East ore body of the Manhattan Consolidated. In the White Caps, and probably to some extent in the Consolidated also, the gold may be present in the minute crystals of pyrite or arsenopyrite scattered through the dark quartz. The stibnite is barren, but the realgar and orpiment are both gold bearing, so it is apparent that if the realgar has been derived from arsenopyrite the gold originally contained in the arsenopyrite has remained with the arsenic through the successive changes to realgar and thence to orpiment.

Whether or not the realgar has been derived from arsenopyrite, it is clear that, as has been shown above, nearly all the orpiment has resulted from the alteration in place of realgar through the action of oxidizing waters. The rare clusters of hairlike crystals of stibnite and orpiment found along watercourses suggest redeposition after transportation by solution.

In the western part of the Manhattan Consolidated and in the mines on Litigation Hill free gold occurs as small flakes in sandy material consisting of minute fragments of quartz and calcite with manganese and iron oxides in irregular solution channels in the limestone. This gold was probably derived from the pyrite of the massive quartz and deposited by supergene waters. The rich surface ores of the workings on April Fool Hill, in which the gold is closely associated with calcite, are apparently due to supergene enrichment. These were very rich close to the surface but nearly barren at shallow depth. Gold carried in acid waters would be quickly deposited in contact with calcite, and thus enrichment could not extend to any appreciable depth.

Oxide minerals are comparatively rare in the White Caps mine. Limonite stains are common, and patches of limonite occur in the ore of the upper levels. Melanterite has been identified from the 210 and 310 foot levels, and possible scorodite from as great a depth as below the 565-foot level. In the lower levels the waters flowing from the mineralized limestone are depositing stalactites and sludgy masses of limonite which contains arsenic, probably as an arsenate. Likewise a manganiferous sludge deposited in a drift in barren limestone on the 665-foot level was found to contain arsenic. As was noted in the discussion of the arsenical ores, orpiment forms by oxidation from realgar, and the portion of the arsenic oxidized, instead of forming oxidized arsenical minerals in place, goes into solution and is precipitated with the limonite. Except for rare minute grains of what may be arsenolite in ore from the upper levels of the White Caps and possibly scorodite in minute amount and for the arsenic occurring in the limonitic material deposited on the walls of the drifts, no oxidized arsenical mineral has been recognized.

A sample of water from the 800-foot level was collected for analysis. This water flowed from a fissure beneath the arsenic-rich ore body and deposited a brown limonitic sludge on the wall of the drift. Owing to the rapid loss of CO_2 after the sample was opened, the analysis could not be satisfactorily completed. The following notes, however, were made by the analyst. E. T. Erickson, of the United States Geological Survey:

This sample loses carbon dioxide somewhat rapidly, accompanied by precipitation of basic constituents when left open to the air. When first delivered to the chemical laboratory the sample contained a small precipitate of iron-like substance. This was initially filtered out and gave by analysis a total of 0.4 milligram of As_2O_3, the volume of the sample being 2,530 cubic centimeters and nearly filling the container. The iron-like precipitate gave evidence of the presence of silica.

The initial carbon dioxide determination after the opening and filtration of the sample was 466 parts per million. On the second day this lowered to 396 parts per million, when the following analyses were conducted in order to represent the composition of the sample on that day:

	Parts per million.		Parts per million.
Ca	175	CO_3	396
Mg	96	Cl	82
Na	42	As_2O_3	4
K	Trace.		
SO_4	270		1,080
HCO_3	15		

Upon the third day of the opening of the sample the Ca determination gave 168 parts per million and the Mg 81 parts per million. After the fifth day, the Ca content lowered to 126 parts per million and the Mg to 70 parts per million. By this time the sample contained much visible precipitate. Sulphides are not appreciably present.

The presence of arsenic is accounted for by the alteration of realgar to orpiment, but it is surprising that water of this type should contain so little SO_4 and little or no iron. Nor can any explanation be offered of the relatively large sodium content. The precipitation of the lime and magnesia suggests that the dolomite crystals found in the cavities of the quartz in the lower levels may be of supergene origin.

Some of the stibnite specimens collected from the 100 and 200 foot levels show a partial alteration to valentinite (Sb_2O_3) and stibiconite ($H_2Sb_2O_5$). The stibiconite appears to have formed both directly from the stibnite and as an alteration product of the valentinite. Kermesite ($2Sb_2S_3.Sb_2O_3$) is rare but in places forms a reddish coating on stibnite crystals. Tufts of hairlike stibnite crystals, which are found here and there in the quartz vugs, probably represent deposition by supergene waters. It is also possible that the small stibnite crystals found in the fault gouge are of supergene origin.

RELATION OF ORE DEPOSITION TO FAULTING.

The productive mines of the district all lie in a belt extending about 10,000 feet from east to west and less than 2,000 feet from north to south. The overthrust fault marks the northern limit of productive mineralization. This fault is older than the numerous faults that cut the ore-bearing limestone and is undoubtedly contemporaneous with the intense folding that preceded the intrusion of the granodiorite.

Movement on the normal faults may have begun at the time of the granodiorite intrusion, for an alaskite dike seems to follow one of the faults, and the coarse calcite of the limestone ores, which, as shown below, may be related to the granodiorite intrusion, follows the minor faults.

The Tertiary rocks to the north show faulting, both before and after the intrusion of the andesite porphyry. The faults of largest throw appear to belong to the earlier group.

Productive ore deposits occur only close to the overthrust fault, along the south side. Although the fault plane itself is nowhere mineralized, it is believed that the presence of this major fault was the determining factor in the localization of the deposits. The mines are all on the hanging-wall side of the overthrust, and most of the deposits are associated with the small normal faults of later date. It may be that the overthrust fault with its narrow zone of comparatively impervious gouge acted as a dam to prevent important migration of the mineral-bearing solutions to the north of the fault, and that the intersection of the overthrust with the minor normal faults determined the principal channels followed by the ascending solutions. If so, it is necessary to assume that the source from which the solutions were derived lay to the south of the fault. This hypothesis furnishes a possible explanation for the restriction of the limestone ores to the White Caps limestone, to the exclusion of the two similar beds at slightly lower horizons. The limestone beds at the White Caps mine and on Litigation Hill, though approximately parallel with the overthrust in strike, have, at least at the White Caps mine, a slightly steeper dip. Thus the White Caps limestone would be cut by the fault plane at a lower level than the two lower beds, and uprising solutions controlled on the north by the overthrust would tend to be diverted along the first soluble bed.

The White Caps limestone is cut out against the fault on April Fool Hill, and the next higher bed, which contains the Mustang ores, meets the overthrust on Mustang Hill 4,500 feet to the west. Between these limestones there are no soluble beds in which replacement deposits could be formed, but the schist offered channels in which vein minerals were deposited, either along the schistose cleavage planes and joints, as in the Big Pine, or along well-defined shear zones, as in the Union No. 9 and similar mines.

The earlier normal faulting is believed to have afforded the principal channels for the ore-bearing solutions, both in the limestone and in the schist. The later faulting was of greater magnitude, but realgar and possibly stibnite are the only minerals that are certainly later than this faulting, and it is possible that the realgar and stibnite found in the fault gouge represent redeposition by supergene waters. In the part of the district in which the schist ores occur the second period of faulting provided channels for the oxidizing waters and controlled the enrichment in mines of the Union No. 9 type.

AGE OF ORE DEPOSITION.

Deep-seated deposits.—Such mineralization as is clearly allied to the granitic intrusion is represented in the Manhattan district by small irregular deposits of too low tenor to be workable. These deposits vary in type and show gradation from silicic aplite dikes carrying a little pyrite through veins carrying sulphides in a mixed quartz and feldspar gangue to lenticular quartz veins, with galena and chalcopyrite, of the type prospected at the Nemo mine.

Productive deposits of similar type and clearly belonging to the same epoch of mineralization have been mined near the granite contact within a few miles of Manhattan. The age of these deposits is therefore approximately that of the granite batholith, which is presumed to be early Cretaceous.

Veins in the Tertiary rocks.—The unproductive veins of the volcanic rocks in the northern part of the district clearly represent a late Tertiary epoch of mineralization and show certain characteristics of veins formed at shallow depths, such as adularia and quartz pseudomorphic after lamellar calcite. As ores of this type occur in the post-Esmeralda andesite, these veins must be of upper Miocene or later date. The andesite intrusions in the region north of the Manhattan district are only a short distance below the post-mature erosion surface, which is presumably of late Pliocene age; therefore this period of ore deposition may be rather definitely dated as latest Miocene or early Pliocene.

Ores in the Gold Hill formation.—The ores in the Gold Hill schists show the same general mineral association that is characteristic of the veins in the volcanic rocks to the north. They are clearly of the shallow vein type, as is shown particularly by the presence of abundant adularia and quartz pseudomorphic after tabular calcite, two features that are nearly constant in the late Tertiary gold deposits of the Great Basin region and are unknown in the deeper-seated deposits of the earlier epochs of metallization. These facts suffice to ally the deposits in the Gold Hill schist on Gold Hill with the veins of similar mineralogic character that cut the intrusive andesite on Bald Mountain.

The late Miocene or early Pliocene was a metallogenic epoch of considerable importance in this region. Other deposits of approximately the same date are those of Goldfield, Divide, and Round Mountain, the later veins of Tonopah, and possibly the ores of Bullfrog.

Limestone ores.—The ores of the limestones are more complex and, to a large extent, lack minerals or mineral associations that are clearly diagnostic of either of the above groups, and it is likely that they represent more than one period of mineralization.

Dynan [53] considers that the ore of the White Caps mine owes its origin to solutions emanating from the intrusive granite. Outcrops of granitic rocks occur much nearer the White Caps mine than the Tertiary igneous rocks. On the ridge north of Litigation Hill there are two small dikes of a coarse-grained alaskite, and a short distance to the south the sediments are cut by several small dikes of aplite. Small masses of what appears to be an igneous rock, now completely altered to sericite, have been encountered in the 565 and 800 foot levels of the White Caps.

The coarse calcite that is found in the limestone mines occurs in places close to the granite. Dynan [54] mentions specimens of coarse calcite and garnet from the granite contact which assayed 0.03 ounce of gold to the ton. Similar coarse calcite in the silver-lead deposits of the Darwin district, Calif., has been described by Knopf.[55] There it seems to be directly connected with an intrusion of granodiorite. On the other hand, calcite of this type is not present in the impure Ordovician limestones of the Belmont district, where the occurrence of the ore seems clearly related to the presence of the granite. With rare exceptions the alteration of limestone to coarse calcite at Manhattan seems to be confined to the purer limestones of the Gold Hill formation, particularly the White Caps bed.

Leverierrite is present in at least one of the ore deposits in the limestone. It is apparently an uncommon mineral, and little is known as to the conditions favorable to its formation. In the Bingham district, Utah,[56] it occurs in ores associated with intrusive monzonite porphyry. Sericite, on the other hand, similar in character to that of the Manhattan deposits has been found by Knopf [57] in the late Tertiary lodes of the Divide district.

Notwithstanding the facts stated in the preceding paragraphs it is believed that the weight of the evidence favors the probability

[53] Dynan, J. L., op. cit., p. 885.

[54] Idem, p. 885.

[55] Knopf, Adolph, The Darwin silver-lead mining district, Calif.: U. S. Geol. Survey Bull. 580, p. 7, 1915.

[56] Winchell, A. N., Racewinite, a peculiar mineral from ore deposits in Utah: Econ. Geology, vol. 13, pp. 611–615, 1918.

[57] Knopf, Adolph, The Divide silver district, Nev.: U. S. Geol. Survey Bull. 715, p. 157, 1921.

that the limestone ores were formed fairly close to the surface and are of Tertiary age, although it is quite likely that the coarsely crystalline calcite may be a representative of the mineralization that followed the intrusion of the granodiorite. The deposits are absolutely unlike those of Belmont, in which the primary ore consists of sulphides, such as galena, sphalerite, tetrahedrite, and chalcopyrite, in a quartz-calcite gangue, nor is there any similarity between these deposits and the small unproductive veins of deep-seated origin found here and there throughout the Manhattan district. On the other hand, there are certain points of similarity between the limestone ores and their near neighbors, the schist deposits, which are clearly of Tertiary age. Adularia, though far less common in the limestone ores than in the schist ores, is present in several of the mines, notably the Earle mine, on Litigation Hill. The fine-grained drusy quartz of the limestone ores is similar in appearance to that of the Gold Hill veins and suggests deposition nearer the surface than the coarsely crystalline veins of the unproductive older series or the Belmont deposits. The large amount of fluorite is likewise considered indicative of deposits of the shallow rather than of the deep vein zone.

The principal minerals of the limestone deposits—quartz, fluorite, leverrierite, and the fine-grained pyrite and arsenopyrite—appear to have been deposited prior to the most recent movement along the larger faults. The stibnite and realgar, on the other hand, appear to represent a still later period of Tertiary ore deposition and may even be younger than the latest faulting. It is probable that there were two periods of mineralization in late Tertiary time.

Two types of intrusive rock of post-Esmeralda age are represented in this district—the Maris rhyolite and the andesite porphyry—and the ore deposition may be genetically connected with either. Probably, if the hypothesis as to two periods of mineralization in the limestone ores is correct, some mineralization followed each intrusion, but there is no evidence by which to connect one with the quartz replacement deposits and the other with the stibnite and realgar mineralization. The Maris pebble mine shows that some silicification followed the intrusion of the Maris rhyolite, and the contemporaneous deposits at Round Mountain are genetically connected with a large mass of intrusive rhyolite, which is mineralogically similar to the Maris rhyolite. On the other hand, studies of deposits of this type show that andesites are common ore bringers. Moreover, if the realgar of the White Caps mine is primary and not derived from preexisting arsenopyrite a slender thread of evidence connects the realgar-bearing Round Mountain ores, which are clearly associated with the rhyolite, with the second and less important period of Tertiary mineralization at Manhattan.

PLACER DEPOSITS.[58]

GENERAL FEATURES.

Placer gold is found in this district in gravel of three types—the older gravel, remnants of an earlier period of stream action, before the erosion of the canyon of Manhattan Gulch; the buried gravel of the gulch, which as shown by the fossils recovered from it is probably of early Pleistocene age; and the recent wash, including both loose material on the hillsides and that deposited by floods in the dry stream courses.

The history of the deposition of the gravels of these three types is outlined in the section of this report on "Development of the present topography" (pp. 61–76). The reader who is particularly interested in the study of the placers should therefore read that section in connection with the following more technical study of the placers as a source of gold.

Placer gold has furnished approximately 30 per cent of the total production of the Manhattan district. Gold had been discovered in the deep gravel of the gulch in a well sunk near Central as early as 1906, but this was overlooked in the prevailing excitement, and it was not until the winter of 1907–8 that the deflation of the first boom turned the attention of the miners to the possibility of mining the deep gravel. Placer mining had begun in the summer of 1906 on the rich surface float of the Little Grey and Indian Camp claims, and to a less extent on the older gravel of the Little Grey claim. Water was scarce, and the work was carried on either by means of dry-washing machines or by sluicing with a carefully conserved supply of water. The following notes[59] give an interesting description of the method of sluicing:

Here water is hauled in barrels and dumped into a large tank. The gravel is shoveled upon a platform, * * * and the water from the tank is then drawn off through the sluice box, the gravel being fed in from the platform. The water from the sluice returns to a pit dug below the tank. It is then raised in a box attached to one end of the long pole. * * * To do this a man walks up the plank * * * and, jumping off, catches hold of the other end of the pole and, lying over it, his weight brings the box up to the level of the top of the tank, and the water is then automatically discharged into the tank for further use.

The saving by the dry-washing machines is not claimed to be over 70 per cent, while the saving by the Manhattan method is undoubtedly much higher. The disadvantages of the latter method lie in decreased capacity, greater expense, and the difficulty of finding a man whose stomach will stand the pressure neces-

[58] The investigation of placer deposits was confined to the field season of 1915, and the results were published in U. S. Geol. Survey Bull. 640, pp. 163–193, 1917. This section of the present bulletin is to some extent a repetition of the earlier publication.

[59] Packard, G. A., Round Mountain camp, Nev.: Eng. and Min. Jour., vol. 83, p. 151, 1907.

sary for operating the pole for a longer time than is absolutely necessary to secure money enough to last while hunting another job.

The water pumped from the neighboring lode mines is now available and sufficient in quantity for the small amount of work still done on the surface placers.

The first placer shaft was sunk on the Nellie Gray claim and reached bedrock at a depth of 23 feet. A shaft near Central was next sunk to pay gravel at a depth of 35 feet. Thomas ("Dry Wash") Wilson, to whose foresight and energy the development of the Manhattan placers is largely due, was the first to develop the pay gravel of the "wet channel."

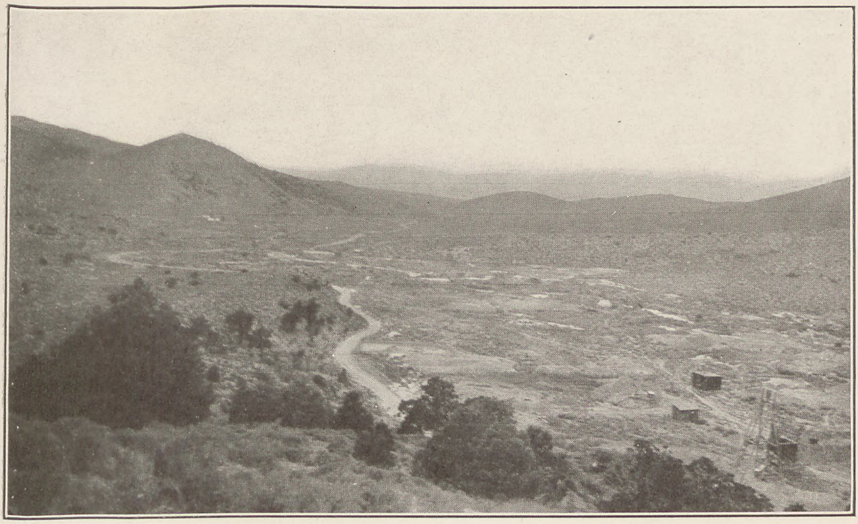
The initial success of deep placer mining gave new life to the camp, and placer production increased rapidly, reaching its maximum in 1912. Since then it has declined, slowly at first but rapidly since 1915, owing both to the exhaustion of the best ground and to the great increase in costs. The best ground in the upper part of the gulch had been largely worked out before 1912, and the center of placer operations moved westward, down the gulch, where the ground was less rich and the gold more finely divided. The flood in the summer of 1914 gave a setback to operations, as the water flowing down the gulch rose above the collars of several of the shafts.

By 1915 the only operators working their own claims were in the western part of the gulch, and the work in the upper portion was being done by lessees who were mining small patches of pay gravel left behind during earlier operations or reworking old dumps. At present, except for a little mining in the western part of the gulch and on small patches left here and there in the upper and central parts, and a little work still done on the older gravels and the surface wash, placer mining has nearly ceased. The accompanying curve (fig. 14) shows the rise and decline of placer mining at Manhattan.

The placers of the gulch are all worked by drift mining (Pl. XVII), as the overburden is too thick for dredging or hydraulicking, even if sufficient water were available. An attempt at mining by means of a suction pipe resulted in failure.

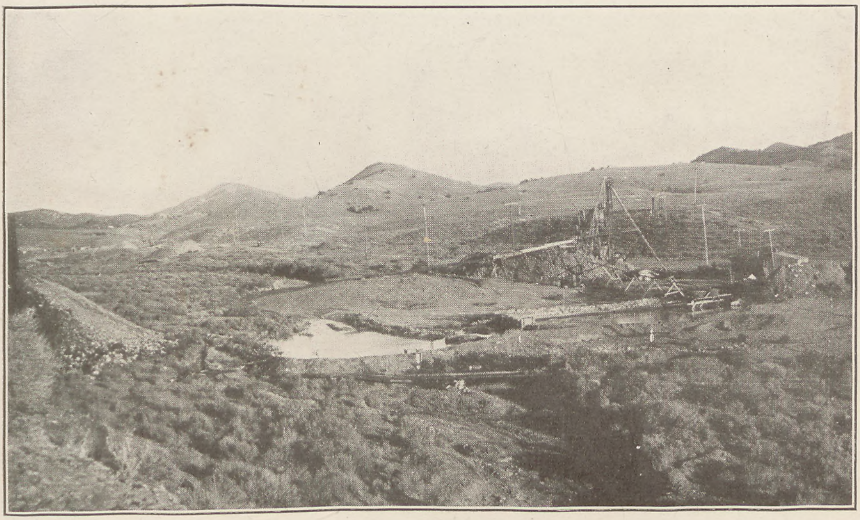
There is a constant flow of water through the pay gravels along the greater part of the deep channel. This flow ranges from 20,000 to 50,000 gallons a day, generally nearer the larger amount, but fails entirely in two places, where the canyon crosses limestone strata and the water is probably diverted to crevices or solution channels.

The water used for washing the gravel is pumped from the wet channel to small ponds below the sluice boxes and from these is pumped to the sluice boxes. The water is thus used continuously, and the amount obtained by pumping compensates for the losses from seepage and evaporation (Pl. XVII, *B*). Drifts are run in



A. MANHATTAN GULCH BETWEEN MOUNT MORIAH AND WOLFE TONE POINT.

Showing placer workings.



B. PLACER MINE IN WESTERN PART OF MANHATTAN GULCH.

Showing sluice boxes and pond.

the pay gravel for a maximum distance of 300 feet from the shaft, and the pay streak is developed by short crosscuts. It is considered more economical to sink a new shaft than to increase the length of the drift beyond 300 feet. When the pay streak has been developed the gravel is stoped back toward the shaft after the manner

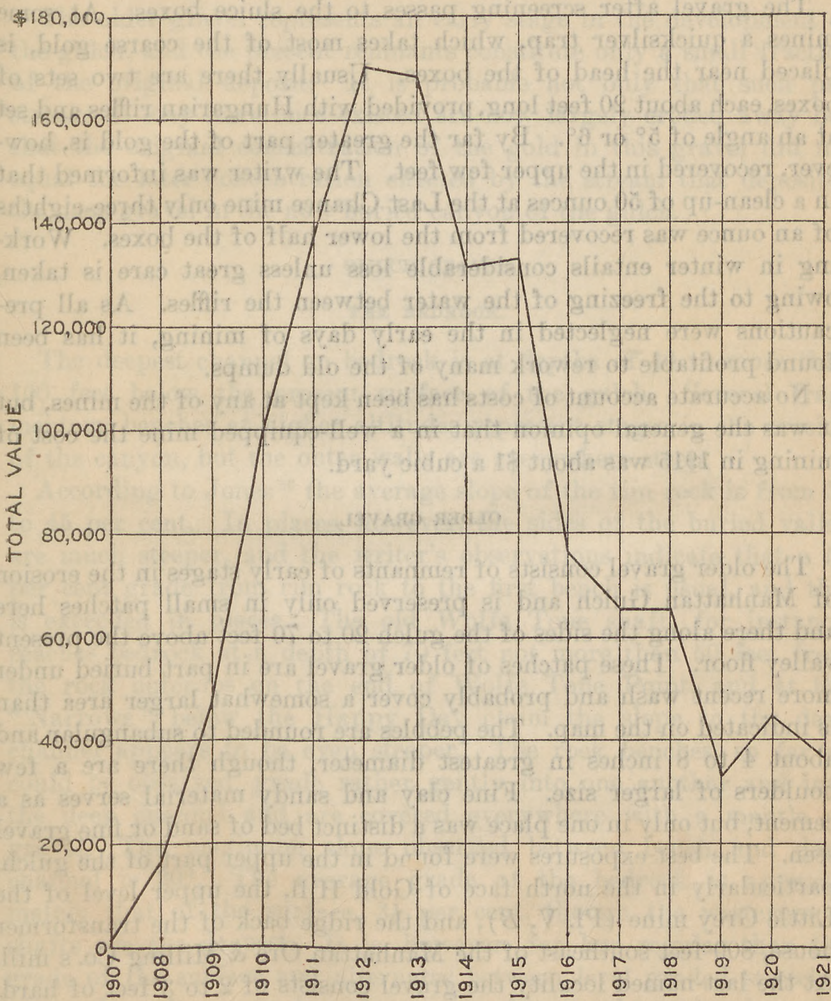


FIGURE 14.—Curve showing placer production in the Manhattan district, 1907–1921.

of long-wall coal mining. The schistose bedrock contains many small crevices in which the gold can lodge and is therefore removed to a depth of about a foot. The coarse, clayey gravel stands well, and few supports are needed in the stopes. Boulders too large to be handled easily are not hoisted but are left behind as the work progresses. In most mines the tramming is done by wheelbarrows, but in a few tracks have been laid and the gravel is taken in cars to a bin instead of directly to the shaft bucket. The power line of the Nevada-California Power Co. entered Manhattan Gulch in 1909, so electric pumps and hoists have supplanted the gasoline engine.

The gravel after screening passes to the sluice boxes. At some mines a quicksilver trap, which takes most of the coarse gold, is placed near the head of the boxes. Usually there are two sets of boxes, each about 20 feet long, provided with Hungarian riffles and set at an angle of 5° or 6°. By far the greater part of the gold is, however, recovered in the upper few feet. The writer was informed that in a clean-up of 50 ounces at the Last Chance mine only three-eighths of an ounce was recovered from the lower half of the boxes. Working in winter entails considerable loss unless great care is taken, owing to the freezing of the water between the riffles. As all precautions were neglected in the early days of mining, it has been found profitable to rework many of the old dumps.

No accurate account of costs has been kept at any of the mines, but it was the general opinion that in a well-equipped mine the cost of mining in 1915 was about $1 a cubic yard.

OLDER GRAVEL.

The older gravel consists of remnants of early stages in the erosion of Manhattan Gulch and is preserved only in small patches here and there along the sides of the gulch 20 to 70 feet above the present valley floor. These patches of older gravel are in part buried under more recent wash and probably cover a somewhat larger area than is indicated on the map. The pebbles are rounded to subangular and about 4 to 8 inches in greatest diameter, though there are a few boulders of larger size. Fine clay and sandy material serves as a cement, but only in one place was a distinct bed of sand or fine gravel seen. The best exposures were found in the upper part of the gulch, particularly in the north face of Gold Hill, the upper level of the Little Grey mine (Pl. V, *B*), and the ridge back of the transformer house, 800 feet southeast of the Manhattan Ore & Milling Co.'s mill. At the last-named locality the gravel consists of 2 to 3 feet of hard, cemented material containing many boulders, particularly of the resistant porphyritic rhyolite. Below this hard material to bedrock is between 10 and 15 feet of loose sand and fine gravel. The coarse gravel is so well cemented as to require the use of a pick in mining, but the underlying sand is loose and unconsolidated.

These remnants of older gravel have not shown sufficient promise to lead to extensive mining. The patch of older gravel on the north side of Gold Hill was found to carry gold in small amounts but not enough to be workable, though the overlying surface wash yielded a profit. The older gravel west of the Little Grey vein has been mined to some extent, also that on the ridge south of the transformer house, where small irregular pay streaks were found in coarse gravel above the fine sand.

The older gravel represents an early stage in the development of the gulch, and the present remnants constitute only a small fraction of the original deposit. It is probable not only that such pay streaks as may have once existed are now largely eroded away but that the original concentration of the gold in this gravel did not equal the later concentration effected by the stream that deposited the deep gravel in the now buried canyon of the gulch.

GULCH GRAVEL.

THE BEDROCK.

The deepest channel on bedrock is at depths of 40 to more than 100 feet below the present surface of the gulch. Several fragmentary benches at higher altitudes represent stages in the erosion of the canyon, but the outer walls are everywhere steep.

According to Jones[60] the average slope of the rim rock is from 30 to 45 per cent. In places, however, the sides of the buried valley are much steeper, and the writer's observations indicate that a 50 per cent grade from rim rock to the first bench is usual, and this is exceeded in places. The old Wolfe Tone shaft, for instance, reaches bedrock at a depth of 70 feet not more than 50 feet from the rock outcrops on the end of Wolfe Tone Point, and at the "Narrows" below the Happy Day claim the slope to the deep channel appears to be even steeper. The rock benches, so far as could be observed, grade rather gently into one another and into the deep channel and are covered everywhere with a mantle of gravel. The maximum slope observed between bench and deep channel is 30°. The average grade of the bedrock is approximately that of the surface, $3\frac{1}{3}$ per cent, though the westernmost shafts are the deepest. It is, however, far less regular than the grade of the surface and alternates between level graded stretches where the softer rocks have been worn down and rapids where the stream crossed the more resistant beds of the sedimentary series.

The deep channel has been explored for practically its entire length, but in the present condition of mining sufficient data to reconstruct its course are difficult to obtain. It meanders about the valley bottom and at several points splits into two or more divisions, leaving small "islands," a few feet high, between the deep parts. The

[60] Jones, C. C., Notes on Manhattan placers, Nye County, Nev.: Eng. and Min. Jour., vol. 88, p. 102, 1909.

course as shown on the map (Pl. XVIII) has been compiled from data obtained from the accessible shafts, supplemented by information furnished by Mr. L. F. Clar.

There is a depth of about 30 feet to bedrock under the town of Manhattan, but the depth increases to 60 feet in the shaft at the west end of the Dexter No. 14 claim, a short distance below the town. Probably the quartzite beds in the lower schist here formed a dam, for above this place the bedrock channel is fairly flat, at least as far as the mouth of Consolidated Gulch, where the depth is between 50 and 60 feet, showing a drop in bedrock of 95 feet, as compared to a difference of altitude on the surface of 125 feet in a distance of about 2,500 feet.

Between the Dexter No. 14 claim and Wolfe Tone Point the grade of bedrock is only slightly steeper than the surface, as the shaft opposite Wolfe Tone Point has a depth of 72 feet. Along this stretch the deep channel follows the south wall of the canyon.

Between Wolfe Tone and African points there seem to be two or perhaps three channels of about equal depth, which reunite on the north side of the valley at African Point. Possibly the variation of the channel is due to the displacement of the stream by the delta of Auction Gulch. This tributary seems to have entered the stream at a steep grade and must therefore have deposited much of its load near its mouth. The grade of bedrock is only slightly less than that of the surface, for the upper shafts have depths of 70 feet or more, and that of the African claim, near the junction of the channels, is 65 feet in depth. Below African Point there is a long stretch in which the bedrock is slightly flatter than the surface, for the depth is about 60 feet on the Searchlight, 50 feet at the Central City, and about 45 feet from the Pedro to the Last Chance claim. The channel swings from the north side of the canyon at African Point to the south side directly north of Mount Moriah and again to the north at the Last Chance. This graded stretch appears to be caused by the extension under the stream of the quartzite bed that forms the crest of Georgey Hill.

Below Georgey Hill there is a comparatively rapid fall, the canyon narrows, and for a short distance the benches are lost. The next known depth to the deep channel is 60 feet on the Arlington No. 3, a drop of 15 feet below the surface grade. The greater part of the fall is believed to be on the Fairview claim and the lower end of the Edith claim. Below the Arlington No. 3 the grade of bedrock is steeper than that of the surface, the depth being 78 feet on the Bright August, 88 feet in the western part of the Jumbo No. 2, 93 feet on the western edge of the Lucky Fraction, and 105 feet on the China. Between the Polaris and the Bright August well-defined bench gravel has been worked, but on the lower end of the Happy Day the canyon again narrows and the benches are lost. At the upper end of the Happy Day claim the depth to bedrock is 70 feet; at the lower end of the same claim it is 90 feet; and at the "narrows," just below, a depth of 98 feet is reached. The bedrock on the Happy Day claim is said to be very uneven and to show numerous "jump-offs." Below the narrows, on the China claim, the canyon is wider and the benches come in again.

Below the China the gulch turns sharply to the north and continues in this direction for about 5,000 feet, where it bends to the northwest. Along this stretch the surface expression of the gulch begins to be lost under the desert wash of Big Smoky Valley. The bedrock canyon seems to continue, however, though the grade is much flatter, for the Japan shaft, 400 feet to the north, is 90 feet deep, and the farthest shaft, on the Hillsdale No. 1 claim, 8,000 feet beyond the China, is said to have a depth of 70 feet.[61]

In the accompanying map (Pl. XVIII) no attempt has been made to show the true width of the deep channel, for sufficient data are not available. In general it is widest in the graded stretches and narrows toward the rapids. In the long graded stretch east of the Last Chance it's width in places exceeds 100 feet. At the west end of the Bright August, just above the "narrows" on the Happy Day, the width is only 10 feet. Below, on the Japan claim, it is said to be 50 feet wide.

Bench gravel has been mined throughout the length of the gulch, but few records have been kept as to the depth and extent of the several benches. The map (fig. 4, p. 67), made available through the courtesy of Mr. C. Phillips, shows the approximate relations of benches and deep channel on parts of the Amboy and Arlington claims in the lower part of the gulch. Here the benches seem to be better developed than in the mines near Manhattan.

THE GRAVEL.

The gravel is fairly coarse throughout the gulch but on the average distinctly smaller near the mouth than in the upper part. Boulders occur here and there, particularly of quartzite and the resistant Diamond King rhyolite. Clay and sand are mixed with the gravel, which is in general sufficiently well cemented to stand without timber. This clayey cement seems to be largely lacking in the westernmost claims. Inspection of the gravel in place and of the dump gives the impression that material derived from the pre-Tertiary rocks forms a larger proportion of this lower gravel than of the more recent material that overlies the stream-laid gravel.

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[61] Jones, C. C., op. cit., p. 103.

The bench gravel does not differ in composition or size from that of the deep channel but commonly has a distinctly rusty appearance, which is due to the later deposition of small amounts of limonite. In places black stains apparently due to manganese oxide are also present. This deposit of limonite is less noticeable in the deep-channel gravel, which is kept wet through the seepage down the gulch.

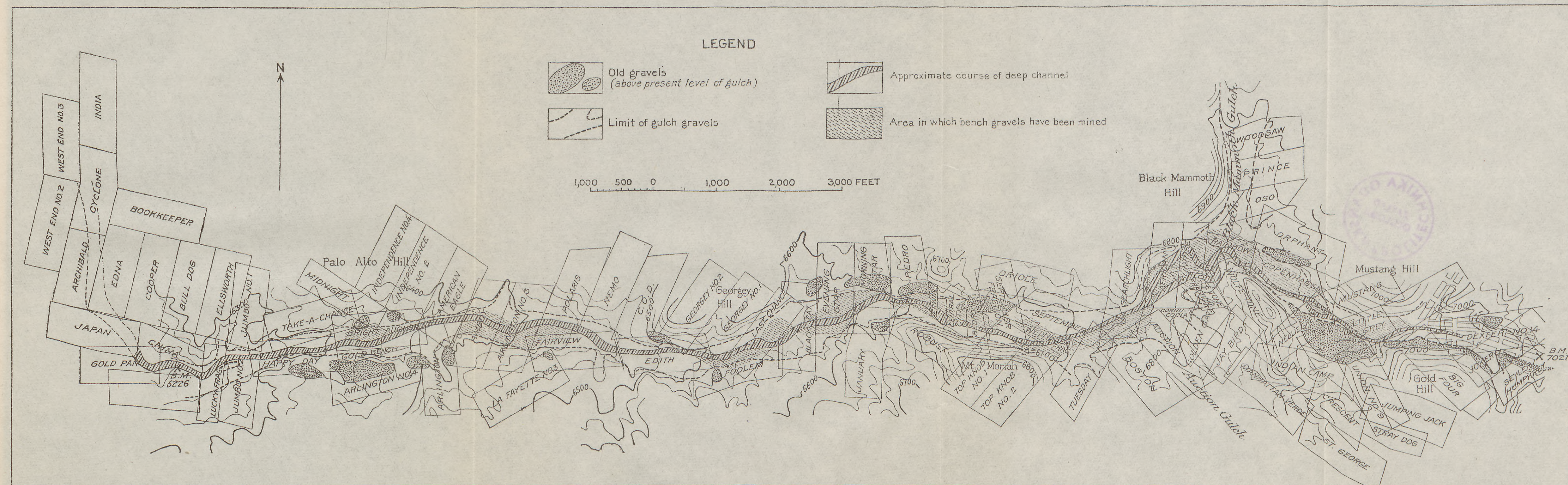
The upper coarse gravels found in places several feet above the pay gravels seem to contain a larger proportion of volcanic rock and commonly show boulders embedded in fine material without much gradation in size. Few opportunities were offered, however, for observation of these gravels.

The thickness of the pay gravel varies greatly from place to place but on the whole is greatest near the west end of the gulch. Local irregularities are of course common. The greater thickness reported in some of the shafts below Wolfe Tone Point is perhaps due to the delta formed by Auction Gulch. In most of the shafts the pay gravel is between 2 and 4 feet thick, though as great a thickness as 12 feet has been found.

GOLD CONTENT.

The gulch gravel has been productive over a distance of about 4 miles, beginning north of Gold Hill and extending down the gulch to the point where the stream valley makes its sharp turn to the north. Below this point a little work has been done, but the gold was found to be too finely divided and scattered throughout too thick a bed of gravel to be profitable for drift mining as at present conducted. North of Gold Hill some work has been done from shafts at the lower end of the town, but the deep gravel above town and that above Dublin, Consolidated, Slaughterhouse, and Black Mammoth gulches have not proved profitable. As gravel with a gold content of much less than $2 a cubic yard is rarely mined, it follows that the parts of the gulch that have been worked represent only those in which the gravel showed the greatest concentration of gold. The richest portion of the gulch, now worked out, was the part between the sharp bend opposite Wolfe Tone Point and African Point. Here the deep channel splits into several smaller ones and some of the gravel was extremely rich. One of these channels is said to have yielded over $50 a cubic yard across a face of more than 20 feet.

The gravel of the benches generally appears to be less valuable than that of the deep channel. On the Boston and Auction claims, however, the bench gravel was extraordinarily rich, probably be-



MAP OF THE PRODUCTIVE PORTION OF MANHATTAN GULCH.

56027—24. (Face p. 124.)

cause the northward-flowing Auction Gulch brought down much gold from the mineralized region just west of Gold Hill. According to information from Mr. Clar, however, the ground 500 feet up Auction Gulch showed no pay.

Only the bedrock gravel has proved workable, but gold is found in small amount throughout the gravel section as far as the base of the angular wash. On one of the western claims a lens of coarse gravel above the fine material overlying the pay gravel was estimated to carry as much as $2 a cubic yard. Streaks here and there in the finer upper gravel may show colors to the value of 50 cents a cubic yard.

The writer desires to acknowledge his indebtedness to Mr. L. F. Clar for the following notes as to the richness of the various claims. These are quoted almost verbatim from his letter of February 19, 1915, to J. M. Hill, of the United States Geological Survey.

> The December Fraction and Copenhagen (Mustang Extension) were very rich pieces of ground. The Wolfe Tone, Rainbow, and Sunrise were all good, but what may be considered as the very best piece in the gulch is the Little Wedge and the adjacent portion of the African and Searchlight. The Little Wedge is the small triangular area bounded by the Searchlight, Auction, and African claims.
>
> The southern part of the Wolfe Tone Fraction proved somewhat of a disappointment to the operators.
>
> The southeastern part of the September and the northern part of the Boston, together with the intervening wedge formed by the southern part of the Searchlight, were all good ground.
>
> The northeast corner of the Auction showed up well, but the greater part of this ground is still unworked.
>
> Downstream the ground proved less profitable as far west as the Central City claim. From this claim westward the placers have all shown good ground as far down the gulch as the Jumbo No. 2. The Robust claim, in which the deep channel is dry, had a pay streak which yielded $7 a cubic yard.
>
> The gulch narrows greatly at the lower end of the Happy Day, and the benches are lost. Below the Jumbo No. 2 the gravel is again poorer until the good ground of the Japan is reached. Westward from this claim the gulch is not sufficiently developed to furnish any information as to the comparative richness of the different claims.

Mr. Clar's notes seem to indicate that in a general way the richer parts of the gulch are those in which the stream flows along a more or less graded stretch above a steeper interval, or, in other words, where there has been some impounding of the gravel.

CHARACTER OF THE GOLD.

No records have been kept with reference to the coarseness of the gold, but the operators agree that the size of the gold particles decreases gradually downstream. Fairly coarse nuggets, the largest of which were an ounce or more in weight, have been found in the upper half of the gulch. In the shafts in the extreme western part, however, the finely divided state of the gold is one of the chief difficulties of mining. Coarse gold is found throughout the gulch. In all the small samples of concentrates collected by the writer from the portion of the gulch between the Wolfe Tone and Amboy claims most of the gold colors were rather thin flakes exceeding 0.5 millimeter (40-mesh) in size, although few were greater than 1 millimeter (20-mesh).

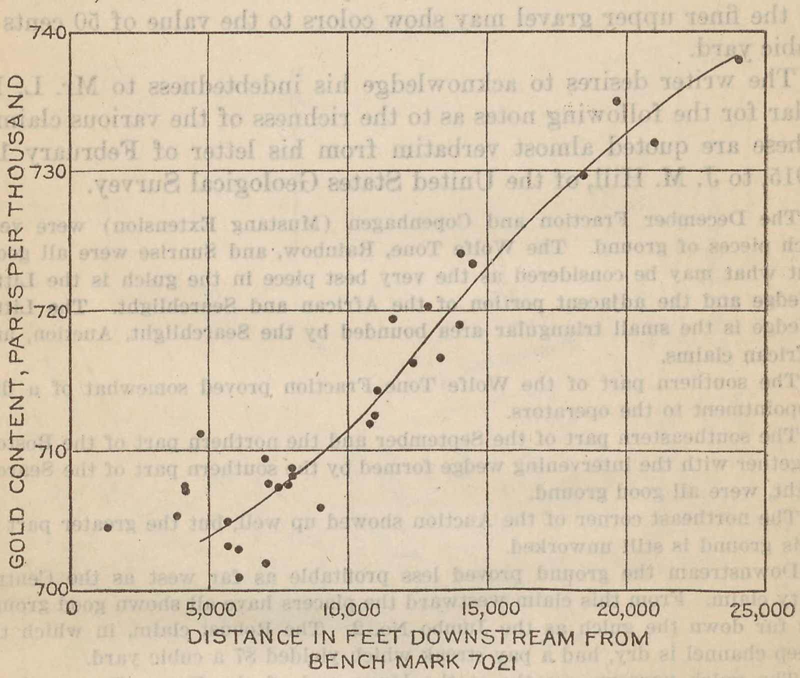


FIGURE 15.—Curve showing variation in fineness of placer gold in the Manhattan district.

For the most part the gold shows very little effect of abrasion and is usually arborescent or feathery in shape. The larger pieces almost invariably contain some quartz. The gold from the deep channel is clean and bright, whereas most of that from the pay streaks on the dry benches is slightly rusty and amalgamates less readily.

Of particular interest is the difference in purity of the gold in different parts of the gulch. The placer gold of the gulch, even in the vicinity of Gold Hill, is probably slightly finer than the gold of the lodes from which it is derived. Down the gulch toward the west the grade of the gold increases with the distance from its source. The fineness of the gold from the different claims, as determined from data collected by the writer and Mr. L. F. Clar, is shown in the accompanying table and the curve (fig. 15).

Variation in fineness of Manhattan placer gold.

Claim.	Approximate distance below B. M. 7021.	Gold (parts per 1,000).	Silver (parts per 1,000).	Base metals (parts per 1,000).	Remarks.
	Feet.				
Dexter 14	1,400	704.5	281.2	14.3	From deep gravel, single clean-up return. Most of the placer production of this claim was derived from the hillside wash, the gold of which showed a greatly varying fineness with a maximum of 0.690.
Mustang Extension (Copenhagen).	3,800	705.5	285.4	9.1	Upper end of claim. Average of 11 clean-up returns. Maximum variation 10 parts per 1,000.
Do	4,300	707.3	284.9	7.8	Middle of claim. Average of 27 clean-up returns. Maximum variation 17 parts per 1,000.
Do	4,300	707.8	285.9	6.3	Data furnished by Mr. L. F. Clar, who states that individual returns show greater irregularity than those from the lower part of the gulch.
Do	4,700	711.3	281.3	7.4	Lower end of claim. Average of 21 clean-up returns. Maximum variation 13 parts per 1,000.
Wolfe Tone	5,700	703.3	290.9	5.8	Average of 11 clean-up returns. Maximum variation 4 parts per 1,000.
Do	5,700	705	....	....	Operator's estimate.
Rainbow, Sunrise, and African.	6,000	700.8	289.0	9.3	Data furnished by Mr. L. F. Clar.
Sunrise	6,000	703.2	291.6	5.2	Average of 5 clean-up returns. Maximum variation 3 parts per 1,000.
Auction	7,000	709.5	281.5	9.0	Average of 6 clean-up returns. Maximum variation 11 parts per 1,000. Gold derived from bench gravel.
Do	7,000	702.0	288.0	10.0	Data furnished by Mr. L. F. Clar. Gold derived from bench gravel.
Boston	7,200	707.2	285.0	7.8	Do.
Do	7,500	707.5	284.75	7.75	Average of 12 clean-up returns. Maximum variation 6 parts per 1,000. Gold derived from bench gravel.
Do	7,800	707.7	284.0	8.3	Data furnished by Mr. L. F. Clar. Gold derived from bench gravel.
September	8,000	708.4	284.1	7.5	Average of 28 clean-up returns. Maximum variation 7 parts per 1,000.
Do	8,000	708.95	285.5	6.55	Data furnished by Mr. L. F. Clar.
Top Knob	9,000	706.0	....	....	Operator's estimate.
Pedro	10,700	712.0	282.0	6.0	Data furnished by Mr. L. F. Clar.
Robust	11,000	714.5	279.0	6.5	Do.
Do	11,000	712.5	279.0	8.5	Average of 2 clean-up returns.
Morning Star	11,700	675 (719.2)	257 (273.8)	68.0 (7.0)	Data furnished by Mr. L. F. Clar. Gold obtained from reworking of old dumps and contains much foreign material. Recalculated on a basis of 7 parts base metal (average of Pedro and Robust) shows fineness given in parentheses.
Black Cat	12,400	706 (716.4)	274 (276.6)	20 (7.0)	Data furnished by Mr. L. F. Clar. Gold obtained from reworking old dumps. Recalculated figures shown in parentheses.
Do	12,800	709 (720.2)	270 (272.8)	21 (7.0)	Data furnished by Mr. L. F. Clar. Recalculated as above.
Last Chance	13,300	717.25	273.75	9.0	Average of 4 clean-up returns. Maximum variation 4 parts per 1,000.
Do	13,300	716.7	275.5	7.8	Data furnished by Mr. L. F. Clar.
Foolem	14,000	724.0	270.2	5.8	Average of 6 clean-up returns. Maximum variation 7 parts per 1,000.
Do	14,000	719.0	273.0	8.0	Data furnished by Mr. L. F. Clar.
Georgey and Edith	14,500	723.25	271.0	5.75	Do.
Arlington	17,200	714–738	....	....	Operator's estimate. (See text, p. 131.) Most gold taken from bench gravel, of which fineness is said to be between 0.719 and 0.738.
Arlington and Amboy	17,500	729.64	264.18	6.18	Data furnished by Mr. L. F. Clar.
Amboy	17,800	700–740	....	....	Operator's estimate.
Bright August	19,700	735	259	6.0	Data furnished by Mr. L. F. Clar.
Happy Day	21,000	732	262.5	5.5	Average of 2 clean-up returns.
Japan	24,000	738	255.5	6.5	Data furnished by Mr. L. F. Clar.

The highest claim in which the deep gravel has been worked is the Dexter 14, just below the town of Manhattan. No data are available for the deep placer gravel of the Little Grey and Nellie Grey claims, next below, but on the Mustang Extension (Copenhagen) the gold shows a marked increase in fineness over that from the Dexter 14. The next claim from which data were obtained is the Wolfe Tone, just below the sharp bend at Wolfe Tone Point. Here the fineness is 8 parts per 1,000 less than that of the gold from the lower end of the Mustang Extension. This claim, however, was famous for the coarseness of its gold. Below this point the grade of the gold increases proportionately with the distance downstream, in the ratio of 1.6 parts per 1,000 to each 1,000 feet. The richer parts of the deep channel all lie below Wolfe Tone Point, and it is believed that the greater proportion of the gold mined from the deep channel entered the gulch at about this point, probably along Auction Gulch.

The fineness of the lode gold, as indicated by mint certificates, shows great variety. For the following figures the writer is indebted to Mr. L. F. Clar. Gold from the limestone lodes on April Fool and Litigation hills had a fineness ranging from 0.527 to 0.740, with an average of about 0.680. The gold from the prospects in the rhyolite on Bald Mountain was even baser, about 0.500. A part at least of the gold from Gold Hill (Big Pine and Big Four) was as fine as 0.717, though the average is probably lower.

The regular increase of fineness within so short a distance implies the action of a solvent in the ground water of the gulch. It has been suggested that the small veinlets on Georgey Hill and elsewhere down the gulch added enough purer gold to bring up the average fineness of the gold in the lower claims, but the regularity of the increase, as shown by Figure 15, seems to invalidate this suggestion. Moreover, these smaller veins are insignificant in comparison with the metallized area around Gold Hill, and if they had added a sufficient amount of gold to raise the average fineness to the points shown on the curve the increase in the tenor of the gravels of the lower gulch would have been enormous. It has also been suggested that to account for this increase in fineness so generally observable in placers it is necessary to suppose that both gold and silver are to some extent dissolved but that the greater part of the gold is soon redeposited.[62] But there is nothing in the appearance of the gold of Manhattan Gulch to suggest that any of it has been thus redeposited.

As already noted, the schist in the vicinity of Gold Hill is heavily pyritized below the present zone of oxidation, and the veins also contain considerable pyrite, although this is now largely oxidized at

[62] Rose, T. K., The metallurgy of gold, 6th ed., p. 97, London, 1915.

the depth to which most of the workings have extended. Wherever a constant flow of water is lacking the pay gravel of the gulch shows a coating of limonite and in places a little manganese oxide. These facts suggest that the oxidation of the pyrite in the schist and lodes of Gold Hill is responsible for the solvent action shown by the waters of the gulch. Two analyses of waters collected by Meinzer tend to bear out this hypothesis. The sample from the water-supply well sunk in the Mayflower schist near the Tonopah road, 1¼ miles southeast of Manhattan, shows the character of the ground water above the pyritiferous belt. The other sample, from a placer shaft at the mouth of Manhattan Gulch, represents the condition of the water after crossing the mineralized zone and passing down the gulch.

Analyses of ground water from Manhattan Gulch.

[S. C. Dinsmore, analyst.]

	Well near Tonopah road.			Placer shaft at mouth of gulch.		
	Total dissolved solids (parts per million).	Reacting value.[a] By weight.	Reacting value.[a] Per cent.	Total dissolved solids (parts per million).	Reacting value.[a] By weight.	Reacting value.[a] Per cent.
Na+K	16	[b]0.6	5.0	56	[b]2.2	3.9
Ca	92	4.5	37.5	397	19.8	35.0
Mg	7	.6	5.0	71	5.8	10.3
Fe	Trace.	....	....	Trace.	....	....
SO_4	69	1.4	11.7	1,174	24.4	43.2
Cl	17	.5	4.2	41	1.2	2.0
NO_3	4	.1	.8	18	.3	.5
HCO_3	236	3.9	32.5	155	2.5	4.4
SiO_2	13	.4	3.3	14	.4	.6
	454	12.0	100.0	5,926	56.6	99.9

[a] Palmer, Chase, The geochemical interpretation of water analyses: U. S. Geol. Survey Bull. 479, 1911. Rogers, G. S., The interpretation of water analyses by the geologist: Econ. Geology, vol. 12, pp. 56-88, 1917.
[b] Assuming Na>K.

The large increase in the content of sulphate in the lower water implies the oxidation of sulphides. It should be noted, however, that at the time the samples were taken pumping was in progress in several of the mines; hence the waters of the lower gulch may have contained some mine water, but its proportion would have been small compared to the total amount of underground flow in the gulch, and it represents the same type of water as that which joins the subsurface flow in the gulch. As the sulphate is balanced by the increased content of calcium and magnesium, a sufficient amount of limestone has been dissolved to neutralize the acid. Apparently the process is somewhat as follows: A comparatively pure water of the type represented by the first analysis in passing through the zone of pyritized schist receives an accession of ferric sulphate from the oxidation of the pyrite. While this remains it is an efficient solvent of the silver and base metal from the surfaces of the gold particles in the gravel. The ferric sulphate, however, soon breaks up; ferric oxide is deposited as on the stream gravel, and the sulphuric acid thus formed is immediately neutralized by the solution of lime and magnesia from the limestone of the bedrock and gravel. As long as ferric sulphate persists, however, there will be some refining of the gold. The record of a trace of iron in the analysis shows that small amounts persist, and the rusty appearance of the lower gravel in places shows that iron in solution has reached the lower part of the gulch. As this process has presumably been in operation since Pleistocene time, during periods of both aridity and comparative humidity, the time element is the principal factor, and it is not necessary to assume that any great amount of the solvent has ever been present in the water at any one time.

The important factors are believed to be the length of time in which the gold has remained undisturbed and subject to a constant flow of water and the decrease in the average size of the gold particles with increase in their distance from the source. As has been shown, the gold of the lower gravel has remained in its present position since Pleistocene time, and moreover a part of the gold was derived from preexisting placers represented by the older gravel. The size of the gold particles, as is natural to expect, likewise decreases down the gulch, the coarser and more compact nuggets being more common in the portion immediately below Gold Hill and the lower placers containing the greater amount of fine scaly gold. The fine gold, of course, offers a greater surface to the solvents contained in the stream water and hence has attained a higher degree of purity. The increase in purity of the gold is therefore believed to be dependent on the distance from the source only in so far as the gold has been sorted by size in transportation. The regular increase in proportion to distance shown by the curve (fig. 15) is believed to be in a large measure a function of the decrease in size of the gold particles. If the gold particles were of the same average size on each claim the fineness should be approximately the same throughout the gulch, for as the bulk of the gold has been undisturbed since Pleistocene time, the difference in opportunity for solution between the head and mouth of the gulch would be negligible. If data were available a similar curve showing decrease in average size of grain downstream would probably exhibit an equal degree of regularity.

No data are available in regard to possible differences in size or purity of the gold of the benches and the deep channel. The Boston claim derives its entire output from a bench 15 feet above the deep channel but shows the same degree of fineness in respect to its distance from the source as the others. On the other hand, it is said that tests of gold from the Arlington claim show difference in fineness as follows: Gold from upper bench, 30 feet below surface, $15.20 to $15.35 an ounce; gold from lower bench, 40 feet below surface, $15 to $15.10 an ounce; gold from deep channel, 60 feet below surface, $14.90 an ounce. This observation is, however, an isolated one and is not adequate to warrant definite conclusions. It may be that in this locality, where the benches are more sharply defined than usual, the gold on the benches was derived from a more oxidized portion of the vein during an earlier period of stream erosion and is therefore purer. Or it may be that local conditions favored the accumulation of finer gold on the benches than in the main channel. Although the deep channel alone has a constant flow of water, and the solvent action might therefore be supposed to be greater, the bench gravel is everywhere moist, owing to seepage from the valley sides.

The greater purity of the placer gold as compared with that of the lodes is no doubt due in part to the refinement through oxidizing processes of the gold near the outcrop. As the formation of the veins is presumed to antedate the mature erosion surface of late Pliocene age, it follows that the outcrops must have been subjected to weathering for a long period, during which the gold would be to some extent refined through solution of a larger proportion of the silver, and the gold fed to the Pleistocene gravel of the gulch was therefore purer than the average now mined from the veins. A similar condition exists with respect to the Tertiary gravels of California.[63]

Although the gold furnished to the placers may have been initially purer than that now produced by the lode mines, the regular increase in fineness toward the mouth of the gulch is believed to be due to solution, through long action of the surface water, of a portion of the silver and base metal originally contained in the gold. To raise the fineness of gold from that of the placer mines near Gold Hill, which contains about 700 parts of gold, 290 of silver, and 10 of base metal, to that of the mines at the mouth of the gulch would require the solution of 15 per cent of the silver and 40 per cent of the base metal, on the assumption that the gold remained unaffected. The fact that the base-metal content of the gold is not entirely eliminated is thus more easily understood. For it may be assumed that the solvents acted only on a thin outer zone of the individual gold particles. Within this zone the solution of the base metal may have been practically complete and sufficient silver taken out to raise the fineness of the whole particle.

[63] Lindgren, Waldemar, The Tertiary gravels of the Sierra Nevada of California: U. S. Geol. Survey Prof. Paper 73, p. 69, 1911.

As has been shown above, a part of the gold may have been derived from the older gravel, and all the gold in the lower gravel, whether added to the placers at the end of the canyon-cutting period or reconcentrated from the older gravel, has certainly been exposed for a long time, probably since the early Pleistocene, to the action of whatever solvent may be present in the water. Smith[64] has shown that the gold of certain gulch placers of Alaska likewise increases in purity away from the source, but at Manhattan the regularity of increase is unusually well marked.

OTHER MINERALS.

Aside from gold no other valuable minerals are recovered from the placers. The concentrates contain a large amount of barite, which is sometimes found in pebbles an inch or more in length. No such large masses were seen in any of the veins, although barite was found in two of the mines in the Cambrian (?) limestones.

As usual in placer deposits, the concentrates contain a large proportion of magnetite, but in many of the samples collected this is exceeded in volume by the barite. Magnetite occurs in minute sharp octahedra, nearly all of which pass through a 40-mesh sieve. The size of the grains probably averages about 0.3 millimeter. A small proportion of the black sand is nonmagnetic and appears to consist principally of psilomelane.

Cinnabar is reported from a number of the placer mines, but only very minute specks were present in the samples of concentrates collected by the writer. Although this mineral was not found by the writer in the lode deposits of the district, it has been reported in the ore of the White Caps mine, and cinnabar prospects have been worked in the mountains to the north.

Fresh pyrite was found only in very rare minute specks. Small cubes of pyrite completely altered to limonite are, however, fairly common.

Fluorite is a common gangue mineral in the mines of Mustang, April Fool, and Litigation hills, but it is extremely rare in the placer concentrates, only two or three small specks being seen.

Besides these heavy minerals the average sample of concentrates contains many minute fragments of schist, the smallest a millimeter in size, quartz both as fragments of crystals from the veins and as small dihexagonal pyramids weathered out of the porphyritic rhyolite, and small crystals of feldspar.

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[64] Smith, P. S., The fineness of gold in the Fairbanks district, Alaska: Econ. Geology, vol. 8, pp. 449–454, 1913.

RECENT WASH.

Placer deposits consisting of recent wash have been worked in the neighborhood of Gold Hill, particularly in the small gullies tributary to Auction Gulch, and to a less extent in the hills north and northeast of Central. These deposits yielded good returns but were soon exhausted, and by 1915 the only work on deposits of this type consisted in scraping the hillside north of the Big Four mine. The material consists of angular fragments of schist with little veinlets of gold-bearing quartz. The gold is coarse and angular and is evenly distributed throughout the 2 or 3 feet of angular schist débris. The material rests on older gravel, which, however, does not contain sufficient gold to be workable.

The gold from the surface placers on the north side of Gold Hill has a very low fineness. The different clean-up returns show great variation, due to foreign matter, such as shot, included with the bullion; but the gold has a maximum fineness not exceeding 0.690, which is slightly lower than the reported fineness of the lode gold formerly mined on Gold Hill. Barite seems to be entirely lacking in the concentrates from the surface material, and the only heavy minerals present with the gold are magnetite, pyrite, and limonite.

FUTURE OF THE DISTRICT.

Mining in the Manhattan district, as in many other gold-producing camps of the country, is at present (1922) in a nearly stagnant condition. Costs of supplies and labor have increased enormously in the last few years, without the compensation of an increased price of the product enjoyed by producers of other metals. Undoubtedly a return to the 1913 standard of costs would result in an increased production, but it is doubtful whether any very large output may be expected in the future.

The district has had several booms, during which large numbers of experienced prospectors carefully examined the entire region. Hence it is not likely that new discoveries of any great value will be made. Nothing of importance has developed or seems at all likely to develop from the quartz veins and lenses of the Nemo type, the product of mineralization following the granite intrusion. Deposits of this type were sought for in this region over 50 years ago, and those recently mined, as at Belmont, were originally worked in that early period.

As noted above, the productive mines of the Manhattan district lie in a narrow belt parallel to and south of the major fault. The prospects so far developed in the volcanic rocks are not encouraging so far as proved by prospecting and development, as the veins are small and irregular and the ore is spotty. On the other hand, the rich gold deposits of Round Mountain, only a few miles away, occur in post-Esmeralda intrusive rhyolite, similar to the irregular dikes of Maris rhyolite in the Manhattan district. The Tertiary rocks at Manhattan, moreover, have also been less diligently prospected than the older sediments, because as the early discoveries were made in the sediments, prospecting in the volcanic area has seemed unattractive.

The Gold Hill region has been most minutely prospected. Apparently supergene enrichment played an important part in the production of the rich ore of the upper levels of the mines on the west side of the hill, which follow definite lodes in schist. The ore does not appear to have extended anywhere to depths of more than 500 feet, and most of the ore produced has come from half this depth. From time to time lessees have mined small bodies of high-grade ore from the upper parts of the old workings and from shallow workings on small lodes in the vicinity. Such discoveries are becoming less frequent, however, and do not add greatly to the total production of the district. There seems small probability that any important bodies of ore remain in mines of this group, though a considerable lowering of costs may make some of the low-grade ore, particularly on the lower levels, worth mining.

The belt of mineralized schist extending southward from the Big Four through the Big Pine, Mayflower, Jumping Jack, and Riley Fraction still contains much low-grade material that is unavailable under present conditions. Should costs be much reduced it is possible that large-scale operations under efficient management might yield a considerable production, but probably less in amount than that already extracted.

It is more difficult to make any prediction with respect to the limestone ores. Production has been confined almost entirely to one of the five limestone beds, the White Caps limestone, although one of the upper beds has yielded ore on Mustang Hill and one of the other lower beds, the Morning Glory limestone, is said to have proved productive in the Toro Blanco workings. Yet the outcrops of these beds have been as extensively prospected as the White Caps bed.

The depth of productive mineralization in the White Caps bed seems to decrease toward the west, being greatest in the White Caps mine and least on April Fool Hill. There may be future productive mining in depth to the east of the White Caps, but no ore was found in the White Caps Extension workings at a depth of 400 feet. The White Caps and Manhattan Consolidated mines both have considerable developed and prospective ore, but they face difficult metallurgical problems in devising a thoroughly satisfactory method of treatment. Probably some ore will also be found in portions of the limestone between these mines. Developments on Litigation Hill appear to indicate impoverishment at depths of 300 to 400 feet. Above this depth, however, there is much unexplored ground in the productive limestone. This may yield some ore.

The placer mines passed the peak of their production in 1913, and the output in recent years has been small. The upper part of the gulch is largely worked out, and only small patches of ground remain here and there. The only hope of a continued placer production seems to lie in developing the extension of Manhattan Gulch out into Big Smoky Valley. Here the finely divided condition of the gold, the greater depth to bedrock, and the greater thickness and lower grade of the pay gravel will make operations less profitable.

In conclusion, it is probable that the district has passed its most productive stage. There does not appear to be much probability of new discoveries that will add greatly to the production, though the discovery of many more small ore bodies, particularly in the schist, is likely. A marked decrease in operating costs should bring about renewed activity in several of the mines that are now idle.

MINES AND PROSPECTS.

It was the writer's misfortune that his visits to the Manhattan district coincided with periods of depression. Only a few of the mines were in operation, and though the accessible workings of most of the idle properties were visited, reliable information as to past operations was difficult to obtain. Hence the individual descriptions are less complete than they would have been had the dates of visits to the district fallen more fortunately. For information as to the production of many of the mines the writer is dependent on an article by Nash.[65] Some information as to past production and development was also obtained from the Mines Handbook and from the annual volumes of Mineral Resources, and additional data were supplied by V. C. Heikes, of the United States Geological Survey.

As the placer mines are all essentially of the same type and are now for the most part exhausted, no individual descriptions of them are given.

The production of the lode mines has been derived almost entirely from the mines in the Gold Hill (Cambrian?) schists in the vicinity of Gold Hill and the White Caps bed of limestone in the Gold Hill

[65] Nash, Percival, Mines and mills of Manhattan: Tonopah Miner, Aug. 15, 1915; reprinted in part in Min. and Sci. Press, vol. 111, p. 523, 1915.

formation. The following estimate of the relative output of each type is based on the production returns of the individual mines:

	Per cent.
Mines in Gold Hill schists	50
Mines in White Caps limestone	48
Mines in other limestones in Gold Hill formation, more than	1
Mines and prospects in Ordovician and Tertiary rocks, less than	1

DEEP-SEATED DEPOSITS.

NEMO MINE (1).[66]

The Nemo mine is the only mine in the Manhattan area in which any considerable amount of work has been done on ore that belongs to the earlier era of mineralization, dependent on the granite intrusion. The mine is near the abandoned camp of Central, in a small hill north of Manhattan Gulch. So far as known it has made no production, though a little good ore was encountered.

The workings comprise a shaft from the summit of the hill and two levels, an adit level entering from the bank of the gulch 40 feet below the collar of the shaft and another level about 30 feet below the adit.

The country rock consists of dark slate, in part somewhat calcareous, with small sills of aplite parallel to the bedding of the slate. Small lenticular masses of glassy quartz were found on the adit level. These commonly contain partly oxidized pyrite and chalcopyrite, but several tons of galena is said to have been shipped from one pocket. The best assays showed a tenor of $130 a ton in gold, silver, copper, and lead. Development on the lower level was unpromising.

It is said that free gold was obtained in a prospect pit about 200 feet north of the shaft.

SHALLOW VEIN DEPOSITS IN THE TERTIARY ROCKS.

BALD MOUNTAIN PROSPECT (2).

The Bald Mountain prospect is on the south slope of Bald Mountain, 3 miles northeast of Manhattan. The workings consist of small tunnels and shafts in the andesite porphyry and surrounding sandstone of the Bald Mountain beds and extend into the overlying quartz latite. There has been faulting both before and after mineralization. Probably that of the first period was the more intense.

The ore consists of small ribbon-like veins following the crushed zones of the earlier faulting. These veinlets commonly consist of comby quartz in small sharp crystals projecting outward from the

[66] Numbers in parentheses refer to the geologic map (Pl. I).

walls. In a few places two generations of quartz crystals are present. The central part of many of the veins contains chalcedonic silica. A little glassy calcite occurs here and there as a border along one or both sides of the veins or intergrown with the quartz crystals. Small specks of limonite, pseudomorphic after pyrite, rest on the older set of quartz crystals and are apparently older than the central chalcedony and the second generation of quartz. No free gold was seen in the ore, but very fine colors are visible in the pan. The best ore is said to have a tenor in excess of $20 to the ton. So far as known this prospect has made no production.

BUCKEYE PROSPECT (3).

The Buckeye prospect is on the western slope of Buckeye Hill about half a mile from the summit of Bald Mountain. The quartz latite and the underlying Bald Mountain beds are here intruded by small dikes and sills of andesite and broken by numerous small faults, which appear to involve the andesite as well as the older rocks.

The principal workings in 1915 consisted of two tunnels, an upper one in the quartz latite and a lower one, 750 feet in length, in the underlying Bald Mountain beds and intrusive andesite.

The mineralized rock consists of small veins of comby quartz with specks of limonite and pseudomorphs of limonite after pyrite. Rarely small specks of gold can be seen in the limonite. The gold is light in color and is said to be worth about $13 an ounce.

The ore is irregular in distribution and appears to occur in small pockets. The quartz veins likewise do not appear to be continuous over long distances. The principal site of mineralization appears to be disclosed by the lower tunnel in the Bald Mountain beds, close to the andesite contact. In places postmineral faulting along the vein has formed a quartzose gouge that pans a little free gold.

WALL MINE (5).

The Wall or Summit mine is in the extreme southern part of the area mapped, close to the divide between Manhattan Gulch and Timber Hill Gulch. The workings are in a coarse breccia that irregularly mantles the older rocks northward from the crest of the ridge to a point near the bottom of the small gulch. This material resembles the Hedwig breccia, which is the earliest of the Tertiary rocks in the northern part of the area, and is probably of the same age and origin—that is, it is an old talus slope preserved by burial beneath the later volcanic rocks. Small patches of tuffaceous rhyolite resembling the Round Rock rhyolite occur on the ridge to the west, and here and there on the hillsides the presence of fragments of platy flow-banded rhyolite mixed with talus material from the older rocks is evidence of the existence of small dikes. A large dike of biotite-bearing rhyolite cuts the older rocks about a mile to the east. This breccia contains material derived from the older rocks, including the dark slate of the Ordovician and the quartzite and mica schist of the Cambrian (?) Gold Hill formation. Rare pebbles that are almost completely kaolinized may represent altered granitic material. The underlying sediments are much metamorphosed, owing to the proximity of the granite.

The principal zone of mineralization appears to follow a shear zone in the breccia, which strikes about N. 60° W. and dips steeply to the southwest. In places it appears as if the contact of the breccia with the older rocks is along a parallel fault, but this impression could not be certainly verified.

The mineralized zone that follows the shear zone is irregular but averages about 25 feet in width for a length of 200 or 300 feet and has been prospected to a depth of 40 feet, though the best ore was mined close to the surface.

The pebbles of the breccia in the mineralized zone are cemented by minutely crystalline quartz much stained with iron oxide and more rarely with manganese oxide. Here and there are patches of a white powdery material, apparently halloysite. Concentrates from this material show light-colored gold in small flakes and hackly particles, together with much cerargyrite in small light-green grains—the only known occurrence of this mineral in the Manhattan district. A small amount of fluorite is also present in the concentrates. The silver is greatly in excess of the gold, the proportion in the surface ore being 10 to 1. The surface ores were spotty but extremely rich in places. Assays as high as $2,000 a ton in silver and gold were obtained.

The deeper workings, at about 40 feet below the surface, gave assays of $5 to $8 a ton, with a higher proportion of gold. Neither visible gold nor cerargyrite is present. Across the gulch a shaft has been sunk in the crumpled black calcareous slate, and a tunnel, now caved, was driven into the hillside near by. It is not known whether any ore was obtained in these workings.

MARIS MINE (6).

The Maris "pebble mine" furnishes tube-mill pebbles for the mills of Manhattan, Tonopah, and Goldfield. The mine is outside the area included in the geologic map, about 8 miles northeast of Manhattan, on the road to Belmont, on the east front of the Toquima Range. The Bald Mountain lake beds here reach the level of the valley and in the neighborhood of the mine are cut by irregular dikes and masses of the Maris rhyolite. Apparently the action of siliceous waters, either connected with the rhyolite intrusion or possibly due to a hot spring at the time the lake beds were forming, has silicified a portion of the fine-grained shaly tuff. The bed mined is about 30 feet thick, and its outcrop can be traced for about 300 feet. The strike is here N. 10° E. and the dip 30° E. Below is clayey rhyolite tuff with small rhyolite fragments, and directly above on the crest of the hill is a few feet of banded onyx, in places showing attractive coloring. In the vicinity at a lower horizon is fine-grained tuffaceous shale carrying imperfect plant remains. The productive bed consists of slightly brecciated tuff with a cement of chalcedony. Under the microscope small angular fragments of tuff can be seen crowded without orientation in the chalcedonic matrix. It is this brecciated structure that gives the material its requisite toughness, as there are no easily developed planes of weakness such as would occur in silicified material that preserves its bedding. Near the top there is in places a little calcite, and such material is rejected. The uppermost material is also less brecciated and consequently less desirable. The banded onyx at the top is too brittle to be of value. Here and there in the vicinity there are small veinlets with comby quartz and quartz after tabular calcite. It could not be determined whether or not these veinlets were contemporaneous with the silicified tuff. According to Mr. Maris, the tuff as mined carries a small quantity of gold, not over $2 to the ton.

The material after quarrying is sorted and broken roughly to size by hand and then milled in 1½-ton lots for half to three-quarters of an hour in a tube mill. The rounded pebbles, which are of about the average size and shape of the Danish tube-mill pebbles, are then sacked for shipment. Owing to the isolated situation of the deposit and the high railroad freights it has not been possible to meet the competition of Danish pebbles over a wide area, but the tube-mill pebbles as furnished by this mine largely supply the demand in the neighboring mining camps.

SHALLOW VEIN DEPOSITS IN THE OLDER ROCKS.

BIG PINE MINE (7).

The Big Pine mine is one of the largest mines in the Gold Hill section of the district. Its production began in 1914 and was continued on a large scale to 1917 and intermittently since then. The total production is probably about $300,000, including the output from ore from leases on neighboring claims. The ore is mined principally from two large glory holes and has been developed to a depth of 200 feet. In 1915, when the mine was being operated on a large scale, the daily production was about 450 tons, of which 200 tons was milled. The cost per ton mined was about 46 cents. The material mined was coarsely crushed, and the oversize, above five-eighths of an inch, was rejected. The tenor of the ore as mined was about $5 a ton. The rejected oversize material was reported to carry less than $1, and the portion milled about $10. The average width of the ore body is between 40 and 50 feet, and the maximum about 75 feet. On the north the same zone continues in the Big Four workings and in the south on the Big Pine. There are no sharp walls, but beyond the limit of ore the tenor grades down within a short distance to $1 or less a ton.

The ore consists of little veinlets, commonly under one-eighth of an inch in width and nowhere exceeding half an inch. These consist of comby quartz, more or less iron stained and carrying small specks of oxidized pyrite and a little finely divided free gold. A few of the larger veinlets also contain quartz pseudomorphic after tabular calcite, together with a little adularia. The pyrite of the veins is oxidized even in the ore from the deepest workings, 200 feet below the collar of the shaft. In places the schist at moderate depth contains a considerable amount of pyrite in small fresh crystals, either irregularly disseminated or embedded in the schist along joint planes. This material is said to be barren. Most of the little veinlets follow either the bedding of the schist and sandstone or a prominent vertical joint system that strikes between N. 20° E. and N. 40° E.

The tendency of the veinlets to break off along the walls, which allowed concentration by screening, was most pronounced near the surface. In 1919 the deeper ore, besides showing a somewhat lower tenor, no longer exhibited this tendency so strongly; hence it was necessary to mill all the material mined.

BIG FOUR MINE (8).

The Big Four mine began production in 1909 and from 1910 to 1913 was worked on a large scale. In the later part of 1913 the declining tenor of the ore in depth caused the closing of the mill. Since that time the output has been intermittent and has come entirely from small operations by lessees. The total production is probably about the same as that of the Big Pine.

The mine has been developed by a shaft 500 feet in depth. At the time of visit water stood at the 400-foot level. The Joker tunnel, from the north side of the hill, near the gulch, joins the Big Four workings on the 200-foot level. The ore is similar to that of the Big Pine mine and consists of minute quartz veins that in a general way follow the joints, which form a well-defined system with average strike N. 35° E. and dip 80° SE. and a less distinct system with strike N. 5° E. and dip 68° W., and the bedding planes of the schist and sandstone, which here strike N. 20°–40° W. and dip 38°–78° SW. The ore body in places seems to follow the direction of a small fault vein, which strikes about N. 30° E. and dips steeply to the northwest and which is possibly the same vein as that developed in the Jumping Jack mine. The largest stope is over 100 feet in drift length and 50 feet in maximum width.

The ore, at least as far as the 300-foot level, is completely oxidized; only rarely are small grains of pyrite observable. It is commonly iron stained. Patches of manganese oxide are present here and there, but manganese oxide is much less prominent than in the ores of the mines on the western slope of the hill, which follow definite fault fissures. The small veinlets consist largely of quartz and adularia, for the most part pseudomorphic after tabular calcite. The interstices between the intersecting plates carry adularia crystals and in places drusy quartz. Here and there are specks of limonite pseudomorphic after pyrite, most commonly resting on the quartz crystals or in microscopic specks in the pseudomorphic adularia that follows the outline of the original calcite crystals. Gold can be occasionally seen in minute specks embedded in the adularia or resting on the quartz crystals. No association of the gold with the oxidized pyrite or with the rather rare patches of manganese oxide was observed. The average tenor of the whole of the ore mined in the first part of 1913 was $8.32 to the ton, but very rich streaks of high-grade ore were encountered here and there. This rich ore does not differ in general appearance from the other small veinlets in the schist. The deepest ore stoped was on the 465-foot level.

Here and there small veins of bluish glassy quartz as much as 1½ inches in width cut the schist irregularly. These veins are barren and appear to have no effect on the distribution of the ore in the later veinlets.

Besides the principal ore body small stringers of high-grade ore of similar type have been mined by lessees at several points on the property, on both the Big Four and the Joker claims, particularly northeast of the shaft. These stringers, however, have not been developed in depth. The body of mineralized schist mined on the Big Pine apparently extends north into the Big Four ground.

The loose material on the hillside north of the shaft carried sufficient gold to mine as placer ground. The underlying older gravel was not productive.

MAYFLOWER MINE (9).

The Mayflower claim adjoins the Big Pine on the south and includes a part of the same ore body. Ore has also been mined from a shaft in the eastern part of the claim. According to Mineral Resources this mine produced ore in 1909, 1913, 1914, and 1917. A large part of the production came from the southward extension of the Big Pine ore body mined in connection with the Big Pine operations.

The workings from the shaft were not accessible at the times of visit. Fragments of ore picked up from the dump of the main shaft are of the same general type as the ore of other mines of Gold Hill. Iron-stained schist is veined along the joints by thin stringers that consist of quartz and adularia, largely replacing lamellar calcite. Manganese oxide is present but rather rare. In one specimen patches of manganese oxide are associated with specks of free gold. In most of the specimens, however, the gold is associated with the adularia and quartz. Small crystals of pyrite, largely oxidized to limonite, occur in the schist but not in the veins.

In the summer of 1919 lessees were mining on another part of the property near the west end of the claim. Here a fault striking N. 53° E. with a dip of 54° NW. had been followed to a depth of 40 feet. Along the fault and in the footwall the schist was irregularly fractured and cemented by minute veins, consisting chiefly of quartz, in part pseudomorphic after tabular calcite, adularia, and a little calcite. In one specimen free gold in clusters of minute crystals rested on drusy crystals of adularia. Patches of gougy manganese oxide along the fault plane and parallel to it are said to be practically barren.

RILEY FRACTION MINE (10).

The Riley Fraction includes the southern continuation of the disseminated ore mined in the Big Four and Big Pine mines. According to Mineral Resources it first produced in 1913. Apparently no important production was made after 1914. Nash estimates that about $100,000 worth of ore was mined.

The schist and accompanying sandstone beds strike about N. 70° W. and dip 45° SW. These beds are cut by small stringers of quartz and lamellar calcite, in large part replaced by quartz stained irregularly with iron and manganese oxide. The accompanying gold is extremely fine grained. The veinlets are less than half an inch in width and commonly follow either the bedding or the joints, which generally strike N. 20°–30° E. and dip steeply to the northeast. The long axis of the open cut strikes N. 5° E., in accord with the ore body of the Big Pine. The open cut is about 200 feet long by 60 feet wide to a maximum depth of about 30 feet below the surface. The ore had a tenor of $3 to $4 a ton. Here, as in the other deposits of this type, the gold content falls off gradually on the sides of the ore body. Here and there the schist is cut by irregular branching veins of barren glassy quartz.

JUMPING JACK MINE (11).

The Jumping Jack mine lies just west of the Big Pine and was one of the first properties developed at Manhattan; it made its first production in 1906. It is mentioned in Mineral Resources as an important producer in 1906, 1907, 1910, and 1913. In 1919 the mineralized schist along the boundary of the Big Pine claim was being prospected by the lessees of the Big Pine property.

The principal development work has been done along a crushed zone, 2 to 10 feet in width, which strikes N. 25°–30° E. and dips 65°–70° NW. This zone has been developed by an inclined shaft that follows the dip and by levels at depths of 80, 125, and 225 feet on the incline.

The mineralized zone carries ore similar to that of the other mines of Gold Hill, consisting of small stringers of quartz and calcite. The lode has been developed for a distance of about 600 feet and stoped extensively though irregularly. In places small stringers along the bedding have been followed for short distances.

The ore developed in the eastern part of the claim is similar to that of the Big Pine and reported to be unprofitable under present mining costs. Small veinlets cutting the iron-stained schist carry comby quartz and quartz pseudomorphic after lamellar calcite, the surfaces of the lamellae coated with minute adularia crystals. Here and there are small botryoidal masses and more rarely small streaks of manganese oxide.

The gold in the stringers is free, and the bullion returns seen by the writer show an average of 715 parts of gold and 268 parts of silver per 1,000.

GOLDEN CRATER MINE (12).

The Golden Crater mine was not accessible at the time of visit. According to Mineral Resources, it was a producer in 1908 and 1915. So far as could be seen from material on the shaft dump the ore consisted in part of irregularly silicified limestone containing much manganese oxide and in part of schistose ore similar to that of the Big Four mine. It is reported that some very rich ore was produced. A shaft close to the border of the Riley Fraction claim shows a zone of shearing striking N. 25° E. and dipping 57° NW. Brecciated schist cemented by small quartz veinlets of the same type as the ore of the Riley Fraction and Big Pine appears to form the ore.

UNION NO. 9 MINE (13).

The Union No. 9 mine was one of the first properties operated in the Manhattan district and was a large producer as early as 1911, but except for a small amount of work done by lessees it has been idle since 1914. Nash gives $500,000 as the total production to that time.

The principal vein strikes N. 10° E. and dips 60° W. It has been explored to a depth of 600 feet down the dip, but no ore was found below the 400-foot level and only small patches below 300 feet.

Besides the main vein there is a vein known as the Wall vein, which strikes N. 45° W. and dips 70° NE. This is faulted by the principal vein, on whose west side it is offset about 30 feet to the north. A smaller vein parallel to the principal vein and 30 feet to the east has yielded a little ore on the 200-foot level.

Most of the ore occurs between well-defined walls along which there has been recent movement. Two ore shoots were developed. One near the shaft, pitching steeply to the south, has an average drift length of 50 feet and an average stoped width of 3 to 6 feet and is said to have yielded some ore from the surface to and below the 300-foot level; the other ore shoot is smaller and follows the northward-dipping intersection of the main vein and the Wall vein. The country rock is fine-grained gray quartzose schist of the usual type, more or less pyritized and commonly showing small mica flakes transverse to the cleavage. Specimens of ore from the 50-foot level show brecciated schist cemented by irregular quartz veinlets. The quartz is mostly in small sharp crystals arranged in comb structure on the walls of the veins. Here and there little nests and discontinuous veinlets of comby quartz occur in the schist. Rare specks of free gold rest on the surface of the drusy quartz crystals. In the larger veinlets irregular septa of quartz cross the center of the veinlets, and the intervening spaces are partly filled with sooty manganese oxide.

In places the vein filling consists of small intersecting flakes of quartz, pseudomorphic after tabular calcite. These are in part covered with minute adularia crystals. Rarely the fine-grained quartz shows gashlike indentations, due to the solution of tabular calcite crystals.

Here and there the ore is stained with iron oxide, but the black manganese oxide is much more prevalent. The high-grade powdery ore found in pockets near the surface is commonly highly manganiferous. The vein material on the dump, probably from the deepest part of the shaft, shows pyrite associated with the quartz.

In another part of the claim a small vertical fissure striking N. 20° E. has yielded a small amount of similar ore from a narrow crushed zone between fault walls.

STRAY DOG MINE (14).

The Stray Dog mine is one of the oldest in the district and in the early years of the camp was one of the main producers. Production began in 1906 and continued to 1909. Since that time a small output has been derived from small-scale operations by lessees.

A shaft 165 feet in depth follows a mineralized fault zone, probably the same as that developed by the Union No. 9 mine. The lode strikes N. 15° E. and is vertical at the surface but dips steeply to the west in depth. The surrounding schist, which strikes N. 65° E. and dips 30° SE., contains thin calcareous beds.

North of the shaft several small stopes along the fault reach the surface. The ore is similar in character to that of the Union No. 9 but is said to decrease greatly in tenor at a comparatively shallow depth.

LITTLE GREY MINE (15).

The Little Grey mine is near the western limit of the productive part of the district, about northwest of the summit of Gold Hill. The mine was first reported as a lode producer in 1910, but dry washing of the surface material had yielded some gold as early as 1906. Lode production was reported for the years 1910 and 1915. Most of the production has been obtained by lessees. The total has apparently not been large, although according to Nash the Briggs-Evans lease in the early days of the camp yielded $120,000 in ore averaging $22.50 to the ton.

The country rock consists of quartz-mica schist of the usual type, with a few bands of quartzite and here and there the thin, somewhat calcareous layers characteristic of the upper part of the Gold Hill formation. The slate has here a gentle westerly dip. A well-marked fault of unknown displacement with an average strike of N. 20° W. and a dip of about 60° W. cuts the slate. The shaft passes through Pleistocene gravel to a depth of 40 feet. This gravel is also exposed in the open stope south of the shaft.

The mine is developed by an inclined shaft following the fault, with levels at depths of 50, 100, 200, and 300 feet on the incline. The schists are pyritized and contain small veinlets of quartz with minor calcite, but the ore produced has come mainly from a major vein along the fault zone. The greater part of the ore was mined from a large stope, which extends from the surface nearly to the 300-foot level. The maximum length at the surface is about 100 feet, and the ore body is said to have been from 5 to 20 feet wide. The pitch of the ore shoot is about 70° N., parallel to the principal direction of slickensiding on the walls.

A smaller ore body averaging 6 feet in width some distance to the south has been mined on the 300-foot level for 110 feet on the drift and about 40 feet down the dip.

The vein in the upper levels consists of a network of quartz stringers cementing fragments of slate between well-defined walls marked by gouge. Associated with this quartz is a powder of iron and manganese oxides and finely divided free gold. The tenor of the best ore is said to have been about $40 a ton. A little calcite occurs on the 100-foot level, but apparently not above. Postmineral movement along the fault is shown in places by the presence of crushed quartz in the gouge. In places this gouge carries gold.

On the 100-foot level there is a marked split in the vein; one branch, as yet unexplored, follows a northerly direction. On the same level a crosscut 120 feet to the west has cut a similar fault zone about 2½ feet wide, filled with stringers of quartz and calcite.

The ore in the lower ore body appears to have been largely unoxidized. The foot and hanging walls are well defined, generally with heavy gouge, particularly along the footwall. The ore here consists of crushed fragments of pyritized schist cemented by quartz-calcite veinlets carrying a little auriferous pyrite. The grade of ore was much lower than in the upper stope. The gouge on the walls in places consists largely of crushed quartz and calcite and carries gold. Here and there, particularly on the lower levels, veinlets of calcite with chlorite are encountered. These are said to be also auriferous, and possibly they represent the earlier phase of mineralization. So far as could be seen they have no relation to the later vein system.

The gravel resting on the schist, which at the shaft reaches as far as the 50-foot level (about 40 feet vertically), is well cemented and contains large boulders of andesite, rhyolite, and schist but little Ordovician limestone and slate. It is said to be barren where cut in the mine workings at the outcrop of the vein, but recent prospecting a short distance to the west is reported to have shown encouraging results. The contact with bedrock is irregular, and the gold is probably concentrated in small channels. There is no evidence of shearing or faulting in the cemented gravel.

THANKSGIVING MINE (16).

The Thanksgiving shaft is on the western point of Mustang Hill, a short distance west of the Mustang workings. The mine has been idle for several years, but some production is reported to have been made in the early days of the camp.

The shaft follows the fault that extends westward from April Fool Hill. This fault is here nearly vertical. A small dike of rhyolite tuff has been intruded along the fault plane between the Gold Hill and Ordovician sediments. Levels were run at depths of 50 and 175 feet below the surface. The mine workings, now largely inaccessible, seem to have been chiefly within the Gold Hill schists.

DEPOSITS IN LIMESTONE.

WHITE CAPS EXTENSION MINE (17).

The White Caps Extension property includes a large number of claims east and northeast of the White Caps mine, including the Thelma prospect, which is described on page 160. A 400-foot shaft, the joint property of this mine and the Zanzibar, its neighbor on the north, is 2,000 feet east of the White Caps shaft. The shaft was sunk during the 1918 boom, to develop the White Caps limestone east of the White Caps mine. Although coarse white calcite was encountered in places, so far as known no ore was developed. The property has been idle since 1918.

ZANZIBAR MINE.

The group of claims comprising the Zanzibar property adjoins the White Caps group on the east. The principal working is a 400-foot shaft on the boundary between this property and the White Caps Extension, the joint work of the two companies. A long tunnel enters the hill just south of the road and extends southward into the hill. The portal is in the Zanzibar limestone, but the overthrust fault, which here dips about 45° SW., is crossed at about 150 feet, and beyond this fault the tunnel crosses the lower members of the Gold Hill formation, including the two lower limestone members (the Pine Nut and Morning Glory limestones).

WHITE CAPS MINE (18).

The property of the White Caps mine follows the outcrop of the White Caps limestone. The main shaft is near the head of Consolidated Gulch, about 1¼ miles east-southeast of Manhattan.

The company was organized in 1906, and the first important production was made in 1911. A mill, the joint property of the White Caps and its neighbor the Manhattan Consolidated, was built and operated during 1913 and part of 1914. The peculiar character of the ore made treatment difficult. As the depth increased the ore was found to be entirely unamenable to cyanidation, and work was soon abandoned.

The report of the company made in March, 1915, showed the following production of ore:

Ore produced at White Caps mine, 1911–1915.

Year.	Dry tons.	Gross value.
1911	1,249	$53,050.95
1912	7,199	152,008.51
1913	8,055	139,721.08
1914–15	3,406	36,272.95
	19,909	381,053.49

The average gross value was $19.14 a ton. The revenue from this production was as follows:

Royalties earned from leases		$26,966.75
Sales of ores and bullion	$22,349.40	
Less marketing costs	3,448.68	
		18,900.72
		45,867.47

During this period the total operating costs had amounted to $65,683.82, leaving a deficit of $19,816.35.

The company was reorganized in June, 1915, under the presidency of John G. Kirchen, of Tonopah, and early in 1916 began vigorous development work and at the same time conducted many experiments to find a satisfactory method of treating the peculiar ore.

Early in 1917 development work had reached the 425-foot level, and the tonnage of ore was considered sufficient to justify the erection of a mill. The method adopted consisted of crushing followed by roasting and cyanidation. It was necessary to control the temperature carefully in order to volatilize the stibnite and realgar without permitting the formation of the nonvolatile oxide of antimony or of excessive amounts of quicklime from the calcite of the ore.

The mill was started in September, 1917, and operated until the fall of 1918. The report of the company for the year ending April 30, 1918, showed sales of gold to the amount of $110,254. For May, June, and July, 1918, a production of 8,480 tons yielded $81,540. The method of extraction did not prove entirely satisfactory, and various changes were made in the process. Among others the addition of sodium bicarbonate was found to give better extraction.

Apex litigation was a very considerable source of expense during the later part of 1917 and the beginning of 1918. The Morning Glory property adjoins the White Caps on the west and includes a portion of the productive limestone bed. The irregular nature of the mineralization and the uncertainty as to whether the transverse fissures or the limestone itself should be considered the lode were the causes of the contention. The suit was decided in favor of the White Caps in May, 1918. The trouble and expense were partly redeemed by the detailed and accurate geologic work done by Messrs. McCraney and Dynan, of the White Caps staff. This work, though undertaken in connection with the litigation, has proved of great value to the development of the mine.

The mill was closed down in January, 1920, and shipments of realgar were made to the Tacoma smelter. These reached a total of 1,496.4 tons, having a content of 669,392 pounds of arsenic and

$38,146 in gold. Developments in depth gave ore that yielded a lower content of realgar, and shipments were discontinued. Since that time development work has been continued. The mill was reopened in 1922, and according to the latest information available[67] a satisfactory recovery was being made.

In 1920 the mine was developed by seven levels, the lowest at a depth of 800 feet below the collar of the shaft. Recent work has extended the depth to 920 feet. The ore is all within the White Caps limestone, which is cut by four major faults, known as the East, White Caps, West, and Morning Glory faults, besides a vast number of minor faults. The main faults strike in a general northeasterly direction and dip to the southeast at varying angles, commonly from 40° to 70°. As shown on the maps and sections (figs. 8, 9, and 10 and Pl. X), the displacement along these faults is considerable.

In the southwestern part of the workings the Morning Glory, West, and White Caps faults appear to unite; hence the fault blocks are wedge-shaped. There has been movement on these faults since the principal period of ore deposition, although the realgar appears to be of later date. The minor faults, on the other hand, are clearly premineral, and where they cross the mineralized limestones they are so thoroughly cemented by the ore as to be hardly observable.

The two principal zones of mineralization lie on the two sides of the White Caps fault. The East ore body has yielded ore from the surface to the 800-foot level. It has a steep easterly pitch, which brings the ore against the East fault below the 550-foot level. The minor premineral faults seem to be more closely spaced in the ore than in the unmineralized limestone and have probably served to localize the ore. The section through the East ore body (fig. 10, p. 87) shows the relations of the two systems of faulting. In a few places the ore and mineralized limestone occupy the entire thickness of the limestone bed and have a horizontal section of as much as 100 by 30 feet. The change from unaltered limestone is fairly sharp, though not all the mineralized limestone carries sufficient gold to be classed as ore. In places large masses of coarse calcite (Pl. XI, *A*) are practically barren.

The ore west of the White Caps fault occurs in the upper levels as two more or less distinct bodies, known as the West and Shaft ore bodies. These coalesce in depth and abut against the White Caps fault between the 450 and 550 foot levels. Workable ore has been obtained from the 100-foot to the 550-foot level.

The limestone east of the East fault has been prospected in two places only, on the 310 and 800 foot levels, and as yet no ore has been found in it.

[67] Eng. and Min. Jour., vol. 114, p. 657, Oct. 7, 1922.

The 310 and 550 foot levels have also been extended to the southwest, and the block of limestone lying to the west of the junction of the Morning Glory, West, and White Caps faults has been developed. On the 310-foot level irregular mineralization has produced some patches of ore, and on the 550-foot level recent work has developed a promising ore body. This work has revealed the same repetition of the limestone bed as was found in the Manhattan Consolidated mine, apparently the result of faulting nearly parallel to the strike.

The mineralogy of the deposit is discussed on pages 97–108 and need be considered here only briefly. The ore from the 100-foot level and parts of the 200-foot level was sufficiently oxidized to permit a fair recovery by cyanidation. Below the water level, which was reached at about 150 feet, the abundance of stibnite and realgar made special treatment necessary. The following analyses, made in the laboratory of the Mackay School of Mines, Reno, Nev., prior to the summer of 1915 and furnished through the courtesy of Mr. Percival Nash, represent the ore from the upper levels:

Analyses of ore from White Caps mine.

	1	2	3	4	5
Insoluble (SiO_2)	44.6	67.6	50.3	55.8	43.0
Al_2O_3	1.8	1.8	1.5	1.8	.4
CaO	21.1	5.14	8.16	7.2	18.0
MgO	.7	.9	2.7	3.17	4.0
Fe	4.8	7.6	8.4	8.9	6.1
S	1.38	3.5	4.0	8.2	4.3
Sb	8.76	6.78	6.78	.71	.6
As				1.44	.6
Mn				.12	.2
Balance largely CO_2.					
	83.64	94.12	82.33	85.32	77.2
Gold, ounces per ton	1.35	.79	1.35	1.02	.77
Silver, do				.02	

1. East ore body.
2. Shaft ore body.
3. West ore body.

(1–3: Possibly antimony content as given includes arsenic as well.)

4. Location not given; apparently same analysis as in Dynan's paper.
5. Quoted from Kirchen, J. G., Eng. and Min. Jour., vol. 104, p. 906, 1917.

The realgar and orpiment are largely confined to the East ore body. The orpiment is present in minor amount only and is rarely found as low as the 450-foot level or in any quantity above the 310-foot level. Realgar is present below the 310-foot level to the bottom of the mine but occurs in greatest abundance between the 450 and 665 foot levels. As the arsenic-rich ore shipped to the smelter in 1920 carried an average of 22.3 per cent of arsenic, it will be seen how greatly the realgar percentage increased from the upper levels to this depth. On the 800-foot level it is present in small amount only.

Stibnite occurs throughout the mine but is more prominent in the West ore body, particularly about the 310 and 450 foot levels.

The water level is said to be at a depth of about 150 feet, and the ore taken out above this depth was largely oxidized. Whenever any of the major faults were crossed in the course of development work heavy flows of water were encountered, which continued until the impounded water in the block penetrated had been drained. A particularly bad flow resulted from cutting the overthrust fault in the shaft between the 665 and 800 foot levels.

MORNING GLORY MINE (19).

The property of the Morning Glory mine consists of two claims, just north and west of the White Caps and between the White Caps and Manhattan Consolidated properties. The mine was not in operation during the writer's stay in the district, and the workings were not examined.

The property covers portions of the White Caps limestone. The westernmost workings are on the same segment as the West ore body of the White Caps mine, and conflicting claims as to apex gave rise to litigation which was decided adversely to the Morning Glory company. Work on this block is said to have reached a depth of more than 400 feet, and some ore is reported to have been developed. Another and deeper shaft is about 600 feet east of the Manhattan Consolidated shaft. There are fragments of Zanzibar limestone on the dump, so this shaft must have cut the overthrust fault. It is not known whether any ore was developed from this shaft.

The mine has been idle since 1918.

MANHATTAN CONSOLIDATED MINE (20).

The main shaft of the Manhattan Consolidated mine is about 1,800 feet west of the White Caps mine, and the ore is found in the same block of limestone. The mine was among the early producers of the camp and according to Mineral Resources was the largest producer in 1907. A mill on the south bank of the gulch was the joint property of the Manhattan Consolidated and White Caps mines until it was sold to the White Caps in 1915. In this mine, as in the White Caps, the ore at comparatively shallow depth proved difficult to treat, and large operations were soon discontinued. Between 1908 and 1915 a small production was made, chiefly by lessees. Since that date operations have been confined to development work. Nash states that the production to 1915 amounted to 9,075 tons of ore, with a gross value of $127,000.

In the summer of 1919 the mine had been developed by five levels to a depth of 500 feet. The 100 and 500 foot levels were not accessible at the times of visit. The vertical shaft cuts the overthrust fault below the 400-foot level, and the same difficulty with water was encountered as at the White Caps mine.

A normal fault known as the Mud fault, from its great thickness of gouge, strikes about N. 30° E. and divides the mine into two parts. The dip is about 70° S. at the surface but flatter in depth. This fault offsets the outcrop of the White Caps limestone about 400 feet to the east on its south side.

East of the fault the mineralization is of the same nature as that in the western part of the White Caps mine. The ore body was formed by the replacement of limestone on both sides of a small northerly fault, which is older than the Mud fault. Coarse white calcite is prominent, particularly near the edges of the mineralized area. The best ore is a dark quartz, much like that of the White Caps but containing only a little if any microscopic arsenopyrite and a much larger amount of pyrite. Stibnite is present in small amount in drusy cavities in the dark quartz and in the limestone and calcite. Realgar is occasionally found but is rare. Small crystals of realgar have been found in the gouge along the Mud fault, particularly near the surface.

Like the similar deposit of the White Caps mine, this ore body contains no free gold. The ore differs from that of the White Caps, however, in that a considerable proportion of silver is associated with the gold. Bullion from the East ore body is said to have a fineness of about 0.620.

The limestone bed is repeated on the 300-foot level west of the fault, apparently as a result of faulting closely parallel to the strike. No mine maps were available, but the accompanying sketch map of the 300-foot and 400-foot levels (fig. 12, p. 91), made hastily by compass and pacing, though inaccurate as to details, shows the general relations.

The ore west of the Mud fault differs markedly from that of the East ore body. Instead of forming a large replacement body the mineralization was closely associated with small fault fissures, producing the so-called "vein deposits." Four of these have been developed: two follow northeasterly faults of small throw; another, less well defined, follows a fault that is nearly parallel to the strike of the limestone, apparently a reverse fault; and the fourth is the result of rather irregular mineralization along the top of the limestone.

The mineralization in the ore shoots west of the Mud fault did not extend for more than a few feet from the controlling fissure, and the ore shoots are small and irregular. Both coarse calcite and fine-grained quartz are present. These occur as replacement deposits along the bedding of the limestone, thinning out away from the fissure. The quartz resembles that of the White Caps in texture but is lighter in color, bluish gray rather than black. Pyrite is present, but the minute specks of arsenopyrite found in the White Caps are probably lacking.

Irregular solution channels, in places following the dip of the limestone for 300 feet or more, are common in the limestone near the fissures. These channels contain irregular deposits of muddy material, apparently chiefly limonite and manganese oxide, in which are found rare specks of wire gold. Although formerly watercourses, they were all dry when cut by the drifts.

Fluorite is plentiful in the ore west of the fault. It is found in amber and green crystals, partly filling the larger cavities in the fine-grained quartz, and is nowhere associated with the coarse calcite. Stibnite and realgar appear to be lacking in the western part of the mine.

A long crosscut on the 300-foot level, run for the purpose of exploring the ground to the south of the limestone, encountered only unmineralized schist and quartzite.

UNION AMALGAMATED MINE (21).

Two of the claims of the Union Amalgamated Co., the Union No. 2 and the Earl, cross the outcrop of the White Caps limestone on Litigation Hill and have been developed extensively. Mining began in 1908 and continued intermittently to 1917. The mine was idle at the times of visit. According to Nash this property had yielded up to 1915 9,615 tons of ore, with a gross value of $183,848. No work has been done since 1918.

The property is developed to a depth of 700 feet on the dip of the limestone by an inclined shaft and several levels. The productive workings are entirely within the White Caps limestone.

The limestone is faulted extensively, and because of the lack of mine maps the geology could not be clearly made out. The major faults strike northeast and show evidence of postmineral movement. On the lowest level from the Earl shaft there appears to be the same repetition of the limestone bed as was observed in the White Caps and Manhattan Consolidated mines, apparently the result of faulting parallel to the strike.

The mineralization followed northerly faults of small displacement, apparently an older series than the major faults with northeasterly strike. Near these fissures the limestone is irregularly replaced for short distances along certain of the bedding planes. In places the limestone is irregularly altered to coarse white calcite. The principal gangue mineral is quartz, commonly occurring in massive fine-grained form replacing the limestone. It is blue-gray in color and contains disseminated pyrite. The replacement of the limestone by quartz has resulted in decrease in volume, and drusy cavities elongate parallel to the bedding are common. Most of these cavities contain fluorite crystals and rarely quartz of a later generation in small sharp crystals resting on the fluorite. Adularia is present in small amount. Here and there later calcite with a little pyrite is also present. In one specimen collected from the 700-foot level quartz is intergrown with sericite or leverrierite.

Apparently almost all the ore was taken from the upper levels, and the development work in depth was unproductive.

UNION NO. 4 MINE (22).

The Union No. 4 claim of the Dexter Union Mines Co. lies at the west end of Litigation Hill. Its production has not been large. The White Caps limestone here strikes N. 68° W. and dips 48° SW. An inclined shaft 120 feet deep follows the dip of the limestone, which flattens to 42° a short distance below the surface. The limestone, which shows in places irregular alteration to coarsely crystalline white calcite, is cut by small fissures that fault it slightly. The mineralization followed these fissures and extended outward for short distances into the limestone. The ore consists largely of dark quartz and also contains fluorite. It replaces the limestone along the bedding for short distances from the fissures. The concentrates show very finely divided particles of free gold. There is considerable gouge in places along the fissures, apparently indicative of post-mineral movement.

APRIL FOOL MINE (23).

The property of the Seyler-Humphrey Gold Mining Co. consists of a group of claims in the central part of the district, two of which, the April Fool and the Tip Top, cover the central and western parts of April Fool Hill and include the outcrop and dip slope of the White Caps limestone from the point of the hill to the overthrust fault at the crest. It was here that the first discovery of ore was made in 1905. After the initial production of very rich ore in 1906 the property was never a large producer, although some output has been made by lessees, particularly since 1915.

The productive work has been confined entirely to the White Caps limestone and done at shallow depths only.

The outcrop of the limestone has been developed throughout its length by several shafts, which were inaccessible at the time of visit, and by irregular shallow workings. Besides these shallow workings three tunnels on the west side of the hill cut the limestone at greater depth.

The ore in the outcrop workings occurs along fissures that cut the limestone and in places fault it slightly. These commonly strike between N. 25° E. and N. 35° E. and are nearly vertical. Mineralization also extended outward along the bedding of the limestone for short distances from the mineralized fissures. The fissures extend into the schist above the limestone but are productive only in the limestone. These small veins carry calcite, in part replaced by dense quartz, comby quartz, fluorite, and a little adularia resting on the drusy quartz crystals. Minute spherical aggregates of sericite occur in the vugs resting on the quartz or more rarely on the adularia crystals. Small specks of limonite after pyrite occur in the more massive quartz. Free gold in small sharp crystals and hackly specks most commonly occurs close to the limonite. Where "specimen ore" is found the gold is commonly in platy masses along one wall of a little veinlet.

Ore of this type has yielded nearly all the production of the mine. The distribution of the gold is extremely irregular, and the workable ore was in small pockets that contained from 1 to 5 tons. The largest body mined measured 40 feet along the outcrop by 20 feet in depth, following a 3-inch vein.

In places the ore was very rich. One small pocket yielded ore assaying over $8,000 a ton. The gold content diminishes sharply at shallow depth, and no high-grade material has been found more than 30 feet below the surface.

The northernmost of the small tunnels cuts the overthrust fault, which is here marked by a dike of rhyolite breccia, and enters the limestone beneath the top of the hill at an altitude of 7,230 feet, or about 100 feet below the highest point of the outcrop. Some ore has been obtained from small fissures in the limestone, which here seem to follow two systems, one trending nearly due north and dipping about 85° W. and the other trending N. 70° E. and dipping north. Along these fissures there has been a slight replacement of the limestone by dark-blue fine-grained quartz. This contains small drusy vugs in which the projecting crystals show staining by iron oxide and also carry small blebs of manganese oxide.

A tunnel on the west side of the hill cuts the limestone at about 60 feet vertically below the outcrop. Here mineralization of a similar type along a small fault that strikes N. 20° W. and dips 70° W. has apparently yielded a little ore.

The lower tunnels have, so far as known, produced no ore. The limestone is dissolved out along solution channels approximately parallel to the bedding, and these cavities, which are in places large enough to crawl through, are lined with peculiar inverted domes that consist largely of banded quartz and sericite with minor fluorite and chalcedony. Material of this type is particularly prominent in the lower of the two tunnels, which follows the hanging wall of the limestone at a depth of about 100 feet below the outcrop. The material contains gold, but not in sufficient amount to constitute ore. The upper of the two lower tunnels also contains roughly banded veins cutting the limestone, which is silicified near the fissures. The filling of these veins consists of irregular bands of fluorite next to the walls, followed by drusy quartz. The projecting quartz crystals are in places thickly coated with little crystals of calcite.

RED TOP PROSPECT (24).

The Red Top prospect, on the south slope of Toro Blanco Hill, near Consolidated Gulch, was in operation during the 1918 boom. According to Weed,[68] the developments consist of a 200-foot shaft with crosscuts and drifts on the 110-foot level. Owing to a heavy flow of water, with which the mine equipment was not adequate to cope, work was abandoned in 1918 and was not resumed.

The dump shows a considerable amount of Morning Glory limestone and also a little of the Zanzibar limestone, which was apparently the last material hoisted. Presumably the flow of water was encountered on cutting the overthrust fault.

It is not known whether any production was made.

TORO BLANCO MINE (25).

The Toro Blanco is the only mine in the district that has found ore in the Morning Glory limestone, the next lower limestone bed below the White Caps limestone. So far as known, however, it has made no important production.

On the southeast side of April Fool Hill the limestone is rather sharply folded, and its attitude changes within a short distance from a flat northerly dip to one of about 40° SE. In the northward-dipping portion irregular workings have penetrated the hill for about 200 feet, following the dip. Here joints and very minor faults contain small veins of compact quartz, which in places extend for short distances out into the limestone along the bedding. These veins have been followed by the irregular tunnels and are reported to have yielded good ore in places.

An inclined shaft follows the dip of the limestone in the southeastward-dipping portion. Water stood in this shaft at a depth of about 100 feet, so its total depth is unknown. A short drift above water level gave no evidence of valuable mineralization.

On the hill east of the road, known as Toro Blanco Hill, the same limestone bed, which closely follows the slope of the hill, is pitted with shallow workings.

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[68] Mines Handbook, 1920, p. 1064, 1921.

MUSTANG MINE (26).

The Mustang is the only productive mine in the upper group of limestones of the Gold Hill formation. The limestone is here about 30 feet thick and is apparently the same bed that crops out on Wolfe Tone Point, on the south side of the gulch. It is white and finely crystalline but in places is largely altered to diopside. On the top of the hill the limestone is cut off by the same overthrust fault that cuts the lower limestone on April Fool Hill. To the north of the fault is the basal quartzite of the Toquima formation of the Ordovician.

The limestone is mineralized in places and has been mined in a large open cut near the summit of the hill. The open-cut workings appear to have followed irregular little veinlets in the altered limestone. These veinlets are mostly approximately vertical and follow the joint planes, which here have an average strike of N. 30° E.; a few of them occur along the bedding planes, which strike N. 75° E. and dip 55° NW. The veinlets are for the most part fine-grained quartz, which replaces the limestone along the fissures and resembles that found in the mines of Litigation Hill. The quartz is commonly brown from oxidation of the disseminated pyrite. Only rarely are small pieces found which show the usual blue color and contain small specks of fresh pyrite. The quartz is cavernous, and some of its small drusy cavities contain crystals of pale-green fluorite. More rarely, near the surface, a little leverrierite is found in the joint cracks of the limestone.

Most of the production has come from the pipelike deposits of quartz and leverrierite. These are roughly circular and are commonly less than a foot in diameter, though the principal pipe at about 6 feet below the surface had in one place an elliptical cross section with axes 5 and 2 feet. At greater depth the principal pipe is roughly circular in section and about a foot in diameter. This pipe follows the bedding near the upper edge of the limestone and although irregular in detail appears to owe its position to the intersection of the bedding and one or more joint planes. Here and there smaller pipes branch off from the trunk, but they have not proved valuable. The filling consists largely of leverrierite with a little quartz, particularly near the rim. Around the pipe for 2 or 3 inches the limestone is replaced by fine-grained quartz similar to that of the replacement veinlets of the open cut. The leverrierite is faintly iron stained and locally contains small specks of partly oxidized pyrite. Gold occurs in small crystals in the leverrierite and in the nests of drusy quartz which occur here and there in the pipes.

The principal pipe is said to have yielded over $40,000 in free gold to a depth of 45 feet.

BRONCHO MINE (27).

The Broncho mine is on the east side of Mustang Hill. According to Mineral Resources it made some production in 1908 and 1909. The shaft, which at the time of visit was accessible to the 50-foot level, is on the same fault that passes through the Mustang and Thanksgiving workings. Here the fault stands about vertical. As in the Thanksgiving shaft, there is a dike of rhyolite tuff along the fault plane between the limestone in the Gold Hill formation on the south, which here wedges out against the fault, and the Mayflower schist on the north.

A short distance south of the shaft an open cut in the limestone shows irregular silicified streaks roughly parallel to the bedding. Besides quartz these carry fluorite and pyrite and a little free gold. Leverrierite, which is so prominent on the same limestone bed just to the west, on the Mustang claim, appears to be lacking.

SUNSET PROSPECT (28).

The Sunset prospect is of interest as being the only place in the district where notable amounts of barite were found and the only place where the upper limestone of the Gold Hill formation contains stibnite.

The prospect consists of a tunnel 480 feet in length, starting in the Mayflower schist and passing through the schist and quartzite of the upper part of the Gold Hill formation. At 150 to 210 feet from the portal the tunnel passes through light-brown, rather dense crystalline limestone, which is mineralized for a short distance along the hanging wall. The commonest type of mineralization consisted of irregular replacement along the bedding planes by fine-grained white quartz in irregular bands. The quartz in places is drusy. In the interstices of the intersecting quartz bands is powdery limonite. Here and there small barite crystals rest on the surface of the quartz, and barite is to some extent intergrown with the quartz. Where the quartz is more massive it contains small grains of pyrite. In places the limestone near the quartz also contains small specks of pyrite and is cut by small irregular streaks of white calcite carrying a little iron oxide.

Another type of mineralization consisted of replacement of the limestone by fine-grained barite that contains stibnite, both in stellar aggregates and in irregular veins, as if cementing the fractured barite. The stibnite, particularly that of the larger crystals, is in part oxidized to valentinite but retains the form of the original stibnite crystals.

The material contains a small amount of gold, but the assays have not been sufficiently encouraging to justify development work.

OSO MINE (29).

The Oso mine, near the mouth of Black Mammoth Gulch, was not in operation at the time of visit. The production has not been large.

Three levels have been opened at depths of 30, 70, and 115 feet. The workings follow a nearly vertical fault, which in different parts of the workings strikes between north and N. 33° W. This fault cuts gray limestone, apparently the Zanzibar limestone, and may be the northward continuation of the fault that limits the Gold Hill formation on the south. The limestone is cut irregularly by small veinlets containing calcite, siderite, and quartz, which appear to be barren. There is also here and there a small quantity of coarse white calcite in the limestone. In places a seam of coarse calcite adjoins the fault.

From the first level to the surface for about 40 feet from the shaft there are narrow stopes along a streak of crushed material from 6 inches to a foot wide. This material is in places rich in free gold, which shows in the pan delicate feathery and arborescent forms. The second level was blocked by waste at the time of visit, so it is not known whether the ore extended to this depth. The third level appears to have been unproductive.

In places along the first level the workings extend up into coarse cemented gravel that marks the bottom of an old stream channel cut down along the soft material of the fault zone. The pebbles are chiefly slate and limestone but include a few of rhyolite, so the gravel is to be correlated with the Pleistocene stream gravel rather than with the Miocene Hedwig breccia.

As the gold is found only in the clayey fault gouge and does not extend to any great depth, its position is presumably the result of deposition by supergene waters, such as formed the rich surface ores of April Fool Hill.

BLACK MAMMOTH PROSPECT (30).

Black Mammoth Hill consists of dark limestone and calcareous slate capped by the quartzite at the base of the Toquima formation. On the southern slope of the hill the limestone and slate are cut by small, generally vertical seams with an average strike of N. 10° W., most of which seem to follow faults of small displacement. The vein filling consists chiefly of crystalline calcite. Quartz is present in minor amount and is apparently later and to some extent replaces the calcite. The veins cut cleanly across the limestone, and the mineralization did not follow the bedding planes as in the limestones of the Gold Hill formation.

Gold occurs in these small veins close to the surface, usually in flat flakes along one wall between the limestone and the vein filling. Although no large amount has been produced a little rich ore has been obtained.

In 1919 a vertical shaft was being sunk on the south side of the hill. It was the intention of the operators to crosscut to the north at depth.

THELMA MINE (31).

The Thelma property is now owned by the White Caps Extension Co. The workings consist of small tunnels and shafts on the hill north of the White Caps mine. Ore rich in silver is said to have been discovered, but so far as known the only production has been a small yield in 1908.[69] Some ore in sacks at the principal shaft showed iron-stained silicified Zanzibar limestone cut by small stringers of comby quartz and quartz intergrown with calcite. The mineralization seems to have followed a vertical fissure that strikes N. 33° E., and the alteration of the limestone has proceeded outward from this fissure along the bedding. In some places the limestone is silicified and heavily iron stained, and elsewhere it carries a little pyrite.

One of the small tunnels follows a 2-inch vein that carries small amounts of quartz and consists largely of orthoclase and muscovite with minor fluorite, evidently being closely allied to the alaskite dikes which crop out in the vicinity. The orthoclase is largely altered to sericite in irregular fine-grained aggregates. These sericite patches also penetrate the muscovite and fluorite to some extent. Near the workings, particularly close to the large alaskite dike, the limestone is in places completely altered to a lime silicate rock and contains small flakes of molybdenite.

[69] U. S. Geol. Survey Mineral Resources, 1908, pt. 1, p. 498, 1909.

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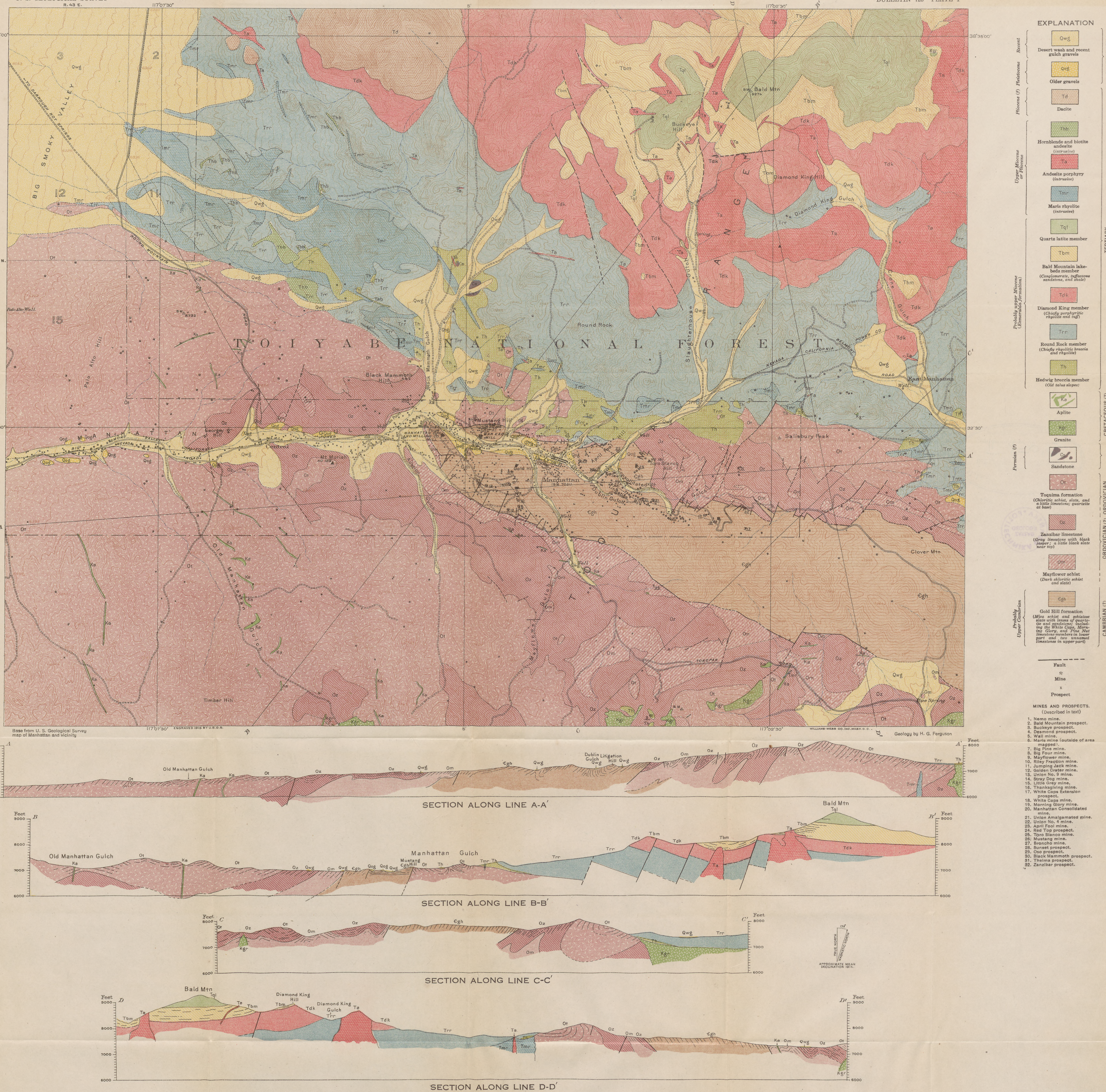

GEOLOGIC MAP AND SECTIONS OF THE MANHATTAN DISTRICT, NYE COUNTY, NEV.

Scale $\frac{1}{24000}$

1 ½ 0 1 Mile

1 ½ 0 1 Kilometer

Contour interval 25 feet.

Datum is mean sea level.

1923