Tombstone
and its
Mines

A Report upon the *Past* and *Present*
Condition of the

MINES OF TOMBSTONE

Cochise County, Arizona
to the
Development Company of America

By
WILLIAM P. BLAKE
Mining Engineer

New York
1902

Arranged and printed at
THE CHELTENHAM PRESS
New York

NEW HAVEN, *July* 28, 1902

THE DEVELOPMENT COMPANY OF AMERICA
NEW YORK CITY

Gentlemen :—

I have the honor to submit a Report upon the Geology and Mines of Tombstone, Cochise County, Arizona.

Respectfully yours

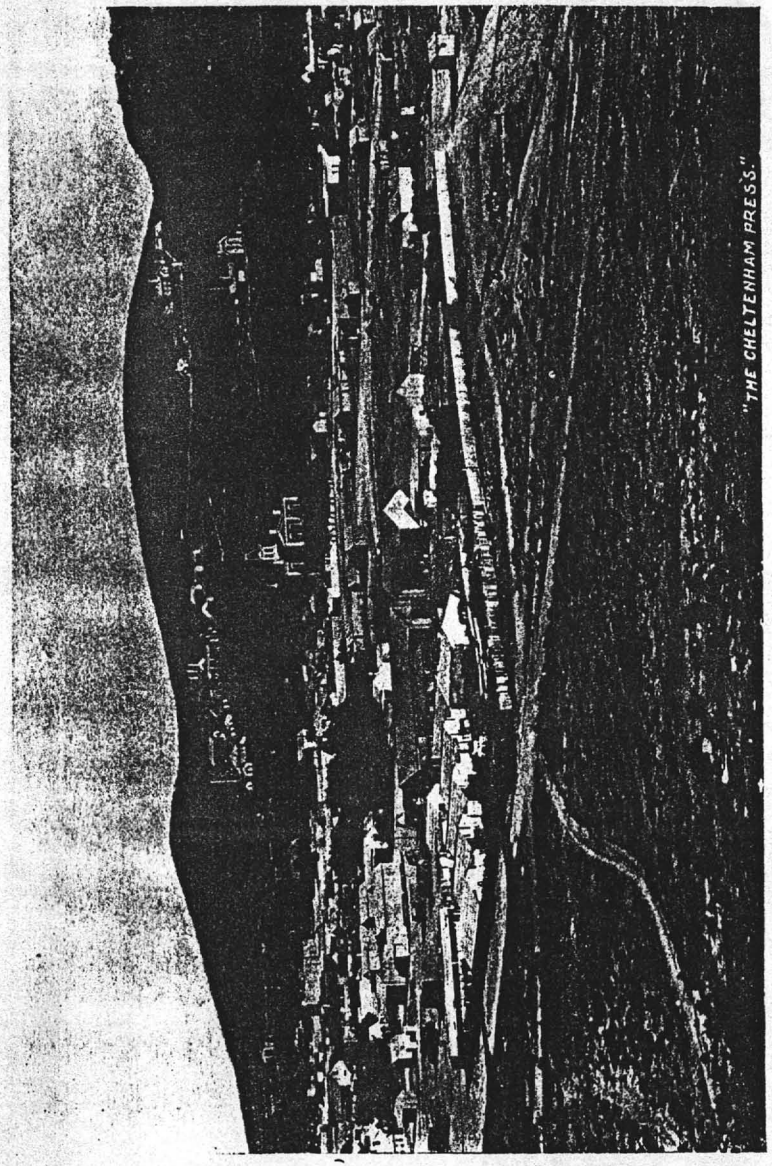
WILLIAM P. BLAKE
Mining Engineer

TUCSON, ARIZONA
and
NEW HAVEN, CONN.

Contents

A List of Illustrations

The Plates



CITY OF TOMBSTONE
Showing, in the background, Grand Central, Contention, and other important mines now owned by The Tombstone Consolidated Mines Co., Ltd.

The Veins and Mines of Tombstone, Arizona

Chapter One—Introductory

Location and History

THE mining district of Tombstone is in Cochise County, Arizona, in the Mule Mountains, known, also, as the Mule Pass Range. It extends from the San Pedro River eastwardly towards the Dragoon Mountain range and has a general altitude of from 4400 to 4600 feet above tide water. The city of Tombstone, including the chief mines, is in latitude 31° 40′ and longitude 110°. It is about 40 miles north of the international boundary line—24 miles south of Benson, on the Southern Pacific trans-continental road, and is 9 miles east of the San Pedro River at the place known as Fairbank, upon the two lines of railway extending southward from Benson, one line being the International, from Benson to Guaymas via Nogales; the other, the Arizona and Southeastern, extending from Benson to Bisbee via Naco Junction, and now extended to Douglas and points eastward towards Deming and El Paso. The surveys have been made and the grading has commenced for a branch

road from Fairbank to Tombstone and beyond. This branch will supersede the nine miles of staging between Fairbank and Tombstone and will give all rail connection with the overland trunk lines. Even now passengers leaving Tucson in the afternoon reach Tombstone early in the evening, but when the road is completed from Fairbank to Tombstone the trip will be much shortened in time and will be by rail for the entire distance.

The grading for this road is progressing rapidly, and it is expected that trains will be running to Tombstone by the end of the year. It is being built by the owners of the El Paso & Southwestern, generally understood to be the firm of Phelps, Dodge & Co., of New York.

Mr. F. M. Murphy, President of the Development Company of America, who has been specially connected with the development of railway communication in Arizona and is President of the Santa Fé, Prescott & Phœnix Railway, has projected a line to extend eastward from Phœnix by way of Florence and the valley of the San Pedro to Benson, where it will connect with the Southern Pacific and with the El Paso & Southwestern, leading to Fairbank, Tombstone, Bisbee, Naco and Douglas. This line, when completed, will place Tombstone in rail connection with the Santa Fé system via Phœnix and Prescott.

The Tombstone Consolidated Company up to the middle of the year 1902 had hauled from Fairbank and erected at the mines an aggregate weight of five hundred tons of machinery and supplies, including four great boilers, each weighing twenty-five tons. These required a specially constructed wagon, a considerable expenditure upon the road, and a team of thirty-four horses.

The position of Tombstone relatively to the railways and to other prominent mining camps is shown upon the accompanying small map of the region (Fig. 1, p. 13).

This map shows the two north and south valleys of the Santa Cruz and of the Santa Pedro, each having its source in Sonora, Mexico, and flowing northwards to the Gila of Arizona.

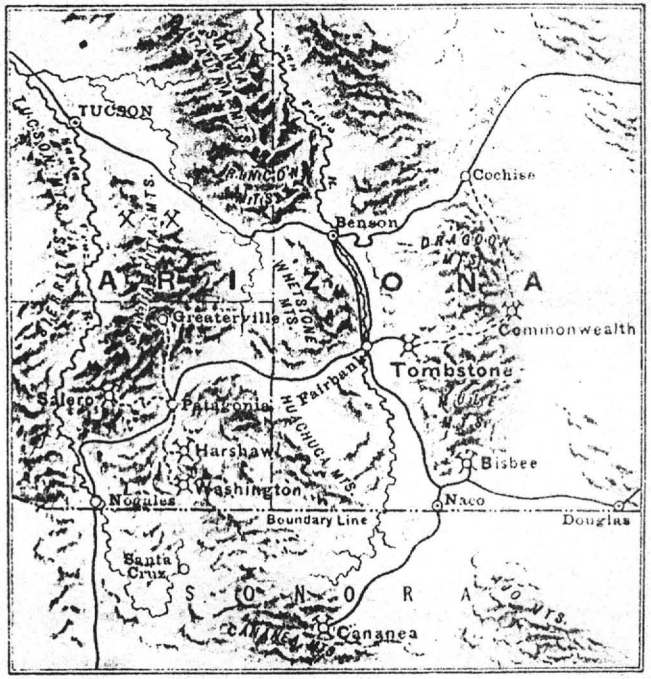


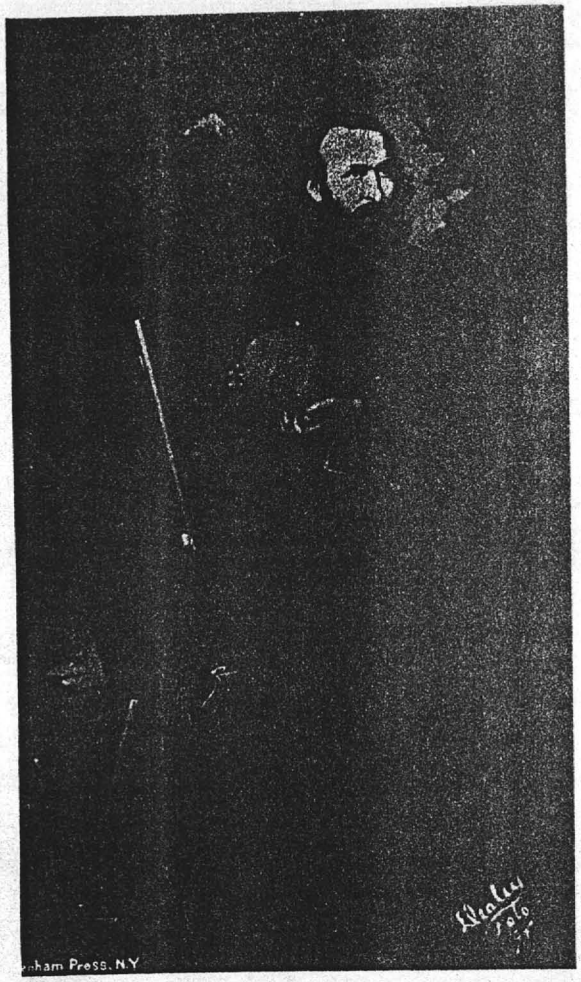
FIG. 1. *Sketch Map to Show Position of Tombstone.*

Discovery by Schieffelin

Up to the years 1877 and 1878 the Tombstone District was a comparatively unknown and unexplored region. It was infested with the murderous Apache savages, and few prospectors dared to go there. Being nearly in the center of known and promising mineral-bearing districts it excited the hopes and expectations of prospectors, but was not explored until Edward L. Schieffelin, braving the danger from the Indians, penetrated to its center and discovered its hidden riches.

Schieffelin had found evidences of mineral wealth in a remote part of the region as early as 1877, and in the spring of 1878 he started from Huachuca with the intention of thoroughly prospecting the Mule Mountains, in which he felt sure great deposits of the precious metals would be found. His expedition was considered a very hazardous one, and Schieffelin was advised to take his tombstone with him. His enterprise and courage were rewarded by finding a heavy outcrop of rich ore at the very surface of the ground. The profusion of ore lying nearly flat, and the absence of any well-defined linear outcrop, it would appear, were somewhat puzzling to him, for he located a claim transverse to the trend of the mineralizing vein and called it the *"Toughnut,"* and to the district he gave the name of *"Tombstone."* Returning with his samples to the settlements he persuaded his brother, Albert E. Schieffelin, and Richard Gird to join him in locating and working other claims.*

*Edward L. Schieffelin was born in the year 1848 in Western Pennsylvania, and moved with his father to Rogue River valley in Oregon. At the age of twenty-two years he went to the State of Nevada, where he worked for a time in the mines and then went prospecting, which was his favorite occupation. He reached Northern Arizona, and as far south as Signal and Wickenburg, on the Hasayampa. Here he joined a party of Indian scouts going to Camp Huachuca, on the west side of the San Pedro, where he left them and crossed the valley to prospect the Mule Mountains, then one of the most dreaded haunts of the bloodthirsty Apache Indians. Making his way alone between the hills he



These locations and the splendid results of mining operations, adding millions of wealth to the country, form a sufficiently enduring monument to the memory of Schieffelin. His remains, in accordance with his dying request, were interred at the summit of the Granite Hill, near the city of Tombstone, and are surmounted by a massive monument of granite bowlders, a view of which from a photograph will be found at the end of this report.

Within four years after the discovery over one thousand claims had been located. The richness and extensive character of the ore-bodies attracted widespread attention, and development was rapidly extended until Tombstone became generally known as one of the most important mining districts of the country. Mines were opened in all directions, the hills were dotted with hoisting works, mills were erected on the San Pedro; a city of thousands of inhabitants sprang up, water was brought in from the tops of the distant Huachuca Mountains, and the greatest mining activity prevailed.

camped the first night near a small rivulet of water, among the granite bowlders, about seven miles east of the river. His prospecting was rewarded by the discovery of the rich ore on the claim which he staked off and called Toughnut. He took samples with him back to the settlements, some say to Globe and others to Tucson, where his brother Albert was working and Richard Gird was assaying. The results of the assay of the samples being highly satisfactory a partnership was formed and the three went to the claim and commenced the development which soon made Tombstone famous in the annals of mining.

Later, in 1880, the Schieffelin Brothers and Gird sold their interests. Gird removed to the Rancho del Chino, California, Al Schieffelin died of consumption and Edward resumed the life of a prospector, reaching as far north as Alaska, but made his home with his mother in Alameda, California. He was on a prospecting tour at the time of his death, about the 14th of May, 1897, alone in his cabin twenty miles from Canyonville, Oregon. All suspicions of foul play or suicide were removed by the evidence. His watch and money were found upon the body, also business papers and his plans for the immediate future.

On May 17, 1897, his brother, Charles L. Schieffelin, telegraphed to Tombstone a request of his brother that when he died he should be buried on the top of the granite hill about three miles west of Tombstone, where his body was laid to rest on Sunday, May 23, 1897, with impressive services. The wife, the mother and his brother were present. The funeral address was given by Colonel William Herring.

W. P. B.

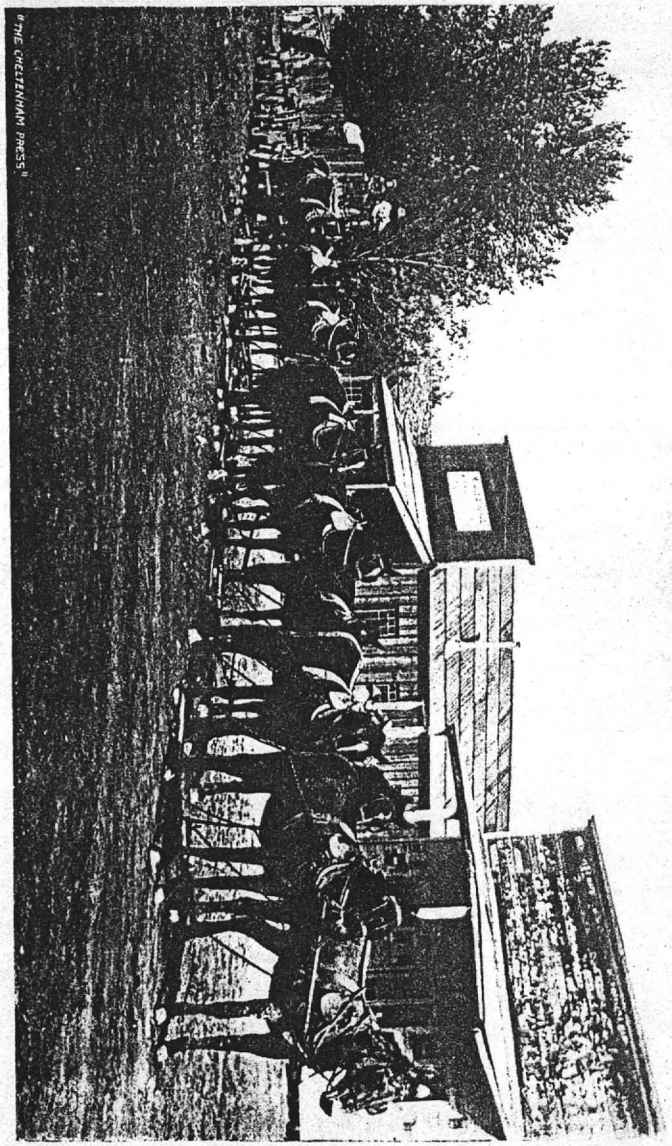
Construction of Mills

Mr. W. F. Staunton writes:*

"Phenomenally rich ore in great abundance led to the speedy construction of mills, and by June, 1879, the Gird 10-stamp mill, the first in the District, and the machinery for which was hauled over 300 miles in wagons from Fort Yuma, on the Colorado River, then the terminus of the Southern Pacific Railway, was started. The ore averaged over $100 per ton in value, and the tailings about $25. Other mills followed quickly, and there were soon 150 stamps dropping on Tombstone ore. It was a dry camp. There was no water available for milling near the mines, and the mills were all located on the San Pedro River, at distances ranging from eight to ten miles away and involving an expenditure of $3.50 per ton for hauling the ore. Wages and supplies were very high; railroads were hundreds of miles away, and the new camp was beset with difficulties of all kinds; but such was the richness of the ores and their abundance that, notwithstanding the difficulties and the fact that treatment of the ores was not at first understood, a large part of the values passed into the tailings.

"Mining was vigorously prosecuted with every prospect of continued success in the numerous claims until a vast body of water was found at the same general level and it became necessary to erect large pumping plants. Two were installed, one upon the Grand Central Claim and one upon the Contention. These powerful pumps steadily lowered the level of the water, showing that it could be controlled. It was also made evident that the surrounding mines were so connected by subterranean passages below the water-level that they could not be independently drained, and that concerted united action would be necessary to an equitable division of the expense.

* Letter of June 29, 1901, to the Development Company of America.



A SIXTEEN-HORSE TEAM HAULING TOMBSTONE ORE

"The camp was at first a dry one, and the mills were located on the river, thus involving the necessity of an expensive wagon haul. There was little in the appearance or surroundings of the camp to suggest the existence of water, and when it was struck in the Sulphuret shaft, at the comparatively shallow depth of 500 feet, it was a surprise to all. Other shafts, including the Contention, Grand Central, West Side, Head Center and Empire, reached the water soon after, and demonstrated that it was to be found at practically the same level throughout the District. The mines at this time were still working in high-grade ore bodies far above the water, and no doubt was felt as to easily pumping it out and continuing down when it should become necessary. The Grand Central Company installed a line of direct-acting steam pumps capable of raising 500,000 gallons in 24 hours; but, to the surprise of all, the withdrawal of this amount of water produced no appreciable effect. The Contention Company then put in a plant of 12-inch Cornish pumps at an expense of about $150,000, and capable of raising 1,000,000 gallons in 24 hours, and again the attempt to sink was made, but it soon became evident that the combined capacity of the pumps was inadequate. The Grand Central then put in a line of 14-inch Cornish pumps of 1,500,000 gallons capacity, and at a cost of in the neighborhood of $200,000, and together the two Cornish plants gained steadily on the water and sinking below began. But much valuable time had been lost, and from a lack of appreciation of the seriousness of the problem the rate of dividends had gone on undiminished, without retaining an adequate reserve for contingencies. Furthermore, there was a lack of harmony among those concerned which prevented the attainment of the best results.

The Water Controlled

"A depth of 100 feet below water-level was reached, and it was demonstrated that the water could be controlled; that it was, in fact, a basin which, once exhausted, could be held in check with a moderate expenditure for pumping. Other mines than the Grand Central and Contention took advantage of the recession of the water and began pushing down, proving the continuance of the ore below the water and its excellent grade. Both the Grand Central and the Contention shafts were vertical, and it was necessary to cross-cut for the ore-bodies. This was going on and very rich ore found—that in the Contention assaying about $100 per ton in gold. Up to this point (May, 1886) the situation was good. The mines were still working in ore above the water, and it had been conclusively shown that the water could be controlled and mining go on indefinitely when a disastrous fire utterly destroyed the fine Grand Central hoisting works and pumping machinery. There is no doubt that the Contention pumps could have held the water in check alone after this disaster until other machinery could have been put on the Grand Central, but differences arose between the companies and pending the settlement of these the pumps were stopped and the shafts allowed to fill. Finally, through the carelessness of a watchman, the Contention plant took fire, and its complete destruction postponed indefinitely the working of the mines below the water."

After this succession of disasters several unsuccessful attempts to effect a consolidation of the various interests were made, and meantime deep mining at Tombstone was suspended. For years past some of the mines have been worked only in a small way on ore-bodies remaining above the water level.

Consolidation of Interests

The Tombstone Consolidated Mines Company, Lt., recently organized, has succeeded in accomplishing the long desired consolidation of the mines, and has secured over seventy claims in the district, including all the more important mines, the superficial area of the claims so secured being, approximately, two square miles.

The list of claims in this consolidation includes:

The Contention Consolidated Mining Company, four claims.
The Grand Central Mining Company, twenty-six claims.
The Tombstone Mill & Mining Company, eighteen claims.
The Head Center & Tranquillity Mining Company, four claims.
And other claims of different companies, together with all mills, millsites, buildings and machinery.

This control and ownership permits of the adoption of a general plan of working to the best advantage, and the reopening of the mines at the most important and desirable points.

New Shaft and Pumps

The Company has already located a new general shaft and has completed it to the water-level. This shaft measures 7 feet by 22 feet in the clear and has four compartments, two for hoisting and two for pumping. A substantial double engine flat-cable hoist is now being erected, and every modern desirable appliance is being added to insure rapid and economical work.

The American Bridge Company has supplied a steel headframe 79 feet high and 30 feet wide. The shaft house will be constructed of steel and made fire-proof.

The pumps are supplied by the Prescott Steam Pump Company of Milwaukee. They are of the direct acting type, triple expansion, with steam cylinders in pairs, of 39 in.,

23 in. and 15 in. diameter. Diameter of water plunger 13 in., stroke 24 in. These pumps are 33 ft. 7⅜ in. in length, 9 ft. 8 in. wide and more than 6 ft. high. These powerful pumps will throw 1,750 gallons of water per minute, which is nearly 60 per cent. more than the combined pumping capacity of the old Grand Central and Contention pumps. They will be placed at the water-level in chambers excavated for them, and two will be laid down there, one to be in reserve.

Other pumps of the same type have been ordered and are under construction, that are proportioned to a 1,000 foot lift and will be ready to install when that depth is reached. All the above will be stationary and the falling water-level will be followed down by four movable pumps called sinkers. These will have 14 in. steam cylinders, water cylinders 8 in. and a stroke of 12 in. Each will throw 800 gallons per minute, an excess that is necessary to provide for moving them in succession without stopping the discharge of water.

There will be four 200 horse-power boilers of the Morrison corrugated internal furnace type, each 10 feet in diameter and 15 feet long. Crude oil will be used for fuel.

This pumping plant will be one of the finest in America. It is of large capacity, but the lift required will be quite moderate. There is a large territory to be drained, for the seams and areas of crushed rock give the water access from one part of the District to another.

The weight of all this material is above a million pounds, exclusive of the hoisting engines, which are already on the ground. The machine shop of the Contention and Grand Central mines has been refitted and is now in use.

The great advantages resulting from the consolidation of interests, aside from the necessity of united centralized effort for the unwatering, are evident. There is not only a great saving in the cost of administration but of working. Instead of independent hoisting works, each with a corps of engineers, firemen and attendants, with the cost of maintenance

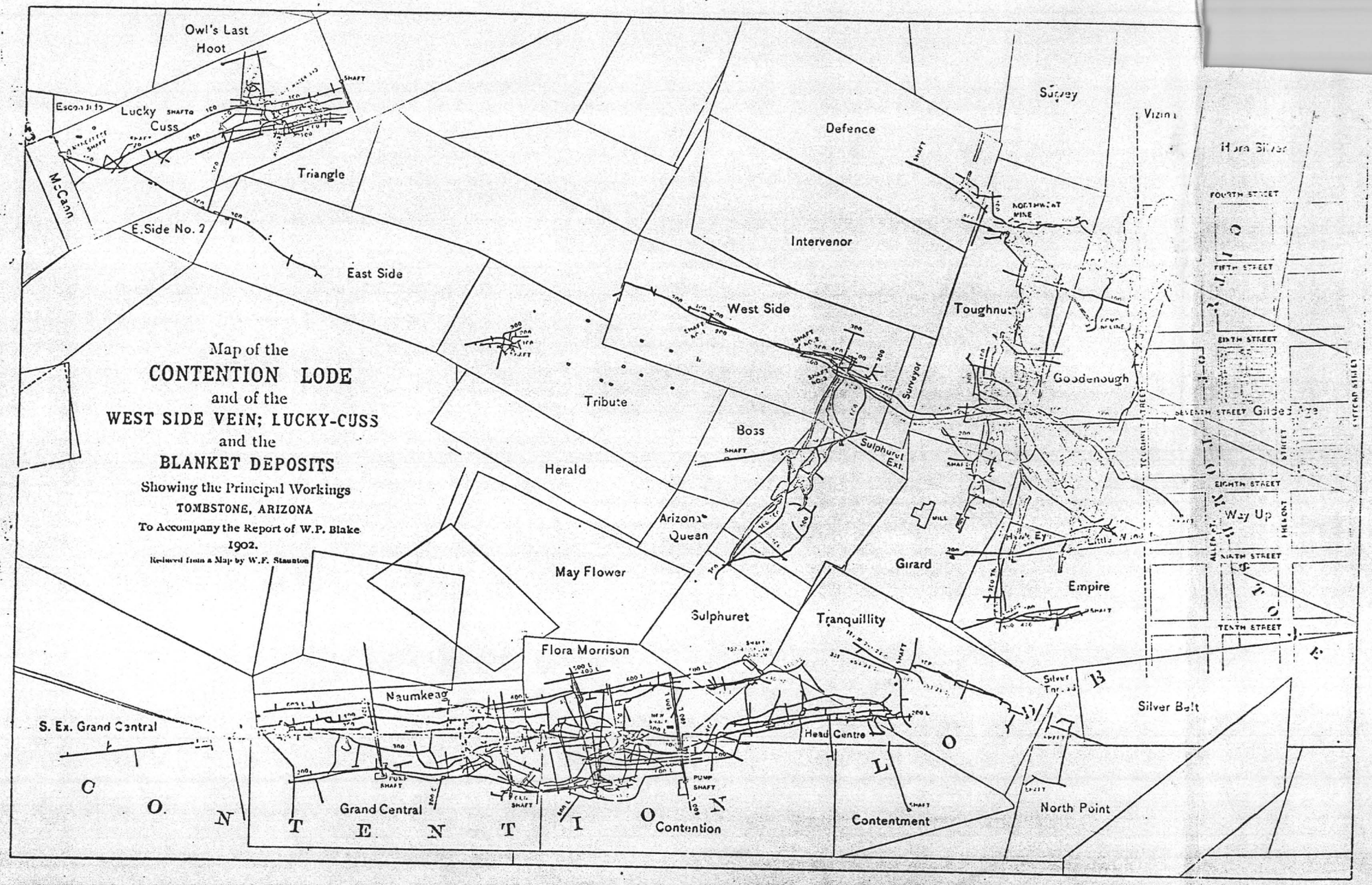
of independent shafts, one central hoisting plant suffices for several claims. Instead of separate underground workings without connection or unity the mining can be projected and carried forward on one comprehensive plan. The office work is lessened and centralized, and fewer large salaries have to be paid. Thus the cost of production per ton is greatly lessened. Costly and vexatious litigation is avoided.

The rapid development of such great stores of mineral riches made every foot, indeed every inch, of length upon the lodes of great value. It is not surprising, therefore, that in the complexity of end lines and side lines, fractional claims and irregularities of locations all under different ownership, differences should have arisen which could be settled only by the courts.

Extent of Workings

Important and costly suits were instituted, involving questions not alone of territorial right but of the nature and extent of the lodes, requiring the most careful underground surveys and the services of experts in mining and mineral deposits. We are indebted largely to this costly and animated litigation in 1882 for suites of elegant maps and sections of the mines and for the intimate knowledge gained of the structure, direction and value of the lodes and deposits. Since the consolidation of interests and the merger of properties and values in the new company their maps and data have become common property and are now deposited in the office of the Company at Tombstone. Dividing lines have ceased to be lines of contention and waste of energy.

The many miles, said to be over twenty, of galleries, drifts, cross-cuts, shafts and winzes in the several properties of the Contention-Grand Central Lode, especially those of the lower levels, are in good condition to-day and have become the property of the new Company. These workings are of great value, giving as they do immediate access to


Map of the
CONTENTION LODE
and of the
WEST SIDE VEIN; LUCKY-CUSS
and the
BLANKET DEPOSITS
Showing the Principal Workings
TOMBSTONE, ARIZONA
To Accompany the Report of W.P. Blake
1902.
Redrawn from a Map by W.F. Staunton
Owl's Last Hoot
Lucky Cuss
Triangle
McCann
E.Side No. 2
East Side
Tribute
Herald
Boss
Arizona Queen
May Flower
Sulphuret
Flora Morrison
Naumkeag
S. Ex. Grand Central
Grand Central
Contention
Defence
Survey
Intervenor
West Side
Surveyor
Sulphuret Ext.
Toughnut
Goodenough
Girard
Empire
Tranquillity
Head Centre
Contentment
Silver Belt
North Point
Hora Silver
Vizina
Way Up
FOURTH STREET
FIFTH STREET
SIXTH STREET
SEVENTH STREET
EIGHTH STREET
NINTH STREET
TENTH STREET
Gilded Age
CONTENTION

different parts of the property, saving hundreds of thousands of dollars which would otherwise have to be expended in exploration preparatory to deeper work.

This combination is one of the notable examples of the value to the laboring man, and to the community at large, of the consolidation of interests. Without such unison the mines would lie idle to-day as for nearly two decades past, but by united effort they are re-opened; Tombstone is resurrected—repeopled—and is connected by rail with the great trans-continental lines.

This beneficent condition has been largely brought about by the personal influence and energy of Hon. E. B. Gage, now the President of the Tombstone Consolidated Mines Company, whose likeness from a photograph appears as the frontispiece of this Report.*

Mr. Gage has changed his residence from Prescott to Tombstone and now occupies the home and offices formerly the headquarters of the Tombstone Mill & Mining Company. He will give his direct personal attention to the work of development and operation of the consolidated properties, and will be aided by W. F. Staunton, M.E., General Manager of the Company, and formerly Superintendent of the Tombstone Mill & Mining Company's mines, and also by

* Mr. Gage was born in Pelham, New Hampshire, Oct. 2, 1839. He was educated in boyhood at the Common School, and at the age of fifteen entered the Preparatory School at Phillips Academy, Andover, Massachusetts, and went from there to Dartmouth College, where he was graduated in the Scientific Department in 1858. In the winter of the year 1877 he went to Arizona, and in April of 1878 he purchased an interest in the Grand Central Mines, then recently opened, and has been connected with that property ever since as President and Superintendent.

In the year 1892 he took up the matter of the purchase of the Congress Mine in Yavapai County for himself and his associates, and has since been connected with the property as the President of the Congress Company. For the past five years Mr. Gage has been the President of the Phœnix National Bank of Arizona, and one of the directors about the same length of time. He has served the Territory officially for four years as one of the Prison Commissioners, and was President of the Capitol Commission during the time of the erection of that building He is now one of the directors of the Santa Fé, Prescott & Phœnix Railway, one of the branches of the Santa Fé System.

W. P. B.

H. J. Gray, all of whom are successful men in the mining business, with wide experience in mining generally, and have a thorough personal experience in, and knowledge of, the mines held by this Company.

The relative position of the more important claims and mines are shown upon the map which accompanies this description. It is on a scale of 666 feet to the inch and exhibits at a glance the chief underground workings marking the course of the Contention Lode and of the several extensive bedded deposits of ore pitching towards the Contention.

Water Supply

Tombstone is supplied with water from the Huachuca Mountains some 25 miles away, across the valley of the San Pedro. This water is gathered from the brooks of the higher canons in the pine forest region. It is derived largely from the melting of the winter snows and is excellent in quality, clear, cold and very pure and soft. It is received in small reservoirs and conducted to a seven-inch wrought iron pipe, through which it flows down the mountain across the valley over rolling hills and elevations to the distributing reservoir on the hill above the Grand Central mine, from which the water is delivered to the mines and the city, under high pressure. This reservoir is cut in the solid rocks and cemented, and is 365 feet higher than the corner of Toughnut and First Street. The principal streets have water mains and fire hydrants at the corners. These water works are said to have cost nearly half a million of dollars, and are in good condition to-day. The possession of such a water supply is of great economic value to the mines and reduction works and greatly facilitates the resumption of active work besides its importance to the health of the place and the protection it affords against destructive fires.

Climate

Tombstone enjoys a most salubrious climate. It is considered one of the most favored places for residence in the mining region of Arizona. The heats of summer are tempered by the elevation and dry air. The nights are always cool. The coldest days of winter are not severe, and outdoor work can continue without interruption from frosts or snow.

Chapter Two—Geology

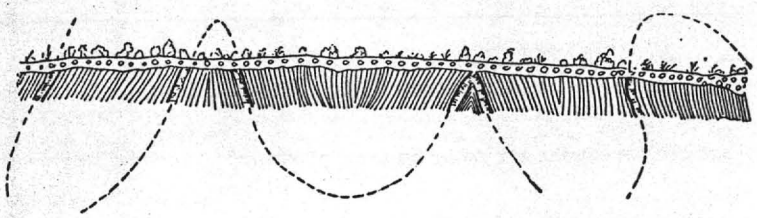
BRIEFLY stated, the rock formations of Tombstone consist of ancient sedimentary strata of limestone, shale and quartzite of Palæozoic age, probably Carboniferous, flanked by granite rock of igneous intrusion and uplift, by which, or from other causes, these strata were thrown into wave-like folds. These folded beds are cut across by a system of plutonic dikes and mineral veins.

Folded Strata

The folded strata present a succession of anticlines and synclines on a small scale as compared with the mountain-making flexures of the Appalachian and other mountain chains, but of the same general form and nature. These folds are locally known as "rolls," and they may be traced along the chief arroyo or dry water course, where they are cut across by erosion, and also in some of the mines. They may be likened in form to the waves of the sea, or to a series of wrinkles, for the larger folds have still smaller subordinate foldings upon them. Some of the anticlines are rounded and arch-like, others are sharp and angular and broken. The amplitude varies from a few feet to many yards. Erosion of these folds brings to view at the surface double lines of outcrop converging to a point, or diverging, according to the pitch of the fold and the angle of the surface cutting. A sketch, vertical section, representing folds visible in the side of the Tombstone arroyo below the Northwest shaft will serve to indicate the nature and form of these

flexures in the limestone and shales of the chief mineral-bearing formation of the camp.

FIG. 3. *Section to Illustrate Rock-folding.*



These folded strata have special importance in the distribution of one of the forms of ore deposit, for ores have been extracted in greater quantity from the upper or arched portions of the anticlines than from the troughs, or synclines.

The folded structure of the Tombstone strata, as also the occurrence of ores in the veins, and in bedded deposits, were described by me in a communication to the American Institute of Mining Engineers in the year 1882.*

The original discovery of ore by Schieffelin, as already noted, was at the outcropping crest of one of such folds on the Toughnut claim, where the anticline came up to the surface, and the upper layer had been worn away, revealing an ore deposit of broad extent following the bedding of limestone in the form often described as "blanket deposit."

The crests of such folds or anticlines are not horizontal, but have a decided pitch or plunge below the surface downwards, distinct from the dip. In the Contention-Toughnut series this downward pitch is towards the course of the Contention lode workings.

It is found by a careful study of the underground works of the different claims that there are several parallel anticlinal folds, locally termed "rolls," traversing the ground

* The Geology and Veins of Tombstone, Arizona, by William P. Blake, F.G.S. Transactions of the American Institute of Mining Engineers, Volume X, pages 334-345. February, 1882.

west of the Grand Central, Contention, Head Center, Tranquillity and Empire, and pitching towards these claims at such an angle as to intersect the dike and lode traversing these claims at a considerable depth below the water-level. These phenomena are more fully described and illustrated in the chapter relating to porphyry dikes and lodes, to which reference is made. See pages 52-55.

In addition to the granite and the stratified beds, so bent, crumpled and folded, there are intrusions of porphyry in the form of dikes coming up from unknown deep-seated sources, filling great clefts and fissures across the beds, and bringing with them, especially along the Grand Central and Contention claims, deposits of the precious metals—gold and silver. There is also a system of veins, marked by outcrops of quartz, cutting the strata in a general east and west direction transverse to the axes or direction of the folds of the beds and making a slight angle with the general direction of the igneous dikes.

Three Groups of Strata

There appear to be three distinct groups or series of stratified formations in the Tombstone District. It will at least be convenient to so divide them for purposes of description:

1. The Contention and Toughnut Series.
2. The Manganiferous or Luck-Sure Series.
3. The Emerald Series.

Each of these groups presents some radical differences of composition, structure, position, or age, justifying their separate consideration. All the strata have been uplifted at different angles, and all have been subjected to more or less breaking and dislocation. The phenomena of plication and folding are shown chiefly in the first or Contention Series of formations, in which the more extensive mines of the District are found. The solid formations are much hidden

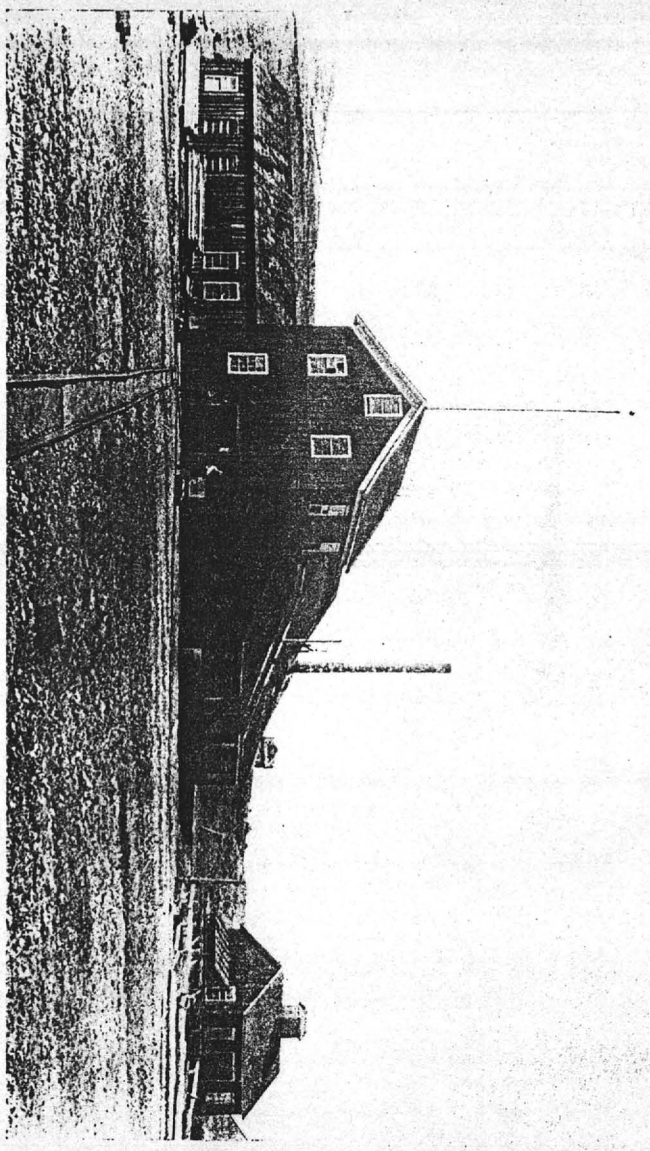
from view by the superficial accumulations of broken fragments spread over the surface and generally known as "wash." This wash is often several feet deep, especially along the course of the larger arroyos.

This surface accumulation as well, also, as the form of the surface; the hills and depressions, show that there was a vast amount of erosion of the rocks; a cutting away of the formations since their uplift, and since the formation of the deposits of ore. This has important economic significance, as will be shown when the relation of the water-level to the ores is discussed.

These three groups of formations will now be considered in succession:

I. Contention—Toughnut Series

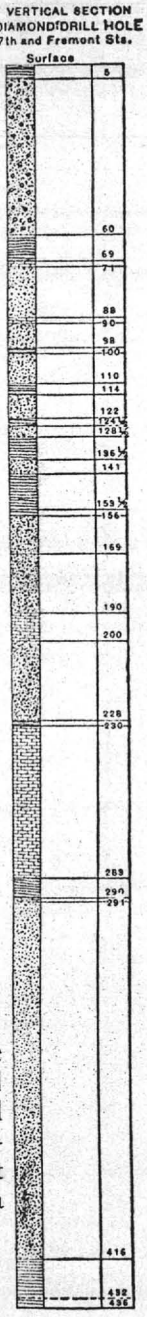
The nature and succession of the beds of the stratified formation can be seen in partial sections along the chief ravines and partly in the drifts, tunnels and shafts of the mines, but the best continuous section of a part of the series was obtained by boring with a diamond drill at a place where the strata were least disturbed, at the corner of Seventh and Fremont streets, in the city of Tombstone, to a total depth of 436 feet. Water was reached at the depth of 432 feet from the surface. The underlying "White Limestone" was penetrated by the drill twenty feet, but its thickness was not determined at that point. It is much thicker than the heaviest bed of blue limestone and is the lowest formation yet reached in the mining operations upon this group of rocks. It is dolomitic. The blue limestones are totally different in appearance and are fossiliferous, but the fossils are confused and broken and are not recognizable specifically but are apparently Carboniferous in type.



SHAFT-HOUSE OF THE TOUGHNUT MINE

Formation.	Thickness.	Total Depth
1. Soil and "cement"—Caliche..	5	5
2. Detrital, Clay with loose rock of limestone and quartzite.	55	60
3. Shale, loose and broken.....	9	69
4. Blue Limestone.....	2	71
5. Broken Shale and Quartzite...	17	88
6. Blue Limestone.....	2	90
7. Grey Quartz, iron stained and broken.....	8	98
8. Black Shale, broken.....	2	100
9. White Quartz, iron stained...	10	110
10. Black Shale, broken.....	4	114
11. Grey Quartz, iron stained, broken.....	8	122
12. Black Shale.....	2½	124½
13. Quartzite, Grey.....	4	128½
14. Black Shale.....	8	136½
15. Quartzite, Grey.....	4½	141
16. Black Shale.....	12½	153½
17. Shale with calcareous seams..	2½	
18. Quartzite, brown stained.....	13	169
19. Quartzite, hard blue, with pyrites at bottom.....	21	190
20. Blue Limestone.....	10	200
21. Hard Quartzite, iron stained.	28	228
22. Black Siliceous Shale.....	2	230
23. Blue Limestone.....	53	283
24. Black flinty quartz, limestone and quartzite (assay 3.2 oz. silver).....	7	290
25. Blue Limestone.....	1	291
26. Quartzite, Novaculite.....	125	416
27. White Limestone.....	—	—
Water-level		432
Bottom of Hole.....		436

FIG. 4.



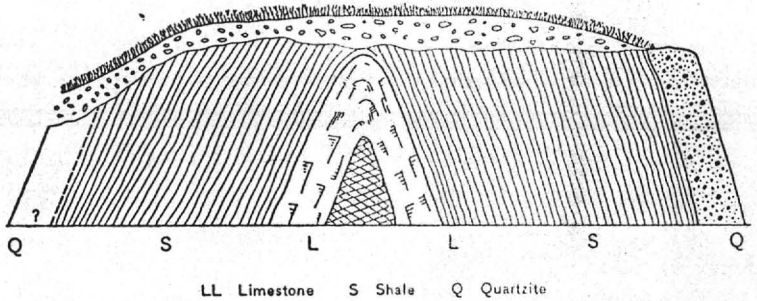
The so-called quartzites of this part of the Section are very fine in grain without the usual granular structure, and may be properly called novaculites, or hone-stones. This is true especially of the lower bed, 125 feet in thickness. It is a white, compact, dense rock, breaking with a conchoidal fracture and without visible grains.

The series of formations represented by this Section is surmounted or overlaid conformably by shales and quartzites, the quartzites being the highest rocks in the series. They are largely developed on the Contention Hill and at the Grand Central mine, where they form the outcropping rocks dipping easterly. They are grey in color, the sandy grains are distinct; diagonal or cross stratification is found, and they might properly be described as sandstones, not being so firmly consolidated and vitrified as typical quartzite. Similar sandstones crop on the Tranquillity claim, and they may be found in most of the cross-cuts on the different levels of the Contention mine and elsewhere. It will be noted that shale beds form an important part of the total thickness of the series of beds perforated by the drill. The shales are generally thinly bedded, and are siliceous rather than argillaceous or calcareous. The outcrops are generally fissile, rusty and much broken, but in depth the color is much darker and often almost black. There is doubtless a general distribution of iron pyrites and perhaps of organic matter in these shales. By weathering, the pyrites are decomposed and the outcrops assume a rusty brown color and break up into fragments.

The hills and slopes lying west of the Contention and Grand Central are underlaid by this shale formation, while lower down at the Toughnut and Goodenough the limestones appear at the surface and are succeeded by the novaculite and the lower limestone, or dolomite, which crops out near the Combination Incline and is again found cropping out along the lower portions of Tombstone gulch towards the granite contact near Fisher's Mill. It is often referred to as the "lower lime" or lower "white lime" and also as the dolomite, to distinguish it from the upper beds of blue limestone, where the chief bedded masses of ores occur. There does not appear to be any well exposed outcrop of this lower limestone in depth, and its exact thickness is not made evident. In tracing out the structure along Tombstone gulch, several outcrops are found below the Defence rolls and are supposed to be portions of this lower series of rocks.

The well-formed crest of a single anticlinal is a good example of folding and at the same time shows a thick body of shale overlying a stratum of siliceous limestone, probably magnesian. It crops out in the lower part of Tombstone gulch not far from the contact with the granite near Fischer's Mill and is no doubt a lower member of the lower white limestone series. The crest or saddle of the bed is occupied by a crushed up body of siliceous rock,—probably a siliceous shale. A bed of grey sandstone crops on the right and is probably repeated on the left but is covered by the overlying

FIG. 5. *Example of an Anticlinal Fold.*



wash. The shales are blue and brown in color and are siliceous. The portion of the rocks shown by the section represents only a part of a succession of folds of siliceous limestones, shales and sandstones, and it is fair to conclude that deep explorations on the Contention Lode will eventually penetrate this series of strata.

II. Manganiferous Limestone

Under this designation I place a series of thickly bedded massive limestones in which ore-deposits characterized by large amounts of manganese ore are found, and from which manganiferous silver ore has been produced in quantities.

This series of limestone beds is developed chiefly in the western and southern part of the District in the higher and more hilly region west and south of U. S. Mineral Monument No. 2, and upon the mineral claims formerly known as the Lucky Cuss, Luck Sure, Wedge, Sunset, Knoxville (Stonewall), Anchor and the Grand Dipper.

The limestone crops out boldly at the Lucky Cuss shaft and west of it to the contact with the granite, along and near which the rock is changed to a white crystalline limestone. This limestone extends around the end of the ridge surmounted by the United States Mineral Monument No. 2 and gradually rises to the top of the ridge, and as the distance from the granite increases the blue color replaces the white. And at the summit of the ridge southwards the limestones are nearly black and are much seamed with small veins of white calcite. The general trend of the strata is east and west. An observation near the summit of the ridge some distance south of the monument gave N. 8° W., dip West, 72°.

Further south the strike and dip change somewhat, with evidences of a curve or bend towards the Emerald Series. In these dark colored and massive beds opposite the Emerald and north of the Emerald arroyo one of the beds is characterized by the presence of innumerable minute encrinal stems visible only upon weathered surfaces where the stems stand out a little and give the rock a peculiar rough feeling to the touch. These little fossil encrinal stems are less than a millimetre in diameter. A freshly fractured surface does not show the presence of fossils, but is fine, granular and sub-

crystalline. Chemical tests show the presence of only a small quantity of magnesia in this rock, and it cannot be classed as a dolomite. An analysis of the Knoxville limestone, a blue and compact sample from the west end of the mine, gave 90.75 of lime carbonate, 2.85 of magnesia carbonate and 5.20 per cent of silica. This and the following analyses were made by Mr. Frank C. Earle for Mr. Goodale.

The limestone from the main working shaft of the Lucky Cuss near the contact with granite, a white and crystalline rock, gave only a trace of magnesia and 6 per cent. of silica. A sample representing the general character of the limestone of the Luck Sure belt was also without magnesia and had only 2.41 per cent. of silica.

The chief mines in this series of rock are the Knoxville, Lucky Cuss and the Luck Sure. These have been liberal producers of manganiferous silver ore. This ore occurs in irregular seams and bodies in the midst of the altered limestones.

Mr. Charles W. Goodale, who for several years was general manager of the Knoxville Mine, has directed special attention to the silver-bearing manganiferous ores of the Lucky Cuss, Knoxville, Luck Sure and Wedge mines, named in the order of their importance. At the date of his paper, July, 1887,* these mines had produced over 750,000 ounces of silver.

The limestone belt in which the Knoxville ore-bodies occur is about 1680 feet wide and rests on granite on the north.

The same authority states that in cross-cutting the limestone from the mine a great variation in its character was observed, some portions were so siliceous as to approach the nature of quartzite, but the greater part of the rock contained 94½ per cent. of lime carbonate. No certain evidences of stratification in these Knoxville limestones were observed.

The ores occur in these rocks in close association with the

* Transactions of the American Institute of Mining Engineers, Volume XVII, page 767. July, 1887.

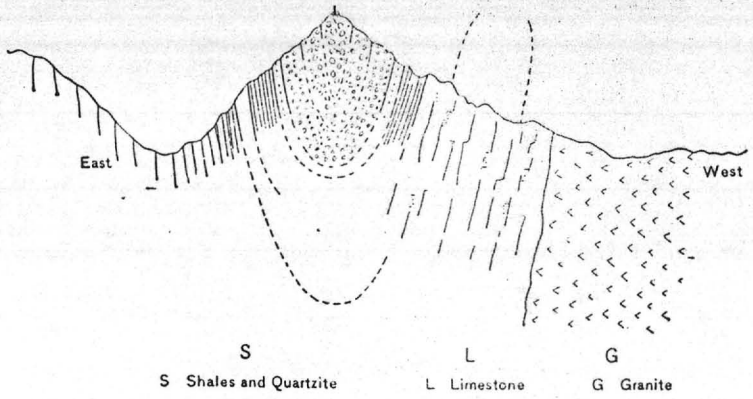
oxides of manganese in the form of irregular pipes, which are more particularly described in the chapter devoted to the description of the veins or lodes, in which also a discussion of the probable origin of the manganiferous ores will be found. See Chapter III, p. 43.

Massive Conglomerate and Breccia

By crossing the limestone ridge from the Luck Sure claim in a southeasterly direction into the valley of Lucky Cuss gulch a very different group of rocks is found in a double line of croppings of massive conglomerate standing nearly on edge. It extends in a general southeast direction from the U. S. Mineral Monument No. 2 across the Luck Sure, the C. O. D., Mizzen Top, Anchor, Telephone and Grand Dipper claims to the Rattlesnake claim where it disappears under the thick deposits of the Emerald Gulch.

For the greater part of this distance, especially where the croppings are near to the heavy croppings of limestone, this broken formation is made up of well-rounded pebbles and bowlders of limestone, mingled with pebbles of quartz and pebbles and bowlders of feldspar-porphyry. There are also intercalated layers of sand, the whole appearing to be a stratum of coarse and sandy conglomerate, such as would be formed along a coast by wave action—a regular beach shingle. As, however, we trace out this conglomerate reef to the top of the hill above the Lucky Cuss and reach the vicinity of the quartzites and novaculite, the fragments of the reef change in character and are made up largely of the adjoining rocks, thus indicating an origin by shearing—a shear zone. But there are bowlders of more distant origin, making it difficult to give an explanation of the origin of this peculiar breccia and conglomerate, which requires further study.

FIG. 6. *Synclinal Fold. U. S. M. M., No. 2.*



This ridge thus gives evidence of a strong, sharp, synclinal flexure, terminating, or running out, just above the Lucky Cuss. It is either a synclinal fold or a double shear zone, and in either case forms a strongly marked division between the heavy croppings of the Lucky Cuss and Luck Sure limestones on the west and the hills which are believed to be formed of the Contention-Toughnut series on the east. The fold extends nearly parallel with the Luck Sure limestones for a part at least of its course and terminates in a bluff-like hill above the Lucky Cuss while the croppings of the novaculites or siliceous shaly beds bend around the hill, parallel with one or more thin beds of limestone lower down the hill. This strongly developed change of formation leads me to question the supposed conformity of the Contention series with the manganiferous series. There seems to be a break in the continuity of the strata along the eastern side of this synclinal fold. But this is not clearly made out, and the relations of these formations are admitted to be extremely obscure and difficult to unravel, requiring further study and accurate mapping. The structure so far as it could be determined is clearly synclinal, with the axis of the trough pitching southeasterly. The northern highest end forms the top of the hill overlooking the Lucky Cuss. The novaculites and

one, at least, of the beds of limestone appear to underlie the conglomerate and to pass in V-like outcrops each side of the ridge. The limestone on the west side, adjoining the granite, is possibly folded upon itself.

The limestone largely developed at the Lucky Cuss is interstratified with white novaculite (generally called "quartzite" in the camp.) These beds with the limestone are generally regarded as the equivalent of the white limestone underlying the Contention and Toughnut beds. It is supposed that this lower limestone is here uplifted from below the series of blue limestones and shales and that these blue limestones and shales rest conformably upon the limestone of the Lucky Cuss, which in its turn is supposed to rest conformably upon the next underlying series I have designated as the Emerald Series, which includes the heavy quartzites of the Ajax Mountain. In other words, all the formations mentioned are regarded as lying in parallel beds from the upper sandstone of Contention Hill to the base of the Ajax quartzite and even lower. This appears to be the view held by Mr. Staunton, Mr. Gray and Prof. Church. It greatly simplifies the subject and may be the correct interpretation of the phenomena. It may be the correct solution of what I believe all of these careful, close observers regard as a difficult problem, especially as it is presented along the eastern base of the Lucky Cuss hill, between the blue limestone series and the Lucky Cuss limestones.

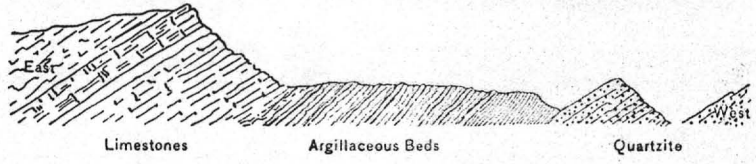
Professor Church, in a recent communication to the Institute of Mining Engineers,* represents in a section entire conformity of the formation from the Randolph limestone at the base upwards through the Ajax quartzite, the Emerald limestone and the Lucky Cuss limestone and Herschel quartzite to the Contention series.

* The Tombstone, Arizona, Mining District, by John A. Church. Transactions of the American Institute of Mining Engineers. New York and Philadelphia, meeting February and May, 1902.

III. Emerald Series

In the western part of the District, beyond the manganiferous series from a deep gulch on the Ecstasy Claim eastward to and across the Emerald Claim, there is an interesting series of beds of limestone shales and quartzites cropping with extreme regularity and all dipping eastward at an angle of about 30°, north and south strike. The upper members consist chiefly of massive limestone weathering with a rough rugose surface forming the mass of the mountain back of and south of the Emerald mine. This limestone rests on a series of argillaceous limestones with many shaly partings forming sharply defined linear croppings. Then under a bed of shales there is a foundation of regularly bedded clean quartzites of vitreous even grain, somewhat colored red with oxide of iron, and over 400 feet thick. These quartzite beds resemble those of the Huachuca Mountains. They are regularly and evenly bedded. They do not resemble in composition or position the sandstone beds of the Contention series. They are apparently lower in geological horizon and older.

FIG. 7. *Sketch Cross-section of the Emerald Series.*



The rough rugose limestone and dolomite of the Emerald is very different in its appearance from the limestones of the Luck Sure, which last are darker in color, often quite black, like coal, and traversed by innumerable small seams of white calcite. This kind of limestone is largely developed on the ridge south of the U. S. Mineral Monument No. 2 and it is

in strong contrast with any of the beds of the Emerald series. This of itself indicates a difference of horizon and that there is a wide separation in age between the rocks of the two series. Moreover the strike or trend of the Emerald series is very different from the trend of the limestones of the Luck Sure, and there appears to be a line of break or demarcation between the two groups following the general course of Emerald Gulch. The lines of strike of the two series of beds here make an included angle of about 120°.

It is also to be noted that the great beds of regularly stratified quartzite cropping in the Ecstasy Claim if prolonged on their line of strike northward, would pass through or under the Luck Sure limestones and the well-defined croppings of the Lucky Cuss without the probability of conformity.

It thus appears that there are great lithological and structural differences between these two series of rocks.

I therefore conclude that the Emerald series is entirely distinct from the Luck Sure series and that the two systems are separated by a great dislocation in an approximately east and west direction.

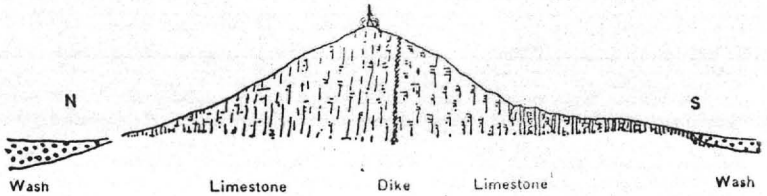
Comstock Hill

An elevation a short distance north of Tombstone consists of a remarkable series of stratified limestones generally in thin layers alternating with siliceous beds all standing on edge and much altered by the underlying granite uplift and by plutonic dikes. This alteration consists in the loss of color of the limestone, it being changed from blue to white and in the formation of crystalline silicates, especially of idocrase (vesuvianite).

There is a thin dike of diorite on the south side of the summit showing at intervals, and on the eastern slope of the hill a cropping of similar rock some ten feet or more in width. The direction or strike of the beds is generally nearly east and west (N. 85°—90° W.) at the summit, but this

direction changes on the eastern end until the strike is nearly N. 45° W., there being apparently a curve in the beds due to folding.

FIG. 8. *Sketch Cross-section of Comstock Hill.*



The accompanying sketch cross-section of the hill will give an idea of its general form, and of the strata, which disappear on all sides under the gravelly accumulations of the plain, the "wash," which conceal the contact with the adjoining granite. This hill is surmounted by the United States Mineral Monument No. 5.

These Comstock Hill strata appear to me to be the equivalents of the similar series of beds observed at the Emerald Claim and west of it. They do not resemble the ore-bearing series of limestones of Central Tombstone, with which there does not appear to be any connection. I am not able to correlate the two groups of strata nor to show the correlation of the Comstock Hill series with those of the Emerald except by similarity of lithological characters and stratification.

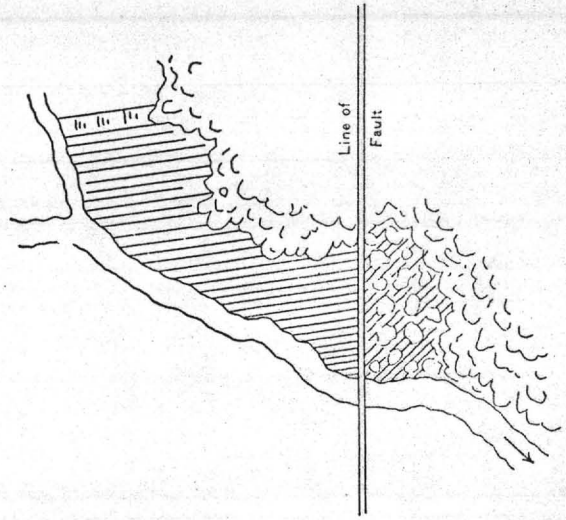
The bordering granite sweeps around from the contact above Fisher's Mill to the foot of Comstock Hill and appears to have been the chief agent of metamorphism of the series of limestones as a whole, while local metamorphism is due largely to the intruded dike. These Comstock Hill dikes do not appear to have any special significance regarding the ore deposits of the camp, and so far have not been found to be ore-bearing.

Faults and Dislocations

The Contention-Toughnut series appears to have been a region of considerable faulting of moderate extent. The surface of the region near the Toughnut workings, and those of the Goodenough and Way Up presented abundant evidences of dislocation. So also the upper levels of the Contention mine developed the presence of several faults by which the normal dip and position of the strata were much disturbed. The shifting of a block of the Contention lode to the westward on the Head Center gave cause of costly litigation. It gave the appearance of two parallel veins. And at other points the dislocation and overlapping of the parts of the lode give, practically, the effect of two or more lodes on the same level. This condition was discussed in my paper of 1882.

Among other interesting phenomena of the formations of the Contention and Toughnut series there is a remarkably well-defined break and fault plane across the strata far beyond the lode showing in the left bank of Emerald gulch some distance from the south end of the Grand Central ground between the Grand Dipper and the Bunker Hill claims. It shows in one side only of the gulch. One side of the break consists of a body of shales standing on edge, of a dark color but hard and siliceous. These are cut off at nearly right angles by the slip or break. The other side of the break is formed of a nearly vertical wall of rocky fragments, the result of the crushing movement, cemented together by infiltrated lime-carbonate, like caliche. It makes a firmly cemented mass of large and small blocks and fragments of limestone, shales and quartzite, evidently the crushed-up strata through which the movement took place. The blocks are angular. The full breadth of this crushed zone is not shown as the cemented mass passes under and is covered by the wash. An attempt has been made to show the break in plan by the annexed illustration.

FIG. 9. *Plan of Faulting Plane Crossing Emerald Gulch.*



The outcropping beds are cut diagonally across by the gulch, showing a succession of siliceous shales, quartzite and a red and green schistose rock to a bed of hard blue limestone about sixty paces up the gulch. These beds trend N. 76° to 80° West magnetic, and are nearly vertical. The trend of the fault-plane is North about 10° to 20° East, magnetic, and its dip is 82°-83° eastwardly. The extent of the throw could not be determined as the detrital material of the surface covers the strata from view. The movement may have been vertical as well as horizontal.

This faulting plane gives every evidence of being of considerable extent. If prolonged northward in the direction seen at its only exposure in Emerald Gulch it would pass through the series of locations lying east of the Grand Central and the Contention, and would be approximately parallel with the Contention dike. In the other direction, northward, it would intersect the Bunker Hill and Rattlesnake claims toward U. S. Mineral Monument No. 6. Other

examples of faulting are described and illustrated in the following Chapter III upon the ore-deposits.

Rhyolite

An area of rhyolite is found on the State of Maine claim. This is far outside of, and west of, the other claims and groups. The ore-deposit, or vein, is also in a very different group of rocks, being in a plutonic mass of syenitic quartz porphyry of a grey color and fine grain and very hard. The XXX Mine adjoining is in similar rock, and is opened by an incline at an angle of 30° dipping westward. The strike of the quartz vein is nearly magnetic north and south.

East of the line of these claims there is a belt of rhyolitic rock in vertical layers, tufaceous and fragmentary, trending N. 20° East, and still further east, a second belt of quartz porphyry and of rhyolite 200 to 300 feet wide. Granite does not appear, but the contact of these rhyolitic and porphyritic plutonic rocks with shales is found near to the Last Chance house on the Charleston road.

Granite

This is a compact homogeneous fine-grain granitic rock without stratiform or gneissic structure, and is no doubt intrusive. It crops for some miles in the direction of Fairbank and forms an abundance of large rounded bowlders of disintegration. This rock has a pleasing grey color, is easily worked into good building blocks and was used for the Schieffelin monument and for the foundation blocks of the hoisting and pumping engines.

It appears to have risen into the midst of the Tombstone formation and forms a broad belt, or dike-like mass, west of the Lucky Cuss and Old Guard claims. It is bordered on the western side by conglomerates, shales, quartzites and limestones, the relation of which to the stratified formations on the east of the granite cannot be ascertained without further surveys and a good map.

Chapter Three—The Ore Deposits

TWO distinct classes of mineral deposits are represented in the Tombstone District: 1. Veins or lodes. 2. Interbedded or Blanket Deposits.

The original discovery was made upon the outcropping of a blanket deposit found in close association with the main bed of blue limestone and, in fact, replacing a portion of the original bed.

The deposits in veins will be first considered.

Porphyry Dikes and the Veins

The sedimentary and folded strata are cut nearly at right angles by a succession of plutonic dikes trending a few degrees east of north and south of west. Five such dikes have been recognized: the Contention, Empire, Hawkeye, Quarry and the Northwest. These dikes cut the country in nearly vertical planes. They occupy fissures or breaks in the stratified rocks and are found traversing the granite rocks also. They undoubtedly extend to great depths in the earth.

Veins and impregnations of quartz are associated with the dikes. In some of them the quartz is closely intermingled with the mass of the dike, in others the quartz is formed in distinct but parallel veins or forming an acute angle with the trend of the dikes. From these facts and others we may justly conclude:

(1) That the veins or dikes were formed together, or in near sequence of time, and that the siliceous deposits represent emanations from deep-seated, probably thermal sources.

The chief dike of the District, generally known as the Contention dike, will be first described.

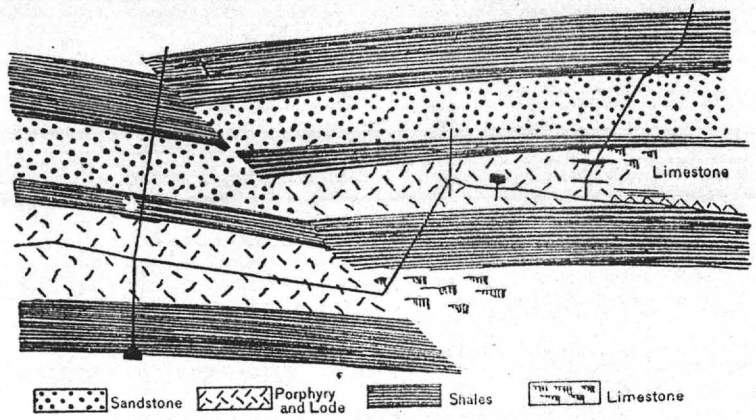
Contention—Grand Central Lode

The porphyry dike of the Grand Central and Contention mines extends not only through these claims but through the Head Center into the Tranquillity and beyond into the Empire. It may be regarded as the one great leading vein or lode of the District. While the dike is a crystalline igneous rock which has broken through and disrupted all the stratified beds in its path, it is so closely connected with siliceous layers and impregnations and with the deposits of gold and silver which are found not alone in quartz alongside of the dikes but in the substance of the dike itself as to permit of its being regarded as the lode.

Its general course or direction is north and south. It cuts the rocks indiscriminately, but in places follows the bedding of the disrupted strata. It is thus bordered in places by shales, by quartzites, or by limestone.

There are dislocations by faulting which give the semblance of two or more parallel dikes, as for example, on the 207-foot level of the Contention, equivalent to the first level of the Head Center, a representation of which is given in the annexed plan of a portion of the ground between the North Shaft of the Contention to and including the cross-cut drift north of the Head Center Shaft. Shales, quartzites (or sandstone) and limestone are here shown traversed by the Contention dike (Fig. 10, p. 45).

FIG. 10. *Porphyry Dike with Adjacent Beds—Dislocated.*

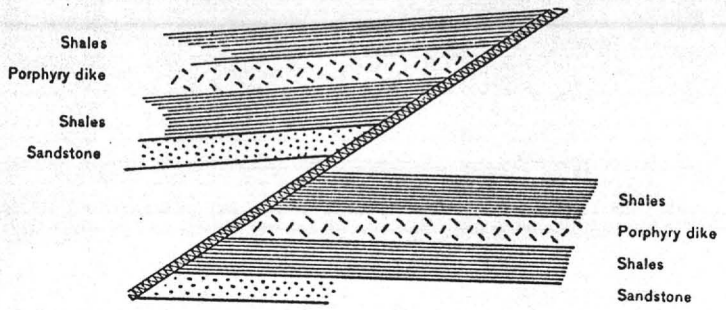


The breaks and throws of the dike may be further illustrated by a second example found on the 258-foot level in the long cross cut from the South Shaft westward into the Flora Morrison, where there would appear to be three dikes nearly parallel to each other. The chief faulting plane here trends north 25° to 30° west and dips to the northeast. It is marked by a heavy belt of crushed material of a bright red color. The distance of the throw appears to be not less than 250 feet.

The dip of the strata is eastward at an angle of 45 to 50 degrees (Fig. 11, p. 46).

The thickness of the Contention dike is variable. In the cross-section westward from the shaft shown in the plan it measures 68 feet from one wall to the other. About 500 feet north it suddenly diminishes to a few feet from side to side. This is indicated at the extreme right hand or north end of the plan (Fig. 10) where, also, a bed of limestone comes in between the porphyry and the shale. It is possible that there is a second break or dislocation at this place. Four hundred feet further north there is a sudden expansion of the dike on both sides of a mass of shale.

FIG. 11. *Northwest and Southeast Dislocation.*



The dominating importance of the Contention lode in the Tombstone District is convincingly shown by the number and extent of the workings upon it, as represented on Map Fig. 2—The Contention Lode, page 22. These workings extend for a great distance through the many claims and, in the aggregate, number many miles, and all above the water-level.

Origin of the Ores

This dike, with its accompanying quartz veins and ore-bodies, is the great leading source of the ores, and is followed by the miner in his search for paying ore-bodies. It was so followed in the Grand Central, the Contention, the Head Center, Tranquility and others, and may be followed at the present day with every promise of success to great depths below the water-level. Indeed, there is no reason to question the probability of the ore-bodies extending as far downward as in lodes in other districts. It is more than probable that the porphyry dike of the Contention group, was charged with mineral sulphides at the time of its intrusion, and that the adjoining beds were also mineralized by the contact. Or, if the metals were distributed in the mass of the sediments the dikes produced the conditions favorable to the concentration and deposition of the ores. The question of the origin of

the ore permits of much theoretical discussion, but has little practical or economical significance aside from the facts of the presence and distribution of the ores. That the paying ore-bodies were found alongside of and in the dike is a familiar fact to the miners and engineers who worked and explored the mines along its course. The opinion and conclusions regarding the existence of paying ore-bodies in depth below the water are based not alone upon the mode of occurrence or form of such ore-bodies in the extensive group of mines worked to the water-level but, also, and convincingly, upon the known ascertained existence of bodies of ore below the water-level. For a further discussion of this subject see beyond under Chapter V, The Lodes in Depth.

A few theoretical details and considerations respecting the origin of the impregnation of the rocks and lode with the noble metals may have some interest and practical application. Reference may be made to my description of the lode read at the Washington meeting of the American Institute of Mining Engineers in February, 1881, from which the following extracts are made:

"The dike has a distinct vertical lamination or structure through most of its substance and is more or less penetrated by veinlets of quartz. In some portions it is highly crystalline and nearly barren, and in other portions it consists chiefly of a feldspathic base in which the feldspar crystals are obscure. It passes into a felsite, which in the decayed portions of the dike, and where it is slaty in structure, might be mistaken for the partly decayed shales or quartzites. Large portions of the dike are so much penetrated by quartz as to consist largely of it, and the mass might be called quartz, although close examination shows the presence of feldspar. . . .

"There is a considerable amount of mineralization of the dike by iron pyrites disseminated irregularly in the mass usually in cubical crystals, most of which have dissolved out, leaving cavities only, indicating the former presence of the

pyrite, making in some places a spongy mass of porphyry or of quartz."

The quartz veinlets appear generally to be later in origin than the dike (though they now seem to be an integral part of it) and they may have been coincident in origin. The extensive decomposition and kaolinization of the feldspar seen on all sides may have yielded the silica.

Again quoting from the description in 1881:

Metallization of the Dike

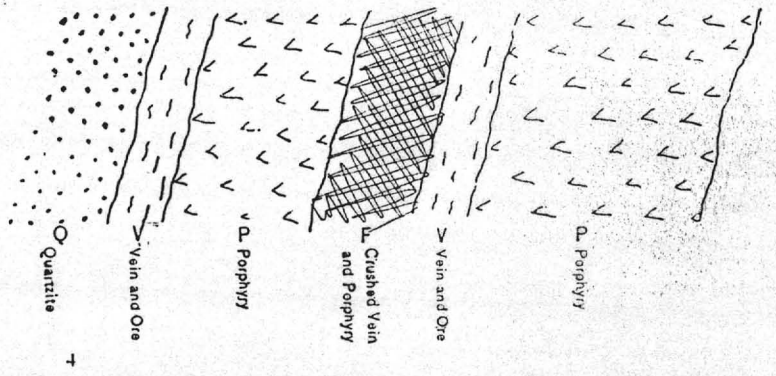
"The time and manner of metallization of the dike may be considered as open questions, for a solution of which we must wait until the mining extends below the permanent water-level of the formation. It seems most probable that the rock, at the time of its intrusion, was pyritous, and the strata adjoining it no doubt were. It is not impossible that there may have been a concentration of the precious metals in the dike from the surrounding beds, the result of the decay and change of the pyrites diffused in the strata. On the other hand, we may suppose that the dike has been the source of the silver and gold we find in and about it.

"In either case the vertical laminated or stratiform structure parallel with the walls has been an important factor in the distribution of the metals, and in the changes and modifications of the original condition of the dike. We may readily conceive of such vertical planes of structure affording planes or lines of least resistance to vertical movements, while the abutting ends of the strata, in contact with the walls of the dike, would offer great resistance by friction. The condition of the dike along a great part of its course seems to sustain and verify this hypothesis. There has evidently been considerable movement of parts of the dike upon itself, resulting in the formation of heavy clay seams and brecciated layers of porphyry and quartz, sometimes occupying a medial position

along the dike, sometimes at one side or the other, and again along the line of contact with the country rocks. Such seams and brecciated ground are sometimes wanting, and the structure and condition of the dike remain unchanged."

That the dike has suffered extensive movements since its consolidation is shown on most of the levels of the mines; in addition to the lateral dislocations by faulting, as already shown, there have been sliding movements along the walls of the contact with the sedimentary beds, and portions of the dike have slid back and forth upon themselves, resulting in the formation of extensive bodies of soft clay or flucan, like the gouge or selvage of mineral veins. There is also extensive fracturing of the abutting edges of the stratified beds shown by a crushed bordering mass of breccia several feet thick, by which the original bedding is obliterated. And when this fracturing passes through beds which have been previously mineralized there is a mingling of ore with the fragments of the wall rocks—ore which is already crushed and can easily be mined. In the upper levels large quantities of such already crushed ore were found. The presence of much highly-colored red hematite in such crushed zones is a good indication of paying ore. At many places on the 600-foot level the smooth slickensided walls of the dike are

FIG. 12. *Section of the Contention Dike and Lode.*

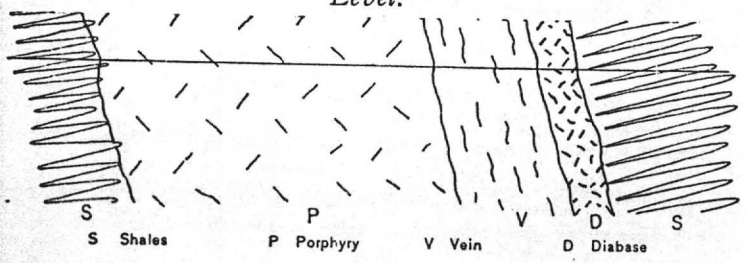


colored a brilliant hematite red and may be regarded as contiguous to important ore-bearing ground below.

The structure of the dike at two distant points is shown by the annexed drawings of places where ore occurs both alongside of and in the dike (Figs. 12 and 13).

The Contention dike, or rather the fissure which it occupies, appears to have been opened a second time, permitting of a parallel intrusion of another variety of plutonic rock of a darker color and finer grain containing hornblende or angite. It is probably a diabase. It may be seen cropping at the surface on the west side of the feldspar porphyry dike south of the Grand Central pump shaft. A similar rock has recently been noted by me in a short cross-cut to the west from the main dike on the 600-foot level of the mine, near the bottom of the Sulphuret Shaft, in close association with rich ore lying between it and the feldspar porphyry, as shown in the section, Fig. 13.

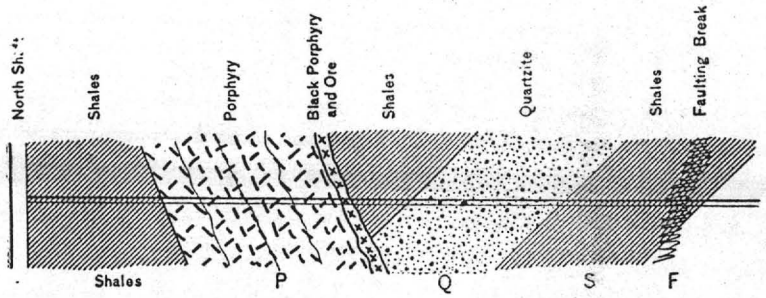
FIG. 13. *Section of the Contention Lode on the 600-foot Level.*



Again, I find recorded in my notes of 1881 a dark colored "black" porphyry at two places on the west side of the dike, on the third or 207-foot level of the Contention, and in each place accompanied by bodies of ore. The notes also show that this was upon the 309-foot level (206 feet of Head Center), a dark colored rock containing gold; "a compact, fine grain, dark green rock or hornblendic porphyry with scales of gold in it, and chloride of silver in yellow crusts and patches." The rock seemed partially altered to steatite.

The valuable ores of the Contention lode were not confined to the limestone contact with the porphyry alone, but were found also at the contact with shales and with quartzites. On the third level north in the Head Center ground, ore was found in 1882 next to the contact of the porphyry and shale, with ore, also, in the shale, which at that point was quartzose and schist-like, as if altered by the dike and the accompanying siliceous emanations, or infiltrations.

FIG. 14. *Section of the Contention Lode from the North Shaft Westward on the III Level.*



This cross-section shows the intersection of different beds by the dike, and a brecciated seam, or broken up zone, in the midst of a mass of shale.

The West Side Vein

The West Side vein has been extensively worked and has produced a large amount of ore, as may be seen from the tabular statements of production. From the original discovery on the Toughnut claim the fissure was followed westwardly leading to the second roll, or anticline, and following the fissure eastwardly it led to the other roll, or anticline, in the Way Up Claim. In parts of its course it is barely more

than a "crevice" similar to many in the lead and zinc regions of Wisconsin, but large enough to permit of the flow of solutions of the ordinary and noble metals for ages, by which heavy deposits have been made not alone on the walls of the fissure but in the adjacent limestone. It has been worked to a depth of 500 feet or more.

The vertical longitudinal section following the West Side vein, herewith presented, serves to show not only the succession of anticlines and synclines cut by this fissure, but the distribution of ore in the fissure as marked by the portions stoped out, indicated by the shading (Fig. 15, p. 53).

It should be noted, first, that Shaft No. 3 reaches to the water-level through a continuous chimney or body of ore deposited opposite the shales and limestones. Second, that another shaft reaches ore-bodies formed opposite the "quartzite" and on the top of the white limestone; thus showing that the ore-deposition on the plane of the vein is not confined to any one kind of wall-rock, although the limestone appears to have been most conducive to the deposition of ore.

Bedded Ores—Blanket Deposits

But while the porphyry dike of the Contention group, with its impregnation of quartz and the precious metals, is the important constant source of value, it has been noted from the first that the contiguity of beds of limestone has had an important influence upon the mineralization. Limestone, as usual in metalliferous deposits, has here acted as a precipitant. And in this District it appears to have acted not only chemically but mechanically, by its form, or position, with respect to the vein-system.

The bulk and greatest value of the bedded or blanket ores are found along the crests or anticlines of the limestone. And the ores are deposited in greater quantity at and near to the

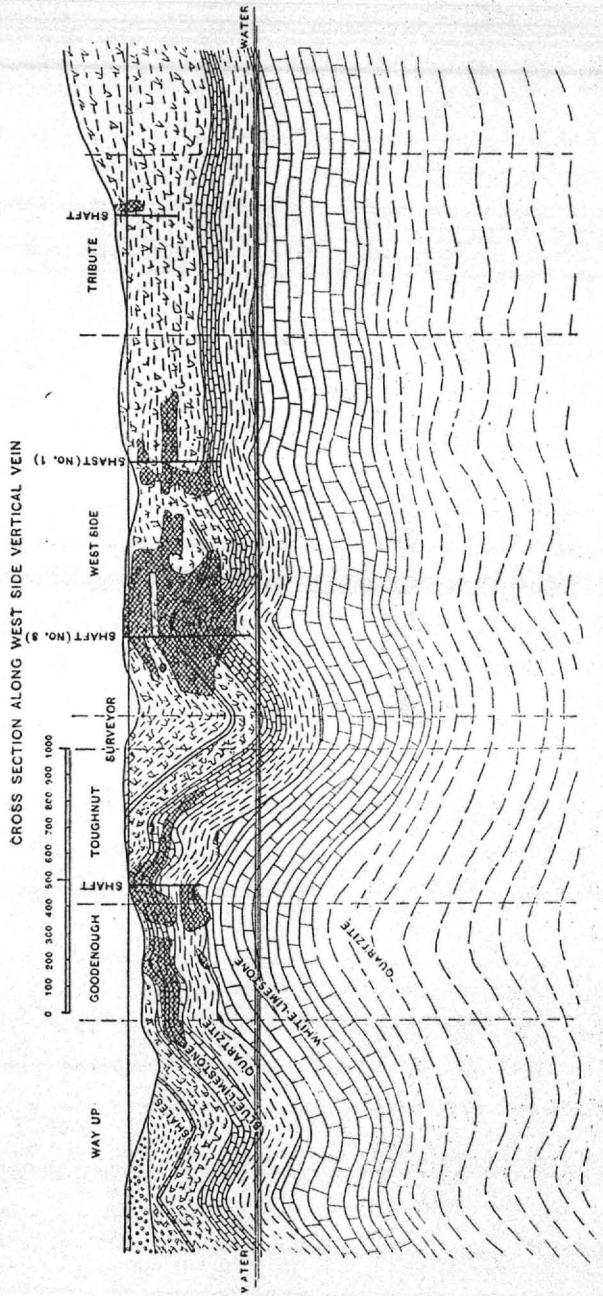


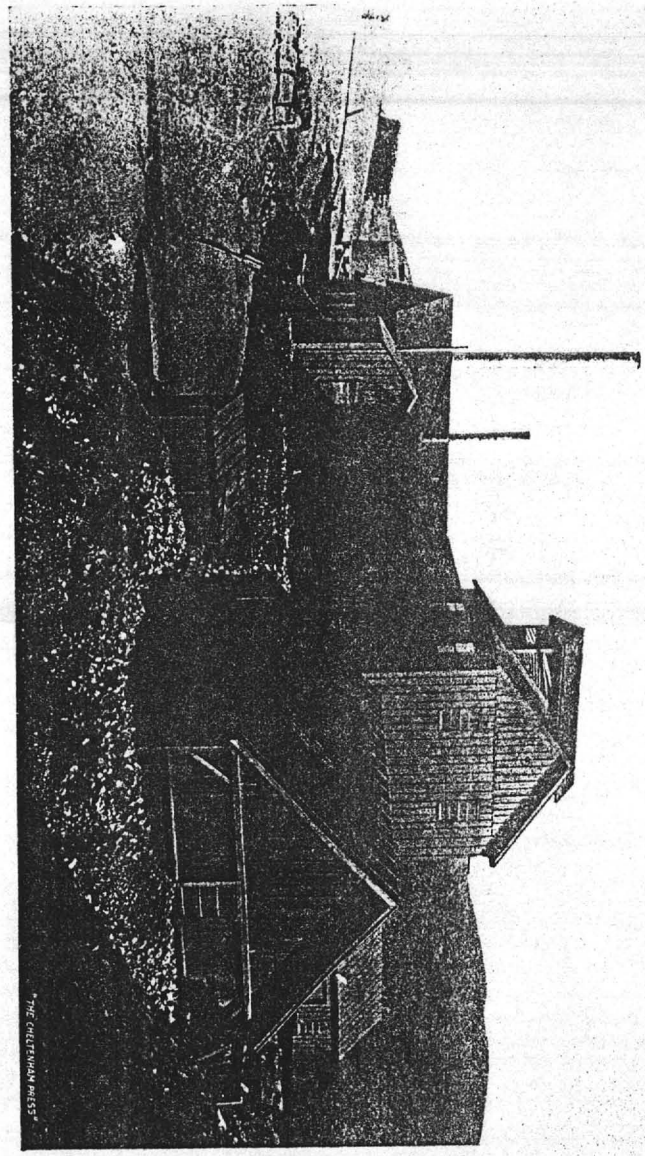
FIG. 15. *Cross-section of the Anticlines and Synclines Crossing the West Side Vertical Vein.*

veins, as if solutions had flowed outward from the fissures and had followed the pitch of the crest of the folds downward. This was shown in a striking way in the Toughnut mine, where the ores were in greater quantity on the down-hill side of the intersection of the folds or "saddles" with the vein. The ores also extended in workable masses for a greater distance from the vein on the lower side than on the other, or up-hill, direction of the pitch.

It appears also that each vein, fissure, or crevice crossing the folds of the rocks has contributed to the formation and maintenance of the deposits of ore in the arches of the rock—the anticlines or saddles—along the line of the pitch from one side of the District to the other. Reference is here made to the map and sections, particularly to the map (No. 2) showing the extent and direction of the stoped ground on the Toughnut and Goodenough claims extending eastwardly from the Defence fissure to the West Side and the Way Up fissure, and from thence into the Girard, Hawkeye and Little Wonder towards the Contention lode.

The accumulation of paying ores in the crests or saddles of the folds having thus been shown to be general in the District, and it likewise having been found that there is local enrichment and deposition at the points where these folds are intersected by dikes or lodes it becomes of great practical importance to determine the number and the direction of the folds. To this end numerous observations have been made by Messrs. Staunton and Gray upon the form and pitch of the ore-bodies. The results have been carefully plotted upon a series of sections following the crests of the main folds and showing their downward pitch to and under the water-level down to the point of intersection with the Contention lode, where it is expected to find heavy accumulations of ore, and such accumulations not alone in the bedded rocks but in the lode itself.

It is interesting to note that the accumulation of ores in the crests of the folds or anticlines of rocks is found to a remark-



SHAFT-HOUSE OF THE WEST SIDE MINE

able degree in the gold mines of Bendigo, Australia, described by Rickard.*

Such deposits are there known as "saddle reefs," the ores being accumulated in the saddle-like folds of the beds.

It is noteworthy that the ore deposits in Australia are not confined to one layer but that they occupy successive layers one under another, but always in the crest of the arch and below it rather than above, or on the sides of the folded beds.

The shaded or hatched areas upon the map show the portions which have been worked out chiefly upon the claims formerly controlled and worked by the Tombstone Mill & Mining Company. It is not supposed that any important masses of ore remain in or near these stopes, but in their extreme downward extension, to and below the water, other similar ore bodies may be found. It is also possible that other blanket deposits may be found in the but partially explored region northeast of the old workings.

Taking the stoped areas of the chief blanket deposits as marking the chief lines of flexure (anticlines or rolls), the general direction of the longer axes is found to be N. 60°-80° W. Four main lines of flexure or saddles are strongly marked. If some of the lesser flexures are enumerated the number would be increased.

1. Anticline through the Defence, Intervenor, West Side, Sulphuret, through the Flora Morrison (near the new shaft) into the Contention. Approximate direction N. 68° W.

2. Anticline through the Toughnut, Girard, towards the Tranquillity, Head Center and Contentment. Approximate direction N. 68° W.

3. Anticline. Goodenough into Hawkeye and Little Wonder. The major axis of this blanket, if prolonged, would pass through the Empire and Silver Thread to the North Point claim. Approximate direction N. 70° W.

* T. A. Rickard. Transactions American Institute of Mining Engineers. And recently in the Engr. Min. Journal. March 29, 1902. Volume LXXIII, page 440.

4. Vizina through corner of Goodenough and Gilded Age and the western end of the Way Up. N. 77° W.

Other flexures to the westward of No. 1, the "Defence Roll," are known to exist, notably at the Tribute, Bob Ingersoll and Blue Monday, but are not sufficiently opened up to permit of a particular description.

The rock of the whole intermediate region is no doubt in a flexed or crumpled condition, but the flexures are hidden from view by the heavy surface accumulations of "wash."

The line of pitch of the chief blanket deposits, or in other words, of the anticlinal folds to which the deposits conform, is invariably toward the Contention lode or its prolongation; and the angle of pitch, or the inclination to the horizontal water level, varies from 10° to 15°.

The section given on page 80 (Fig. 19), drawn on a scale of 400 feet to 1 inch, and following the West Side anticline, shows this inclination, or pitch, and the distance to which the blanket deposit has already been worked out, and the distance remaining on the pitch down to the intersection with the Contention lode, in which distance, or area, ore may be found. The portions worked are indicated by heavy black lines. It will be noted that for a part of the distance there were three superimposed beds following three layers of limestone.

The section shows, also, the probable depth to which the prolongation of these deposits, or of the limestone beds in which the deposition occurs, would extend below the present water level at the Contention lode. Assuming that the same pitch continues beyond the explored portion this depth should be from 150 to 250 feet. Other sections give similar figures, assuming that the angle of pitch remains constant.

Inasmuch as there has been found at the places where the anticlines have been intersected by veins an enrichment by greater deposition on the lower side of the planes of intersection it is not unreasonable to expect to find similar conditions on the lower or eastern side of the Contention lode if the

limestone beds are continuous there without faulting or displacement.

It appears, also, that the rolls or anticlines pitching under the Empire and Silver Belt and adjoining claim towards the northern end of the Contention lode have been less explored than the others, and that they perhaps intersect the lode at a greater depth, and may form important ore-bodies yet to be reached when the water is removed.

Knoxville Mine

This mine in the southwestern part of the District beyond the Lucky Cuss and Luck Sure is in the limestone of the Lucky Cuss and Luck Sure series. It had been opened up in the year 1887 to a depth of about 375 feet, as shown by a longitudinal vertical section given by Superintendent Goodale in his paper in the Transactions of the Institute of Mining Engineers.*

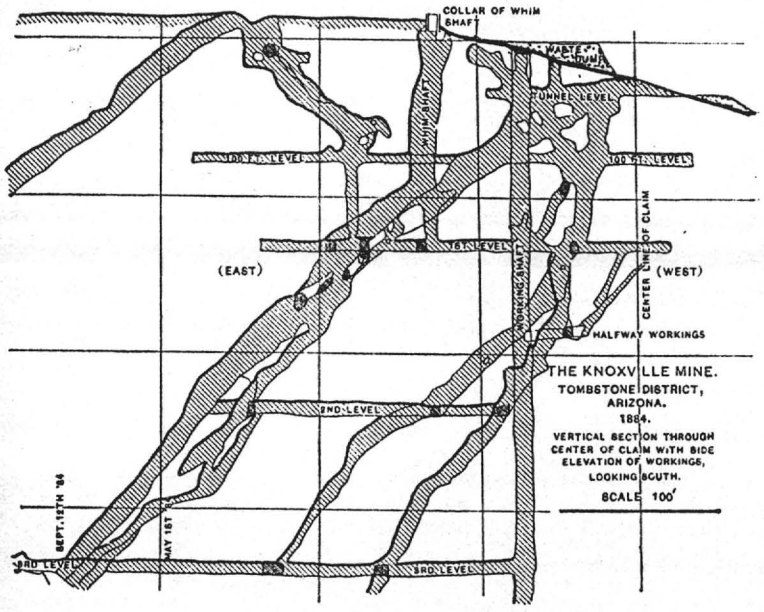
This section exhibits a series of pipe-like ore-bodies or "chimneys" extending from the surface diagonally downward, eastwardly from the surface to and below the third level. There are four of these chimneys or ore-chutes which, as far as then explored, had produced over 12,000 tons of ore containing at least 7,000 tons of manganese oxides. These ore chimneys pitch eastwardly at an angle of about 45°, or from 40° to 50°, and follow a crevice, or plane of cleavage, having an easterly and westerly strike, thus conforming to the direction of the structure of the beds of limestone which is found to be about N. 78° E. magnetic. Four of these ore-bodies or chimneys were more or less united near to the surface. Three of them were developed to a depth of 400 feet and the fourth to 150 feet.

The plane of the crevice was a sure guide to the ore-bodies,

* Volume XVIII, page 911.

though "its width was not appreciable," and there was nothing in the crevice like clay or gangue. The conditions were thus very similar to those seen in the lead and zinc regions of Wisconsin, and which conditions, in fact, occur in the limestones on the Way Up and other claims in the Contention and Toughnut series in the heart of the Tombstone District. Mr. Goodale describes the filling of these chutes or chimneys as follows:*

FIG. 16. *Section of the Knoxville Mine.*



"There were no indications of ore until the drifts were within a few feet of the ore-bodies, where the walls of the crack were stained with black oxides of manganese and some carbonate. Small detached pockets of pure manganese oxide also indicated proximity to the chimneys, but these small bodies carried very little silver. The filling of the chimneys

* Transactions American Institute of Mining Engineers, Volume XVII, page 768.

included, in a great variety of forms, pyrolusite, wad and psilomelane. It is not improbable that a searching examination would have discovered the rarer oxides; braunite, manganite and hausmannite. The gangue was quartz and calcite, galenite, cerussite, pyromorphite, cuprite, melaconite and malachite were occasionally observed, and the assay showed a little gold."

Origin of Manganiferous Ores

The question of the origin of these manganiferous ores in deposits apparently the result of the decomposition and replacement of the enveloping limestone by solutions has excited much interest and considerable discussion. After a somewhat hasty visit to the mine while it was being worked by Mr. Goodale I formed the opinion that the manganese was derived from portions of the limestone containing protoxide of manganese similar to the massive beds of pink limestone bordering or associated with the Franklinite and red zinc ores of Sterling Hill and Mine Hill, Sussex County, New Jersey, which, after being quarried and exposed to the weather, gradually assume a brown and even a black color. This view was strengthened by finding fragments at the Knoxville mine of pink colored limestone, which, on analysis, gave me 0.1 per cent. of manganese, a small quantity, but enough possibly to form large bodies of manganese ore if the solution and segregation was sufficiently extensive.

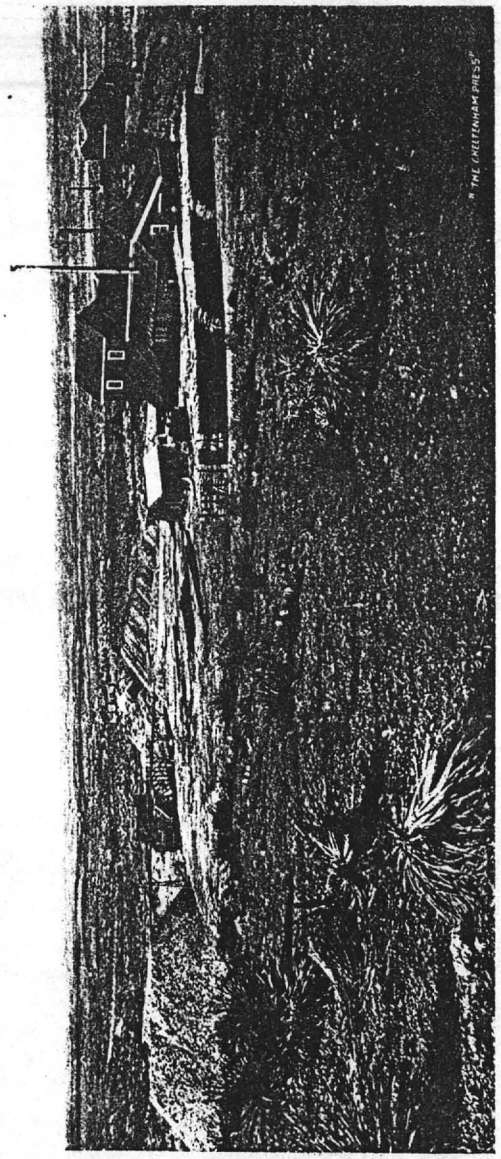
At the time of my recent visit to the claim (1902) I looked in the waste piles for evidence of quantities of such limestone in the mine and was not successful. It is probable that the samples I had were from some masses of secondary deposition. Since, also, the operations upon the Lucky Cuss Claim disclosed a body of manganese sulphide—the mineral species Alabandite—the mystery to me is solved. Alabandite is the sulphide of manganese, and I have no doubt that the original included masses or kidneys of this sulphide, formed

in the midst of the limestone, are the source, by decomposition and precipitation, of the manganese ores of the pipes or chimneys, the solutions having spread laterally and downward along the crevices, enlarging them by the corrosion of the walls with the formation of the pipe-like ore-bodies of manganese oxide, and, in places, the deposition of calcite, snow-white in part, and in other places possibly containing manganese oxide.

This explanation of the origin of the manganiferous ores would make clear the origin of the peculiar and irregular forms in which the ores are found. They occupy irregular crevices without the tabular form characteristic of the filling of deep-seated fissures. It may be safely assumed that the extent of such ores, laterally or in depth, depends upon the magnitude of the original bunch or pocket of sulphide which has undergone decomposition. Deep mining below the water may be expected to encounter, as in the Lucky Cuss, unchanged masses of manganese sulphide. Masses above the water and exposed to atmospheric influences have undergone oxidation with the formation of oxides precisely as is the case with sulphide of iron. The source of the silver and gold in the manganiferous ores is no doubt the original manganese sulphide with which they are combined or closely associated. Analyses of the alabandite will throw light upon this question.

From tests and analyses made at the Massachusetts Institute of Technology it was concluded that the portion of the silver in the ore (not in the sulphide) which was not in combination with chlorine was united with copper, antimony and sulphur as in the mineral species grey copper, or tetrahedrite. Analyses of milling ores showed from 42 to 74 per cent. of sesqui-oxide of manganese, and from 18 to 25 per cent. of silica, in round numbers, with various other constituents in small quantities, including the precious metals.

All of the chimneys yielded ore assaying from 30 to 50 ounces of silver per ton near the surface.

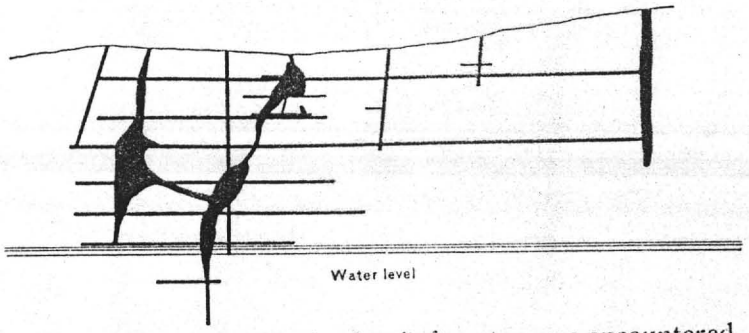


HOISTING WORKS, LUCKY CUSS MINE

Lucky Cuss Mine

The Lucky Cuss Mine, situated a short distance below U. S. Mineral Monument No. 2, is the deepest mine in the camp as respects the water-level and the geological horizon. It is opened on or adjoining the contact of limestone with the granite, and also on the line of one of the veins crossing the series of anticlines and synclines and prolonged beyond the limestone into the granite, where the fissure can be plainly seen, and has been explored sparingly by a succession of pits from which ore can be taken.

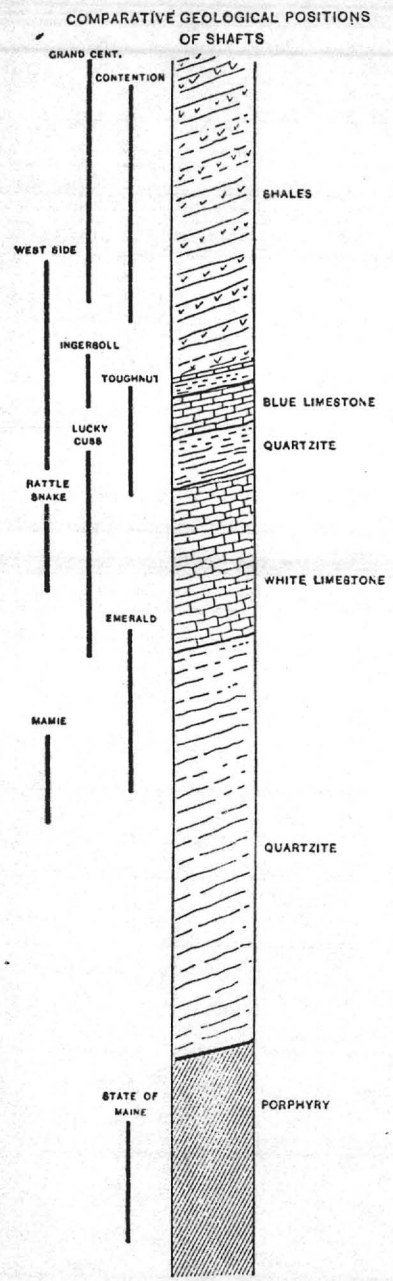
FIG. 17. *Section of the Lucky Cuss Mine.*



At a depth of 490 feet in the shaft water was encountered. This mine has yielded over $400,000 in value of ore. The ore was good to the water level and below it. It assayed well in gold and silver and lead. Free gold has been found and a telluride is reported. The ores are manganiferous, and a considerable amount of manganese oxide has been taken out. The interesting mineral—the sulphide of manganese "Alabandite"—occurs here in the limestone under one of the intruded tongues of granite or dike rock.

The accompanying drawing represents the mine in longitudinal section. It shows the form of the ore deposits, and the several shafts and levels extending to and below the water (Fig. 17).

FIG. 18.



Comparative Geological Position of Shafts

A very interesting illustration has been prepared for me by Engineer Staunton showing the comparative geological position of the chief shafts of the District as respects the geological horizon penetrated in each case. The vertical section of the formation is in accord with the view held by Mr. Staunton and others that the manganiferous limestones underlie the Contention and Toughnut series conformably. It shows at a glance that ores have been found and mined in all the formations.

Chapter Four—The Production

THE value of the aggregate production of gold and silver from the mines of Tombstone is placed by competent judges at not less than $34,000,000. This is partly from records of yield and is partly from estimates.

Table of Production to 1882

At the time of the publication of my paper upon the Geology and Veins of Tombstone in the year 1882,* the output of the precious metals, gold and silver, up to the first of January, 1882, aggregated $7,359,000, and over $3,000,000 had been disbursed in dividends. This product was distributed among the following-named mines and mills:

Tombstone Mill & Mining Company	$2,704,936.33
Contention Consolidated	2,703,144.39
Grand Central	1,050,875.30
Head Center	191,520.52
Vizina	526,716.98
Ingersoll	15,000.00
Sunset	15,000.00
Corbin Mill	40,000.00
Boston Mill	112,007.83

Dividends.

Tombstone Mill & Mining Company	$1,100,000.00
Contention Consolidated	1,375,000.00
Grand Central	600,000.00
Vizina	80,000.00

It is the opinion of Mr. J. W. Dean that the Tombstone District has yielded at least $40,000,000 in value that can be accounted for.

* Transactions of the American Institute of Mining Engineers, Volume X, pages 334-345. May, 1881, to February, 1882.

Mr. A. L. Grow, who has been familiar with the mining operations of the camp since the discovery in a statement made to me some years ago, before the consolidation, says:

"About 1887 it was reported that the Tombstone District had produced something over $34,000,000. Official records show that the Grand Central gave $7,000,000 ($2,000,000 dividends) and a large amount for improvements and purchase of other mines. The Contention gave $6,030,142—$2,575,000 in dividends. The Tombstone Mill & Mining Company gave about $8,000,000, but have no data as to dividends.* The Head Center & Tranquillity Company took out over $600,000, but spent all in improvements and litigation. The Vizina, $700,000; Watervale Company, $600,000; Telephone Company, $200,000; other mines that we have no record of, about $7,000,000."

These figures show the relative importance of the chief properties at that time as producers. Corroborative data from other sources and some further historical notes may here be presented relative to the three leading groups of mines; the Contention Consolidated; the Grand Central and the Tombstone Mill & Mining Company.

The Contention Consolidated

Patrick Hamilton, in his Resources of Arizona, published in 1884, wrote of the Contention property, that it was first incorporated in 1880 as the Western Mining Company, which, about the close of the year 1881, on the consolidation of the property with the Flora Morrison and 600 feet of the south end of the Sulphuret, was changed to the Contention Consolidated Mining Company.

"In 1882 the company extracted a total of 25,017 tons of

* Mr. W. F. Staunton, formerly superintendent of the Tombstone Mill & Mining Co., states that the net earnings of this company were over $2,000,000, of which $1,500,000 was paid in dividends and the balance absorbed in litigation and purchase of property.

ore, an average of 2,086 tons per month. That produced 632 bars of bullion, valued at $1,676,705.96.

"In the first five months of 1883 the ore saved and treated amounted to 13,652 tons, which produced 205 bars of bullion, valued at $553,085.91."

At that time there were five levels opened; the depth of the main shaft was 600 feet, and the amount of underground workings on all of these properties in the consolidation, including drifts, cross-cuts, winzes, raises, intermediary levels, etc., measured twenty miles.

The following tabular statement shows the value of the yield of the Contention Company for one year (1882):

January	$121,886.33
February	128,726.01
March	148,704.15
April	126,152.69
May	116,820.03
June	166,041.22
July	148,017.43
August	154,511.64
September	152,173.74
October	139,328.39
November	144,226.84
December	133,766.31
Total	$1,678,354.68

The Grand Central Mining Co.

The first claim of this group was one of the earliest located and one of the largest producers of the District. It adjoins the Contention on the south and is one of the group consisting of the Grand Central, the Grand Central South Extension, the Naumkeag and the Leviathan. Also the Emerald and other claims were under the same ownership and control. As early as the year 1882 the shaft had reached a depth of 600 feet, and the principal levels and openings had been connected with the Contention. Full reports of the value

of the production are not obtainable, but the amount for a period of eight months and thirteen days up to December 31, 1881, was $1,061,520; and during the last six months of that period monthly dividends of $50,000 each were paid, aggregating $300,000. During the same time an equal amount ($300,000), advanced to erect the company's mill and plant, was repaid.*

The 30-stamp mill was located on the San Pedro River, about two miles above the Contention mill. About 90 tons of ore were raised daily and worked at this mill.

This large mining property and milling plant was from the first under the able and conservative management of Mr. E. B. Gage, who resided on the property, and directed its operations. Some interesting facts recently communicated by Mr. Gage regarding the ore-chutes of the Grand Central Mine will be found under the head of Chapter V—The Lodes in Depth (page 75).

Tombstone Mill and Mining Co.

The several properties of this Company were for many years under the efficient management of Professor John A. Church, whose systematic and complete reports upon the progress of operations and on the weight, fineness and value of the bullion produced permit of the presentation of figures in detail for several years of the most active operations. Some of the latest figures are from the annual reports made by Mr. W. F. Staunton, while superintendent. These tables all have special value as concise records of what the mines produced from the blanket or interstratiform deposits.

The mines of the Tombstone Mill & Mining Company reached the greatest productiveness they have ever known during the year April 1, 1881, to March 31, 1882, the total yield having been:

* Report of the Director of the U. S. Mint upon the annual production of Precious Metals in the United States. Pages 314-315.

Ore	29,211.66	tons
Number of bars	478	
Crude Bullion	1,390,763.00	ounces
Fine Gold	2,462.84	"
Fine Silver	1,198,118.92	"

Approximate market value:

Of Silver	$1,325,040.23
Of Gold	51,006.90
Total	$1,376,047.13

One ton of ore has yielded on the average:

Of fine Silver, 41 ounces	market value,	$45.60
	assay "	53.02
Of fine Gold, 0.084 ounce	"	1.74
Total market value per ton		47.34
Total assay value per ton		54.76

Ore Production

October 1, 1881, to March 31, 1882

	No. 6 Tons	Combination Tons	Main Shaft Tons	North West Tons	West Side Tons	Total Tons
October	Merged in combination.	1,361.25	852.04	368.87	83.64	2,665.80
November		1,147.56	1,023.04	248.77	45.31	2,464.68
December		1,264.97	1,021.70	264.01	88.80	2,639.48
Jan., 1882		1,496.25	1,470.94	261.00	66.60	3,294.79
February		1,442.95	1,136.80	181.24	54.73	2,815.72
March		1,564.83	1,324.72	167.78	44.78	3,102.11
Second 6 mo.		8,277.81	6,829.24	1,491.67	383.86	16,982.58
Total		11,946.35	12,792.68	2,600.56	508.02	29,211.66

Bullion - Product

April 1, 1881, to March 31, 1882

	Net Value	Silver Ounces	Fineness Silver	Gold Ounces	Fineness Gold	Base Metals	Percent. Base
April,'81	$83,554.78	70,942.83	859	263.00	.003	11,288.17	14.1
May	92,806.69	79,170.76	898	268.29	.003	8,723.57	9.9
June	135,496.08	118,781.64	885	192.28	.001	15,203.08	11.33
July	123,245.31	107,617.97	887	201.56	.001	13,582.47	11.19
August	151,279.15	133,199.12	896	178.25	.001	15,223.63	10.25
Sept	111,495.97	97,520.04	877	172.16	.001	13,557.80	12.19
1st 6 mo.	$697,877.97	607,232.36	...	1,275.54	....	77,578.72	.....
October.	$114,229.70	97,694.96	851	174.06	.0015	17,015.79	14.8
Nov	112,092.73	97,789.62	829	183.74	.0016	20,386.19	17.3
Dec	130,730.26	114,387.44	825	170.84	.0012	23,970.16	17.3
Jan.,'82.	130,156.05	112,272.52	922	257.19	.002	11,910.75	9.6
Feb	116,165.52	99,732.68	860	254.91	.0022	15,875.91	13 7
March	79,084.74	68,909.34	740	146.56	.0016	24,039.68	25.9
2d 6 mo.	$682,459.00	590,886.56	...	1,187.30	.....	113,198.48	.....
Total.	$1,380,336.97	1,198,118.92	862	2,462.84	0.0017	190,777.20	13.72

Number of bars	478
Gross weight	1,390,763
Average fineness, Silver	861
" " Gold	1.7
" percentage Base Metals	137.2

The product from April 1, 1882, to March 31, 1883, was:

Ore mined	21,991.02 tons
Ore milled	21,474.00 "
Fire clay and limestone mined for furnace	60.67 "

The mill produced:

Number of Silver bars	232
Crude Bullion (Mint weight)	642,830.02 ounces
Fine Silver	532,372.03 "
Fine Gold	1,813.00 "
Base Metal	102,823.82 "
Market value of Silver, deducting discount, freight and shortage	$565,790.67
Market value of Gold	37,474.71
Total	$603,265.38
The furnace produced	2,708 bars
Containing fine Silver sold	40,883.57 ounces
" " Gold "	298.81 "
" Lead "	263,333.00 pounds
Market value of furnace product, deducting freight and charges	$55,062.31
Base Bullion on hand	6,000.00

The total marketed product of the year's work was:

Silver,	573,255.60 ounces	value, $609,960.85
Gold,	2,111.81 "	" 43,487.93
Lead,	131.67 tons	" 4,878.91
		$658,327.69

Bullion Product

April 1, 1882, to March 31, 1883

(By Mint returns)

	No. of Bars	Gross Weight Ounces	Silver Ounces	Gold Ounces	Base Metal Ounces
April, 1882	40	112,864.30	75,258.24	257.58	37,348.48
May	30	76,017.30	35,631.71	102.55	40,283.04
June	18	49,140.70	47,649.62	42.39	1,448.69
July	20	54,020.90	51,154.01	50.08	2,816.81
August	15	42,021.90	41,146.04	50.64	855.22
September	18	49,357.35	48,755.54	97.04	474.77
First 6 months	141	383,422.45	299,595.16	600.28	83,227.01
October	16	44,983.10	43,551.95	163.42	1,267.73
November	16	43,032.00	38,297.24	202.00	4,532.76
December	14	39,717.50	35,364.61	157.83	4,195.06
January, 1883	12	34,449.10	30,072.01	169.45	4,207.64
February	14	38,845.70	36,375.10	219.55	2,251.05
March	19	52,559.00	49,115.96	300.47	3,142.57
	91	253,586.40	232,776.87	1,212.72	19,596.81
Total for year	232	637,008.85	532,372.03	1,813.00	102,823.82

Average fineness, Silver	835.74
" " Gold	2.85
Percentage, Base Metal	161.41
	1,000.00

Ore Production

April 1, 1882, to March 31, 1883

	Main Works Tons	Combination Tons	West Side Tons	Lucky Cuss Tons	Defence Tons	Northwest Tons	Total
April, 1882	1,211.67	1,393.12	61.55	....	....	144.06	2,810.40
May	1,187.72	1,390.84	53.02	....	...	143.28	2,774.86
June	108.23	1,469.21	177.32	....	....	.....	1,754.76
July	104.02	1,522.05	257.46	....	....	.....	1,883.53
August	367.75	1,334.53	198.57	....	....	.....	1,900.85
September	366.52	895.81	533.08	78.20	....	.....	1,873.61
First 6 mos.	3,345.91	8,005.56	1,281.00	78.20	....	287.34	12,998.01
October	504.65	460.03	746.87	148.84	....	Limestone and	1,860.39
November	481.70	463.04	764.58	164.53	50.00	Fire Clay	1,923.85
December	494.21	373.95	766.17	152.83	Tribute	11.05	1,787.16
January, 1883	336.32	61.80	635.90	133.00	....	37.50	1,167.02
February	230.37	63.20	570.30	17.35	50.78	12.12	932.00
March	257.48	45.68	768.90	185.53	65.00	.....	1,322.59
Second 6 mos.	2,304.73	1,467.70	4,252.72	802.08	165.78	60.67	8,993.01
Total for year	5,650.64	9,473.26	5,533.72	880.28	165.78	348.01	21,991.02

The operations of the year, April 1, 1883, to March 31, 1884, were as follows:

Ore mined	17,410.79 tons
Limestone mined	109.73 "
Ore milled	16,042.67 "
Tailings concentrated	16,969.00 "
Ore and Flux smelted	1,527.85 "

The mill produced:

Number of Silver bars	169
Crude Bullion	466,395.05 ounces
Fine Silver	402,063.89 "
Fine Gold	1,896.27 "
Base Metal	62,434.89 "
Market value of Silver, deducting all charges but transportation	$431,739.92
Market value of Gold, deducting Mint charges	39,195.91
Total	$470,935.83
The furnace produced	11,851 bars
Weight of product	654.47 tons
Containing fine Silver sold	193,560.70 ounces
" " Gold "	1,178.60 "
" Lead "	645.84 tons
Market value of furnace product, deducting charges	$254,267.22

The whole record of the Tombstone Mill & Mining Company and its predecessors in the mining of ore and production of metals is as follows, the table including only the marketed product:

	Ore Tons	Gold Ounces	Silver Ounces	Lead Tons
June–September, 1879	2,025.00	284.86	129,215.81	.....
October, 1879–March, 1880	3,733.00	450.60	137,375.06	.....
April–September, 1880	7,242.00	745.70	392,017.11	.....
October, 1880–March, 1881	9,363.05	1,099.42	474,831.77	.....
April–September, 1881	12,229.08	1,275.54	607,232.26	.....
October, 1881–March, 1882	16,982.58	1,187.30	590,886.56	.....
April–September, 1882	12,998.01	600.28	299,595.16	.....
October, 1882–March, 1883	8,993.01	1,212.72	232,776.37	131.67
April–September, 1883	8,545.12	1,734.54	299,297.75	266.48
October, 1883–March, 1884	8,975.39	1,340.34	296,326.84	379.35
Total	91,086.24	10,931.30	3,459,554.69	777.50

Ore was mined and marketed from the Lucky Cuss and West Side claims as follows:

	Dry Weight Tons	The Ore Contained: Silver Ounces	Gold Ounces	Lead Pounds
Lucky Cuss, Apr. 1, '88, to Apr. 1, '89	2,566.423	107,978.66	1,519.27	68,501
" " Apr. 1, '89, to July 1, '89	687.264	25,706.94	355.66	....
West Side, Apr. 1, '88, to Apr. 1, '89	480.796	40,674.03	893.49	70,298
" " Apr. 1, '89, to July 1, '89	150.797	12,663.89	240.63	13,980
Total	3,885.279	187,023.52	3,009.05	152,779

Ore was mined and marketed during the year July 1, 1889, to June 30, 1890, as follows:

	Dry Weight Tons	The Ore Contained: Silver Ounces	Gold Ounces	Lead Pounds	Average Grade per Ton: Silver Ounces	Gold Ounces
Lucky Cuss	2,487.532	110,953.63	1,161.03	61,193	44.60	0.466
Sulphuret	500.319	42,411.44	966.35	44,828	84.77	1.931
Northwest	274.367	23,895.48	38.71	58,674	87.09	0.141
Total	3,262.218	177,260.55	2,166.09	164,695	....	....

Shipments to the smelter for the year ending June 30, 1891, were as follows:

	Dry Weight Tons	Contents: Silver Ounces	Gold Ounces	Lead Pounds	Average Grade per Ton: Silver Ounces	Gold Ounces
Lucky Cuss Mine	2,270.865	124,681.89	1,681.87	145,313	54.905	.74
W. Side-Sulphuret Mine	1,105.252	81,004.58	1,526.90	316,136	73.29	1.38
Northwest Mine	458.002	30,751.46	98.69	116,836	67.14	.215
Assay Office, Clean-up	14.884	773.96	8.18	2,082	52.00	.55
Charleston Slag Dump	42.406	2,589.91	23.67	6,066	61.07	.56
Total	3,891.409	239,801.80	3,339.31	586,433	61.625	.858

Shipments to smelters for the year ending with June 30, 1892, were as follows:

	Dry Weight Tons	Contents: Silver, Ounces	Gold, Ounces
Lucky Cuss Mine	2,683.63	116,973.40	1,253.53
West Side–Sulphuret Mine	1,489.77	99,025.61	1,688.87
Northwest Mine	1,413.06	124,061.79	500.94
Toughnut Mine	1,101.69	97,455.42	603.29
Assay Office, Clean-up	16.97	899.35	8.82
Charleston	322.70	22,090.17	152.35
Total	7,027.82	460,505.74	4,207.80

	Lead Pounds	Average Grade per Ton: Silver Ounces	Gold Ounces	Percent. Lead
Lucky Cuss Mine	280,606	43.58	.46	5.24
West Side–Sulphuret Mine	381,912	66.47	1.13	12.82
Northwest Mine	262,407	87.79	.35	9.30
Toughnut Mine	248,956	88.45	.55	11.30
Assay Office	2,476	53.00	.52	7.30
Charleston	86,469	....	....	....
Total	1,262,826	65.52	.598	8.98

Shipments to smelters for the year ending with June 30, 1893, were as follows:

Mines	Dry Weight Tons	Contents: Silver Ounces	Gold Ounces	Lead Pounds	Average Grade per Ton: Silver Ounces	Gold Oz.	Percent. Lead
Lucky Cuss	3,728.93	93,801.93	430.63	193,328	25.15	.11	2.59
West Side–Sulphuret	1,183.89	57,547.92	971.12	179,659	48.61	.82	7.58
Northwest	1,427.35	124,253.19	256.82	288,990	87.05	.18	10.12
Toughnut	2,095.62	116,200.58	1,288.68	541,208	55.45	.61	12.91
Charleston	16.59	361.55	2.98	1,824	21.80	.18	5.50
Total	8,452.38	392,165.17	2,950.23	1,205,009	46.39	.35	7.12
Total previous year	7,027.82	460,505.74	4,207.80	1,262,826	65.52	.598	8.98

Value of the Ores

There are two classes of ore produced at the Tombstone mines—the milling ores and those best adapted to smelting. Both classes are high grade. They yield gold, silver and lead. The average value of the ore worked by milling in 1881 was reported as $70 per ton. It is said and believed by competent judges familiar with the yield of the ores of the Tombstone District that the general average value was $45 per ton, being the highest average value ever reached in any important district on the Pacific Coast. Averages of samples and the certificates of returns from the smelters sustain that claim. The figures given in the preceding pages may be consulted for detail of the returns from large quanti-

ties of ore, both milling and smelting, and from different mines.

A recent assay of a sample taken by me from the lode on the 600-foot level of the Contention, a few feet above the water level, showed the presence of 47.07 ounces of silver and 2.31 ounces of gold, worth $47.74 per ton, or a total value of about $76 per ton, estimating the silver at 60 cents an ounce. Samples taken by Mr. Gray, selected ore, ran as high as 3.2 ounces gold and 98 ounces of silver. Examples might be multiplied, but returns on large lots as shipped are more satisfactory. Reference is made to the description of the Contention lode, in Chapter V, for a report of the result of more recent assays. See p. 78.

The lot of ore from the Tranquillity Mine shipped in April, 1902, 40,224 pounds, yielded per ton gold 2.4 ounces; silver, 98 ounces, and contained 14 per cent. of lead, making a very desirable ore for smelters. According to Mr. J. W. Dean, one of the former owners, the smelting ores shipped from Tombstone in 1899 averaged in value from $4,000 to $6,000 to the car load; assuming the car load at 20 tons this would be from $200 to $300 per ton in value. Such ores were selected so as to justify the great cost of hauling and transportation, but with a railway connection, and possibly a smelter in the camp, ores of a much lower average would be worked profitably.

Increase of Gold Relatively to Silver in Depth

The bullion produced from the ores, especially from those of the Contention lode, consisted largely of gold. The relative amount of gold and silver varies with the different mines and ores. In the year 1881, at the Contention, the gold formed 20 per cent. of the total value, but as greater depths were reached the value of the gold increased to 25 per cent.

This relative increase holds good for other mines, and for the blanket deposits as well as for the veins.

In the Toughnut and Goodenough claims the ores carried a little gold at the surface, but in depth they carried $30 per ton in value in the ore-chutes pitching towards the Empire claim.

An increase in the amount of gold relatively to silver in the lower levels of the Grand Central was noted in 1882. It is said that the value in gold at that time ranged from $85 to $112 per ton.

In the West Side claim the ore in the upper levels carried about $7.66 per ton, with an increase of $13 per ton in the ores from the lower levels. The ores from the deep workings on the Sulphuret claim carried about $20 in gold per ton.

In the Contention the gold content increased as compared with the silver, as already indicated, and it is reported that at 75 feet below the water-level mining was carried on in an extensive body of ore that averaged $100 per ton in value of gold.

Perhaps the most notable example of increase in the amount of gold relative to the silver was found at the Lucky Cuss mine opened in the manganese-bearing limestone. Starting at the surface with only a trace of gold in the ore, at the water level the average value was $35.14 in gold in car load lots. The increase was almost in a direct ratio with the depth as shown by the returns from the smelters. In some shipments the value of the gold was as high as $51 per ton.

It is not to be inferred from these examples that the ratio of the gold to the silver, or the increase in the value of the ore, will increase with depth indefinitely. The augmentation is believed to be confined to the surface ores, or to ores lying above the permanent water-level. Below this level there is no reason to expect a constant increase in value with depth, for the ores may be assumed to have their normal condition where covered permanently by water.

The decompositions and recompositions incident to atmos-

spheric influences, and the percolation of surface waters, may be considered as sufficient to affect the amount of gold at the different distances from the surface.

At the Contention mine in 1882 flakes of native gold were common in the seams and surfaces of the porphyry, and it occurs at the present time in the ores of the Tranquility mine in visible grains, making rich and handsome cabinet specimens.

Second Class Ores

Large quantities of ores extracted from the Contention and from the Grand Central and other mines upon the Contention lode, in which the average content in gold and silver was not sufficient in value to justify carting to the mills on the San Pedro have been profitably treated by the cyanide process.

The erection of mills at the mouth of the mines, or the rapid and cheap transportation which will be provided by the railway will permit of working ores to advantage that formerly had to be left on the dumps.

Nature of Ores Below the Water

It is to be expected that in this Tombstone camp and its mines, as in all other mines, the ores below the permanent water-level will be more pyritic—will contain more sulphur —than the oxidized ores above the water. We may, in short, look for ores that are not oxidized. The values will be there, but the method of treatment for the extraction of the values will be different from the treatment of ores from above the water. It is not yet possible to state what process will be best adapted to the end. It may be that roasting and chlorination will be resorted to, or it may be best to smelt. The smelting furnace will no doubt be the proper destination for such ores as are heavily charged with lead, as is now the case with some of the ores from the bedded deposits in the limestone and in the stopes of the Tranquillity.

Chapter Five—The Lodes in Depth

Contention Mine

IN the winter of the year 1882 I made an extended and careful study of the various workings of the Contention, Head Center and the Tranquillity mines in company with the late Mr. Isaac E. James,* the engineer and surveyor, and have notes of the lode and ore-bodies and stopes. I was able to trace these ore-bodies from the surface to the 600-foot level, just above the water line, and to note their continuity and the satisfactory evidences of the downward extension of the lode and its ores into and below the water. I was not present when the water was lowered by pumping, but in company with Mr. James had previously been to the lowest winze on the lode and saw a strong lode of quartz extending into the water. It had the appearance of being leached out at the water level and for a few feet above it, as if by the seasonal changes of water-level the ores had been removed, leaving a cellular skeleton-mass of white quartz. The inference was unavoidable that greater depth under the water would show good ore in the lode.

* "Ike" James, as he was familiarly known by the miners and intimate friends upon the Comstock Lode, and later at the Contention, was an accomplished surveyor and draughtsman. He was thoroughly familiar with the workings of Tombstone mines, especially of the Contention, and made beautiful and accurate maps of the lodes and a model of the whole mine. He made the earliest maps of the Ophir and other mines on the Comstock Lode. After the fire which destroyed the pump and hoisting works of the Contention, Mr. James was engaged for a time at other mines and then went to San Diego, California, where he died. He was a most genial, intelligent and charming companion in my underground investigation of the Contention Lode.

W. P. B.

The concensus of opinion and statement by competent observers and judges at that time, and since, is that ore values will be maintained in depth. This is my belief also. It is based upon the knowledge gained as above stated and upon the fact that I have recently visited different parts of the 600-foot level of the mine, where winzes have been sunk to and into the ground now covered by water and have seen good ore there.

Other points at which ore has been shown to extend to and below the water were visited by me in the extreme east workings of the Contention on the 600-foot level, where two winzes show ore of good grade.

It is interesting to take note of the experience in deep mining at the celebrated Commonwealth, at Pearce, one of the nearest precious metal mines of great extent. The ores at that lode were in an oxidized state above the permanent water line, and it was supposed that on mining below the water only sulphuretted ores would be found. But the oxidation has extended to a greater depth and no radical change of treatment of the ore has been found necessary. The ore is as rich below the water as above. This fact alone is sufficient, if there were no other evidences, to relieve any doubts regarding the downward extension of the ores in the Tombstone Camp.

At the several points where mining operations on orebodies have reached water-level the evidences of continuity have been highly satisfactory. It would be an anomaly in mining if the ores so liberally formed above the water did not extend with equal value below its level. It is geologically certain that the present surface level of the country is now much lower than it formerly was, this lowering or cutting away being the result of the mighty erosive agencies to which Arizona has been subjected. The ancient surface was probably some hundreds of feet higher than now and the ancient water level was correspondingly higher than now, so that the ore deposits we have been able to mine were once below the water. And if we now lower the water artificially we may expect to uncover ores as rich or richer than those uncovered by the gradual subsistence of the water level from natural causes.

This question of the continuity of ore below the water has been much discussed. That ore should so continue, theoretically, has already been sufficiently stated and shown. But it is now a matter of *fact* rather than of theory. While not present when the two great pumps were in action, one at the Grand Central, the other at the Contention, I am most credibly informed that the water was drawn out enough to permit of winzes being sunk at intervals below the 600-foot mark for the purpose of testing the lode. Owing to the broken character of the ground, the water receded at points quite remote from the shafts almost as fast as in the shafts. The shafts themselves were extended downward for approximately 100 feet below the water-level, an important fact, showing that the water can be controlled by proper pumping.

High grade gold ore was found in the winze upon the east ledge, about 400 feet north of the Contention pump shaft. A letter from the then president of the Contention Company stated that at a depth of 75 feet in this winze "a drift was run for a distance of 140 feet, and that the ore taken therefrom averaged over $100 per ton in gold." Ore of excellent grade was found in the other winzes, but this winze was the only one in which any considerable amount of drifting was done.

In a recent letter from Engineer Staunton (Sept. 4, 1902) he says: "We are now running a drift on this east ledge northward from the top of the winze on the 600-foot level, and are getting a good showing of ore, an assay from which, received that morning, showed 22.6 ounces silver and 2.9 ounces gold, or a total value of $71.24, figuring silver at 50 cents an ounce. Another assay received to-day also shows the same strikingly high proportion of gold to silver, which we are finding to be the rule on the water level. It is from

one of a number of bunches of ore found in the country rock east of the east ledge, where we are excavating a station for a hoisting engine to be used in sinking the winze and running drifts when the water is lowered. The assay was 7.4 ounces silver and 2.2 ounces gold; a total value of $49.57, of which $45.87 was gold and $3.70 was silver."

The influence of wall rocks upon ore deposition is a factor not disregarded. It has been pointed out fully that the ores of the Contention were deposited not only where the lode intersected limestone beds but also where the walls were of shale and of sandstone or quartzite. It is therefore just to expect ore deposition along the walls formed by the lower formations, especially where these formations are the downward prolongation or extensions of beds known to be peculiarly ore-bearing above the water. The structure of the beds, as already shown, gives evidences of an extended area of such contacts along the deeper parts of the Contention lode now submerged, but which will become accessible when the water is sufficiently lowered.

Grand Central Mine

In regard to the extreme south portion of the Contention lode the following facts are important.

Mr. Gage, as president and manager of the Grand Central Mine was familiar with the ore developments, and at my request informed me regarding the indications at the south end of the property, where it is believed that thorough exploration will reveal bodies of ore yet untouched. He writes: "We found some very good ore-bodies near the southwest corner of the mine which I have no doubt will extend below the water level, as the ore continued as strong to the water-level as it did in the north end, but not in quite as large bodies. In fact we had three ore-chutes in the Grand Central Mine. One was the extension of the same ore-body the Contention had in the south end of that mine. One to the south

of and near to the old working shaft, and the third near to the southwest corner, which chute extended partly into the Naumkeag, a side line claim on the west of the Grand Central, and which the Grand Central owned."

New Shaft

At the bottom of the new Combination Shaft, on excavating for the pump station just above the water, a mass of heavy sulphide ore was found. This ore consists of pyrite and galenite, and it appears to occupy a saddle or roll of the beds. This mixture of galenite and iron pyrites is characteristic of the interstratified bedded deposits rather than of the ores of the dikes and veins.

Intersection of the Lode by Bedded Deposits

It is just to expect great results from the deep contacts of the limestone beds with the lode. Of the several sections upon the line of greatest extension of the workings upon the anticlinal folds carefully drawn to scale from the notes and sections of Mr. Gray and Mr. Staunton, one alone has been chosen as typical of the rest and as sufficiently illustrating the fact of the pitch of the rolls, the depth to which the stoping on ore has extended and the theory of the prolongation of the limestones and other beds with their accompanying blanket deposits of ore under the water-level to the Contention lode. This has already been discussed in Chapter III.

The section shows the succession of the strata from the surface down; the several dikes crossing the strata, and also the veins. The Contention lode is on the extreme east, where the shaft and the several levels are indicated. The general water level is shown by the horizontal line. The blanket ore deposits, so far worked, are indicated by the heavy black lines, dipping downwards toward the

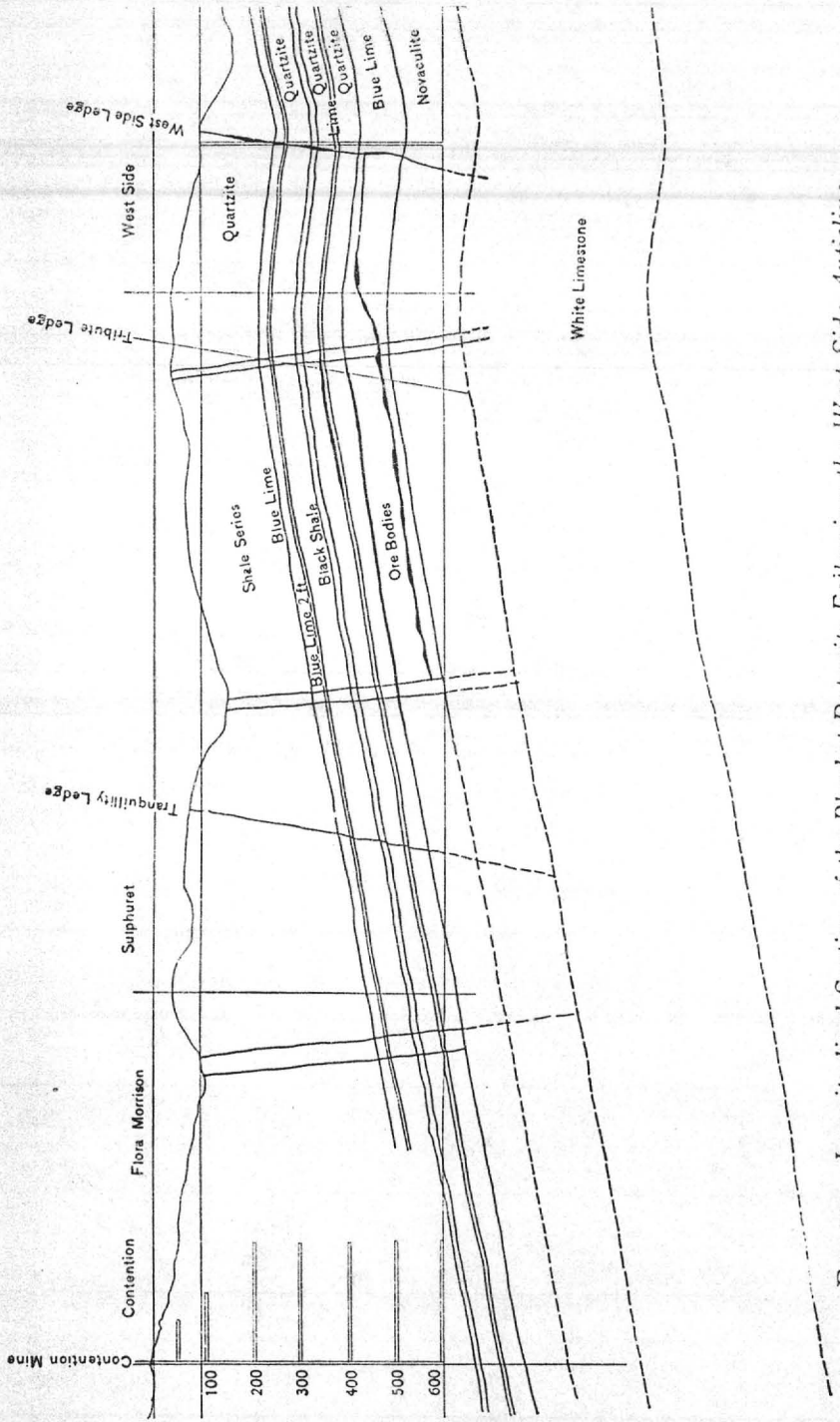


FIG. 19. *Longitudinal Section of the Blanket Deposits Following the West Side Anticline.*

Contention and extending nearly to the water line. I am indebted for the original of this illustration to Mr. H. J. Gray and to Mr. Staunton, who have made several such sections, following the crests of the different anticlinal folds. It will be noted that the prolongation of the ore-bearing ground downwards on the pitch if maintained unchanged would intersect the Contention lode about 200 feet below the 600 level (Fig. 19, p. 80).

Bottom of Sulphuret Shaft

As early as the year 1882 a body of sulphide ore was found where the lode intersected limestone, and ores, as already stated, are found there to-day, and give great promise of quantity and value. These ore-bodies are on the 600-foot level, near the shaft, and are opened up in part by a winze which has been sunk on an incline following the ore to the water on and in a bed of limestone. A considerable quantity of ore has been taken out from the sides of this winze.

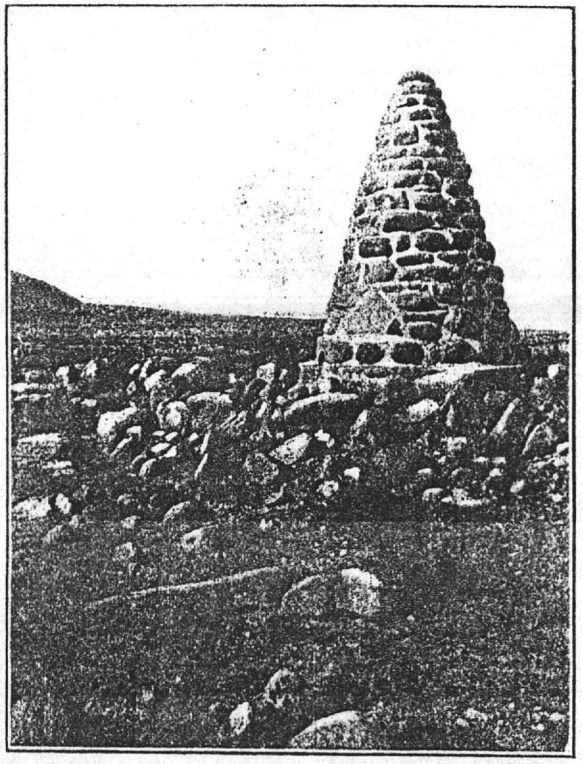
Empire and Silver Belt

Mr. A. L. Grow reports to me a zone or body of rich argentiferous lead ore cutting across the Herald claim, Last Chance, Sulphuret, and the corner of the Tranquillity following near to the line between the Tranquillity and the Girard into the south end of the Empire and the Silver Belt. This body has been worked on by August Baron, and considerable ore has been shipped from it.

Tranquillity

In the Tranquillity some excellent ore, showing free gold, is now being stoped out from bedded or blanket lodes by Mr. Grow. There are several places in this mine above water level from which ores of high grade can be extracted without

delay. The mine is well-equipped for immediate work, having levels opened, tracks laid and good hoisting works in running order. Ores have been regularly shipped from this property up to the date of its recent transfer to the Tombstone Consolidation.



View of the Monument to E. S. Schieffelin.

In Conclusion

HAVING in the foregoing pages described the mines of the new Tombstone Consolidated Company and presented evidences of the nature and extent of the ore deposits, I do not hesitate to express the opinion based upon this evidence, and upon my experience of other localities, that paying ore-bodies will be found below the water-level on the Contention lode corresponding in value, extent, and distribution to those found on it above the water-level.

The Tombstone, Arizona, Mining District.

BY JOHN A. CHURCH, NEW YORK CITY.

(New York and Philadelphia Meeting, February and May, 1902.)

TWENTY years ago Tombstone was the most noted mining camp in Arizona. It presented a combination of fissure-veins and bedded deposits in relations which were most puzzling, and impossible to make out until the extensive development of the mines permitted every detail of the structure to be observed. These details have been studied with great success by W. F. Staunton, now Manager of the Congress mine, in Arizona, and subsequently by H. J. Gray, and the facts upon which the following description is based are mostly the discovery of Mr. Staunton, though confirmed by my own examination.

Tombstone is situated in a country that contains several important mines. On the south, at Bisbee, are the Copper Queen, which Prof. Douglas has described in our *Transactions*,* and other valuable mines; on the east the Commonwealth gold-mine and the recently opened copper-mines at Turquoise, or Gleeson, and the older Middlemarch and Black Diamond. Northeast are the Peabody copper-mines. The wolfram discoveries of two years ago were in the Dragoon mountains, towards which Tombstone looks on the north and east.

Though the town has no railroad at present, it lies but ten miles from Fairbanks, through which place both the Southern Pacific and the El Paso and Southwestern railways run, and it is expected that in a few months a cut-off on the latter road, between Fairbanks and College Peak, passing through Tombstone, will place the camp practically on the main line.

Its general situation is shown in the accompanying map. It lies on the Gadsden Purchase, and is in Cochise county, 25 miles from the Mexican line. The San Pedro river, at Fairbanks and Charleston, afforded an ample supply of water to

* *Trans.*, xxix., 511.

the old mills, and the water-supply of the town is drawn from the Huachuca mountains through a pipe-line about 25 miles long.

Considered as a whole, the formation consists of sedimentary beds in contact with an extensive eruptive mass of granodiorite; but with two exceptions (the Lucky Cuss and Knoxville) the best mines are not near the contact, and the eruptive rock does not underlie the productive part of the measures, unless at a depth greater than 3000 feet.

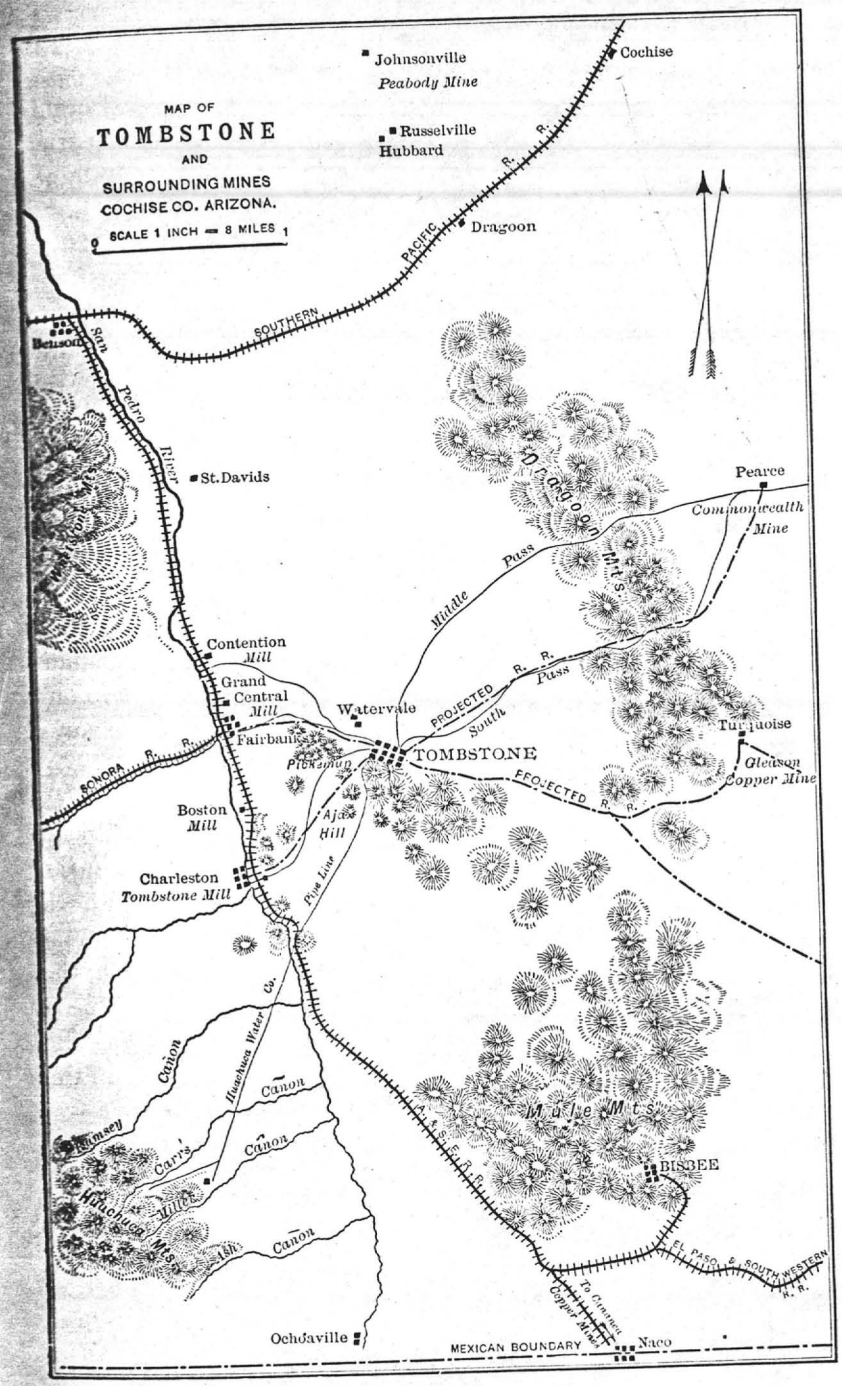
The Lucky Cuss claim has a fissure-vein within 300 or 400 ft. of the granodiorite, and has yielded nearly a million dollars; the West Side, another fissure-vein, is 2000 ft. from the contact, and has produced a million and a half; and the principal fissure of the district, which passes through the Grand Central, Contention and Head Center mines, and has yielded about twelve million dollars, is 4000 ft. from the eruptive rock. A few of the minor bedded deposits are 600 to 900 ft. from the contact, but their total product did not exceed $900,000, while the principal deposits of this type which have produced more than six million dollars are half a mile distant.

In a district like Tombstone, where surface-deposits of small extent have been opened at a great many points, exception can be taken to almost any statement that can be made, on the ground that ore has been found under conditions that do not agree with the general statement; but the preponderance which I have expressed in values could be given also in tonnage, if the books of all the mining companies had recorded the output by weight, and it is clearly shown by the comparative extent and permanence of the stopes and veins. It is by the study of the leading mines that the facts of the formation have been obtained. They show that the deposition of the ore has an intimate and interesting relation to the structure and dynamical history of the sedimentary rocks.

The observable measures of Tombstone consist of 2850 ft. of sedimentary strata, an intrusive mass of granodiorite and a surface-flow of rhyolite.

The Sedimentary Rocks.

At the bottom of the sedimentary series is the Randolph limestone, numbered I. in Fig. 1, so called from the mine of that name in the Charleston side of the district. A thickness



of 300 ft. is allotted to it, as it is certainly more than 200 ft. thick. It has not been an important producer of ore.

Above it is the Ajax quartzite, II., a strong anticlinal in this rock forming Ajax hill, the highest elevation in the district, rising 900 ft. above the town. The Mamie and other mines have been producers from this rock, which is 500 ft. thick.

Over the quartzite is the Emerald limestone, III., 420 ft. thick. About the Emerald, the most important mine in it, this stratum consists of thin limestones interleaved with thinner shales. At other localities it is made up of thicker and purer limestones, with thicker beds of quartzite; but wherever seen it indicates variable conditions of formation. It contains several mines.

Next in the series is the Lucky Cuss limestone, IV., which has several productive mines besides the prominent one that gives it its name. Its thickness is taken at 400 ft., but in the southern part of the district it covers a great extent of country, and undoubtedly thickens rapidly, indicating steady and long continued subsidence. It is often fossiliferous, but metamorphism has made it difficult to obtain satisfactory fossils in any variety. It is full of crinoid fragments and imperfectly exposed corals, the crinoids being most abundant.

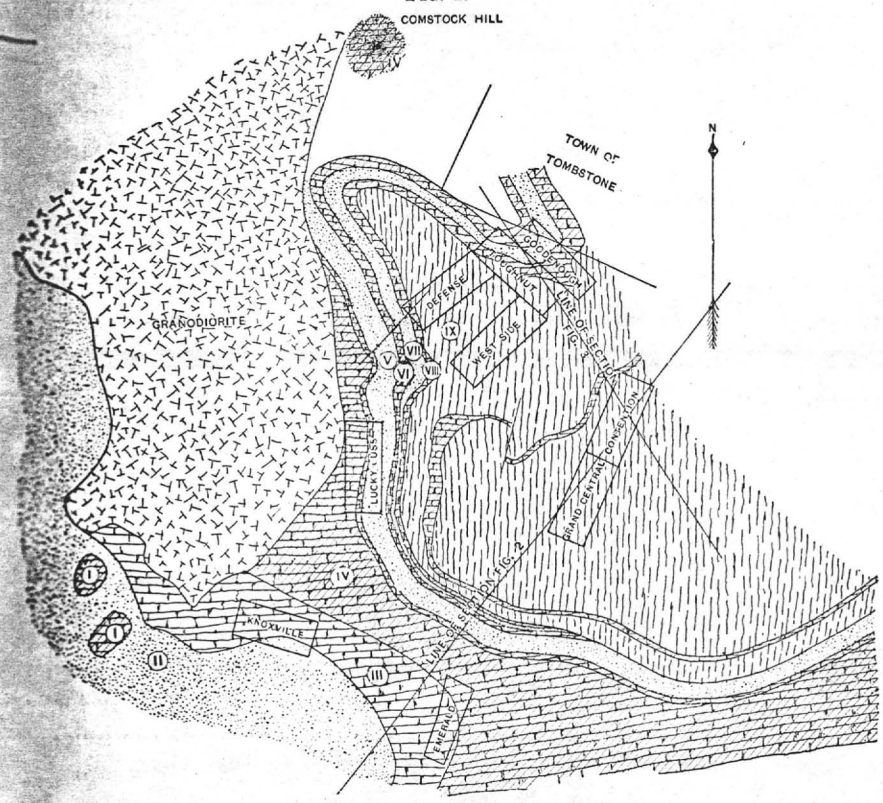
Upon this limestone rests the Herschel quartzite, V., which varies in thickness, but in the section given is taken at 270 ft., a minimum. At the surface it has a shaly structure, but in the East Side crosscut is found to be mostly a dense, fine-grained quartzite.

Above it is the first of the more important ore-strata, the White Lime, VI., 60 ft. thick. This rock, which has produced some of the most valuable ore-bodies in the district, has the usual appearance and softness of pure limestones, but in the ore-bodies and their neighborhood becomes very siliceous—so much so that Prof. Kemp, though deciding it to be limestone, found that the specimen sent him resembled a quartzite with lime intrusions. Its character as a limestone is undoubted; and the siliceous intrusion which characterizes it is probably to be ascribed to the solutions which brought in the ore, for it is not present away from the ore-bodies.

Above the white limestone lies the Toughnut quartzite, VII., 120 to 140 ft. thick. It is one of the three rocks first recog-

nized in Tombstone as belonging to the most prolific ore-measures. It appears to have shared in the silicification due to solfataric action; for, though a quartzite of very fine grain, it gives to one familiar with it the impression of a rock that is not altogether clastic. Prof. Kemp, who examined the rock under the microscope, confirmed this impression, as he reported that, in addition to fragments of quartz, it has much cherty

FIG. 1.



Geological Sketch-Map of Tombstone District, Arizona.

silica, and little veins run all through it. The specimen submitted to him was taken in the heart of the mass, and was not near ore. In the mine it appears a massive, fine-grained rock, but not composed of impalpable siliceous paste, like some of the quartzites in the shales.

This rock sometimes contains ore, but not abundantly. There is one small ore-body in it that seems to be connected

with low vertical stopes in a crevice or crevices, and another that shows some limestone, and may have formed in a limited bed of this rock. Another, which unites the Quarry and Girard anticlinal ore-bodies, lies on the Quarry dike, and extends vertically for 40 ft. There are other small irregular stopes near the same dike. Thus, though ore can make in the quartzite, special preparation seems to be needed for it. Of occurrences where ore makes in it in contact with an ore-body in limestone it is not necessary to speak. Such exceptions occur in all mines.

Over the quartzite is the third of the original ore-series, the Blue Lime, VIII., 90 ft. thick. Unlike the white limestone, this is a soft, deep-blue rock, a typical limestone; and it is remarkable, considering the silica imported into the lower members, that this rock has been unchanged, except in definite lines like veins or in limited areas. In general, the rock is pure.

In the places excepted, there is a dark-blue silicified fossiliferous limestone, evidently an alteration of the parent rock, in which no original characteristic except hardness has been disturbed. The blue limestone has been one of the best ore-carriers in the district, as might be expected from its softness and purity.

Finally, we reach the highest stratum with which we have to deal, known in Tombstone as *the* shale, IX., to which I will add the name Contention, as that mine has been the principal producer from it. It contains a heavy bed of quartzite, and many thin limestones and thin quartzites; but the ore-bodies of the fissure-veins go down through all its constituents, and it is sufficient to regard it as a single, though a composite, member. The Grand Central pump-shaft has penetrated it vertically for 681 ft., and is supposed to be still 150 ft. above the blue limestone. It forms the surface over most of the productive area, and its thickness there may be taken as 700 ft.

These four rocks—the shale, blue limestone, quartzite and white limestone—will sometimes be spoken of as the Toughnut series, from the mine where these leading members of the Tombstone formation were first recognized.

The limestones are non-magnesian, and often fetid, even when bleached nearly white.

Few recognizable fossils were found, though all of the limestones are fossiliferous. *Fusulina cylindrica* was found in the

quartzite above the Lucky Cuss limestone and *Spirifer rockymontanus* in the blue limestone. An undetermined *Chætetes* and a *Productus* were the only other fossils obtained. The indications are that the Tombstone beds belong to the higher measures of the Lower Carboniferous, and, perhaps, to the Carboniferous.

The sedimentary rocks are folded into a synclinal about 4000 ft. wide, measured on the center line of the Toughnut claim, with a nearly east and west axis, which pitches from the granodiorite eastward. The outcrops lie in an irregular horseshoe which has a deformation near the point of the curve that suggests pressure against the granodiorite. They have not been traced beyond a point east of the San Diego mine, but the Lucky Cuss limestone continues there in a line of prominent hills eastward. Except the three Toughnut rocks, this is the only one of the series that can be found near the town—Comstock hill, a mound 100 ft. high, being composed of it.

The composition of these rocks shows that the geologic history of Tombstone was mostly a very quiet one. There are two or three pebbly limestones, and two or three conglomerates with quartz pebbles like walnuts, but nearly all the other rocks are of extremely fine grain. The Ajax quartzite and the thick one included in the shale series are of ordinary visible grain, but the others are mostly of shaly fineness though siliceous in composition. The land mass which furnished the material for these rocks probably lay to the north and west, and sufficiently distant to send only fine sediments to the locality under consideration.

The massive fine-grained quartzites of Tombstone seem to be nearly pure silica, the coarser kinds often containing a large proportion of highly crystalline feldspar, opaque and pink in color. As the quartz grains of the granular quartzites are often perfectly limpid, the combination of these rounded glassy grains with well-developed feldspar makes a product that resembles closely one of the dike eruptives. Other quartzites, less frequently found, have much hornblende. These impure rocks resist erosion better than the pure. Sometimes they have a linear direction like dikes, and I suspect these are to be affiliated with the lines of silicified limestone as a result of the action of hot water or hot gases.

Elevation succeeded the formation of the rocks, and the steep dips in places where it can hardly be attributed to subsequent history indicate that this movement was not insignificant.

The Eruptive Rocks.

The next step in the process of preparing Tombstone for its mineral wealth was the intrusion of an extensive mass of granodiorite. It has a maximum width of about 10,000 ft., and a length of 15,000 from its contacts on the south to the line where it disappears towards the north, under the gravel of the 12-mile-wide valley which separates Tombstone from the Dragoon mountains. It may have some relation to the granitic rock which forms the front of Cochise's stronghold in those mountains, and reaches several miles out in the floor of the valley.

This mass intruded somewhere below the lowest of the known measures, and faulted the rocks at the southern contact, lifting a block from which the sedimentary rocks have been mostly removed by erosion; but patches of them, and in one case a considerable hill, are found scattered over its surface. These patches are mostly limestone which contained a decided proportion of silt, if we may judge from the products of contact-metamorphism. Sometimes quartzite is found, and the composition of these remnants recalls the Randolph and Emerald limestones.

It is evident that the eruptive rock has suffered but little erosion except towards the valley. Near the southern contact it is possible often to walk on the original surface. This fact permits the minimum thickness to be calculated, for the upper surface is now on a level with the Herschel quartzite, and the granodiorite has risen 1600 to 1800 ft. above the level of its entrance, even if it intruded directly under the Randolph limestone.

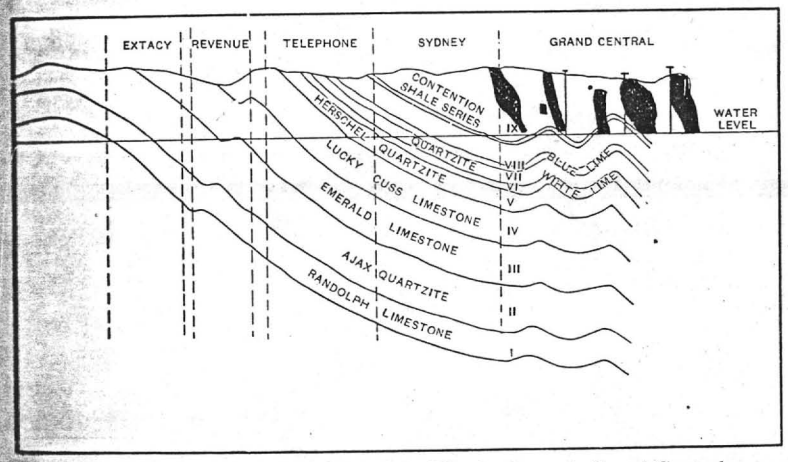
The eastern face of this mass, on which the ore measures abut, is, so far as it can be observed, a sheer fault. At the Lucky Cuss a crosscut on the 140-ft. level reaches the granodiorite at a point vertically under the contact, and on the 340-ft. level a crosscut directly underneath failed to reach the eruptive rock, though pushed nearly to the same distance. The mine is nearly 700 ft. deep, but the dip of the vein takes the openings at the bottom about 600 ft. away from the granodiorite.

Northward from the Lucky Cuss the surface is covered by

gravel, and the eruptive rock is exposed only in gulches on its eastern side; but the conditions indicate that the whole of this side, for a distance of nearly a mile, is a fault-face, and the presence of this vertical face of rigid rock has been one of the factors in Tombstone's history. The western side is also a fault, and abuts on the Ajax quartzite, the width of the block being about 4000 ft., opposite the mines.

The surface-distribution of the rocks in the Tombstone basin is shown in Fig. 1. Fig. 2 is a section taken in a NE.–SW. line through, and nearly parallel to, the Grand Central mine, on a line north of the area where the extreme thickening of the Lucky Cuss limestone begins. The ore-bodies of the

Fig. 2.



NE.–SW. Section on Line Shown in Fig. 1, through Grand Central.

Grand Central are indicated in longitudinal section, to show their position in the so-called shales.

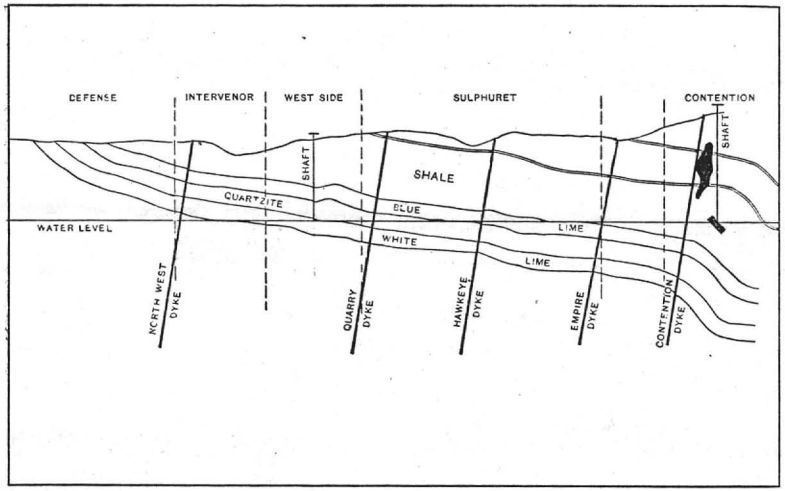
Fig. 3 shows the ore-measures from the outcrop at the town to the Contention mine, being a section taken at right angles to that in Fig. 2. The position of the dikes is indicated, and two of the ore-bodies of the Contention in cross-section. This is the region of the bedded deposits in limestone where the structure is exhibited by extensive mine-openings, and the section is confined to the rocks that outcrop here.

The last addition to the surface-rocks of the district was a flow of rhyolite, which covers an extensive field lying entirely on the Charleston side of the divide which separates that de-

funct town from Tombstone. Not even fragments of it can be found on the surface of the latter's territory. It rests on the Ajax quartzite, at least on its eastern side, and reaches from Ajax hill, which will be found on the map, northwest beyond Fairbanks and southwest to the hills on the San Pedro river, through which the Huachuca pipe-line passes.

Great numbers of dikes are found in the granodiorite, in the sedimentary rocks and in the rhyolite. In the first-named eruptive rock they run in all directions, and are remarkable only for their occasional small size. One of granophyre was

FIG. 3.



NW.–SE. Section on Line Shown in Fig. 1.

4 in. thick and 60 ft. long. The sedimentaries are especially rich in dikes at their contact with the granodiorite.

In that part of the sedimentary rocks where the ore-deposits are found the dikes are very regular in strike, parallel, and probably a mile and a half long, and they owe this regularity, probably, to the influence of the fault-face of the granodiorite. The fault runs nearly N., the dikes N. 23° E., dipping W. 80°. Against this fault-face, also, folds of the strata have been developed, whatever beginnings they had before, and the dips are steeper near it than elsewhere.

In the area traversed by the five dikes of the mines there are

none in other directions; but in the Lucky Cuss limestone and eastern part of the basin there are quartz-felsite dikes 150 ft. thick, striking N. 70° E.

The materials of the very thin dikes are always granophyre, usually a pink variety, with well-marked granitic texture, and these are abundant in the granodiorite, as also are dikes, usually much thicker, of a dark granophyre with large feldspars. It is the latter variety which is found exclusively in the dikes of the ore-ground, except one diabase dike in the Northwest and Vizina mines. Several diorite dikes are found in limestone near the contact, and though several feet in thickness, they are often very short. It may be that there is an uneroded portion in the limestone. They are probably a portion of the great eruptive mass in dike form, and have not been found at any great distance from it.

The two varieties of granophyre are not infrequently associated in one dike. The distinction made between them here is due to the absence of the pink variety from the ore-measures. An interesting occurrence of minette in granodiorite near its contact with Lucky Cuss limestone is referred to in connection with the mine of that name. In the rhyolite, dikes of quartz-augite-porphyrite and mica-hornblende-porphyrite were noticed. Erosion, of course, has been strong, for whatever mass was lifted up by the granodiorite has been removed almost completely; and this has been done since the rhyolite eruption, for the summits of that rock now stand 1000 ft. above the granodiorite and within half a mile of it. That flow would certainly have poured into the Tombstone basin, and left its traces there, if it had not been restrained by some lofty barrier.

It is to be hoped the United States Geological Survey will turn its attention to this interesting field, which is too extensive to be studied by private enterprise alone. The formations of the Whetstone, Dragoon and other mountains that encircle Tombstone stand in evident relations with each other and with the developments of eruptive rocks, which form a more extensive series than I have indicated. If properly studied, this would probably be found to be one of the simpler types of structure in Arizona.

Position of the Ore.

There is nothing in Tombstone that indicates the original seat of the metals which formed the ore; but the structural conditions point strongly to some underlying source from which they have risen, through fissures, to be deposited in the fissures and in strata which had been prepared by folding for the entrance of solutions. The granodiorite has not acted except by its inertness, and the *rôle* of the dikes has been almost equally inferior. The rocks owe their ores almost entirely to the two results of pressure—folding and fissuring.

The folding is in two directions, producing anticlinals, with axes varying in direction from S. 15° E. to S. 65° E. from their outcrops, and monoclinal flexures which lie across the anticlinals. They are usually of gentle slope while the anticlinals are often highly compressed, and, in two or three instances, faulted. The level parts of the monoclinals sometimes rise a little, instead of descending; but the rise is too unimportant to destroy the contrast between the folds in the two directions.

The bedded deposits lie in the anticlinals, sometimes on the flank, sometimes in the apex; but the synclinals are barren. The monoclines do not seem to have limited the deposition of ore, which is found both where they dip strongly and where they are nearly horizontal. The compound surface produced on any stratum by these cross-folds, with their varying direction of axes and steepness of dip, is of unending variety, and undoubtedly has been a controlling factor in the distribution of ore, which is found in all shapes, from long, narrow tongues to broad sheets. There is nothing like the superposed saddle formation, made familiar to us by Rickard and others. In the Goodenough incline, especially, there are as many as three sheets of ore at different levels in the blue limestone, and they coincide vertically for portions of their extent; but they differ in the direction of their axes and dips. The simple anticlinal structure of the saddles is disturbed by the monoclinals.

Fig. 4 shows the anticlinal folding along the line of the West Side vein and across the Toughnut and Goodenough claims where the flat ore-bodies have been most important. It will be seen that there are two principal anticlinals, one in the West Side and one at the Quarry in the Toughnut. On the

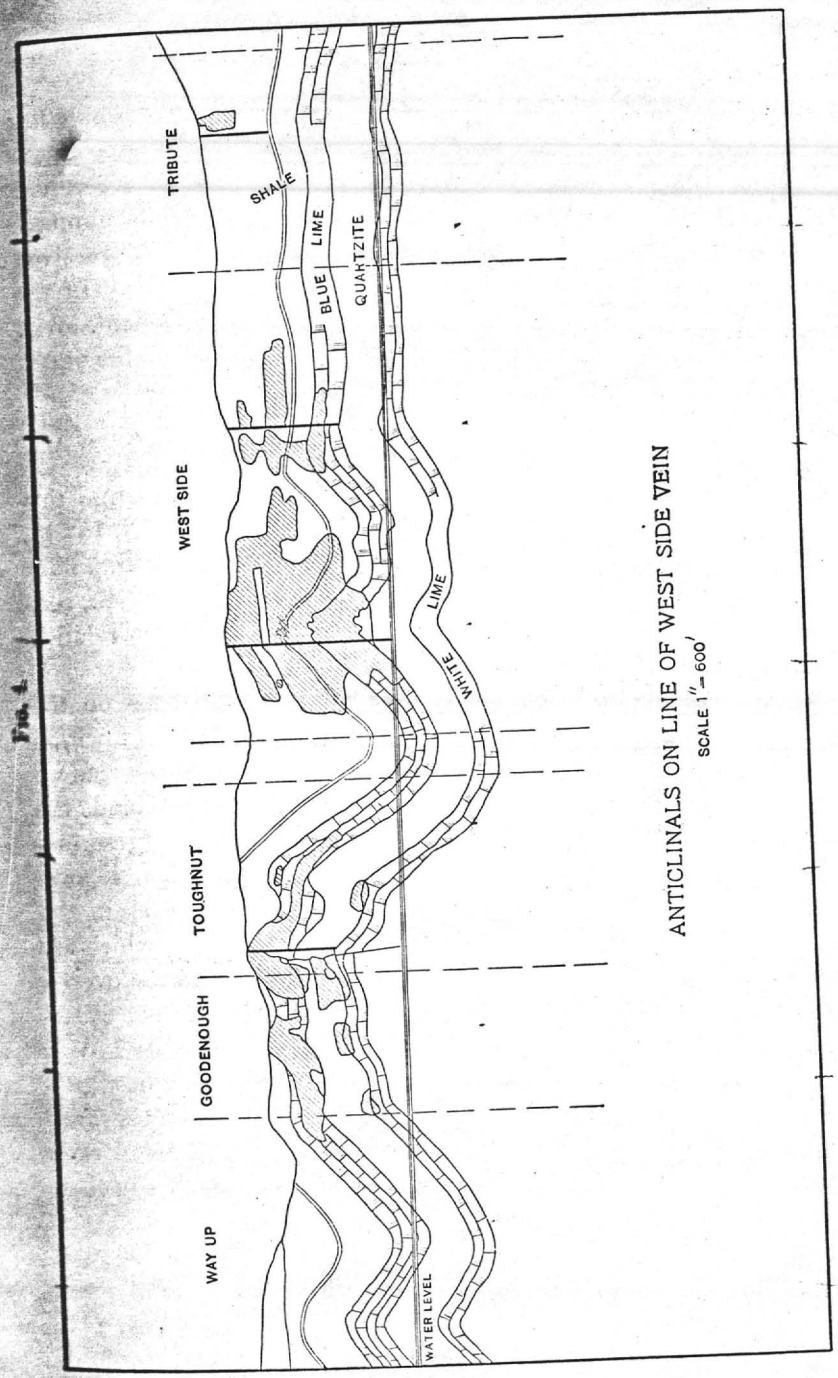


FIG. 4.

flanks of these are subordinate folds, which constitute the other anticlinals shown in Fig. 6.

One of the monoclinal flexures across these anticlinals has been plotted in Fig. 5, showing the irregular stopes in the Northwest mine of the Toughnut claim, which have received the name of Hoodoo. On this line there are great numbers of small, vertical crevices, which have sometimes received enough ore to join two overlying bodies together. In the section of this figure the ore-body B occupies the flank of an anticlinal which dips towards the spectator. A and all the others are seen in true section.

Compression-Fissures.

Two lines of vertical fissures are found lying across this system of anticlinals. On one, which has a strike of N. 15° E., the Grand Central, Contention, Head Center and Tranquillity mines are opened, while the other, striking N. 42° E., contains only the West Side mine. Their positions with relation to the anticlinal deposits are shown in Fig. 11.

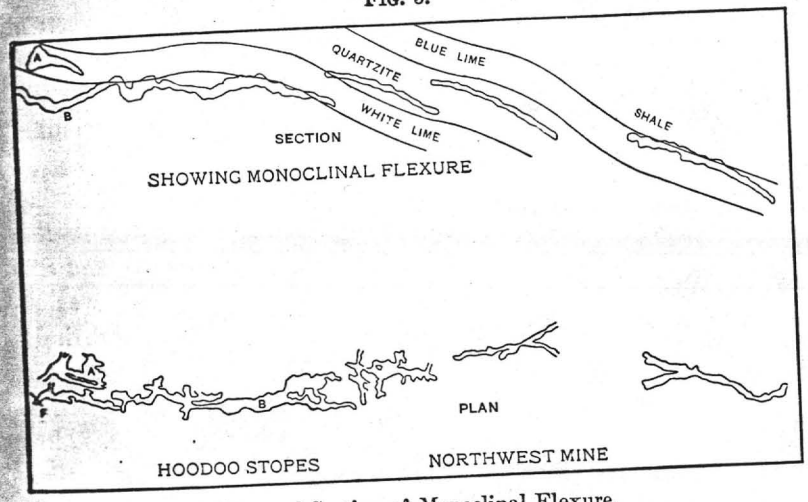
The anticlinals are persistent from their outcrops on the Vizina, Goodenough and Toughnut claims, near the town, to the Contention and Grand Central, and in the fissure-veins we find the distinctive peculiarity of Tombstone, which binds the bedded deposits and fissures in one system. The largest ore-bodies of the fissures are found within the lines of these anticlinals, whether the fissure has been deep enough (as in the West Side mine) to reach the blue and white limes, which are the rocks that contain the bed deposits, or are still in the overlying shale (as in the Contention and Grand Central). The water-level in the last-named two mines is calculated to be 150 ft. above the blue limestone, which contains the highest ore-bodies of the Toughnut series; but the influence of the anticlinals upon the deposition of ore in the fissures is as marked in the overlying shales through which the fissures pass in their upper levels as in the limestones of the bedded deposits.

The second result of dynamic action was the production of these vertical veins, which I regard as compression-fissures. They have been studied most thoroughly in the West Side mine, where the principal ore-body of the fissure was confined to a strongly compressed anticlinal about 450 ft. long. This

fold is succeeded on the north by a broad and barren synclinal and on the south by a narrow synclinal and a gently rising anticlinal. The fissure passes through shale for the first 200 ft. of its depth, and there is a small ore-body within the synclinal in the shale. It does not extend into the blue limestone below, and is probably due to secondary deposition.

There are at least three known parallel fissures within a width of 400 ft. at the West Side, two of which have yielded ore, though the West Side is the only important producer. The walls do not indicate faulting; and though a cross-fault of small throw is observable, it is probably a dislocation of slabs rather than of a section of the country.

Fig. 5.



Plan and Section of Monoclinal Flexure.

In Fig. 4 the ore-bodies shown in the West Side mine are all in the fissure, the anticlinal deposits stretching away from the vein on the side opposite the spectator. The ore-bodies of the Goodenough and Toughnut, on the other hand, are exclusively anticlinal. In order to show the grouping of the ore-bodies on the anticlinal, it was necessary, in a drawing on this scale, to project the flat bodies on their entire dip. The figure is faulty, therefore, in showing the ores of the fissure in section and the ores of the anticlinal in projection. Still, the figure exhibits the anticlinal deposition both in the beds and fissures, and the synclinal barrenness. Of the two ore-bodies in the West Side,

the one lying in the sharp anticlinal is markedly superior, both in size and grade of ore. The inferior one occupies the fissure where it passes through strata of gentle dip, and here there is no deposition along the anticlinal axis, as there is in the sharp fold.

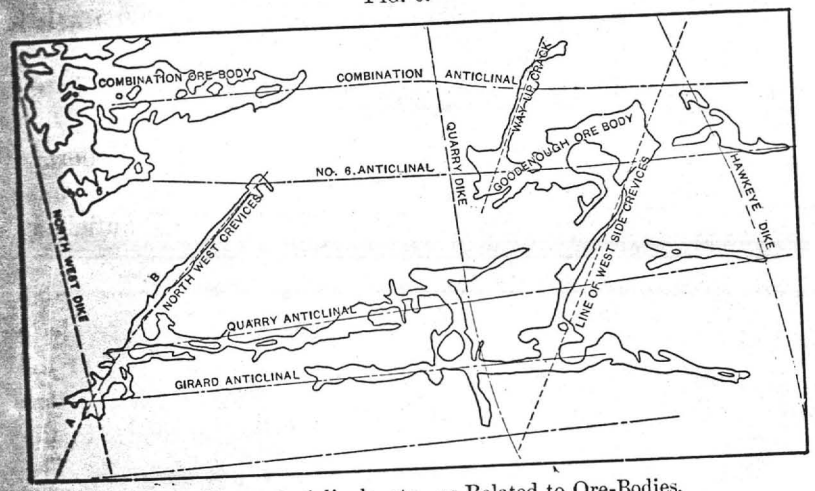
Although the Contention and Grand Central mines are not yet sufficiently cleaned up from the effects of the fires which closed them to permit examination, the extent of their ore-bodies is shown in a report made about 1890, by the late H. G. Howe, who was for many years the leading surveyor at Tombstone. He gives sections of the ore-bodies, reproduced in Fig. 8, which are taken from the south end of the Grand Central to about the center of the Contention. They show very clearly the combination of inclined anticlinal deposits and a vertical vein; and the relation of the two is more striking here than elsewhere in the district, because the two classes of deposits dip in opposite directions—the vertical to the west, the anticlinal to the east.

What is called commonly the Contention vein is a series of nearly vertical ore-bodies which extend northerly through the Grand Central, Contention, Head Center, Tranquillity and Silver Thread claims, a distance of nearly a mile. There was no one continuous vein along this line, but a series of large individual ore-bodies lenticular in cross-section, dipping to the west (with the dike) and pitching to the north. Thus, it is not to be supposed that the upper ore-body in Sec. 3, Fig. 8, has given out abruptly in full width. The figure shows a vertical section through an inclined mass, but the latter did not reach to the next section 320 ft. north.

There were several of these bonanzas in the 400 feet of shales that separate the Contention and Empire dikes, and in the shale east of Contention dike. Mr. Howe says the Grand Central had four "of these chimneys of ore," the Contention three, Head Center one and Tranquillity two. The largest of these is figured in Sec. 4, Fig. 8. Mr. Howe says it outcropped on the surface and extended to the 600-ft. level, pitching to the north; but the section shows that it was formed by three fissures in echelon. On the 300-ft. level it was more than 400 ft. long, and had a maximum width of 30 ft. A hundred feet lower it was 200 by 40 ft. These are large dimensions for so rich an ore. The sections

show that the ore-bodies lay in echelon, several of them appearing in some of the cross-sections, only one in others. It is probable that the parallel crevicing found in the West Side mine is present here also. Three sections show anticlinal deposits. Of that in Sec. 2, Fig. 8, Mr. Howe says: "This ore-body was discovered on the 300-ft. level, and followed up by a raise for 50 ft., where a large body of ore was discovered which lay almost flat; and development also showed that it pitched to the east, and a winze was sunk for 60 or 70 ft., following down upon its dip; but no drift was run along this ore-body at the bottom of the winze, and its extent is not known." No effort was made

FIG. 6.



Subordinate Anticlinals, etc., as Related to Ore-Bodies.

to cross-cut to this ore from lower levels. The three sections showing anticlinal ore-bodies are not successive sections, being separated by two others, in which only vertical bodies are shown. The meaning of this cannot be determined from the old maps, and partly for the reason that the anticlinal ores were not mined or even drifted upon, except one below the water-level, though the grade was good. The "East bodies" shown by Mr. Howe are opposite the anticlinals mined in the Toughnut series further north. The largest of the anticlinals has been followed on ore for 1150 ft. from the West Side vein, or about half the distance to the Contention. The disposition of ore-bodies along anticlinals was not generally known when

Mr. Howe made his sections, and it is probable that the Grand Central and Contention system consisted of nearly vertical ore-bodies along or near the dikes, and of others, more gently inclined, in anticlines crossing from one dike to another and beyond. The west dip of the vertical shoots and the east dip of the flatter deposits is strong evidence of this. The vertical ore-bodies were found in the center of the ground, between the dikes as well as under them.

This series of ore-bodies was the most productive of the Tombstone mines, and the explorations in depth are anticipated with great interest. When the great ore-formations of the district, the blue and white limestones, are reached by the Contention-Grand Central vein in the next 200 to 300 ft., it is expected that the conditions of maximum dynamic effect will coincide with the presence of the most favorable ore-rocks the district has had.

These compression-fissures are one of the most important features of the formation, and have probably been the most prominent factor in the introduction of ore, as the anticlinals have been in its distribution.

Until the Contention and Grand Central are opened sufficiently to allow of careful inspection, it will not be possible to say whether their ore-bodies occupy similar fissures; but the occurrence of ore in the middle ground between the Contention and Empire dikes, which are about 400 ft. apart, leads to the supposition that compression-fissures will be found there. The Head Center fault which cuts the Contention vein and dike is parallel to the West Side fissure.

Nowhere in the district is ore found in the shale except in the fissures, but its presence there proves that this rock was not unfitted for the reception of ore, by whatever method it was formed. The mobility of shale under pressure is supposed to prevent the maintenance even of minute openings, and the general absence of ore from this formation is new evidence of the controlling necessity of crevices as a preparation for ore. In Tombstone there is a contrast between the behavior under pressure of bed-seams and vertical crevices in the shale that is worthy of note. The weight of the rocks, which may not have been more than 500 or 600 ft. thick, was sufficient to close the bed-seams, but not to crush the vertical fissures, and the

delicacy of this difference is shown by the fact that a limestone 2 ft. thick has been mineralized for hundreds of feet on its dip, while the shale in which it is inclosed is barren. If such a stratum is what Mr. Bailey Willis calls "competent" enough to protect and keep open a bed-seam, the pressure of the overlying rock must have been small.

There is another kind of fracture which is found very abundantly in the blue and white limestones, and to some extent in the Toughnut quartzite, but not in the shale. Cracks of this class occurring in limestone often end abruptly at the contact with quartzite, and I suspect that is the rule, and that these crevices have been produced by a force that affected each stratum of rock for itself, without necessarily producing the same effects in other strata.

Torsion-Cracks.

The most important of these cracks is the Defence vein, which strikes N. 57° E. It is in outcropping blue limestone, and does not enter the underlying quartzite. Another is the Way Up crack, which has most of its length in the Goodenough. Its strike is about N. 65° E. Near it are two minor vertical stopes in the Goodenough incline, one striking E. and the other S. 83° E. On the 200-ft. level of the same mine there is one with strike N. 67° E., which has yielded more ore than any other except the Defence. None of these penetrate the shale, and the few stopes in quartzite nearly on the line of the Way Up crack are close to the Quarry dike, and probably due to its influence. There are some small vertical stopes in the quartzite on the Toughnut claim where the Hoodoo stope enters it; but here, as elsewhere in the quartzite, these crevices are few and insignificant, in comparison to those in the limestones.

The restriction of these crevices to the limestones and quartzite points to an origin different from that of the compression-fissures which penetrate rocks of all kinds and have vertical continuity. I am inclined to ascribe these inferior cracks to the results of torsion accompanying the deformation of the strata by pressure at an acute angle against the granodiorite, the results being produced in each stratum independently of the others. Being confined to the firm rocks, it might be expected that the brittle quartzite would show them most

prominently, which is contrary to the actual conditions; but the quartzite occasionally shows crushed areas where the rock has been broken to a mass of breccia, entirely non-coherent, for several feet in thickness, and these may show how this rock adjusted itself to a strain which made crevices merely in the limestones.

The crevices are most abundant in the area of Fig. 7, and especially toward the Defence vein, which is just outside the figure, below the lower left-hand corner. Fig. 7 is but a poor representation of the number and diversity of strike of those at the northern end of the Hoodoo stopes lying in that quarter. Probably not half of them were noted. Many are barren cracks; others make small vertical stopes confined to one or more layers in the limestone. The crevices here are not long, continuous cracks, though some run for a few hundred feet; and it is noteworthy that these are not the best carriers of ore, probably for the reason that their length and direction take them out of the narrow limits of anticlinal deposition.

Though the Defence vein is in blue limestone exclusively, the crevices shown in the same line in Fig. 7 are in the lower white limestone, the upper stratum being entirely eroded at this point, and they depart strongly from the strike of the Defence, the line curving until it is nearly east and west. Ore has been mined from the outcrop of the overlying quartzite, but it is obviously of secondary origin, and has no continuance in depth.

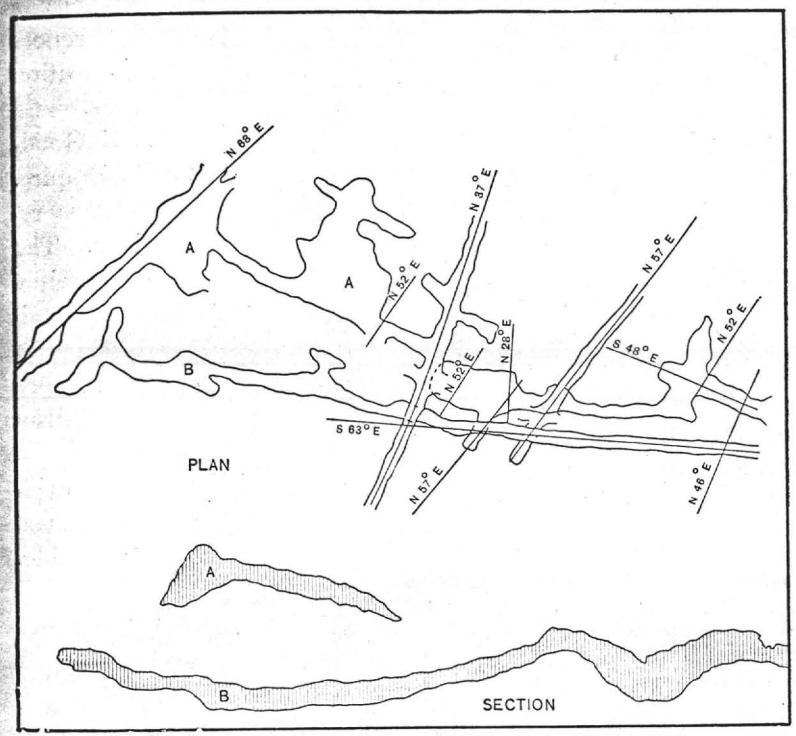
These cracks are found throughout the area of Fig. 7, but they are more abundant near the line of the Defence vein, which is in the area of greatest deformation, and on the line of the West Side fissure, which is 500 ft. or more below the right-hand half of the figure. There is no fissure passing through these places, no continuity in the cracks, parallelism or other connection between them. The whole Defence system belongs to what I will style these torsional crevices, and they are also strongly developed in the line of greatest compression in that neighborhood, the line of the West Side fissure.

Relation of the Dikes to Ore.

The third factor in the forces which have made the Tombstone formation is the series of dikes, the filling of which has

been determined as granophyre and diabase. Nearly all the ore derived from it has been taken from the 2500 ft. of ground lying between the Northwest dike on the west and the Contention dike on the east; but the deposition of ore is not confined to the space included between these two dikes. It has been mined in the Defence 500 feet and in the Ingersoll 1000 feet west of the Northwest dike, and in the Tranquillity some distance east of the Contention dike.

Fig. 7.



Plan and Section of Torsion-Cracks, Northwest Mine.

Fig. 3 shows that one of the principal vertical ore-bodies of the Contention and Grand Central is east of that dike. At least one of the anticlinal ore-bodies in these mines has the same position.

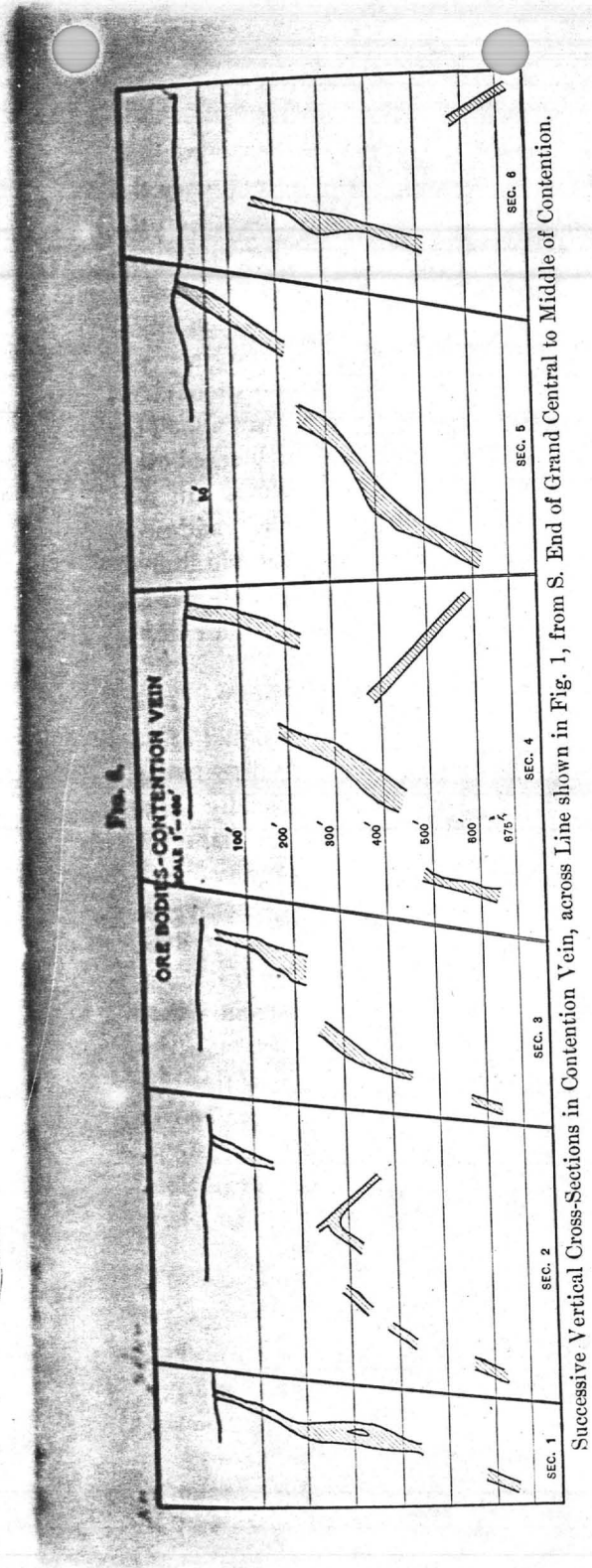
These facts show that the dikes did not have a limiting effect upon the passage of ore solutions. Locally they have modified deposition, but in general their presence was so inert that we must look elsewhere for the controlling factor, and that, as already said, is probably the two results of pressure—folding and

fissuring. All these elements of the problem, except the fissures, are combined in Fig. 6, which shows the ore-bodies (in outline) of the blue and white limestones, the axes of the anticlinals, the directions of some of the crevices, and the positions of the dikes. It shows that along the Quarry dike there is ore connecting the deposits of the Quarry and Girard anticlinals, and that on the Hawkeye dike there is some spreading of the ore in No. 6 anticlinal. The Combination and other ore-bodies begin at the Northwest dike; one small deep-lying ore-body in white limestone ends at the Hawkeye dike. These occurrences are, however, very inferior in importance to the deposition along the crevices and anticlinals.

This figure covers the territory of the Toughnut and Goodenough mines, with a portion of the Hawkeye and Empire. The names given to the different elements of the figure refer, of course, to mines and particular openings in mines. The Northwest and Quarry are both on the Toughnut. Combination, No. 6, Goodenough and Way Up are all on the Goodenough. The crevices are named from the places of their principal development. Each class of occurrences exhibits more or less parallelism in its members, but there is no parallelism between different classes.

In no case that I have found has a dike been a seat of original ore-deposition. The ore-body in the Toughnut quartzite along the Quarry dike is in the slabbed ground by its side, though the dike is thoroughly decomposed. The dikes have been drifted on and cross-cut in the anticlinals, and in all other situations, and the trivial amount of ore they have yielded must be attributed in part to secondary deposition, aided, perhaps, by the quickly diminishing influence of some crevice. In the Contention and Grand Central, where it is probable the deposition of ore has been determined by strong fissuring, the dikes may have been more affected than elsewhere; but all that is known about those mines indicates that their ore-bodies lay near, but not in, dikes.

On the surface the dikes often retain their original character unchanged, and their outcrops can be distinguished at a glance. Underground they are completely decomposed, and it is often impossible to distinguish between the rocks derived from them and from the quartzite. On the other hand, in the fissures it



Successive Vertical Cross-Sections in Contention Vein, across Line shown in Fig. 1, from S. End of Grand Central to Middle of Contention.

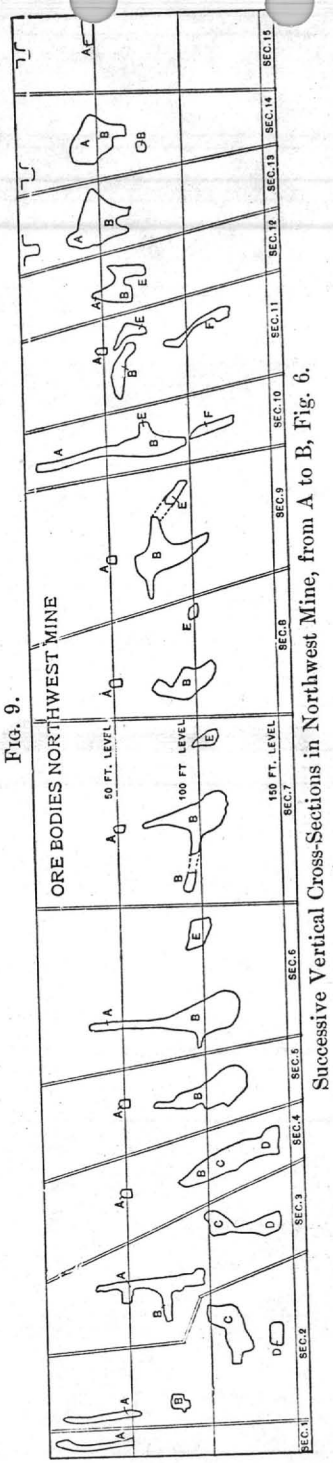


FIG. 9.

Successive Vertical Cross-Sections in Northwest Mine, from A to B, Fig. 6.

is common to find an ordinary appearing quartzite where there should be none of that rock, and with curious frequency the phenomenon is found on one side of the vein and not on the other, though in a few feet more the crossing of a stratum disproves the possibility of faulting. Apparently the vein, before its decomposition, acted as a dam, on one side of which silicification took place, while the other side was free from it.

It is odd that the conditions of dike-decomposition mentioned are not found outside of the especial ore area. The Comet mine has passed through decomposed to unchanged dike in 400 ft. In the granodiorite many of the dikes have suffered so much surface decomposition that they are now oxides of iron, calcite, etc., in a feldspathic magma. They resemble altered limestone, but in a few feet their original texture returns, reversing the conditions found in the Toughnut and Contention.

Ore-Deposition in Limestone.

It is evident that the Tombstone ores are the product of replacement, both in the crevices and the anticlinals. In the latter, especially, alteration-products, of the sort usually found in limestones, are common and are often rich in metals. The capriciousness of the attack of the ore-bearing waters upon the limestone is sometimes extraordinary, especially in the region of torsional fracturing. An example is shown in Fig. 9, Secs. 1 to 15, made from careful measurements of the 50- to 150-ft. ore-body in the Northwest mine on the Toughnut claim, where torsional cracking is especially strong. This body, or series of ore-bodies, extends almost from the surface to near the 150-ft. level, and the sections, taken from A to B, on Fig. 6, cover a length of 250 ft. The ore is entirely in the white limestone, with the overlying quartzite showing in a surface cut in Secs. 13, 14 and 15. The ore-bodies that lie in one vertical plane are enclosed in a panel numbered for each section.

The ore began near the shaft in a vertical fissure which is marked A throughout the series of sections. In Sec. 2 three flat ore-bodies, marked B, C and D, came in below the vertical, and Sec. 3 shows that one of these joins the vertical, which drops down about 40 ft. in a horizontal distance of 15 ft., while the other two stopes have coalesced.

In Sec. 4 the vertical stope has disappeared, and A marks the position of a drift along the crack. Now all three of the

flat stopes have run together, and form an inclined body with a steep dip, but not vertical. In Sec. 5 the vertical comes in again, joining the highest of the three flat stopes in Sec. 2, and in Sec. 6, only 6 ft. distant, the vertical stope has gained no less that 40 ft. in height. Meanwhile the two lower ore-bodies, C and D of Sec. 2, have disappeared, and do not appear again until we reach Sec. 9; but in Sec. 6 a new ore-body, E, comes in, which continues through seven sections. Only one of the flat ore-bodies has marked persistence. B of Sec. 2 continues through a variety of changes to Sec. 14, and it is notable that the whole series begins and ends with the vertical stope A standing alone, though it has frequently disappeared entirely in intermediate sections, and in Sec. 15 looks like a flat stope. In Sec. 10 a new ore-body, F, comes in, which is the beginning of the Hoodoo ore-body along the Quarry anticlinal, Figs. 5 and 6.

A study of these sections shows that there is nothing like a vertical vein in this place. There is verticality in certain stopes along one line for a short distance; but as an ore-body it is fully as irregular as the most variable of the flat stopes, and it is less persistent than one of the latter. It is entirely probable that the vertical arrangement which the flat stopes assume when they coalesce is due to the existence of other cracks in their path. The deposition of ore may have changed from one crack to another, limiting itself to a certain width, within which lie the flat stopes which show by their dip that their shape and position have been determined by the anticlinal folds.

This is well shown in Fig. 5, which is a plan and section of the Hoodoo stope, in the same Northwest mine. Its beginning is the stope F of Secs. 10 and 11, Fig. 9. The position of Sec. 10 is shown on Fig. 5 at F. The strike of these two series of ore-bodies is nearly at right angles. On the lower edge of the plan, Fig. 5, beginning at F, narrow stopes will be noticed following one general horizontal direction. This is the line of the Hoodoo crack, which is ore-bearing only at isolated points. Whether it is one continuous crevice or a series of nearly parallel cracks crossed or touched in slight echelon by the flat stopes cannot be determined. The general conditions of the creviced area incline me to believe that the ore is not always in the same crack. As in Fig. 9, the vertical deposition of ore

is very limited. Besides the Hoodoo crack, there are several others at various angles that show vertical deposition for small heights.

The silicified fossiliferous blue limestone already mentioned is another product of this fissuring, and also of replacement. It is found on the surface and underground in lines of limited length, appearing like veins, and in the mines areas 100 ft. wide have been passed through. They consist of this silicified rock, with scores of open crevices several inches wide. Nothing like this is known in the white limestone. This replacement was not accompanied by metalliferous deposition, except to a feeble extent. Assays of 1 to 3 ounces of silver are sometimes had from the rock, but not always. There is no recognizable relation of this rock to the ore-bodies. It is found both near to and distant from them, and is, perhaps, the only rock in the district that shows no sign of yielding to the influence of secondary deposition. This may be due to the filling of the pores in the original rock by silica before the replacement began.

Some of the thin limestones lying in the shale have been ore-carriers in the vertical veins and anticlines, and the richly mineralized layer which was called the East body of the Contention was probably one of these shale limestones.

Manganese of the Lucky Cuss Mine.

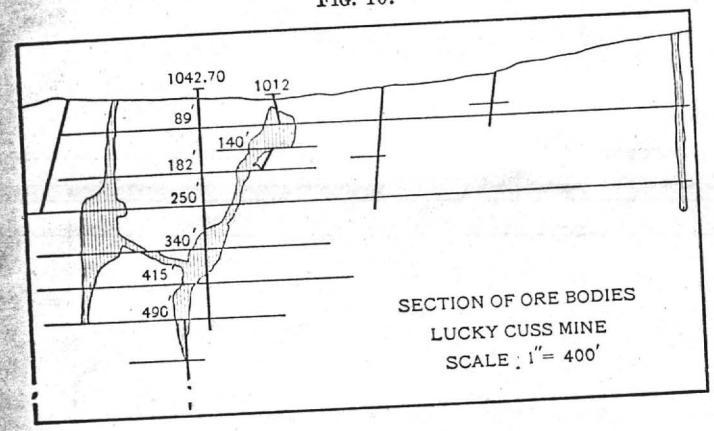
Of the mines in the lower measures, the Lucky Cuss, Fig. 10, is the most interesting. It lies within 400 ft. of the granodiorite, and outcrops about 350 ft. from a dike which Prof. A. A. Julien determined to be a minette, and which lies in the granodiorite close to the contact with limestone. A mass of this rock, 15 ft. thick, encountered below the 350-ft. level, is attributable to an apophyse from the dike. A section from it showed some chlorite, which seems to be absent from the dike. Similar occurrences are found in the Combination ore-body and elsewhere, but none so far from a dike as this.

The Lucky Cuss has had two principal ore-bodies, connected by a cross-shoot at about the fourth level, and several pipes of manganese ore, of which only one is shown in Fig. 10. Most of them are of limited depth; but this one, though otherwise of small dimensions, had a vertical depth of 350 ft.

The origin of the manganese in this mine, and also in the Knoxville and others, is a question of great interest, and was

discussed by C. W. Goodale in a paper before the Institute.* The subject received enlightenment when, under the tongue of minette on the 350-ft. level of the Lucky Cuss, a mass of rock was found which was rich in alabandite, or manganese sulphide, mingled with galena and pyrite. In this position, protected by the dike-rock from the infiltration of surface-waters, the original form of the manganese seems to have been preserved. It is difficult to believe, however, that all the manganese-oxide deposits, which usually form pipes disposed in an erratic manner over the surface of the limestone, represent old deposits of alabandite in place. I am disposed to regard some or all of them as secondary depositions derived from masses or impregnations of the sulphide in the limestone, and probably, in part, from its eroded portion. There is some manganese-oxide in all or most of the Tombstone mines, but the quantity is small in the strata above the Lucky Cuss limestone. This and the Emerald limestone produce basic ores wherever opened; but, as Mr. Goodale has pointed out, the true manganese-ores are confined to two localities. The first comprises a series of mines, the Knoxville, Wedge, Lucksure and Lucky Cuss, lying very near the contact of the granodiorite. The second group, containing the Emerald, Bunker Hill, Rattlesnake and Mammoth, is about a mile S. of E. from the contact, and the Comet is still farther away. This group yields basic ore, but the proportion of iron and lime is greater, and of manga-

Fig. 10.



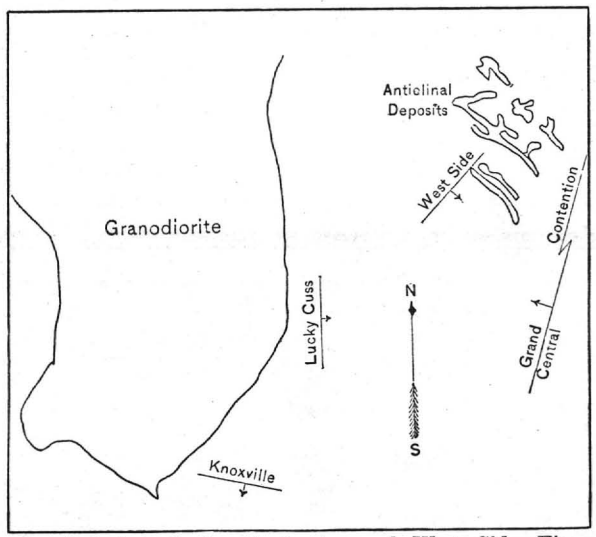
* *Trans.*, xvii., 767, and xviii., 910, with section of ore-bodies.

nese much less, than in the mines near the granodiorite. In both groups the manganese seems to decrease with depth.

The most extensive deposits of manganese are those of the Lucky Cuss and Knoxville. The Lucky Cuss has a fissure with chamber deposits of small extent reaching from it into the limestone walls. The Knoxville is described by Mr. Goodale as a series of four ore-shoots lying in the line of a continuous closed crack. The relation of these two mines to the granodiorite is shown in Fig. 11.

The distinctive manganese deposits are the only ones in the

FIG. 11.



Plan, Showing Relation of the Contention and West Side Fissures to the Anticlinal Deposits, and of the Lucky Cuss and Knoxville Mines to the Granodiorite.

district that indicate by their position an intimate connection with the granodiorite. The mines in the Randolph limestone, which also yield a basic and somewhat manganiferous ore, are about 3000 ft. from the contact. The presence of alabandite under an apophyse which is derived from a dike in the granodiorite, and the occurrence of the Comet ore under a granophyre dike, are indications that the entrance of manganese did not follow immediately upon the intrusion of granodiorite. It must therefore be ascribed to aqueous deposition. There is strong evidence that the bodies of oxide are depositions from solutions, but it cannot be determined whether they always oc-

cupy the position of original sulphide bodies, which they have enlarged, or have sometimes entered barren cracks and replaced the limestone walls. The Lucky Cuss ore, which was so rich at the surface that slags made from it contained 43 per cent. MnO, gradually lost manganese and gained silica and lead. This vein undoubtedly received large accessions of oxide as a secondary deposition. Something of the same kind seems to have taken place in the Knoxville, where, Mr. Goodale says, the ore-pipes had a siliceous center, surrounded by a richly manganiferous shell next the limestone.

All the manganese-ores were very poor in gold at the surface, and I believe the Knoxville did not change; but the Lucky Cuss improved so much that the ore below the water-level contained $12 per ton of this metal. The alabandite of the Lucky Cuss was not a solid mass of that mineral, but a local enrichment of the sulphides of manganese, lead and iron, the greater portion of the mass being silica and limestone, though there were masses of the manganese sulphide several hundred pounds in weight.

The Comet mine, the largest of the manganese deposits, is an instance of the wide extent of ore-deposition in the district, lying 2200 ft. east of the Grand Central. Active deposition has taken place over an area in the Tombstone basin about 10,000 ft. long from north to south and 7500 ft. from east to west. This does not include the mines on the Charleston slope.

The Comet vein lies under and in contact with a granophyre dike 60 ft. thick, and has been mined for a length of 2000 ft., and to the 400-ft. level. Its ore is valuable for its fluxing quality, besides the silver.

MINES IN THE RHYOLITE.

A mine of great interest from its position in the rhyolite is the State of Maine. The rhyolite on the side nearest Tombstone is poured out on the Ajax quartzite. In the State of Maine there are two nearly parallel veins in the rhyolite which reach down to the underlying quartzite, 375 ft. deep on the inclination of the shaft and 240 ft. vertically. The quartzite has been cracked by the heat to a shaly condition, or at this point one of those changes of composition which are frequent and sudden in this district may have occurred.

The sedimentary rocks are folded, and at one point appear

to be broken. It is possible that the rhyolite takes the form of a dike there, about 60 ft. thick, but the question cannot be determined until greater depth is reached or the rhyolite is cross-cut. The veins are from 2 to 7 ft. thick, and quite irregular in strike, so that they come to a junction with an angle between them of 20°. When parallel they are about 50 ft. apart, and both dip NW. 45°. These interesting veins have been very profitable for the amount of metal they have yielded, which was probably $600,000. The mine is not now in condition for proper examination, but the stopes resemble strongly those in limestone. The hanging is a smooth continuous wall of rhyolite, the veins very soft and decomposed, and apparently they carried ore in individual ore-bodies rather than a continuous vein. Their average strike is N. 35° E., and dip of the incline 40° N. 55° W. The dip varies from about 33° to 48°, with much larger variations for short distances. The ore was manganiferous and rich in silver.

There are many other openings in the rhyolite, and the mineralization of this rock appears to have been quite extensive, though the number of profitable mines was small. The Maine was the most successful, and the San Pedro, near it, probably stands next in productiveness. The Bronco, near Charleston, 7 miles away, is in siliceous schists, entirely surrounded by rhyolite. It is the oldest mine in all this region, having been a developed property before the outcrops of Tombstone were found. It has had a most checkered history, and is now worked with more vigor than ever before. In general, I believe the veins in the rhyolite have had rich ore, but have been small and irregular.

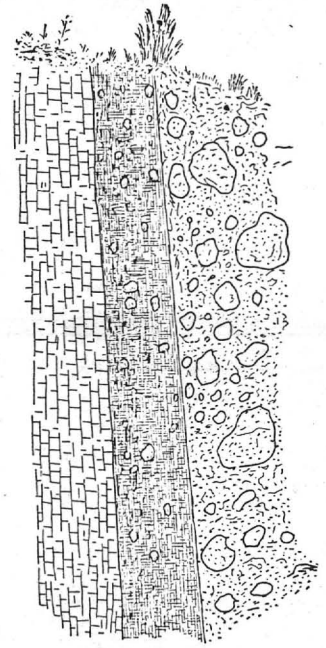
Faults.

One of the curiosities of Tombstone is a fault in Emerald gulch with shale on one side and caliche on the other. Its strike is N. 32° E., dip E. 80°. A shaft in it is 20 ft. deep, without disclosing the full extent of the throw. This interesting fault is shown in Fig. 12. It is marked by the usual zone of laminated or crushed material, which contains both caliche and shale fragments. As the caliche is entirely a product of local erosion and modern calcareous cementing, and must have been formed since the time of powerful erosion, this fault, which seems to be equal in throw to others in the district, must be quite recent.

On the hill back of the Grand Central mine there is an open crevice which is said to have opened, or at least enlarged, within recent years. It is therefore commonly attributed to the caving of the stopes in that mine, its strike, N. 32° E., being about the same as that of the ore-bodies. This explanation is not satisfactory, for the thickness of rock between it and the stopes would, in this locality of shaly quartzites, be sufficient to fill the widest stopes of the Grand Central without producing any effect upon the surface. The parallelism between this open fissure and the caliche fault is suggestive. They are about 3000 ft. apart, the crack being nearly due north from the fault.

There are several faults in the district, but none of moment. The largest vertical fault known is in the Empire part of No. 6 anticlinal, 50 ft. The Quarry anticlinal is faulted 35 ft. Of cross-faults, the best known is on the Contention-Head Center line, where the dike and vein have been shifted 120 ft. horizontally. There is also a small horizontal throw of 20 ft. in the Empire dike, and others noticeable in the outcrops of the shale limestones. The anticlinal faulting preceded the deposition of ore. In the Empire there is ore under the shale on the upthrow side, but none on the downthrow side. In the Quarry fault there is ore on both sides, but here we have not only one of the strongest anticlinals in the district, but a dike just through the outcrop. There is no sign of an ore-body faulted after its deposition. The dikes do not seem to have caused faulting, no instance of it being known. The torsion-crevices, on the contrary, frequently faulted the ground. In the Hoodoo stopes there is occasionally a jumble of limestone and quartzite blocks, but with small throw. The Head-Center fault is interesting because it is

Fig. 12.



Fault between Shale and Caliche in Emerald Gulch.

closely parallel to the West Side compression-fissure and crosses the Contention vein at an angle of 30°.

With this example of faulting in a crevice, it is somewhat remarkable that the West Side fissure shows no faulting, but abundant disproof of it. There is some slipping of slabs on each other, but very little, and the bedding-lines across the drifts prove that there has been no general movement. The West Side and Contention represent the strong lines of compression-fissuring, and no faulting along their lines is known.

Ratio of Gold and Silver.

The entire yield of Tombstone is estimated at 163,000 ounces of gold, 21,500,000 ounces of silver, and 5000 tons of lead. The losses by pan-amalgamation, which was the method by which most of the product was obtained, would require an addition of 15 per cent. to the gold and silver to obtain the gross total of these metals, making somewhat more that 187,000 oz. gold, and 22,500,000 oz. silver. The proportion of gold was, therefore, only 0.827 of one per cent., by weight, of the precious metals.

The total value of all products as marketed was about $25,000,000, to which about $4,000,000 must be added for losses, and somewhat for unreported product. Some mines report only their net returns, leaving the expenses of marketing to be surmised, though they belong to the net yield.

The mines varied extremely in their proportions of gold and silver. The Contention and Grand Central produced about 20 gold to 80 silver, by value, which corresponds to about 1 ounce gold to 80 ounces silver, as the latter metal was worth about $1 at that time. Other mines show a much smaller proportion, the Tombstone Mill and Mining Company having 1 gold to 180 silver, and in mines which were confined entirely to superficial deposits in limestone the proportions may have fallen to 1 : 400 by weight.

The relative proportions of gold and silver in the ore forms one of the most interesting and important problems of the district, and there are indications that a favorable change is taking place with depth. The gold value was greater in the fissure-veins than in the anticlinal deposits, and it improved in both going downward.

In the Contention, a drift run for a length of 140 ft. about

90 ft. below the water-level gave an average assay of more than $100 per ton in gold, and this was in an anticlinal deposit. The condition in the vertical bodies is not reported. In the West Side the ore found at the lowest points mined in the anticlinal, 1150 ft. from the vertical vein, yielded $17.20 per ton as the average of 55 shipments, which is probably four times the average of the West Side vein near the surface.

The same increase is found in both vertical and flat deposits. The Lucky Cuss, which had little more than a trace at the surface, produced ore worth $12 a ton below the water-level and the last two shipments contained 1.7 ounces, or $35 a ton. The lowest ore of No. 6 anticlinal yielded 1.63 ounces, or $33.58 per ton, as the average of 71 shipments. The ore now mined in the Tranquillity is also rich in gold.

While these are merely specific instances, we obtain from the books of the Tombstone Mill and Mining Company a comparison of the product by periods, which is more exact and also more instructive. From June, 1879, to March, 1884, inclusive, that company produced 10,931 ounces of gold and 3,459,555 ounces of silver, or 1 : 317. From March, 1884, to December, 1893, the product was 26,745 ounces gold and 3,247,603 ounces silver, or 1 : 121, the proportion being 2.6 times as high in the second period as in the first. The only mine opened from the grass roots in the second period was the Lucky Cuss. All others were opened in the first period, and had their deep mining in the second period. This company mined two fissures and nearly all the anticlinals in the camp, and its results must be received as representative of the true conditions in the district. This increase of gold with depth is as interesting in a scientific sense as it is important to the future prosperity of the district.

If I understand Prof. Comstock* correctly, he ascribes this increase in gold tenure to impregnation following an ancient uplift and folding, which was succeeded by a later uplift that brought in silver, the latter being geologically higher than the ores of the first deposition.

Confining myself to this district, without considering evidence to be obtained from other districts in Arizona, I do not find facts at Tombstone to sustain his view. There have been two well-marked periods of folding there. One preceded the

* "The Geology and Vein-Phenomena of Arizona," *Trans.*, xxx., 1038.

intrusion of the granodiorite; the other came after the intrusion, and crowded the strata against the eruptive mass, producing effects strongly marked in its neighborhood; but I see no evidence of different ore-depositions after these events. The entrance of all the ore was later than the second folding. The difference of level in the Goodenough incline between the poorer gold-ores of the surface and the richer of the Empire is less than 300 ft., the continuity of the ore is complete, and the ore itself is as uniform in character as oxidized ores ever are.

Roughly speaking, about half the gold and silver produced in Tombstone has been taken from the upper shales, about a third from the blue and white limes, and most of the remainder from the Lucky Cuss limestone at various points of its extensive outcrop. The quartzites over and under the white lime have carried the least ore, but neither of them has been reached in the larger fissure-veins which have had richly paying ground in the quartzite included in the upper shale. The Toughnut quartzite was ore-bearing in the West Side mine.

The town of Tombstone occupies a flat gravel mesa, or table, quite level for a width of a third of a mile from north to south, and sloping gently to the west for a mile and a half. The gravel lies on the anticlinal shown on the extreme left of Fig. 4, and the white limestone of Combination and No. 6 anticlinals outcrops on the southern side of the town. Toughnut gulch is a natural boundary on that side, and, with the exception of Comstock hill, the rock exposures stop at the gulch. Some do not reach it, being covered by gravel. To the north is a waste of gravel, which a shaft near the town penetrated for 300 ft. without reaching rock.

After lying idle for several years, the reopening of the Tombstone mines has been undertaken by gentlemen who were prominent in the early mining of the district. A new shaft, with two hoisting compartments 4 by 7 ft. and two pump compartments 5 ft. 9 in. by 7 ft., has been sunk near the Contention fissure, and has reached the water-level at a depth of 569 ft. This work was done and the shaft strongly timbered in less than five months. Pumps to throw 1750 gallons a minute will be installed. It may seem remarkable that pumps of such capacity should be needed in a region that is not only

arid, but one where the underlying rocks receive an unusually small part of the rain that falls. The caliche which Prof. Blake described in a recent paper* covers a large part of the district and sheds the surface-water, and the run-off is abnormally large. The calculations are made on the results of pumping done in 1884, when about 1,500,000 gallons a day were thrown out. The water has never returned to its old level by 6 or more feet; and, though there is a great body of water in the ground, it is believed that, when once removed, the rocks will be permanently dry.

The water-level on the west side of the granodiorite is about 250 ft. higher than on the Tombstone side, which may indicate a great depth of rhyolite between the mines there and the San Pedro river, 6 miles distant and 400 ft. lower.

One of the principal objects of my examination of the Tombstone district was to ascertain what measures are likely to be encountered below the water-level. The presence of the "granite" formerly led to the supposition that it underlaid the town and ore-bearing rocks; but the evidence contradicts that impression. The mines still have about 2000 ft. of known sedimentary rocks under them, and perhaps much more.

The revival of these mines is a matter of more than usual interest, for it is based upon convictions derived from a knowledge of the structural geology of the district, and this knowledge is in no sense a theory nor an ordinary scientific explanation of facts. The mines in the anticlinals were managed for years in the light of this knowledge, and thousands of feet of drifting was done to reach anticlinals at the contacts of their rocks. The work began on a theory of Mr. Staunton's, but repeated successes soon lifted it from the plane of reasoning to the solid basis of experience.

It is this experience which will guide operations in future, and the projectors have the greatest faith in their successful outcome. All the fissure-veins, all the most productive mines in anticlinals, and many of second importance, have been consolidated in one ownership, as was necessary before a company could be formed to pay for draining the entire district.

---

* *Trans.*, xxxi., 220.

RANSOME (1908)
FIELD NOTES

(4) (2) 78

Excerpts from U.S.G.S. Tombstone District, Arizona, Notebook II (1911)
F. L. Ransome

Page 4 - 7

Tombstone, Jan. 12/11 Thurs.

Water pressure in E. drift 1000 - 71 lbs sq. in, Dec. 1, 1908
Original water level 460'

Water pumpt (Depth 886' in Dec. 1905)

1906		
	J.	77,496,538 gals
	F.	83,381,838
	M.	109,288,293
	Apr.	146,288,497
	May	140,473,765
	June	128,229,963
	July	127,779,745
	Aug.	123,353,800
	Sept.	119,851,223
	Oct.	124,650,725
	Nov.	120,182,247
	Dec.	125,456,690
1907		
		138,705,029
		110,399,525
		136,224,454
		135,571,865
		142,598,587
		143,566,288
		155,035,670
		159,477,665
		158,675,158
		159,572,471
		145,609,309
		146,482,664
1908		
(29 days)		143,017,089
		132,242,100
		139,145,247
		132,782,287
		137,882,732
		132,537,564
		139,651,341
		179,752,127
		177,003,697
		173,024,312
		172,046,980
		183,620,677

1909

196,434,225
182,846,700
193,921,743
190,339,148
197,606,534 (Got water in oil fuel & lost
124,196,316 (pumps on 1000
66,637,877 (water rose this mo. to 15' below
58,404,619--(800 level on Aug 27
89,136,881-- 13' below 800 at end of mo.
105,718,697--Holding at 800 lev. at end of mo.
101,623,296-- Holding at 800
158 bbls. oil a day 108,854,399 " " "

1910

Started lowering water Jan. 4 and lowered it 45' by 9th and held it there to end of mo.

140,700,355
150,301,179-- 80' below 800 end of mo.
186,515,665-- 120' " " " " "
194,164,504-- 170' " " " " "
124,223,623-- Roof of 1000 level just reacht when 5 boilers were lost because of leaking. Sinkers submerged. Water rose again to 800. On May 21 were 100' below 800 level. Held there to end of mo.
100,699,996
173,429,854
206,977,036
196,222,828-- Recovered 1000' level ab. Sept. 9
219,228,076
203,933,024
203,708,980

- - -

In Jan. 1911 at time of visit, were doing no development and holding 1000 level by pumping about 6,500,000 gals in 24 hours. Could handle 10,000,000.

1911

116,540,928 gallons

Mine closed Jan. 19, 1:45 P.M.

Tombstone Consol. Mines Co. Ld. has spent ab. $6,000,000. Produced ab. $2,500,000 gross or ab. $1,500,000 net. Raised most of money on interest-bearing bonds. Devel. Co. of Am. advanced money and has now taken over property.

All ore yet seen by me is clearly secondary enricht. Generally a mixture of sulfides, oxides, chlorides, carbonates etc.

Minerals noted: pyrite, chalcopyrite, galena, sphal., cerargyrite! cerusite! wolfenite, alabandite, pyromorphite.

- - - -

R.R. reacht Tombstone in 1903.

Page 13 - 17

Tombstone, Jan. 13/11 Friday

1000' level of Contention (Pump Shaft)

Pump station all in socald white lime. No bedding planes visible. Mostly a grey, fine-grained ls. Varies somewhat in color and is traversed by many small irreg. cracks filled with calcite. In places coarser-grained than elsewhere. Some veinlets are white and some darker than ls. Close to shaft a few little efflorescent specks of iron sulfate indicate a little pyrite. No indication of ore seen.

T69 - Limestone close to shaft - on N. side of pump station. Water pours into this level thru cracks and channels in ls. enlarged by solution, even where there is no shattering. Pressure at one time according to Kinsley was 71 lbs per in. Now ab. 13 lbs. No loose ground bet. shaft & dike. Many jets of water from band solid ls.

Contention dike ab. 33' wide at X-cut. See map. For ab. 4 feet next to E. wall dike is fine-grained, finely sheeted & decomposed. Looks something like basalt dikes in Cripple Creek. Small // cracks 1/4-1/2" wide filled app. with calcite. No gouge and no important movement along this side of dike. Main part of dike is distinctly porphyritic & carries a little dissem. pyrite.

T70 - Spec. this dike. Middle part. Limestone next to dike is not noticeably metamorphosed altho it has been more fissured and veined with calcite than elsewhere & is yellowish.

West contact of dike not well exposed. S. drift follows it, but the ground app. was comparatively soft & lagging had to be driven along E. side of drift. Roof also lagged.

Just W. of dike at main X-cut is what appears to be quartzite. Fractured & a little rusty.

T71 - Spec. this quartzite looks like real quartzite but I am not so sure since seeing E. X-cut. App. very little of the qtzite here. The drift follows a fault fissure of which one branch seems to run just W. of qtzite, coming out into drift ab. 35' S. of crosscut and from there to the face, separating the dike on the east from ls. on the west. No crosscuts into this ls. & its character can be judged only by the more or less fissured and veined material near dike.

T72 - Spec. this ls. No bedding shown. App. is the "white ls". No mineralization seen altho a little limonite occurs along fissure as it disappears behind the qtzite. Fault along drift app. ab. vert. Not well exposed, owing to lagging.

At S. end of drift large quantities of water are spurting in. As usual clear and not very cold. Just N. of face on W. side a large stream jets from an irregular hole 6-7" in diam.

North drift follows W. side of dike for ab. 60 feet. Dike then disappears app. in E. wall. Quartzite disappears at ab. same place and drift is entirely in ls. to face. Small X-cut at end also all in ls. The drift follows a fault fissure which appears to dip W. 75-80°. Little or no real gouge but some slickensiding. Rather small striae grooved in ls. pitch N. 45°. In places along W. side of fault ls. is fractured & has many vuggy cavities lined with crystals white calcite. No sulfides seen. Limestone app. all same as last spec.

T73 - Spec. ls. N. face of drift on W. side of slickenside

T74 - Spec. ls. from face of little crosscut on E side of fissure.

Some ls. along W. side of N. drift is very horny and siliceous.

T75 - Spec. of this from about 60' N. of main X-cut

East of Pump Shaft - same massive medium to fine-grained light-colored ls. extends to N. drift.

The S. drift follows a generally close fissure with curved strongly grooved faces. Striae pitch W. ab. 70°. Fissure dips 70-75° to E. At face is 12-18 inches of gouge. Abundant water from this fissure & from crevices in walls. No mineralization.

Horny part. Mainly qtz some grains perhaps detrital.

T76 - Spec. ls. from main X-cut just W of N. drift.

North drift - follows no distinct fissure but marks a rather indefinite & irreg line of change from the white lime to the so-cald Toughnut qtzite which continues to end of crosscut. This is certainly not a real qtzite but is silicified ls. Ls mottled and very irregularly streakt. The streaks app. represent fractures from which silicification has workt out. The mottling is app. due to kernels of partly replaced ls. surrounded by the "qtzite". In the north drift bands of horny siliceous material alternate with white ls. No regularity and no distinct bedding, altho bands may be twested beds.

Limestone Much epidote and other silicates with qtz

T77) Specs. of the material occurring in intimate association at face
T78) of N. drift. Much water here. No mineralization.

From this drift to face of main X-cut material is very hard and siliceous. Mottled streakt & varying in grain. No true qtzite shows such variations. Clearly a replacement product. The following specimens are all from this X-cut E of N drift. One of them shows corals.

Page 19 - 28

Tombstone, Jan. 14/11 Sat.

Collected water from large stream issuing from solid ls. on W. side of S. drift along Contention dike on 1000 level. Bottles used had held IdCl and $IdNO_3$. Washed well & rinsed 3 or 4 times with the mine water as bottled. corkt where bottled with new corks washt in the same water. Temp. 26.1 C. or nearly 80 F.

800 Level

Down winze on dike 135'. Connects with 1000. Dike generally fractured and rather loose. Some movement along foot. A little gouge. Striae pitch 40-45° to N. Ls on foot where winze meets upraise, 135' down.

Fissure that runs thru this level near shaft is the one followed on S. drift from E. X-cut on 1000. Ralph says had assays up to 10% Cu from this drift altho I saw no ore.

Dike dips W. ab. 75°. A short drift N on h.w. Some movement here also. Striae pitch N. varying. Some as low as 20°.

Just W. of winze X-cut is in massive ls., app. white ls., overlain by calc. shale in roof. Dip ab. 30° to S 15° W.

T87 - Spec. shaly ls with some pyrite. W face of 800 level.

The longer N. drift W. of shaft runs along E wall of dike & then X-cuts to W. wall. Both walls ls. On W. side very hard, ' variable in grain. Psuedo qtzite.

T88 - Spec from W. side of dike.

Dike itself crumbling & decomposed. Some movement along both walls. Gouge & slickensiding. Pitch of striae to N but very variable. No ore seen. Along E. side of dike is ls. Some fairly soft, massive white ls., some horny and qtzitic like 22.

Just E of winze in X-cut ls. dips 30° to N 60 E.

Ab. 35' W. of shaft is a fissure in the ls. Close. Dips W ab. 70°. Another west of it dips W. No app. faulting. Close, altho there are vuggy solution channels along it.

All rock bet. shaft & dike is essentially same. One formation of ls. with some calc shale. Much of it very siliceous. Some espec. the shale is horny or flinty. Ls. irreg. altered to pseudo qtzite. The same fissure th t was followed on the S. drift from E. X-cut on 1000 has been followed N. by a drift from the pump station on the 800 et ft E of shaft. A strong fissure with up to 1' of gougy material. Ls brecciated along it and vuggy. Footwall fairly massive silicified ls. td. W thin-bedded or shaly ls. Very fine-g.

Ls with diopside

T89 - Spec. from N. face of drift on W. side fissure. The difference in rocks is app. very local for the pump station E. of drift is in massive white ls. Dip of a shaly band at E end pump station is 25° to S 10 E. Some of the ls. here is a white sugary-textured marble. Grain in places coarser than sugar.

Probably blue ls.

This granular white marble is overlain by some shaly finer-g ls. in which is the layer of low-grade ore followed down in inclined winze. Runs up to ab. $10 at $100 1982 prices.

T90 - Spec. the granular ls.

Incline goes down at ∠ of 22° for ab 100 ft. Follows bedding in general altho not accurately. At ab. the 100' mark a strong fault cuts off the indications followed. A zone of shattered ls. rather loosely cemented with vuggy calcite. Much of material is soft crushed ls. stained with ox. iron & mn. In places 10-12' wide. Several slip surfaces. Crushed material in places 10-12' wide. General dip is E ab. 60° St. app. ab. S. 20 W but sight too short to be of much value. No ore recognized. An obs. on the main h.w. crushed zone gave St. S. 35W & dip 55'. A well defined fissure here filled with 1 ft. or more of soft crushed material. Striae pitch ab. 90°.

Beyond fault incline continues at ab. 25° thru greatly shattered & faulted calc shale. All soft & broken & traversed by gouge.slips generally dipping E. A strong one at bottom of winze. No ind of ore.

T91 - Spec. shaly ls. from bottom of winze. All same shale, even beyond last gouge.

Some ox. & suggestion of leaching for 40-50 feet down or possibly 100' down incline but below that goes into hard, partly met ls. showing no evidence of enrichment.

Silicates & scattered qtz grains

T92 - Spec. this ls. just above fault & perhaps 125 down.

T93 - Spec low grade ore from drift at head of winze. Contains some obscure dark specks sulfide. Raise a few feet above 800 level on this streak shows

Tombstone, Jan 15/11. Sunday

~~Office in morning.~~

Walked with kinsley & Macy in afternoon over reservoir hill, past Herschel, Royal Guard, Lucky Cuss, Lucksure, Oregon, Emerald & Rattlesnake mines.

Page 19-28 (cont.)

The rocks of the Contention, Toughnut, West Side & Herschell mines are pretty certainly younger than the Carb. ls. to S. & ore faulted down against this consist chiefly of epidotized ls & beds of qtzite in upper part. Lower levels of Pump Shaft prob. in Carb. ls. under this younger series.

A distinct fault crosses R.R. cut S of Pump Shaft. According to Macy has downthrow to S of 90'.

T94 - Devonian fossils. W. slope of hill N of Emerald & on opp. side of ravine. I collected before from this locality, perhaps a little higher up hill, in Carb.

Tombstone, Jan 16/11. Monday.

700' level

At S.E. end, middle branch follows a close fissure in rather massive ls. Partly granular & partly horny. Fissure shows no mineraliz. Dip N.E. ab. 88°. Beds at ju of three spurs dip 33° to S.E. Are horny fine-g. siliceous ls. Bedding well shown.

Between branches & c. is a bed of fine even-grained true qtzite ab. 6' thick. Under it at C. some aphanitic ls. Continue to b. Drift a-b is along strike. Dip S.E. 22° here. Some beds fairly thin. Ab. 1'. Are aphanitic argillaceous gray-brown ls. Brittle.

N[illegible] much ls. i[illegible] thin sec. Qtz grains with a [illegible]bind matrix

T95 - Spec. this material found Argillac. calc. sandstones. Same beds continue ab. 72' N.W. along main drift, becoming a little thinner and more shaly. At this pt a fault crosses drift at nearly rt /s.

T96 - Spec. from a 2' bed of ls.

T97 - Shale just above 30. These represent charact. rocks in the series cut in long S.E. drift.

T98 - Ls. from drift N of shaft on 700 level. Face.

T99 - Ls. Elbow of same drift.

On 700 level the fault thru station app. separates the "white ls" on W from the more shaly ls on E. This ls. is fairly massive, but is banded & variable in texture & appearance. Consid. Silicified & altered. Some at shaft is pseudo-qtzite. Bedding much less distinct than in thinner beds to E.

- [illegible]i. p? Not fresh

T100 - Tribute dike

T101 - W. wall of dike

T102 - Altered ls. bet. dike & winze

Page 19-28 (cont.)

(Am working from Tribute dike back to shaft)

26 Stope Altho Ralph said that ore was sulfide except near top of stope, the pillars indicate that it was at least partly ox. Appears to have formed by replacement on top of Blue ls. to a thickness of 3 or 4 ft. Blue ls. generally light fossiliferous altho fossils are not well preserved. Same as fossils collected by me some years ago near Toughnut shaft.

T103 - Characteristic fossiliferous Blue ls. from Intermediate level near 26 Stope. Full of fossils but not well preserved. Close to ore ls. is white or pinkish and has undergone consid. recrystallization.

T104 - Nearest approach to primary mineralization seen. Sphal. galena, pyrite etc in met. ls.

T105 - So-cald qtzite (altered ls.) in main X-cut W of Contention dike. App. a qtzite with wollastonite developt in matrix. Like material in Content. 1000' level, E.

Tombstone, Tues. Jan 17

T106 - Ls. (altered) just under blue ls. in drift along fault (see map) Blue ls. a few inches above retains traces of fossils

For noteworthy change in structure along Tribute dike see map. A similar steepening of the beds is said to be apparent in the Ingersol incline. Abandoned but accessible.

T107 - So-cald qtzite. Bottom of winze in drift on Ariz. Queen. See map*

T108 - Met. ls. Wall of underhand stope just W of Sulphuret dike. Prob. represents original mineralization. All ore from this stope was oxidized according to Ralph. This is met. Blue ls. and according to Ralph is a common facies of it near ore.

*Shows well the attack of qtz grains by silicates that apparently were developt first in the Calcareous material bet. the qtz grains. Garvel & wollastonite?

Page 33 - 36

Tombstone Jan 18/11 Wed.

West Side

N.E. drift ab. 350' from shaft on W side ledge, a little blue ls. appears in back. App. just bottom of syncline. App. some conglom. along drift.

Page 33 - 36 (cont.)

W. Side ledge strong fissure with many open crevices. Ox. material.

Shaft below to 800, said to be in "qtzite" with some streaks of ls. On examining 800 I found more ls. than qtzite. Rather heavy beds. Dip 15-20° to N 15 E. Some X-ine ls. and some banded horny ls. Ledge strong ox. fissure. In places 5' wide. Cu stains. Only small indic of ore. A winze ab. 20' below N.E. drift is said to go into regular white ls.

To 600 level. Long drift S. on Boss dike. Beds dip S. ab. 20°. Striae on wall of dike pitch N 35°. Close to Boss shaft, ab. 50' N of it. Bottom of Blue ls. ab. at this level, st Boss sh. Top of Blue ls. ab. 40' S on this drift.

Under micros like some of material from E 1000' level Contention

T114 - Ls. conglomerate. 350' level, W side.
Similar rock in Ingersol Incline

600 Level Pump shaft

Big fault exposed just W of shaft. Same as noted below. Block bet. this fault & Contention dike said by Macy to be raised ab. 125' relative to rocks on either side.

T115 - Sulphuret Stope
T116 - " "
T117 - " "
T118 - " "

These specimens were collected as illustrating what I believe to represent the original mineralization in the Blue ls.

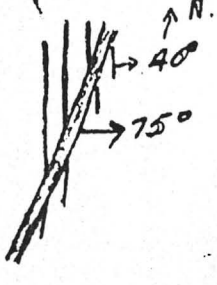
Herschell

Vein St. ab. N 33 E Dip SE ab. 75°

Beds N end of 600 level St. N 20° W Dip E 40°

650 feet deep. No water. No sulfides seen. Native & horn silver. Shoot ab. 80' long & up to 6 ft. wide. Pitches N ab. 70°
Douglas Gray, Mgr. Production ab. $280,000 gross. Shipping to El Paso

The Herschell ore occurs along a fissure that cuts the steeply upturned beds app. below the Blue ls. if that rock is present at a small angle.



This makes vein a little difficult to follow as there are numerous bedding slips which often look more prominent than the vein. The latter moreover is not straight but breaks across some beds at a different angle from its course in others. Generally some little slipping along vein. Ore ox. all way to bottom which is dry at present. Ranges from $800 to $3000 per car of ab. 40 tons. Some higher grade is sackt. Dip of beds in Herschell is fairly uniform. No sign seen of the Ingersoll roll.

#20
#75

Page 33-36 (Cont.)

Ingersol. Lies just E of Herschell. Incline goes down toward E. at about 30° (not measured). App. goes thru some of the ls. conglomerate characteristic of basal part of Contention series. Farther down follows fossilif. Blue ls.

This incline shows a remarkable structure. As one goes down one can see beds on right hand side steepen abruptly to a vertical attitude. Stopes below show what appears to be a complete overturn. Clearly the incline is close to axis of sharp fold but I am not clear as to just what happens. The relations suggest a close fold, synclinal, overturned to N. and running out into air to W. Careful mapping necessary to clear this up.

Had consid. ore in Ingersol Stopes still show consid. sphal. & galena in streaks in Blue ls. especially at under surface. Much like Sulphuret Stope.

Duplication of Contention dike by faulting is said to have given ab. 1000 vert feet of dike to stope in an actual depth of ab. 400'. Best ore made above fault slips.

Page 43 - Dec. 14/11

Talk with Gus Baron

Scheffelin had his camp near the Bronco mine, just this side of Charleston. He first located the Graveyard claim about 5 miles SW of Tombstone. Next he located the Lucky Cuss. Then he came on to Toughnut Gulch and found much carbonate ore lying in the Gulch N of the present Toughnut mine. Located the Toughnut & gave it the name on account of the difficulty he had in determining how the vein lay. Afterwards went up the hill and found some one else staking out claims. Some difference as to ownership gave rise to Contention claim. Followed by Contentment, Tranquility etc. Goodenough was located just after the Toughnut.

Stonewall shaft 400'. Never X-cut to fault under pyrite uncovered in shaft to SE of main shaft.

Had some low grade ore at 400 in Vizina, but never opened it up.

Dike in Vizina now bet. shaft and station of RR.

(3)

Excerpts from U.S.G.S. Tombstone, Arizona, Courtland, Arizona,
Notebook III, 1911-1912, F. L. Ransome

Page 1 - 12

Courtland, Tues. Oct. 17/11

Began ab. 1908*. The Great Western has shipt ab. 30,000 tons ore av. ab. 7% from one ore body. C & A has shipt ab. 15,000 - 20,000 tons from same body. Ship to El Paso.

At Gleason one mine is active. Ship a very low grade pyrite which is used for sulfur at Clifton.

*There was earlier work however in 1901 and consid. ore shipt from near surface. Humbot claim $100,000.

Turquoise mine to W said to be owned by Tiffany. Has produced a large quantity.

The Great Western has two shafts, the Mary to NE where a body of ox. ore occurs in ls. under ls. and the Mamie shaft, to SW where ore is sulfide, app. in Abrigo ls. and porphyry. Consid. work was done by Phelps D & Co. on Casey & other claims; west of Casey are the two Leadville shafts. Near Mary are the Germania, April Fool and Maid of Sunshine claims (C & A Co.)

Courtland, Wed. Oct. 18/11

C & A did ab. $250,000 work on Leadville claims in 1907-8. Found a little low grade sulfide.

Shaft E. of Mary is Silverton. Ab. 400'. Sunk by Phelps Dodge & Co.

Turquoise on W side Turquoise Hill, just below summit outcrops in a bed of qtzite. St. N & S. Dip E 65°. Turquoise occurs in fractures in the qtzite. Stoped out ab. 4' wide. An incline which connects with X-cut tunnel ab. 50' down. Appear to have worked ab, 75 or possibly 100' down to water.

Tunnel enters in decomp. porphyry or gran. All kaolinized and altered.

Country around mines at Courtland is exceedingly complex in structure. At the Mary is an area of Cambrian qtzite which is all much fractured. On the SE this mass is separated from the Carb. ls. by a heavy gossen with consid. qtzitic fault breccia & some ore. Some Carb cu ore in pockets in ls. just SE of this gossan. Gossan clearly marks a fault. The qtzite and Alrigo are clearly overthrust on the Carb.

Along RR in Hard Up claim qtzite is all much fractured, the fissures inclining to east as would be case in mass thrust from W.

W E

Courtland, Thurs. Oct. 19/11

With McBride over hills to Gleeson. Leonard Copper Co. mine at Gleason operated under lease by the Shannon Cop. Co. Copper Belle mine. At contact bet. carb. ls. which forms a ridge to E. and a dark dioritic or monzonitic porph. Blocks of porph on dump show dissem. pyrite.

Just E of holdings of Leonard Cop. Co. is old Gleason mine & the claims of the Tejon Mining Co. Idle.

Write to Shannon Copper Co. for prints of geolog maps of 3 levels. Also sections.

The ridge E of Gleason in which the ores occur is mainly carb. ls. dipping E 30-50°. Along W base of ridge are generally longitudinal intrusives of a di or monz. porph. like Cl, but more altered. Form very irregular sills. The low ground W. of the ridge is chiefly a decomp. granitic rock like that W of the Courtland hills. Also some shattered qtzite resting on ls. just W. of mine (overthrust?) and app. overlying the qtzite a flow of much decomp. rhyolite. Weathers black with mw. ox. and on fracture shows dendrites.

The Copper Belle mine is situated at W base of ridge. Shaft 300' with 3 levels. Ore is mainly pyrite (fine granular) with a little chalcop. and occasionally some bornite, sphalerite and galena. Worked mainly for sulfur in smelting but the ore is graded into 2 classes. (Pembertly, Supt.)

Ore bodies extend ab. 500' N & S and occur along contacts of two slabs of ls. included in or separated by porph. Are irreg. replacements if ls. Pyrite occurs also in small stringers and dissem. in the porph.

Ls. shows no particular contact met. No silicates. No pyrrhotite. Bodies dip generally E. like ls. but are variable. Lie generally on upper side of ls. but some bodies on lower side also.

Gleeson

No other mines now working. There were formerly three or four which worked ox. gold, silver, lead, copper ores from irregular bodies in the ls. higher up ridge.

Courtland

The broad pass W of the qtzite hills is occupied chiefly by a much altered alaskitic rock. Nowhere fresh.

Intrusive into qtzite which is locally schistose at contact. No areas of schist however. App. cuts ls. also, altho I saw no good expos. of contact and no contact met.

Courtland (cont.)

Closely connected with this alaskite and not seperable without consid. work is a bleached and highly altered white qtz porphyry. This is abundant as irreg. intrusions in ridge W of Courtland and forms round hill S of town. Nowhere even approx. fresh. I believe it is distinct from Cl altho Gruton cald it qtz. monz. porph.

Courtland, Friday Oct. 20/11

In morning thru Mary Mine with McBride.

Ore all ox. and all above 2nd level. See map for outline. Generally soft typical "Bisbee ledge matter". Limonite, malachite, azmite, cuprite, native Cu and chrysocolla. Cuprite & native not abund. An irregular undulating body up to 50' thick. Av. prob. ab. 15'. Rests on ls. & porph. Overlain by decomposed porphyry & qtzite. All consid broken up. Most of ledge matter is altered ls. Contains residual masses. No sulfides and no met. of the ls. Some doubt whether ore was originally sulfides or is exotic. Prob. some porphyry involved in ledge matter, especially where kaolin is abund. But mostly replaced ls. Porph. under ore is rather generally fractured & more or less decomp. but is not metallized.

Ore makes out from main body to some extent along NW slips, which dip NE.

Mary sh. 115' thru qtzite. Then ledge matter ab. 50' to bottom of 1st level.

Now shipping from all workings, mainly Mary, 9 50-ton cars a week.

Maine Mine

Examined 100' level only. In abrigo fm cut by dikes & sheets of very much altered White porph. Abrigo also much met. Carries garnet, siliates & pyrite with a little chalcop. A little chalcocitic enrichment in places but ore is mostly primary. Occurs in lenses generally following bedding, espe. near the porphyry. Very difficult to tell ore from worthless pyrite. One grades into the other.

Distinc. bet. altered porphy and qtzite and altered ls. most difficult.

Ore of Maine chiefly primary and they expect to find it on lower levels. Have followed some down 40' or more in winze.

Have shipt ab. 1500 tons ore from development.

Leadville No. 1 has sulfide ore like Maine. In Humbot ore was ox. Have not yet developt sulfide ore in quantity. Whole belt of abrigo is met. and extensively metallized espec. with pyrite. Rusty gossans abundant. Along belt.

Now exploring with Star churn drill.

Page 1 - 12 (Cont.)

Courtland, Sat. Oct. 21/11

At knob of qtzite on Germania claim qtzite rests on ls. Contact here dips ab. 35° to NE. Much crushing along it and inclines show ledge matter and a little ore. This thrust plane I believe turns up gulch across Hard Up and accounts for tremendous shattering of qtzite as exposed in RR cut.

Page 76, 77, 78
Tombstone District, Ariz. Wed. Nov. 8, 1911

Large scale map S. of Contention mine.

For beds in arroya (Grand Gulch) on Morning Star claim see notes on map. App. some very sharp folding in qtzites, neither crests nor saddles being well shown. For little basalt dike see first or second notebook.

Contact bet. Carb. and Cret. shown E Rattlesnake mine in Grand Gulch. Not very well exposed but the Carb ls. is overlain by conglom. not more than 10' & certainly less than 20' thick. Pebbles subangular mainly chert and less than 1"! Dip steep to N. app. nearly or quite conform to bedding of ls. Overlain by green shale and thin qtzite (at least one bed) but these are very poorly exposed.

Shaft S. corner S. Ex. Grand Central. Just N of shaft is a bed ab 15' thick of light gray impure ls. App. contains consid. elastic material. Below it shale. Above it shale also, but just above the ls. is ab. 18" conglom. This is not sharply marked off from shale. Seems to be streaks of small cherty pebbles & coarse sand in the shale. Dip NNE 85°. From shaft SW to ravine mostly shale. One thin band imp. ls. Just W of ravine a band coarser cong. Pebbles chert ls. qtz & qtzite up to ab. 4". Subang.

Telephone work done by lessees. Stript consid 10-12 years ago. An irregular fissure or crevice in ls. Dip SW 65-70°. Manganif. ore. Lessees now screening dump & shipping fines. Low grade but treatment changes very little. Have shipt 5 cars. Crevice conforms or nearly so to bedding of ls.

Section across basalt part of Cret. in middle of Telephone claim. At base ab. 25' hard epidotized shale.

Then ab. 10' conglom. with pebbles ls. chiefly with somechert & qtzite up to 4". Variable & app. grades along strike into grits or shales.

Then ab. 10' shale.

Then more epidotized shale with lenticular streaks of conglom & grit. Clearly these are lenticular originally or they are squeezed folds. The individual bands are not persistent.

Page 79, 80, 81

Tombstone District, Ariz. Thurs., November 9, 1911

Large scale map. Traverse from base of Contention series N.E. toward Pump Shaft.

Tribute dike narrow. Probably not over 20'. App. dips W. ab. 80°. About 18' on top Hardup Hill. Some faulting along it prob. accounts for disappearance of white cherty ls. band which runs around W side of hill.

Shaft on fault thru saddle S. Hardup Hill. App. had a little ore here. Fissure dips S 70-75° with h. w. No distinct striae. No black mang.

At W. corner of Alps claim occurs same band of characteristic cherty light-gray ls. as I noted at S.W. end of S. Ex. Grand Central claim and near Tribute. All same kind of ls. & ab. same thickness. If this is an identical continuous bed it will be useful.

Lens of hard brown novaculite on ridge 1000' S.E. Military Hill was misleading. Appears to be in Carb. but I at first supposed it to be the met shale at base of Cret.

Saddle W. of Alps Claim. Just W of this (12') is a band 12' wide of ls. conglom. i.e. pebbles mostly grey ls. Up to 6". Between are thin beds shale and pebbly grits or qtzites. No sharp line bet. congloms. and finer rocks. Bottom of saddle is purple & green shale but bet. this & Carb. there are 10 or mo e bands of cong. E of saddle, below gray cherty ls. I noted two thin bands conglom with thin qtzites and hard shales.

Cherty gray ls. E. of saddle 25-30' thick. Overlain by a peculiar speckled rock which weathers buff & looks at first glance like a porph. Contains elastic fragments, some recognizable as ls. 3-4' thick but grades upward irreg into a coarse grit containing ls. fragments.

From ls. to top Alps Hill beds not well exposed. Prob. nearly vert. No very thick beds. Thin-bedded rusty-weathering qtzites, grits, shales hard banded cherty rocks (prob. met. shales). The fine-g-qtzites also often banded. Same rocks with vert or nearly vertical dip app. continue over Alps Hill and down to saddle on N. So far there is no evidence of duplication by folding, anywhere bet. this saddle and the base of the series.

Saddle on Alta Claim. Band in rusty qtzites.

Tombstone District, Ariz. Frid. Nov. 10, 1911
Page 83, 84

Large scale map. S. of Reservoir Hill

Old Pump shaft on Con ention. Caved to open pit shown on map. Dike as usual shattered & decomposed. Dip W. ab. 60°. Shattered qtzite both walls. Dip easterly ab. 50°. Strike not well shown.

Page 83, 84 continued

North of Grand Centr ~ Shaft dike straight & regular to R.R. cut. Stoped up to 15' wide along _ootwall. Dip 75° (or more in places) to W. In R.R. cut this part of dike ends against a vertical fault striking N 33° E and which therefore cuts dike at small angle. This fault shows in R.R. cut and heads for Gray's blacksmith shop.

The most notable feature of the Contention open cuts is a strong fault fissure which crosses dike very obliquely. Dips 85° or more to E. In one place strong horizontal striae & grooves in footwall. This fissure was stoped where it ran thru the dike and app. carried the richest ore.

As the fault dips E & the dike W, it would have effect of repeating the dike on any given level.

Page 102, 103, 104, 105

Tombstone District, Ariz. Thurs. Nov. 16, 1911

With Macy looking up dikes, via Contention, Rattlesnake & Lucky Cuss Mines. Out to Silver Plume.

Look for piece of dike under compressor room at Pump Shaft.

Flora Morrison Shaft on stub of dike at 500'.

Shaft in saddle N. Tribute Hill is on Ariz. Queen.

Piece of dike in which Gray is working goes down a little below 200.

Ore along dike acc. to Macy occurred where little belt white cherty ls. came against dike. This belt bet. dark shales below & qtzites above.

Old shaft on Contention, on R.R. An incline now filled. Had piece of dike down to ab. 300.

Anchor Tunnel on fault. Dip SE 45°. Striae pitch 70° to SW. Connection allong incline on fault with incline on top of Anchor Hill.

Fissure that faults Tribute dike on Lucksure Hill is the Lucky Cuss fault acc. to Macy. He says this fault is wide at junctions with East-side vein but not noticeably displaced by latter.

Dip of Emerald vein at collar, 72° W. Shows a good outcrop of brecciated and dark manganif. material to S. as far as (?) house and air hole. Corresponds to contact bet Dev. & Camb. Overthrust fault ?

The cherty gray ls. promises to be useful. Marks line bet the characteristically shaly division of the Morita, with lenses ls., conglom & some qtzite and the characteristically qtzitic division with some shale.

Page 102, 103, 104, 105 continued

Tombstone District, Ariz. Nov. 18, 1911

To Silver Thread, Tranquility & Pump Shaft mapping on large scale map
Followed cherty ls. W. Hardup Hill.

Exposed in cut N. Gray's house, where it is app. of consid. width.
In very bottom of ravine on S. end Way Up, ab. 1' of decomp. porph.
exposed.

Macy says that there is no porphyry around N. Point shaft where Bishop is working. He considers it a part of vein workt thru Skip shaft, slid off to E. on bed fault. Quite likely. The two dikes worked in Tranquility & Silver T. Also a case of fault duplication. Not [illegible]

Porphyry on Yellow Jacket is much wider than I had thought. No distinct bed fault with overlying shale as I at first supposed. Fault, if present, is to E. of open pit. The porphyry however is much broken & decomposed and its width is prob. due to faulting.

Traced cherty gray ls. W. from Pump Sh., or more accurately, from old Flora Morrison Shaft. At Mayflower ab. 10' thick. Not very distinct on slope W. of gulch but shows well on 1st spur W. of Mayflower ravine. No faulting that could see at Mayflower.

On San Rafael, on ridge & down N. side a well marked zone of sheeting & fissuring with two zones of crusht material ab. 25' apart. I could find no porph. buththis seems to be line of Boss dike. Dip SE 85°.

Across middle of East-side claim the characteristic grey cherty ls. outcrops in a band ab. 25' wide on average. In places 18-20. App. dips steeply to E. Separates reddish shales below from buff qtzites etc. above.

Pages 112, 113, 114

Tombstone District, Ariz. Thurs. Nov. 30, 1911

Large scale map. Central Part.

Shaft in S.E. corner of Townsite Claim starts in blue ls. dip 35°, goes thru much "white qtzite" and into white Carb ls. Blue ls. here is app. unusually thin.

Blue Monday shaft, E. of Ingersol, reaches blue ls. thru shale.

It appears that east of Herschell there is a sharp, short-irreg. anticline overturned to W. On the overturned limb the blue ls. is bleache and not so charac. in appearance as usual. Shows consid. disturbance and is faulted. Ingersol is at nose of anticline & this accounts for peculiar behavior of blue ls. in that mine.

Page 112, 113, 114 continued

The extension of this anticline to N.W. needs revision (E. of Fisher's Mill)

I am coming to the view that the puzzling structure of Lucksure Hill is prob. due to comprest overturned folds. Some rocks that I originally supposed to be shale are the "white qtzite".

Shales in ravine just E. of Lucky Cuss & S. of pipe line are very much broken and disturbed. Prob. the axis of a sharp fold.

Tombstone District, Ariz. Tues. Dec. 12, 1911

Large scale map from near Fisher's Mill to Lucksure Hill

Band of impure gray ls. in shales, perhaps 5-6' thick, accompanied by some thinner bands, runs S. along ridge S. of Herschell mine. It than turns S.W. and swings across gulch east of Lucky Cuss, where it dips 75° to S. After crossing gulch exposures are not so good but same calcareous band seems to run N. past Old Guard. Clearly a sharp anticline here, with remarkably steep dip where the beds turn in gulch. Beds, as previously noted are considerably disturbed along gulch just S. of pipe line, they being in the axis of the fold.

Found blue ls. on E. side of Lucksure Hill. Altho thin and consid. bleached and squeezed it shows traces of the charac. fossils.

Page 118

Tombstone District, Ariz. Thurs. Dec. 14, 1911

On large scale map around Tribute Mine

Relations on W. side Hardup Hill extremely puzzling. There are two main bands of cherty gray ls, both dipping easterly and evidently repeated. Neither is overturned as just under each is the same peculiar ss. with angular fragments of white qtzite.

Between these bands on N. end of Independence claim is an unusually broad band of the ls. showing consid. disturbance at its S. end in the gulch. The main bands prob. repeated by a fault but I cannot find it. Exposures on slope are generally poor.

Fragments of ls. & qtzite surrounded by shells of the fibrous silicate which appears to have formed partly at their expense. An exceedingly tough rock.

Page 131

Elevations above sea of shafts and levels

	Empire	Girard	Westside	Toughnut	S.T.	N.P.	Tranq.	Pump
Collar	4599	4590	4585	4558	4568	4581	4588	4681
1	4499	4440	4496	4442	4457	4485	4467	4605
2	4409	4386	4420	4375	4356	4426	4374	4534
	4291*				4253*		4315*	4472*
3	4209	4311	4346	4291	4210		4283	4430
4	4150	4261	4260		4118		4183	4342
5			4175		4018		4118	4243
6			4116					4142
8								3888
7			3998					3978

	H.C.	Sulph.	Boss	G.C.	N.W.	Emerald	Comet	L.C.
Collar		4631	4564	4777	4498	4788	4777	4600
1	4506			4621	4449	4662	4609	4511
2	4431	4385		4542	4403	4560	4472	4417
3	4335	4284		4443	4360	4468	4373	4351
4	4235							
5	4129	4159				4374		4264
6						4280		4188
8						4187		4110
7						4053		
						4118		

Water pressure 1000 Level pump shaft T.C.M. Co. Tombstone

Dec 1/08	71	lbs to sq. inch
15/08	69	" " " "
Jan 1/09	67	" " " "
15/09	65	" " " "
Feby 1/09	64	" " " "
12/09	62½	" " " "
Mar 1/09	60	" " " "
15/09	55	" " " "
Apr 1/09	55	" " " "
15/09	52½	" " " "
May 1/09	46	" " " "
15/09	42½	" " " "

Pumps submerged May 31/09 for period 15 months. Recovered Aug. 26th, '09
1000 Level

Sept. 12/10	36	lbs to sq. inch
Oct 1/10	31	" " " "
15/10	23	" " " "
Nov 1/10	21	" " " "
15/10	19	" " " "
Dec 1/10	17	" " " "
15/10	15	" " " "
Jan 1/11	13	" " " "

notes out of here
Seyrence

97

Page 133, 134, 135

Tombstone District, Ariz. Sept. 29, 1911, Frid.

Contention Mine

Douglas Gray leasing. Caving porphyry footwall into old open stope. Much of this is good oxidized ore. Shows cerargyrite and massive lead carbonate. Best where porph is veined and silicified with black bands & blotches of Mn ox. and yellow ditto of lead oxide? Cost 35 cts a ton to mine. 2.30 to mine, ship and smelt at C & A smelter at Douglas. Old operators app. did not explore this footwall at all in this part of lode which is where discovery incline was sunk.

Tombstone District, Ariz. Mon. Nov. 20, 1911

With Brown to 700 level of Pump Shaft
700 ft. level, east of shaft.

1 Fault crosses X-cut nearly rt. /s. Dip E 70° 2-3' crusht shale with gouge seams. App. not a strong fault.

2 Much stronger fault 74' from branch to S.E. ab. 6' crusht material with well defined gouge seam.

3 175' W of above is a strong fault zone which crosses X-cut obliquely St. up ab. N 15° W. Dip steep to E app 70-75°. Between these faults the shales are somewhat broken & disturbed.

20' west of this is app. the main fault zone. It extends west for at least 25'. Shale broken and traversed by several gouge seams. Timbered and lagged. Dip & strike not shown.

84' West of 3 a well defined bed slip with 3-4" soft gouge. Dip E ab. 25°

4 Dip changes here. App a little local roll with pitch of 30° to N.E. Little upraise on it.

Just under upraise hard horny rock with pyrite

Roll is app. very local.

Drift S. from shaft station (compass survey) is on a strong regular fault in shale. It dips E. from 65-75°. Well defined regular seams of gouge on foot & hang. sep. by from 1-4 ft crusht shale. Striae on gouge vary but generally nearly vertical.

The drift N. from station follows fault for a way, dip ab. 75° to E and then turns into footwall, thru very hard rock. Prob. part of shale series but much met. and in places qtzitic.

Rock in h. w. of fault is certainly the shale series below the gray cherty ls. which appears at east end of level.

Page 137, 138, 139

Tombstone District Ariz. Nov. 20, 1911

700 level W. of Shaft

Pump station in massive so-called white qtzite. Shows banding in places Also streaks and bunches calc carb. Prob the specs. collected in the N drift from station are in same rock, the shales being faulted down against it by the fault thru station.

This qtzite contains bunches and stringers pyrite. More or less cupriferous Effloressence in station gives good reaction for copper.

West of dike are rusty shales. These, S of point where X-cut, reaches dike, dip 35° to S 15° W. Dike therefore occupies a fault or there has been faulting since. Prob. originally a fault-fiss. but there is a good gouge 6-8" on h.w. of dike where crost by main X-cut on this level.

After X-cut goes thru dike, what I suppose to be the blue ls. shows in a little stud X-cut in h.w. of dike. Is partly white and fine crys. (sugary) partly gray. Very faint traces of the characteristic fossils. can be traced N for at least 30' along wall of dike. Then comes in the white novaculite & qtzite.

X-cut between contention dike & Sulphuret dike is in the white qtzite. Not pure qtzite. At least one bed ab. 4' thick in hard gray ls. Also banded novaculite and streaks (app. not regular beds) of ls. Contains consid. scattered sulphides.

X-cut follows bedding in main Dip 52° near Sulphuret dike.

Consid faulting along Sulphuret dike. Porph. squeezed & slickensided. Striae & grooves pitch to N. 25°. Porph up to 6' wide.

Blue ls. comes into bottom of drift just W of Sulphuret dike. Stopes on it. It and the shales above it are met. and not typical. Blue ls. full of fibrous silicates.

Stopes on it below & above level.

69' from fault X-cut E to where Boss fissure crosses.

Winze end of Ariz. Queen fissure dip of shales 25° to S 20 W. Just where branch goes off to winze the Arizona Queen fissure, indistinct at best, is cut off by a small fault.

Fault followed by X-cut N from Ariz. Queen varies in dip but on whole nearly vert. Good grooves & striae; pitch N 72. Some fissuring in line of Arizona Q. W. of fault but exceedingly indistinct & prob. not same as that E. of fault.

White ls. for ab. 30' from end of X-cut on W side. Contact not definite bet. white qtzite & white ls.

Nov. 20, 1911 continued

Today's work impresses strongly the belief that the so-cald white qtzite is not a normal qtzite. In places it is evenly granular and the formation may contain one or more beds true qtzite. Other beds show indistinct irregular banding of cherty material in more granular material. Some contains visible calcite in places in considerable quant. Other places show a novaculitic texture. Others show an app. met. ls. with silicates and sulfides. See specimens. A little pyrite in dissem. xx, small bunches & stringers common in this rock on the 700 level. Some of the effloresce from this gives a strong copper test on knife blade.

Poindexter tells me that he made a lot of silica tests of the "white qtzite" to determine its character for furnace or converter lining. It generally fell below 85%. Some contained only ab. 60% SiO_2 and 30% CaO.

Tombstone District, Ariz. Tues. Nov. 21, 1911

600 Level from Tranquility to Pump Shaft with Brown

600 Level - Straight drift SE Tranquility Sh. in shale all rather fractured and as a rule not showing good bedding. Drift follows a little very indistinct fissuring but app. no continuous or important fissure.

Drift S. from the above X-cut in much fractured shale. In or close to fault zone. Bedding not well shown. 300' from crosscut dips 22° to N 65 E

At 128' in, crosscut A cuts a strong fault in shale. Up to 3' crushed material with regular clay gouge St N-S dip E 65.

46' farther in,* another fault St. ab. N & S. Dip E85°. 2' thoroly crusht shale with regular gouge slips. Subsidiary slips for 10' farther in X-cut.

55' from * X-cut is filled. App. from a raise, but may be cave in soft ground.

Up little raise 15-20' from this (T.D. 600') level to real 600 level of Pump Shaft. Still shales. Hard and flinty at head of raise. Dip 25° to E.

At B. porphyry appears with from 1-3' of crusht material and gouge slickensides along footwall.

At C. an incline goes down on bed planes E. of dike for 150-200' on streak of ore. Partly sulfide.

Goes down at 25°. App. a thin lens ls. in the shale. Just under C is a little sub level (ab. 10' below) app. not on map. From this another similar incline goes down on small streak of ore. This sublevel crosses dike and has a drift on h.w. Smooth & regular. Dip W 75°. Dike ab. 30' wide. Yellow, ox. & fragile.

Page 141 - 161 continued

Sulphuret stope on 600. This mineral "rose silicate" accompanies sulfides, generally around the irreg bunches of sphal. py. & galena. It is clearly a metamorphic product of the blue ls. and has formed along fractures & fissures in the ls. which where unfractured is bleacht & marmorized or retains its orig. character.

This pink material is exceedingly hard & tough.

From Sulphuret shaft to stope the X-cut goes thru solid flinty banded shales. Color nearly white to nearly black.

Shows met. of a thin band blue ls. in shale. From turn to stope drift follows a few small tight small veinlets--less ½" carrying pink mineral qtz & sulfides. Rock mostly very hard flinty shale.

Dip at burn ab. 18°.

Went up above level into stope. Workt ab. 6' thick. Sulfide ore. Pyrite sphal & galena. Reacht Sulphuret dike at W end of stope and crost it. From this point on W side of dike a long incline on a pipe like shoot of ore runs N 25 W up to an upper (West Side?) level at old forge. Flattens to ab. 8° as one goes up. App. lhad good ox. ore. Dip of main Sulphuret stope just above 600 is ab. 30°. Is on an anticlinal roll pitching to SE. Some close E-W fissuring without faulting crosses main stope on 600 & prob. was one of the factors in ore deposition.

Went down winze from intermediate Sulphuret Stope just W of dike towards 700. Dike ab. 12' wide rather irregular. Ore of stope & blue ls. turn down almost vert. App. a sharp fold, with the dip increased by distributed small faults (Poindexter believes it to be merely steep fold.)

Crosscut from dike to Pump station on 600 in exceedingly hard flinty rocks. Prob. in shale series but not as characteristic as same places. Much met. with little nests of pyrite & prob. a little chalcop.

A fault thru X-cut just W of Pump Station and another, dip 73° E app. goes thru shaft.

Tombstone District, Ariz. Wed. Nov. 22, 1911

With Brown to 600 Level Pump Sh east of shaft, up shaft to 500 level and on 600 P. Sh. level bet. Tranquility & Empire shafts.

Drift NW from E 78' not on map cuts irreg fault in shattered shale. App. nearly a bed fault. Dip & St not well shown. Prob. same as in main E crosscut.

25' NE of F a distinct fault in shale. Good regular gouge on f.w. with 6-8' crusht shale on h.w. Dip E 65°.

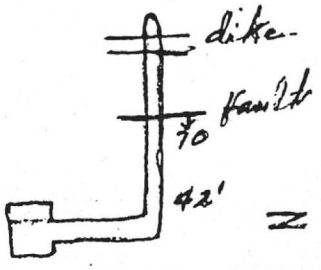
Page 141 - 161 continued

Another fault just reacht in back of winze station at G. This dips W 85° Winze is sunk on a fissure carrying porous ox. material with iron ox. & wulfenite. Latter abundant. Stoped a little ore above sublevel. Ab. this level the ore is app. cut off or ends against some irreg faulting, but the manner of its end is not quite clear. In some places comes against a vert. fault with a foot or two of brecciated shale. ∠ of winze = 60° Consid. movement along the fissure itself and much minor irreg faulting in here; all shale.

Drift to H is on the vein followed in winze. A little wulfenite here & there but no ore NE of winze. Is a decided fault fissure with crushing and gouge. Dip 60-80°. Rather variable. At face ab 1' of gouge & ground up shale. Ox. all way along.

Climbed Shaft to 500 level. Xcut west to drift on footwall of dike. Faulting along f.w. X-cut thru shale. X-cut goes thru to shales in h.w. Dike 50' wide.

42' W of where drift from station meets X-cut a fault; disp E 70°. Usual crusht shale & smooth gouge slip.



S.E. drift at L on 500 is on fault dip NE
S.E. drift from shaft is in broken shale. Much disturbed and lagged at turn to right.

<u>From Tranquility N.E. on 600 Level</u> (See Toughnut section of map)

Thru shales to Contention or Empire dike which on this X-cut appears to be separated by a horse of shale 10-15' wide. Look at this again.

Drift N at first on h.w. of dike along strong fault gouge. In places drift is wholly in dike but is heavy ground & tightly lagged. Presumably it follows line of principal fissuring. From dike W. to Sulphuret more massive than the shale app. some blue ls. Look at this again.

<u>Tombstone District, Ariz. Friday, Nov. 24, 1911</u>

With brown to 600 Pump level east. Back to Empire shaft and west. Up to Toughnut 3rd.

600 Level N. Tranquility Shaft. Cross-cut W from dike to No. 6 raise nearly follows bedding. Beds thicker than shale. For 165' W they are fine-g white crys ls. with some aphanatic but not very flinty ls. Virtually all ls. No qtzite seen so far.

Page 141 - 161 continued

Just west of this some hard flinty met. ls. or shale and then more ls. Some of this met. and contains pink fibrous mineral & sulphides--chiefly dissem pyrite & veinlets of pyrite. I believe at present that whole X-cut is in blue ls.

X-cut N.W. of Shaft thru white ls. to Boss dike. Up to 5' wide. Yellow decomp. porphy. Faulted by a N.W. S.E. fissure with strong grooves pitching 62° to S.E. Fissure dips ab. 80° S.W.

Went up Empire incline and over to Toughnut shaft by 300 level.

Drift S from shaft in white ls. (Carb.) to point 50 beyong branch drift to E. Thence flinty novaculite to end of S. drift. Just in face same blue ls. shows. Not sure whether it is the blue ls., but prob. is. Dip at face 29°, a little W of S. Dip of white ls. at X-cut 65° S 55 W. Some solution along contact white ls. & novaculite & original character not clear. From end of S. drift a drift (not on my photo map) turns off west - prob. to West Side.

Drift to A, E of dike, is in very hard "white qutzite".

Much fine-g flinty novaculite. Also a little white ls.

Drift ESE from shaft. in white ls. Cross-cut B cuts same fissure that faults Boss dike. N. of it in X-cut is white ls. but some is hard and flinty. A little hole from X-cut opens into open stope on this fissure.

In ls. around Toughnut shaft are crevices a foot or more wide. One on the E-W fissure just W. of Boss dike.

White ls. to D. Here a branch drift N 70 W on a fissure dipping 60° S. N.W. of D change in rocks. Become hard & flinty, more like 279.

Drift F 100' in, blue ls. dips 40° N. 70 E.

45' farther contact main blue ls. & overlying shale. Dip 84° N 40 E.

Ab. 30' farther to face there flinty black shale & some horny novaculite that I should say was "white qtzite" were it not for its position. Just in face a little blue-black ls. Prob. one of the upper bands.

Tombstone District, Ariz. Friday, Dec. 1, 1911

With Rafferty to Dipper and Ingersol workings

Down Dipper Shaft 200 - 250' to long drift N to Brady stope. The ore of this stope in Contention dike, mainly near footwall. See notes on small map.

Page 141 - 161 continued

Down winze to Pump Shaft 400 Level. See notes on 50' map. Altho dike appears to be faulted at end of stope, the ore appl stopt some distance N. of fault.

Ingersol incline confirms structure workt out yesterday on surface. A remarkably sharp overturned anticline the nose of the anticline beautifully shown in incline near its mouth--not more than 25 or 30' down. Beds of ls. can be seen bent sharply over. An almost unbelievably sharp fold and ls. is not noticeably fractured. Evidently ls. is very pliable.

From 4th level down sulfide ore shows in incline. Follows bedding planes and makes near fractures. Largely sphalerite. No large body seen. Irregular streaks less than 1' thick.

Tombstone District, Ariz. Sat. Nov. 25, 1911

with L. M. Brown on Toughnut 3rd & Girard levels.

Down Empire Incline from Toughnut 3rd to Sublevel

On N.E. side, blue ls. all way down. Along S.W. side there appears to be a fault, with some porphyry along it, which has dropt the blue ls. against rusty rather shaly novaculite. This fissure well shown in sublevel drift X. Ab. vert. but undulates consid. crushing but no regular gouge slip. Prob. a comparatively old break. Carries some ore.

Back up incline and round by Empire shaft. Down raise to Girard level 30' ± below Toughnut 3rd.

The Empire incline goes down in upper part of the main blue ls. Ore was 6' or more thick in places. Irreg. boundaries. No sulfides seen.

Girard incline in white (Carb. ls) just under "white qtzite". Ore body very irregular. Met. replacement of ls. near fracture zones. Where ore ended at lower end of incline I saw a few small bunches of sphalerite & pyrite, with possibly other sulfides. Ore as a whole ox.

All porphyry dikes on T.N. 3rd level are thoroly decomposed and ox. Rusty yellow.

I have failed to find as yet any evidence of unconformity bet. the white qtzite & blue ls. The latter rocks seems to have been deposited directly on a clean surface of the latter and in places there appears to be a gradation. On other hand there is usually more or less solution & ox. bet. the W. qtzite & white ls. At the head of the Girard incline the ls. appears to have been brecciated or else there was a little ls. conglom. just under the "white qtzite". I begin to question whether the "white qtzite" does not belong with the Cretaceous series. Study this further in surface.

Page 141 - 161 continued

Tombstone District, Ariz. Tuesday, Nov. 28, 1911

With Harry Rafferty thru Tranquility

From Tranquility bet. 1st & second level. Taken by lessees thru Skip shaft.

All ox. ground in Tranquility and main features of interest are the faults. Continuation of steep E dipping faults & bed faults. Unfortunately conditions for studying these now are not good.

Tombstone District, Ariz. Wed. Nov. 29, 1911

Silver Thread and Head Center Mines with Rafferty

Silver Thread 400 level. The wulfenite abundant but not regarded by miners as ore, or as any particular ind. of ore.

380 ft. level No map. Station in W. qtzite, near base. Drifts to N. W. cut white ls. Dip near sh. 30° N 60 E. Usual layer of porous vuggy material just under qtzite. Stoped irreg. Wulfenite, qtz & calcite & cerrisite (?) crystals.

Did not go below 400 level. Ladders in shaft not safe. Might be possible to get down thru stopes.

Some ox. ore on 400 but prob. not much deeper.

Tombstone District, Ariz. Sat. Dec. 2, 1911

Old workings bet. Toughnut and Vizina

Near Hoodoo Crack. 1st level N.W. workings. Remnants of orig. ore. In part ox. and accompanied by porous silic material from which sulfides have been leacht.

Between the Toughnut and the Vizina is a maze of stopes that extends partly under the town. They come to surface just west of town and extend down to east - following the upper beds of the white ls., just under W. qtzite. Not a uniform layer of ore but a series of very irregular bodies connecting and overlapping in an extraordinary and complex way. Some of these bodies were 12 or 15' or more thick and of large area. All ox. ore.

Tombstone District, Ariz. Nov. 21, 1911

Page 172

Sulphuret Stope on 600 shows no oxidation. Sulfide ore. Consid. left on edges of the lens stoped. Formed at top of blue ls. by met. & replacement of ls. This plainly connected with fissures, not necessarily large or faults. Turns down very sharply almost to 700 and then flattens out as sharply, or nearly so. No distinct faulting. Mainly at least a sharp bend. The pink fibrous mi[illegible]al closely associated with ore, which in the main was primary but prob. secondarily enricht just below ox. zone.

Page 176, 177

Tombstone District, Ariz. Sept. 29, 1911

Herschel Mine

Sank to 700' level and had good sulfide ore. Drifted 84 ft on this and then stoped up. This level now under water.

Tombstone District, Ariz. Monday, Dec. 4, 1911

Lucky Cuss with Porifirio Padillas

7th level (8 under water) drift N. along fault, which is well exposed at N face. Dip E 65°. Main and deepest striae pitch S 40°. There are other less distinct sets. Ab. 4' crusht ls. & gouge bet smooth walls. X-cuts from fault W. into ls. At one place a little bunch of ox. man. ore on a side fissure dipping S. Carb. ls. only rock seen in this level N. of incline.

Page 181

Tombstone District, Ariz. Dec. 5, 1911

Lucky Cuss 3rd and second levels with Padillas

Ls. breccia or conglom. Underlies shale. Lucky Cuss 3rd S of shaft. Clearly fragmental but not clear whether brecciated & frags rounded by solution or conglom. with cemented calc matrix. It is prob. a conglom.

Main E X-cut 3rd level. East of this in X-cut a band 65' wide along X-cut of white crys. ls. Hard shaly ls. and flinty novaculite. These are most intimately interbanded. No folding could account for the association nor are the different rocks in distinct beds. They occur one in the other as irreg. lenses streaks & bunches. No sharp lines bet. the facies.

Page 187, 188

Tombstone District, Ariz. Nov. 17, 1911

The State of Maine shows a great many fissures in porph. which meet at small angles without crossing or faulting. On each level there are generally two curved main fissures that enclose a horse of country rock of eye-like outline. I am not sure that these fissures are everywhere simple or that the so-called footwall and hanging wall fissures are respectively identical on every level. Make sections.

These fissures generally show a smooth slip plane with nearly vert. striae. In places billowy but often remarkably straight and even for short distances. No vein filling proper, but here and there along the fissures cerargyrite in a narrow seam. In places the cerargyrite appears to have occurred in subsidiary cracks, the stopes showing widths of 5-6'.

Page 188

At the bottom of the mine some Morita shale, in great part reddish and gray calc. shale, occurs under porph. In sharp intrusive contact close to bottom of shaft yet porph. seems generally to overly shale nearly ho.izontally. This, however, is not clearly shown. The relations of shale and porph on bottom level indicate that throw along slip planes is not great

Page 195, 196, 197, 198

Tombstone District, Ariz. Thursday, Nov. 23, 1911

In office with C. L. Poindexter tracing maps.

History: Consolidation effected mainly thru Grow, who had obtained options, in 1901, year of Queen's death! Arranged in San Francisco.

Poindexter says that the anticlinal rolls are very persistent but that ore is not invariably along crest. May be one side or a shoot may run down diagonally.

West Side and Sulphuret ore said to occur on same anticline.

Tombstone District, Ariz. Sun. Oct. 1, 1911

Office work

Knoxville mine afterwards called Stonewall and then relocated as Oregon.

It and Comet mine were able to work low grade mang. ox.ore because smelter at Charlston need flux and gave them a bonus of 2 or 3 dols. a ton. (Macy)

Mang. ore of Oregon carries up to 7% zinc (Macy)

Tombstone District, Ariz. Nov. 12, 1911

Talk with Macy

In Emerald bet. 4 & 5 levels a bedding slip throws vein ab. 200'. See map where they began to X-cut to W.

According to Macy bedding slips common and displace the vertical faults just as they do the dikes. He says that the big fissure that is exposed just N of S center post of Grand Central claim is the same as the fissure W of it, being repeated by bed faulting. The steep faults nearly parallel with the Contention dike are offset by the bed faults.

He says that the Comet dike can be traced thru Bunker Hill mine over Contention Hill and thru Silver Thread.

Tribute traceable nearly to Oregon. A dike also in Abrigo belt near Silver Plume. Also 2 dikes on Telephone claim.

Page 195-198 continued

Upper part of Tribute dike near shaft displaced by bedding fault.

Dec. 3, 1911

Baron found Tribute ore body ab. 40' from surface. Widened down to an ore body ab. 40' long and 16' wide near 100' level. Pincht out at ab. 150' Was rich; some 340 oz. silver and 10 oz. gold. Prod. ab. $120,000 Showed large xx hornsilver with native gold on top of the cerargyrite.

Accord. to Baron, "petanke" (not sure of spelling) is "black metal" or argentite.

He came to T in 1878. All Vizina ore above 100'. Sunk 400' to water level. Ore began E of Tribute dike which he says past just E of shaft and extended down under town to corner of Russ House. No sulfides.

According to A. L. Grow the companies prior to consolidation were the Contention Consol. Min. Co. (most productive), the Grand Central Min. Co. (28 claims), the Head Center and Tranquility M. Co., The Tombstone Milling & Mining Co. (owned Toughnut), the Vizina Min. Co. and the Bunker Hill Mining Co.

E&MJ article (7-8-11)

The Development Company of America

In order to satisfy the creditors of the Development Company of America, the following securities were sold at auction in New York, June 2, for $100,000; $1,015,000 Imperial Copper Company, 6 per cent. bonds; $30,000 Development Company of America, 15-year 6 per cent. gold trust bonds; $250,000 Tombstone Consolidated Mines Company, 6 per cent. special contract bonds; 100,000 shares Tombstone Consolidated stock; $725,000 demand notes of the Imperial Copper Company and $1,500,000 of Tombstone Consolidated demand notes. It is stated that these securities were bought by interests friendly to the Development Company.

The Subsidiary Companies

The Development Company of America was incorporated in Delaware, Nov. 23, 1901, with authorized stock capitalization of $3,000,000 and bonded debt of $5,000,000. It owned the entire stock of the American-Mexican Lumber Company and the Congress Consolidated Mines Company, Ltd., and controlled the Poland Mining Company, Lookout Copper Company, Imperial Copper Company and the Tombstone Consolidated Mines Company.

The American-Mexican Lumber Company, owning 500,000 acres of pine lands in the state of Chihuahua, Mexico, is capitalized at $5,000,000. The Congress Consolidated Mines Company, Ltd., capitalized at $5,000,000, owns a gold mine in Yavapai county, Ariz., the workings of which extend to 2050 ft. below surface. The property is equipped with two 40-stamp mills, cyanide plant and modern surface mine equipment. In 1906 and 1907 $150,000 in dividends was paid to the Development Company of America.

The Poland Mining Company is capitalized at $3,000,000, of which the Development Company of America owned $1,452,020. There have also been issued $1,000,000, 7 per cent. income bonds. The property is in Yavapai county, Ariz., and the veins were worked to a depth of 900 ft. The 20-stamp mill shipped iron concentrates to the Sasco smeltery, and lead concentrates to the smelting plant at Needles. The Lookout Copper Company, capitalized at $2,000,000, of which the Development Company of America owned $1,700,000, owns properties in Yavapai county.

The Imperial Copper Company is capitalized at $5,000,000, and has issued $2,000,000 income bonds, of which the Development Company of America owned $1,505,000 of the former and $1,015,000 of the latter. The company owns all the stock of the Arizona Southern Railroad Company, and the Southern Arizona Smelting Company. The mines are at Silverbell, Pima county, Ariz. Shipments began in September, 1903, and to July, 1908, the mine had produced 22,000,000 lb. of copper, as well as some silver and lead. Two dividends of $100,000 each were paid in 1906 and 1907. The smeltery, at Sasco, was blown in early in 1908. The Tombstone Consolidated Mines Company is capitalized at $15,000,000, of which the Development Company of America owned $6,500,000; the income-bond issue was $3,000,000, 6 per cent. The 67 mining claims owned by the company are at Tombstone, Cochise county, Ariz.

The Discovery of Tombstone

Tombstone was discovered in 1878. The ore contained gold, silver and lead. At first the silver was the principal valuable constitutent of the ore, but as the mine workings were extended in depth, it was found that the proportion of gold to silver rapidly increased, so that the value of the gold greatly exceeded that of the other metals. The camp became one of the largest in the Southwest and produced about $35,000,000. At a depth of 560 ft. below surface the water level was reached, where the flow was so great that all attempts to control it failed and the miners were obliged to discontinue operations.

The Problem of Unwatering the Mines

About seven years ago, E. B. Gage and associates brought together the principal properties under one ownership. Funds were raised through the Development Company of America, which were then thought ample to install the pumping equipment necessary for working the mines at greater depth and to provide for such developments on the deep levels that would place the properties in such a position that production could be commenced.

A modern four-compartment shaft, equipped with a steel headframe, was sunk to the 560-ft. or water level, where a station was cut for pumps capable of raising 1750 gal. per min. When the shaft was cut to a depth of 700 ft., another pumping station was cut and equipped and a third pumping installation was made at the 800-ft. level. The shaft was bottomed at 1000 ft., and on that level a large pumping plant was built.

Upon reaching the 1000 level, drifting was started to cut under those parts of the mines from which the $35,000,000 was produced. Oil was being used as fuel. An accident occurred to the fuel-supply pipes, and by the time repairs had been made the water had risen to the 800 level. An attempt was then made to recover the pumps on the 1000 level by using four sinking pumps; but as this was unsuccessful, the installation on the 800 level was enlarged by adding a plant practically duplicating that on the 1000 level. The heat from the exhaust of the pumps was so great, that a compressor was installed to operate the sinking pumps by air. Just as the 1000-level pumps were being recovered another accident occurred to the boiler plant; during this delay the water again rose to the 800 level. Arrangements were then made to reduce risks from accidents to the boiler plant, and the lowest pumps were recovered and drifting to the ore was resumed. The total pumping capacity was 10,000,000 gal. per day.

Funds Prove Insufficient

The funds realized from the sales of securities proved not to be sufficient, and in order to go on with the elaborate prospecting campaign, large sums of money had to be borrowed. Not having the mine on a paying basis soon resulted in the exhaustion of the company's credit, and on Jan. 19, 1911, pumping was stopped.

Steps are now being taken toward a reorganization of the subsidiary companies, the securities of which were recently sold, so that funds may be raised for resuming the work at Tombstone.

About 125 men are now working for leasers in the old stopes above water level, and besides paying royalty, are making a fair profit. After the reorganization it is possible that a new scheme will be followed to reach the lower parts of the orebodies; the shoots will be followed downward and the water level lowered only as developments in the ore require.

Bear Lodge District, Wyoming

Special Correspondence

A mining boom of small proportions is now in progress in the Bear Lodge mountains, in Crook county, eastern Wyoming. The district has been prospected and gold veins known to exist for a number of years, but within the last year developments have been more encouraging, and the first mill to be erected in the camp is now being taken in. The mines are 20 miles from a railroad, which fact has probably retarded their development. The country rock is largely Algonkian slate, cut by numerous well defined dikes of porphyry, phonolite and trachite; the best veins so far opened, lying on the contact between the slates and the eruptives. Sundance, Wyo., is the nearest town and outfitting point. E. A. Bock has recently installed an air compressor and drills and is blocking out ore for the mill. The plant, which was purchased from the Montezuma company, at Rochford, S. D., consists of a crusher, Huntington mill and concentrators, and is to be equipped with a cyanide annex. A large portion of the machinery is now on the ground and excavations for the mill are well under way.

JOHN CHURCH
AIME DRAFT

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Tombstone, Arizona, Mining District.

BY JOHN A. CHURCH, NEW YORK CITY.

(New York and Philadelphia Meeting, February and May, 1902.)

TWENTY years ago Tombstone was the most noted mining camp in Arizona. It presented a combination of fissure-veins and bedded deposits in relations which were most puzzling and impossible to make out, until the extensive development of the mines permitted every detail of the structure to be observed. These details have been studied with great success by W. F. Staunton, now Manager of the Congress mine, in Arizona, and subsequently by H. J. Gray, and the facts upon which the following description is based are mostly the discovery of Mr. Staunton, though confirmed by my own examination.

Tombstone is situated in a country that contains several important mines. On the south, at Bisbee, are the Copper Queen, which Prof. Douglas has described in our *Transactions*,* and other valuable mines at Bisbee; on the east the Commonwealth gold-mine and the recently opened copper-mines at Turquoise, or Gleeson, and the older Middlemarch and Black Diamond. Northeast are the Peabody copper-mines. The wolfram discoveries of two years ago were in the Dragoon mountains, towards which Tombstone looks on the north and east.

Though the town has no railroad at present, it lies but ten miles from Fairbanks, through which place both the Southern Pacific and El Paso and Southwestern railways run, and it is expected that in a few months a cut-off on the latter road, between Fairbanks and College Peak, passing through Tombstone, will place the camp practically on the main line.

Its general situation is shown in the accompanying map. It lies on the Gadsden Purchase, and is in Cochise county, 25 miles from the Mexican line. The San Pedro river at Fair-

* *Trans.*

banks and Charleston, afforded an ample supply of water to the old mills, and the water-supply of the town is drawn from the Huachuca mountains through a pipe-line about 25 miles long.

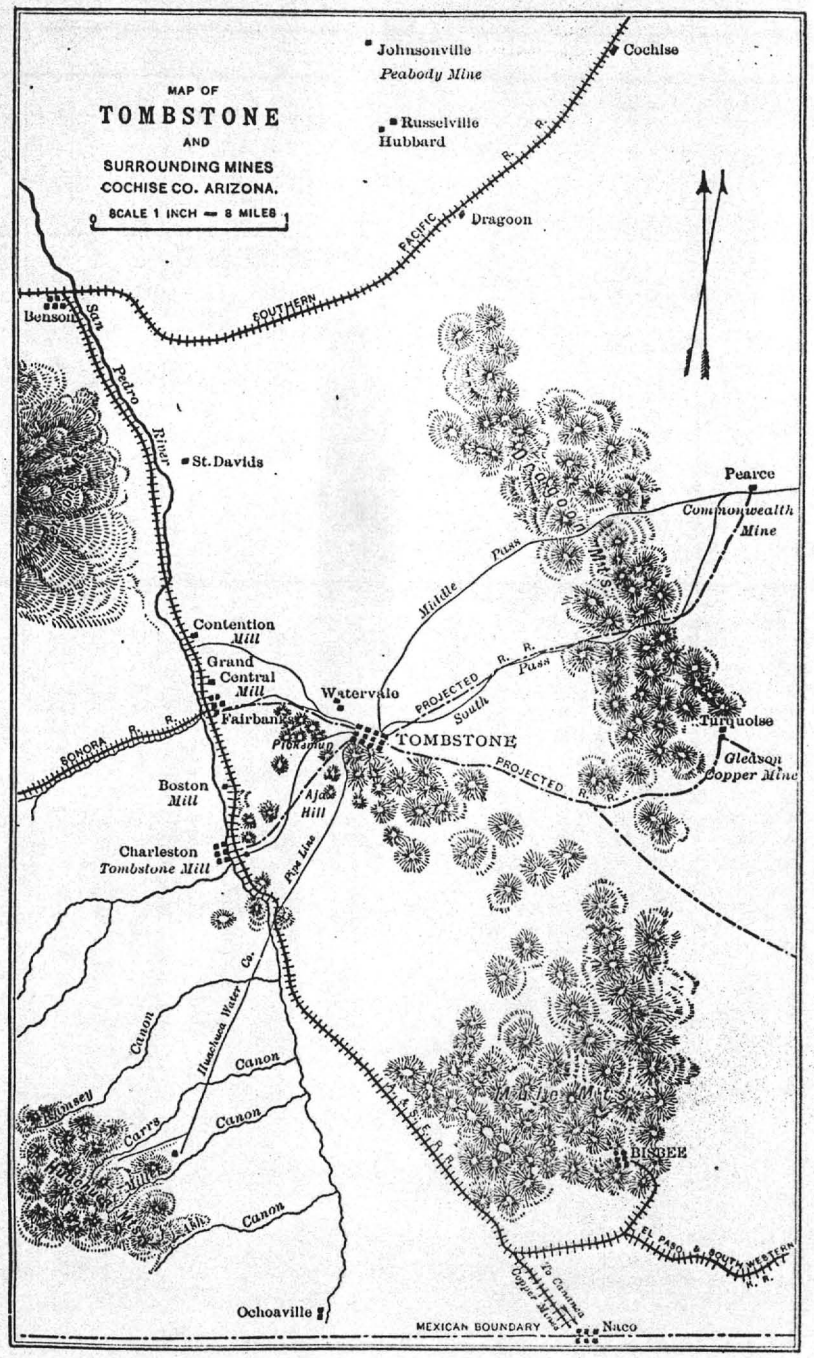
Considered as a whole, the formation consists of sedimentary beds in contact with an extensive eruptive mass of granodiorite; but with two exceptions (the Lucky Cuss and Knoxville), the best mines are not near the contact, and the eruptive rock does not underlie the productive part of the measures, unless at a depth greater than 3000 feet.

The Lucky Cuss claim has a fissure-vein within 300 or 400 ft. of the granodiorite, and has yielded nearly a million dollars; the West Side, another fissure-vein, is 2000 ft. from the contact, and has produced a million and a half; and the principal fissure of the district, which passes through the Grand Central, Contention and Head Center mines, and has yielded about twelve million dollars, is 4000 ft. from the eruptive rock. A few of the minor bedded deposits are 600 to 900 ft. from the contact, but their total product did not exceed $900,000, while the principal deposits of this type which have produced more than six million dollars are half a mile distant.

In a district like Tombstone, where surface-deposits of small extent have been opened at a great many points, almost any statement that can be made can be excepted to on the ground that ore has been found at some place that does not come within the general statement; but the preponderance which I have expressed in values could also be given in tonnage, if the books of all the mining companies had recorded the output by weight, and it is clearly shown by the comparative extent and permanence of the stopes and veins. It is by the study of the leading mines that the facts of the formation have been obtained. They show that the deposition of ore has an intimate and interesting relation to the structure and dynamical history of the sedimentary rocks.

The observable measures of Tombstone consist of 2850 ft. of sedimentary strata, an intrusive mass of granodiorite and a surface-flow of rhyolite.

At the bottom of the sedimentary series is the Randolph limestone, numbered I. in Fig. 1, so called from the mine of that name in the Charleston side of the district. A thickness



of 300 ft. is allotted to it, as it is certainly more than 200 ft. thick. It has not been an important producer of ore.

Above it is the Ajax quartzite, II., a strong anticlinal in this rock forming Ajax hill, the highest elevation in the district, rising 900 ft. above the town. The Mamie and other mines have been producers from this rock, which is 500 ft. thick.

Over the quartzite is the Emerald limestone, III., 420 ft. thick. About the Emerald, the most important mine in it, this stratum consists of thin limestones interleaved with thinner shales. At other localities it is made up of thicker and purer limestones, with thicker beds of quartzite; but wherever seen it indicates variable conditions of formation. It contains several mines.

Next in the series is the Lucky Cuss limestone, IV., which has several productive mines besides the prominent one that gives it its name. Its thickness is taken at 400 ft., but in the eastern part of the district it covers a great extent of country, and undoubtedly thickens rapidly, indicating steady and long continued subsidence. It is often fossiliferous, but metamorphism has made it difficult to obtain satisfactory fossils in any variety. It is full of crinoid fragments and imperfectly exposed corals, the crinoids being most abundant.

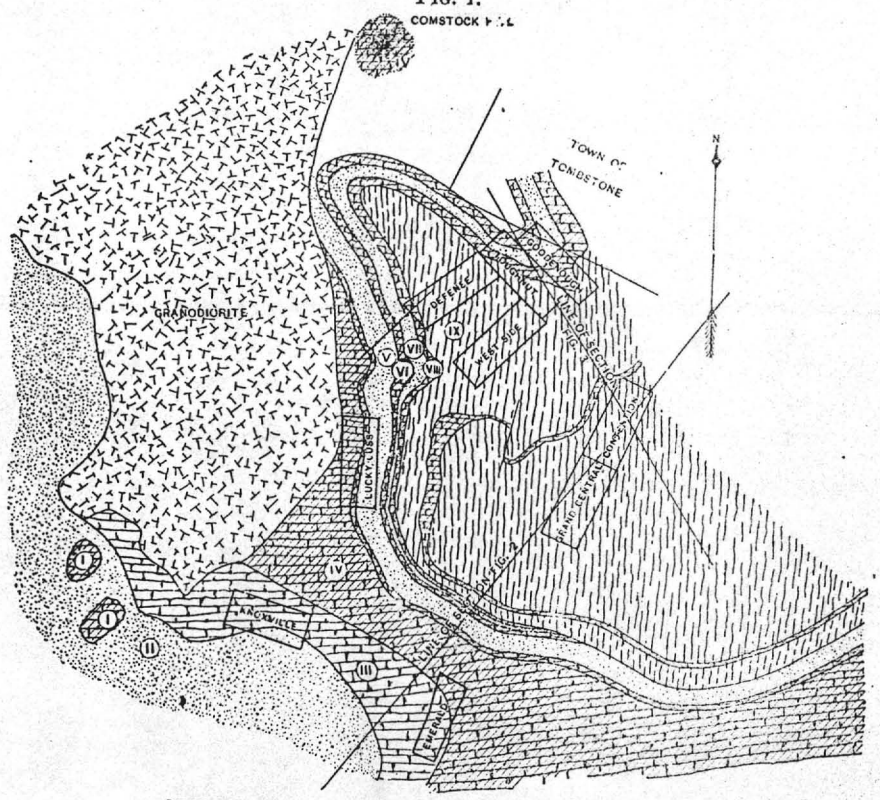
Upon this limestone rests the Herschel quartzite, V., which varies in thickness, but in the section given is taken at 270 ft., a minimum. At the surface it has a shaly structure, but in the East Side crosscut is found to be mostly a dense, fine-grained quartzite.

Above it is the first of the more important ore-strata, the White Lime, VI., 60 ft. thick. This rock, which has produced some of the most valuable ore-bodies in the district, has the usual appearance and softness of pure limestones, but in the ore-bodies and their neighborhood becomes very siliceous—so much so that Prof. Kemp, though deciding it to be limestone, found that the specimen sent him resembled a quartzite with lime intrusions. Its character as a limestone is undoubted; and the silicious intrusion which characterizes it is probably to be ascribed to the solutions which brought in the ore, for it is not present away from the ore-bodies.

Above the white limestone lies the Toughnut quartzite, VII., 120 to 140 ft. thick. It is one of the three rocks first recog-

nized in Tombstone as belonging to the most prolific ore-measures. It appears to have partaken in the silification due to solfataric action; for, though a quartzite of very fine grain, it gives to one familiar with it the impression of a rock that is not altogether clastic. Prof. Kemp, who examined the rock under the microscope, confirmed this impression, as he reported that, in addition to fragments of quartz, it has much cherty

FIG. 1.



Geological Sketch-Map of Tombstone District, Arizona.

silica, and little veins run all through it. The specimen submitted to him was taken in the heart of the mass, and was not near ore. In the mine it appears a massive, fine-grained rock, but not composed of impalpable siliceous paste, like some of the quartzites in the shales.

This rock sometimes contains ore, but not abundantly. There is one small ore-body in it that seems to be connected

with low vertical stopes in a crevice or crevices, and another that shows some limestone, and may have formed in a limited bed of this rock. Another, which unites the Quarry and Girard anticlinal ore-bodies, lies on the Quarry dike, and extends vertically for 40 ft. There are other small irregular stopes near the same dike. Thus, though ore can make in the quartzite, it seems to need especial preparation for it. Of occurrences where ore makes in it in contact with an ore-body in limestone it is not necessary to speak. Such exceptions occur in all mines.

Over the quartzite is the third of the original ore-series, the Blue Lime, VIII., 90 ft. thick. Unlike the white limestone, this is a soft, deep-blue rock, a typical limestone; and it is remarkable that, with all the silica imported into the lower members, this rock has been unchanged, except in definite lines like veins or in limited areas. In general, the rock is pure.

In the places excepted, there is dark-blue silicified fossiliferous limestone, evidently an alteration of the parent rock which has not disturbed any original characteristic except hardness. The blue limestone has been one of the best ore-carriers in the district, as might be expected from its softness and purity.

Finally, we reach the highest stratum with which we have to deal, known in Tombstone as *the* shale, IX., to which I will add the name Contention, as that mine has been the principal producer from it. It contains a heavy bed of quartzite, and many thin limestones and thin quartzites; but the ore-bodies of the fissure-veins go down through all its constituents, and it is sufficient to regard it as one, though a composite, number. The Grand Central pump-shaft has penetrated it vertically for 681 ft., and is supposed to be still 150 ft. above the blue limestone. It forms the surface over most of the productive area, and its thickness there may be taken as 700 ft.

These four rocks—the shale, blue limestone, quartzite and white limestone—will sometimes be spoken of as the Toughnut series from the mine where these leading members of the Tombstone formation were first recognized.

The limestones are non-magnesian, and often fetid, even when bleached nearly white.

Few recognizable fossils were found, though all of the limestones are fossiliferous. *Fusulina cylindrica* was found in the

quartzite above the Lucky Cuss limestone and *Spirifer rockymontanus* in the blue limestone. An undermined *Chætetes* and *Productus* were the only other fossils obtained. The indications are that the Tombstone beds belong to the higher measures of the Lower Carboniferous, and, perhaps, to the Carboniferous.

The sedimentary rocks are folded into a synclinal about 4000 ft. wide, measured on the center line of the Toughnut claim, with a nearly east and west axis, which pitches from the granodiorite eastward. The outcrops lie in an irregular horseshoe which has a deformation near the point of the curve that suggests pressure against the granodiorite. They have not been traced beyond a point east of the San Diego mine, but the Lucky Cuss limestone continues there in a line of prominent hills eastward. Except the three Toughnut rocks, this is the only one of the series that can be found near the town—Comstock hill, a mound 100 ft. high, being composed of it.

The composition of these rocks shows that the geologic history of Tombstone was mostly a very quiet one. There are two or three pebbly limestones, and two or three conglomerates with quartz pebbles like walnuts, but nearly all the other rocks are of extremely fine grain. The Ajax quartzite and the thick one included in the shale series are of ordinary visible grain, but the others are mostly of shaly fineness though siliceous in composition. The land mass which furnished the material for these rocks probably lay to the north and west, and sufficiently distant to send only fine sediments to the locality under consideration.

The massive fine-grained quartzites of Tombstone seem to be nearly pure silica, the coarser kinds often containing a large proportion of highly crystalline felspar, opaque and pink in color. As the quartz grains of the granular quartzites are often perfectly limpid, the combination of these rounded glassy grains with well-developed felspar makes a product that resembles closely one of the dike eruptives. Other quartzites, less frequently found, have much hornblende. These impure rocks resist erosion better than the pure. Sometimes they have a linear direction like dikes, and I suspect these are to be affiliated with the lines of silicified limestone as a result of the action of hot water or hot gases.

Elevation succeeded the formation of the rocks, and the steep dips in places where it can hardly be attributed to subsequent history indicate that this movement was not insignificant.

The next step in the process of preparing Tombstone for its mineral wealth was the intrusion of an extensive mass of granodiorite. It has a maximum width of about 10,000 ft., and a length of 15,000 from its contacts on the south to the line where it disappears towards the north, under the gravel of the 12-mile-wide valley which separates Tombstone from the Dragoon mountains. It may have some relation to the granitic rock which forms the front of Cochise's stronghold in those mountains, and reaches several miles out in the floor of the valley.

This mass intruded under the lowest of the known measures, at least, and faulted the rocks at the southern contact, lifting a block from which the sedimentary rocks have been mostly removed by erosion; but patches of them, and in one case a considerable hill, are found scattered over its surface. These patches are mostly limestone which contained a decided proportion of silt, if we may judge from the products of contact-metamorphism. Sometimes quartzite is found, and the composition of these remnants recalls the Randolph and Emerald limestones.

It is evident that the eruptive rock has suffered but little erosion except towards the valley. Near the southern contact it is possible often to walk on the original surface. This fact permits the minimum thickness to be calculated, for the upper surface is now on a level with the Herschel quartzite, and the granodiorite has risen 1600 to 1800 ft. above the level of its entrance, if it intruded under the Randolph limestone.

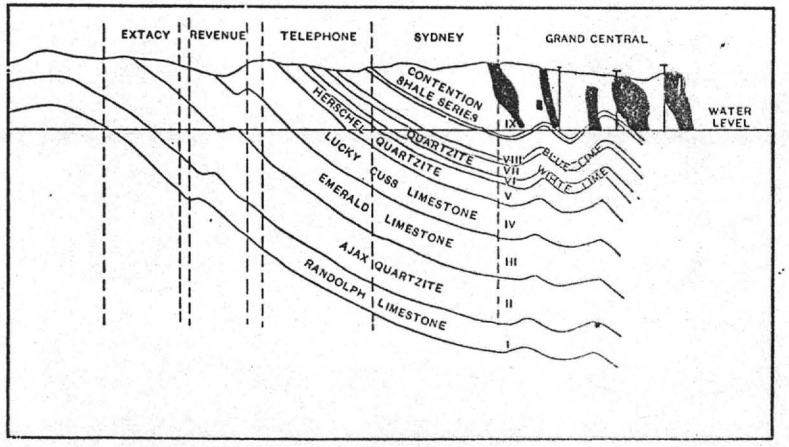
The eastern face of this mass, on which the ore measures abut, is, so far as it can be observed, a sheer-fault. At the Lucky Cuss a crosscut on the 140-ft. level reaches the granodiorite at a point vertically under the contact, and on the 340-ft. level a crosscut directly underneath failed to reach the eruptive rock, though pushed nearly to the same distance. The mine is nearly 700 ft. deep, but the dip of the vein takes the openings at the bottom about 600 ft. away from the granodiorite.

Northward from the Lucky Cuss the surface is covered by gravel, and the eruptive rock is exposed only in gulches on its eastern side; but the conditions indicate that the whole of this

side, for a distance of nearly a mile, is a fault-face, and the presence of this vertical face of rigid rock has been one of the factors in Tombstone's history. The western side is also a fault, and abuts on the Ajax quartzite, the width of the block being about 4000 ft., opposite the mines.

The surface-distribution of the rocks in the Tombstone basin is shown in Fig. 1. Fig. 2 is a section taken in a NE.–SW. line through, and nearly parallel to, the Grand Central mine, on a line north of the area where the extreme thickening of the Lucky Cuss limestone begins. The ore-bodies of the Grand Central are indicated in longitudinal section, to show their position in the so-called shales.

FIG. 2.



NE.–SW. Section on Line Shown in Fig. 1, through Grand Central.

Fig. 3 shows the ore-measures from the outcrop at the town to the Contention mine, being a section taken at right angles to that in Fig. 2. The position of the dikes is indicated, and two of the ore-bodies of the Contention in cross-section. This is the region of the bedded deposits in limestone where the structure is exhibited by extensive mine-openings, and the section is confined to the rocks that outcrop here.

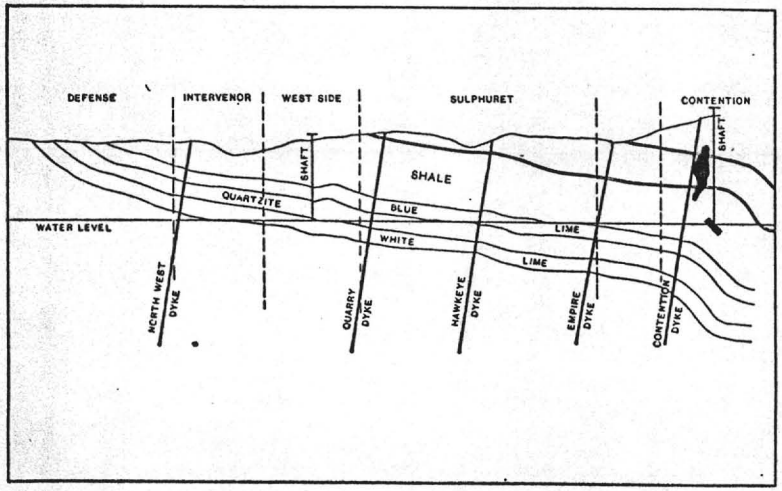
The last addition to the surface-rocks of the district was a flow of rhyolite, which covers an extensive field lying entirely on the Charleston side of the divide which separates that defunct town from Tombstone. Not even fragments of it can be found on the surface of the latter's territory. It rests on the

Ajax quartzite, at least on its eastern side, and reaches from Ajax hill, which will be found on the map, northwest beyond Fairbanks and southwest to the hills on the San Pedro river, through which the Huachuca pipe-line passes.

Great numbers of dikes are found both in the granodiorite, in the sedimentary rocks and in the rhyolite. In the first-named eruptive rock they run in all directions, and are remarkable only for their occasional small size. One of granophyre was 4 in. thick and 60 ft. long. The sedimentaries are especially rich in dikes at their contact with the granodiorite.

In that part of the sedimentary rocks where the ore-deposits

FIG. 3.



NW.-SE. Section on Line Shown in Fig. 1.

are found the dikes are very regular in strike, parallel, and probably a mile and a half long, and they owe this regularity, probably, to the influence of the fault-face of the granodiorite. The fault runs nearly N., the dikes N. 23° E., dipping W. 80°. Against this fault-face, also, folds of the strata have been developed, whatever beginnings they had before, and the dips are steeper near it than elsewhere.

In the area traversed by the five dikes of the mines there are none in other directions; but in the Lucky Cuss limestone and eastern part of the basin there are quartz-felsite dikes 150 ft. thick, striking N. 70° E.

The materials of the very thin dikes are always granophyre, usually a pink variety, with well-marked granitic texture, and these are abundant in the granodiorite, as also are dikes, usually much thicker, of a dark granophyre with large felspars. It is the latter variety which is found exclusively in the dikes of the ore-ground, except one diabase dike in the Northwest and Vizina mines. Several diorite dikes are found in limestone near the contact, and though several feet in thickness, they are often very short. It may be that there is an uneroded portion in the limestone. They are probably a portion of the great eruptive mass in dike form, and have not been found at any great distance from it.

The two varieties of granophyre are not infrequently associated in one dyke. The distinction made between them here is due to the absence of the pink variety from the ore-measures. An interesting occurrence of minette in granodiorite near its contact with Lucky Cuss limestone is referred to in connection with the mine of that name. In the rhyolite dikes of quartz augite porphyrite and mica hornblende porphyrite were noticed. Erosion, of course, has been strong, for whatever mass was lifted up by the granodiorite has been removed almost completely; and this has been done since the rhyolite eruption, for the summits of that rock now stand 1000 ft. above the granodiorite and within half a mile of it. That flow would certainly have poured into the Tombstone basin, and left its traces there, if it had not been restrained by some lofty barrier.

It is to be hoped the United States Geological Survey will turn its attention to this interesting field, which is too extensive to be studied by private enterprise alone. The formations of the Whetstone, Dragoon and other mountains that encircle Tombstone stand in evident relations with each other and with the developments of eruptive rocks, which form a more extensive series than I have indicated. If properly studied, this would probably be found to be one of the simpler types of structure in Arizona.

There is nothing in Tombstone that indicates the original seat of the metals which formed the ore; but the structural conditions point strongly to some underlying source from which they have risen, through fissures, to be deposited in the

fissures and in strata which had been prepared by folding for the entrance of solutions. The granodiorite has not acted except by its inertness, and the *rôle* of the dikes has been almost equally inferior. The rocks owe their ores almost entirely to the two results of pressure—folding and fissuring.

The folding is in two directions, producing anticlinals, with axes varying in a direction from S. 15° E. to S. 65° E. from their outcrops, and monoclinal flexures which lie across the anticlinals and are usually of gentle slope; while the anticlinals are often highly compressed, and, in two or three instances, faulted. The level parts of the monoclinals sometimes rise a little, instead of descending slightly, as they usually do; but the rise is too unimportant to destroy the contrast between the folds in the two directions.

The bedded deposits lie in the anticlinals, sometimes on the flank, sometimes in the apex; but the synclinals are barren. The monoclines do not seem to have limited the deposition of ore, which is found both where they dip strongly and where they are nearly horizontal. The compound surface produced on any stratum by these cross-folds, with their varying direction of axes and steepness of dip, is of unending variety, and undoubtedly has been a controlling factor in the distribution of ore, which is found in all shapes, from long, narrow tongues to broad sheets. There is nothing like the superposed saddle formation, made familiar to us by Rickard and others. In the Goodenough incline, especially, there are as many as three sheets of ore at different levels in the blue limestone, and they coincide vertically for portions of their extent; but they differ in the direction of their axes and dips. The simple anticlinal structure of the saddles is disturbed by the monoclinals.

Fig. 4 shows the anticlinal folding along the line of the West Side vein and across the Toughnut and Goodenough claims where the flat ore-bodies have been most important. It will be seen that there are two principal anticlinals, one in the West Side and one at the Quarry in the Toughnut. On the flanks of these are subordinate folds, which constitute the other anticlinals shown in Fig. 6.

One of the monoclinal flexures across these anticlinals has been plotted in Fig. 5, showing the irregular stopes in the

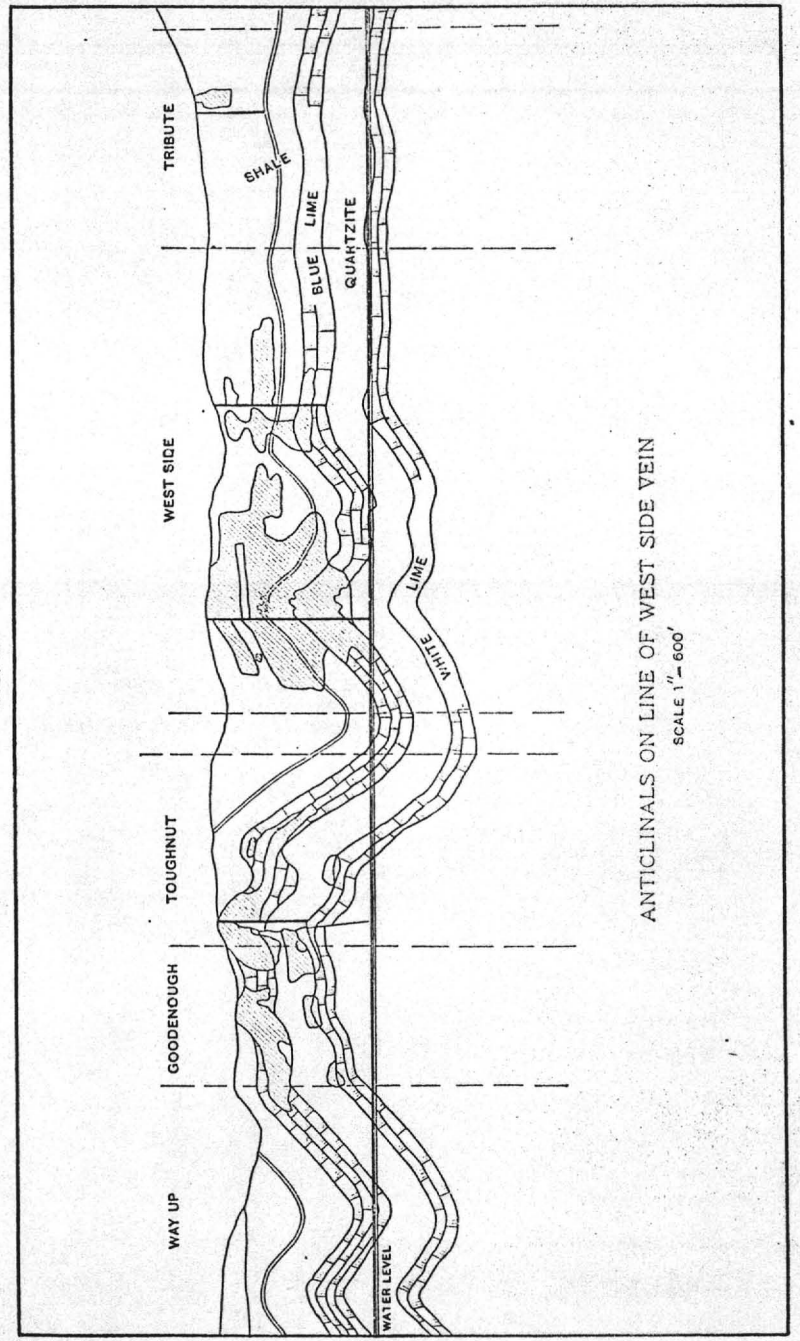


FIG. 4.

Northwest mine of the Toughnut claim, which have received the name of Hoodoo. On this line there are great numbers of small, vertical crevices, which have sometimes received enough ore to join two overlying bodies together. In the section of this figure the ore-body B occupies the flank of an anticlinal which dips towards the spectator. A and all the others are seen in true section.

Two lines of vertical fissures are found lying across this system of anticlinals. On one, which has a strike of N. 15° E., the Grand Central, Contention, Head Center and Tranquility mines are opened, while the other, striking N. 42° E., contains only the West Side mine. Their positions with relation to the anticlinal deposits is shown in Fig. 11.

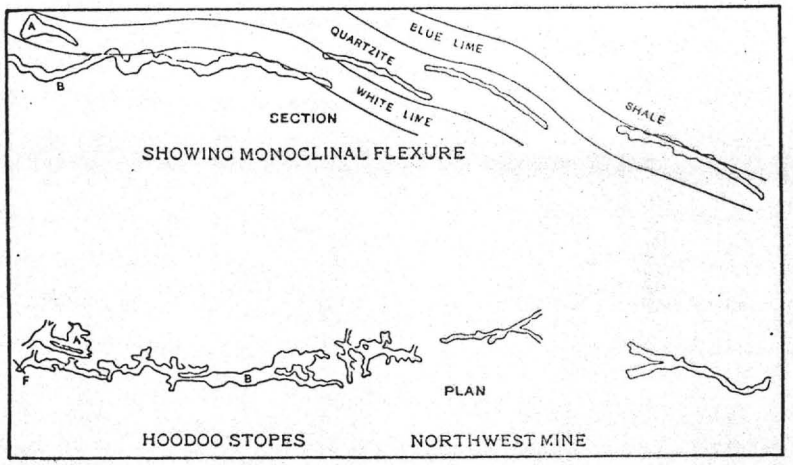
The anticlinals are persistent from their outcrops on the Vizina, Goodenough and Toughnut claims, near the town, to the Contention and Grand Central, and in the fissure-veins we find the distinctive peculiarity of Tombstone, which binds the bedded deposits and fissures in one system. The largest ore-bodies of the fissures are found within the lines of these anticlinals, whether the fissure has been deep enough (as in the West Side mine) to reach the blue and white limes, which are the rocks that contain the bed deposits, or are still in the overlying shale (as in the Contention and Grand Central). The water-level in the last-named two mines is calculated to be 150 ft. above the blue limestone, which contains the highest ore-bodies of the Toughnut series; but the influence of the anticlinals upon the deposition of ore in the fissures is as marked in the overlying shales through which the fissures pass in their upper levels as in the limestones of the bedded deposits.

The second result of dynamic action was the production of these vertical veins, which I regard as compression-fissures. They have been studied most thoroughly in the West Side mine, where the principal ore-body of the fissure was confined to a strongly compressed anticlinal about 450 ft. long. This fold is succeeded on the north by a broad and barren synclinal and on the south by a narrow synclinal and a gently rising anticlinal. The fissure passes through shale for the first 200 ft. of its depth, and there is a small ore-body within the synclinal in the shale. It does not extend into the blue limestone below, and is probably due to secondary deposition.

There are at least three known parallel fissures within a width of 400 ft. at the West Side, two of which have yielded ore, though the West Side is the only important producer. The walls do not indicate faulting; and though a cross-fault of small throw is observable, it is probably a dislocation of slabs rather than of a section of the country.

In Fig. 4 the ore-bodies shown in the West Side mine are all in the fissure, the anticlinal deposits stretching away from the vein on the side opposite the spectator. The ore-bodies of the Goodenough and Toughnut, on the other hand, are exclusively anticlinal. In order to show the grouping of the ore-bodies on

Fig. 5.



Plan and Section of Monoclinal Flexure.

the anticlinal, it was necessary, in a drawing on this scale, to project the flat bodies on their entire dip. The figure is faulty, therefore, in showing the ores of the fissure in section and the ores of the anticlinal in projection. Still, the figure exhibits the anticlinal deposition both in the beds and fissures, and the synclinal barrenness. Of the two ore-bodies in the West Side, the one lying in the sharp anticlinal is markedly superior, both in size and grade of ore. The inferior one occupies the fissure where it passes through strata of gentle dip, and here there is no deposition along the anticlinal axis, as there is in the sharp fold.

Although the Contention and Grand Central mines are not

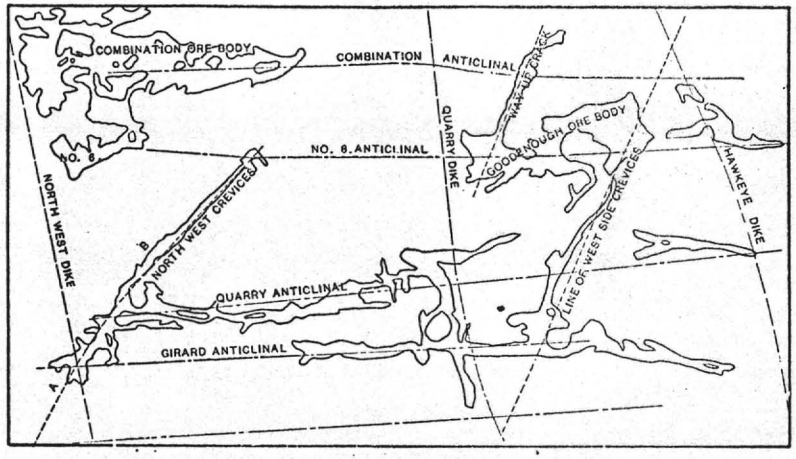
yet sufficiently cleaned up from the effects of the fires which closed them, to permit examination, the extent of their ore-bodies is shown in a report made about 1890, by the late H. G. Howe, who was for many years the leading surveyor at Tombstone. He gives sections of the ore-bodies, reproduced in Fig. 8, which are taken from the south end of the Grand Central to about the center of the Contention. They show very clearly the combination of inclined anticlinal deposits and vertical vein; and the relation of the two is more striking here than elsewhere in the district, because the two classes of deposits dip in opposite directions—the vertical to the west, the anticlinal to the east.

What is called commonly the Contention vein is a series of nearly vertical ore-bodies which extend northerly through the Grand Central, Contention, Head Center, Tranquility and Silver Thread claims, a distance of nearly a mile. There was no one continuous vein along this line, but a series of large individual ore-bodies lenticular in cross-section, dipping to the west (with the dike) and pitching to the north. Thus, it is not to be supposed that the upper ore-body in Sec. 3, Fig. 8, has given out abruptly in full width. The figure shows a vertical section through an inclined mass, but the latter did not reach to the next section 320 ft. north.

There were several of these bonanzas in the 400 feet of shales that separate the Contention and Empire dikes, and in the shale east of Contention dike. Mr. Howe says the Grand Central had four "of these chimneys of ore," the Contention three, Head Center one and Tranquility two. The largest of these is figured in Sec. 4, Fig. 8. Mr. Howe says it outcropped on the surface and extended to the 600-ft. level, pitching to the north; but the section shows that it was formed by three fissures in echelon. On the 300-ft. level it was more than 400 ft. long, and had a maximum width of 30 ft. A hundred feet lower it was 200 x 40 ft. These are large dimensions for so rich an ore. The sections show that the ore-bodies lay in echelon, several of them appearing in some of the cross-sections, only one in others. It is probable that the parallel crevicing found in the West Side mine is present here also. Three sections show anticlinal deposits. Of that on Sec. 2, Fig. 8, Mr. Howe says: "This ore-body was discovered on the 300-ft. level, and followed up by a raise for 50

ft., where a large body of ore was discovered which lay almost flat; and development also showed that it pitched to the east, and a winze was sunk for 60 or 70 ft., following down upon its dip; but no drift was run along this ore-body at the bottom of the winze, and its extent is not known." No effort was made to cross cut to this ore from lower levels. The three sections showing anticlinal ore-bodies are not successive sections, being separated by two others, in which only vertical bodies are shown. The meaning of this cannot be determined from the old maps, and partly for the reason that the anticlinal ores were not mined or even drifted upon, except one below the

FIG. 6.



Subordinate Anticlinals, etc., as Related to Ore-Bodies.

water-level, though the grade was good. The "East bodies" shown by Mr. Howe are opposite the anticlinals mined in the Toughnut series farther north. The largest of the anticlinals has been followed on ore for 1150 ft. from the West Side vein, or about half the distance to the Contention. The disposition of ore-bodies along anticlinals was not generally known when Mr. Howe made his sections, and it is probable that the Grand Central and Contention system consisted of nearly vertical ore-bodies along or near the dikes, and of others, more gently inclined, in anticlines crossing from one dike to another and beyond. The west dip of the vertical shoots and the east dip of the flatter deposits is strong evidence of this. The vertical ore-

bodies were found in the center of the ground, between the dikes as well as under them.

This series of ore-bodies was the most productive of the Tombstone mines, and the explorations in depth are anticipated with great interest. When the great ore-formations of the district, the blue and white limestones, are reached by the Contention-Grand Central vein in the next 200 to 300 ft., it is expected that the conditions of maximum dynamic effect will coincide with the presence of the most favorable ore-rocks the district has had.

These compression-fissures are one of the most important features of the formation, and have probably been the most prominent factor in the introduction of ore, as the anticlinals have been in its distribution.

Until the Contention and Grand Central are opened sufficiently to allow of careful inspection, it will not be possible to say whether their ore-bodies occupy similar fissures; but the occurrence of ore in the middle ground between the Contention and Empire dikes, which are about 400 ft. apart, leads to the supposition that compression-fissures will be found there. The Head Center fault which cuts the Contention vein and dike is parallel to the West Side fissure.

Nowhere in the district is ore found in the shale except in the fissures, but its presence there proves that this rock was not unfitted for the reception of ore, by whatever method it was formed. The mobility of shale under pressure is supposed to prevent the maintenance even of minute openings, and the general absence of ore from this formation is new evidence of the controlling necessity of crevices as a preparation for ore. In Tombstone there is a contrast between the behavior under pressure of bed-seams and vertical crevices in the shale that is worthy of note. The weight of the rocks, which may not have been more than 500 or 600 ft., was sufficient to close the bed-seams, but not to crush the vertical fissures, and the delicacy of this difference is shown by the fact that a limestone 2 ft. thick has been mineralized for hundreds of feet on its dip, while the shale in which it is inclosed is barren. If such a stratum is what Mr. Bailey Willis calls "competent" enough to protect and keep open a bed-seam, the pressure of the overlying rock must have been small.

There is another kind of fracture which is found very abundantly in the blue and white limestones, and to some extent in the Toughnut quartzite, but not in the shale. Cracks of this class occurring in limestone often end abruptly at the contact with quartzite, and I suspect that is the rule, and that these crevices have been produced by a force that affected each stratum of rock for itself, without necessarily producing the same effects in other strata.

The most important of these crevices is the Defence vein, which strikes N. 57° E. It is in outcropping blue limestone, and does not enter the underlying quartzite. Another is the Way Up crack, which has most of its length in the Goodenough. Its strike is about N. 65° E. Near it are two minor vertical stopes in the Goodenough incline, one striking E. and the other S. 83° E. On the 200-ft. level of the same mine there is one with strike N. 67° E., which has yielded more ore than any other except the Defence. None of these penetrate the shale, and the few stopes in quartzite nearly on the line of the Way Up crack are close to the Quarry dike, and probably due to its influence. There are some small vertical stopes in the quartzite on the Toughnut claim where the Hoodoo stope enters it; but here, as elsewhere in the quartzite, these crevices are few and insignificant, in comparison to those in the limestones.

The restriction of these crevices to the limestones and quartzite points to an origin different from that of the compression-fissures which penetrate rocks of all kinds and have vertical continuity. I am inclined to ascribe these inferior cracks to the results of torsion accompanying the deformation of the strata by pressure at an acute angle against the granodiorite, the results being produced in each stratum independently of the others. Being confined to the firm rocks, it might be expected that the brittle quartzite would show them most prominently, which is contrary to the actual conditions; but the quartzite occasionally shows crushed areas where the rock has been broken to a mass of breccia, entirely non-coherent, for several feet in thickness, and these may show how this rock adjusted itself to a strain which made crevices merely in the limestones.

The crevices are most abundant in the area of Fig. 7, and especially toward the Defence vein, which is just outside the

figure, below the lower left-hand corner. Fig. 7 is but a poor representation of the number and diversity of strike of those at the northern end of the Hoodoo stopes lying in that quarter. Probably not half of them were noted. Many are barren cracks; others make small vertical stopes confined to one or more layers in the limestone. The crevices here are not long, continuous cracks, though some run for a few hundred feet; and it is noteworthy that these are not the best carriers of ore, probably for the reason that their length and direction take them out of the narrow limits of anticlinal deposition.

Though the Defence vein is in blue limestone exclusively, the crevices shown in the same line in Fig. 7 are in the lower white limestone, the upper stratum being entirely eroded at this point, and they depart strongly from the strike of the Defence, the line curving until it is nearly east and west. Ore has been mined from the outcrop of the overlying quartzite, but it is obviously of secondary origin, and has no continuance in depth.

These cracks are found throughout the area of Fig. 7, but they are more abundant near the line of the Defence vein, which is in the area of greatest deformation, and on the line of the West Side fissure, which is 500 ft. or more below the right-hand half of the figure. There is no fissure passing through these places, no continuity in the cracks, parallelism or other connection between them. The whole Defence system belongs to what I will style these torsional crevices, and they are also strongly developed in the line of greatest compression in that neighborhood, the line of the West Side fissure.

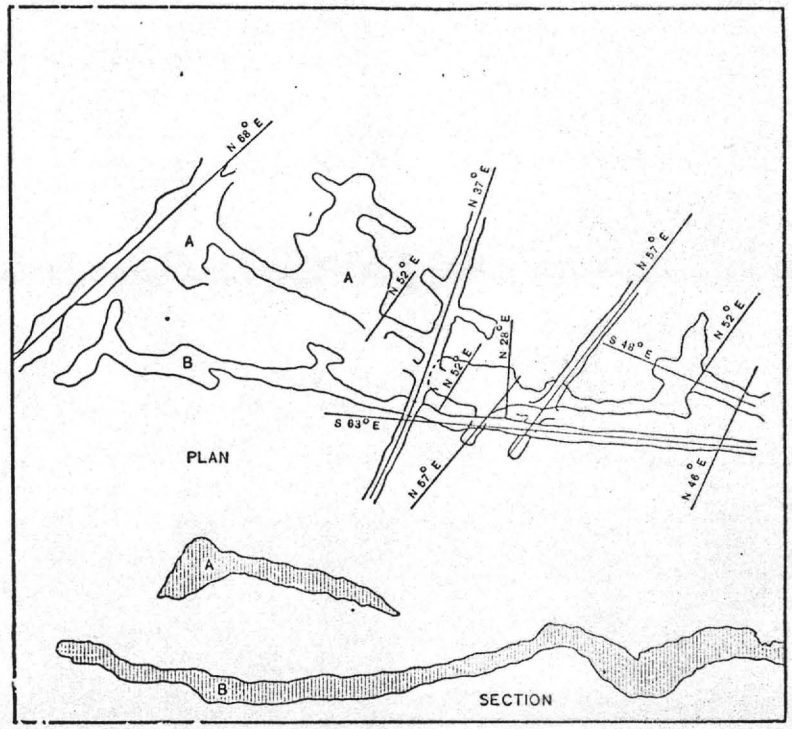
The third factor in the forces which have made the Tombstone formation is the series of dikes the filling of which has been determined as granophyre and diabase. Nearly all the ore derived from it has been taken from the 2500 ft. of ground lying between the Northwest dike on the west and the Contention dike on the east; but the deposition of ore is not confined to the space included between these two dikes. It has been mined in the Defence 500 feet and in the Ingersoll 1000 feet west of the Northwest dike, and in the Tranquility some distance east of the Contention dike.

Fig. 3 shows that one of the principal vertical ore-bodies of

the Contention and Grand Central is east of that dike. At least one of the anticlinal ore-bodies in these mines has the same position.

These facts show that the dikes did not have a limiting effect upon the passage of ore solutions. Locally they have modified deposition, but in general their presence was so inert that we must look elsewhere for the controlling factor, and that, as already said, is probably the two results of pressure—folding and

FIG. 7.



Plan and Section of Compression-Fissures, Northwest Mine.

fissuring. All these elements of the problem, except the fissures, are combined in Fig. 6, which shows the ore-bodies (in outline) of the blue and white limestones, the axis of the anticlinals, the direction of some of the crevices, and the position of the dikes. It shows that along the Quarry dike there is ore connecting the deposits of the Quarry and Girard anticlinals, and that on the Hawkeye dike there is some spreading of the ore in No. 6 anticlinal. The Combination and other ore-bodies

begin at the Northwest dike; one small deep-lying ore-body in white limestone ends at the Hawkeye dike. These occurrences are, however, very inferior in importance to the deposition along the crevices and anticlinals.

This figure covers the territory of the Toughnut and Goodenough mines, with a portion of the Hawkeye and Empire. The names given to the different elements of the figure of course refer to mines and particular openings in mines. The Northwest and Quarry are both on the Toughnut. Combination, No. 6, Goodenough and Way Up are all on the Goodenough. The crevices are named from the places of their principal development. Each class of occurrences exhibits more or less parallelism in its members, but there is no parallelism between different classes.

In no case that I have found has a dike been a seat of original ore-deposition. The ore-body in the Toughnut quartzite along the Quarry dike is in the slabbed ground by its side, though the dike is thoroughly decomposed. The dikes have been drifted on and cross-cut in the anticlinals, and in all other situations, and the trivial amount of ore they have yielded must be attributed in part to secondary deposition, aided, perhaps, by the quickly diminishing influence of some crevice. In the Contention and Grand Central, where it is probable the deposition of ore has been determined by strong fissuring, the dikes may have been more affected than elsewhere; but all that is known about those mines indicates that their ore-bodies lay near, but not in, dikes.

On the surface the dikes often retain their original character unchanged, and their outcrops can be distinguished at a glance. Underground they are completely decomposed, and it is often impossible to distinguish between the rocks derived from them and from the quartzite. On the other hand, in the fissures it is common to find an ordinary appearing quartzite where there should be none of that rock, and with curious frequency the phenomenon is found on one side of the vein and not of the other, though in a few feet more the crossing of a stratum disproves the possibility of faulting. Apparently the vein, before its decomposition, acted as a dam, on one side of which silicification took place, while the other side was free from it.

It is odd that the conditions of dike-decomposition men-

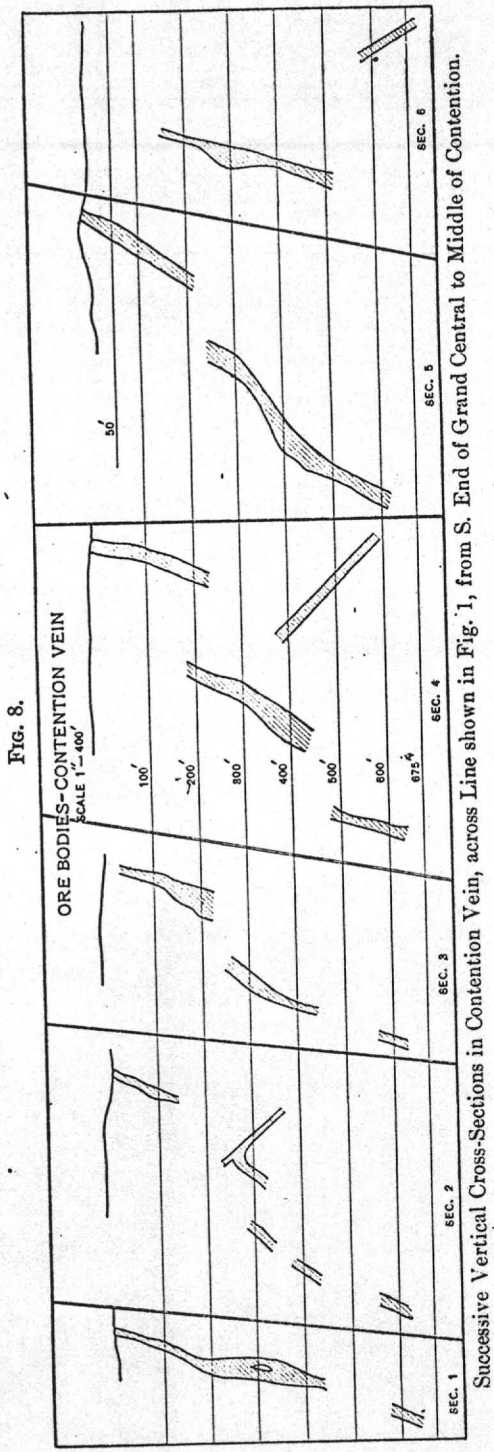


FIG. 8.

Successive Vertical Cross-Sections in Contention Vein, across Line shown in Fig. 1, from S. End of Grand Central to Middle of Contention.

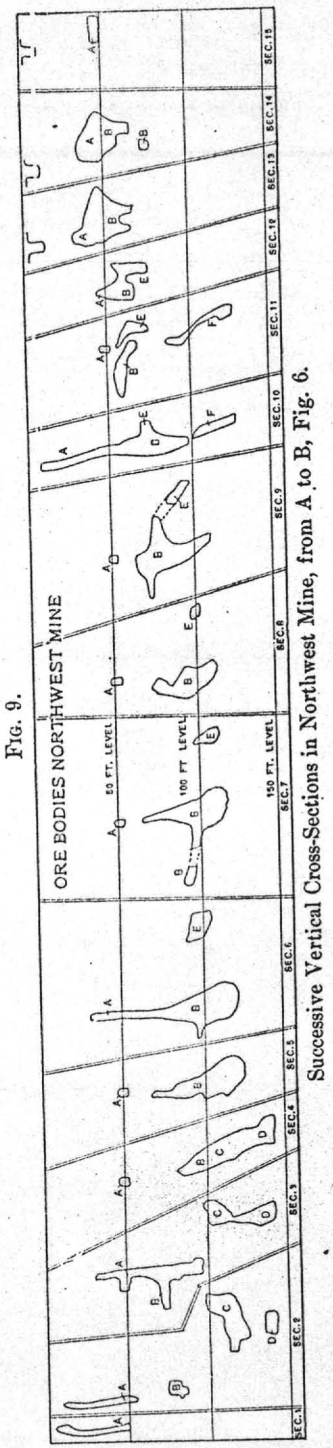


FIG. 9.

Successive Vertical Cross-Sections in Northwest Mine, from A to B, Fig. 6.

tioned are not found outside of the especial ore area. The Comet mine has passed through decomposed to unchanged dike in 400 ft. In the granodiorite many of the dikes have suffered so much surface decomposition that they are now oxides of iron, calcite, etc., in a felspathic magma. They resemble altered limestone, but in a few feet their original texture returns, reversing the conditions found in the Toughnut and Contention.

It is evident that the Tombstone ores are the product of replacement, both in the crevices and anticlinals. In the latter, especially, alteration-products that are of the sort usually found in limestones are common, and often are rich in metals. The capriciousness of the attack of the ore-bearing waters upon the limestone is sometimes extraordinary, especially in the region of torsional fracturing. An example is shown in Fig. 9, Secs. 1 to 15, which are careful measurements of the 50- to 150-ft. ore-body in the Northwest mine on the Toughnut claim, where torsional cracking is especially strong. This body, or series of ore-bodies, extend almost from the surface to near the 150-ft. level, and the sections, taken from A to B, on Fig. 6, cover a length of 250 ft. The ore is entirely in the white limestone, with the overlying quartzite showing in a surface cut in Secs. 13, 14 and 15. The ore-bodies that lie in one vertical plane are enclosed in a panel numbered for each section.

The ore began near the shaft in a vertical fissure which is marked A throughout the series of sections. In Sec. 2 three flat ore-bodies, marked B, C and D, came in below the vertical, and Sec. 3 shows that one of these joins the vertical, which drops down about 40 ft. in a horizontal distance of 15 ft., while the other two stopes have coalesced.

In Sec. 4 the vertical stope has disappeared, and A marks the position of a drift along the crack. Now all three of the flat stopes have run together, and form an inclined body with a steep dip, but not vertical. In Sec. 5 the vertical comes in again, joining the highest of the three flat stopes in Sec. 2, and in Sec. 6, only 6 ft. distant, the vertical stope has gained no less that 40 ft. in height. Meanwhile the two lower ore-bodies C and D of Sec. 2 have disappeared, and do not appear again until we reach Sec. 9; but in Sec. 6 a new ore-body, E, comes in, which continues through seven sections. Only one of the flat ore-bodies has marked persistence. B of Sec. 2 continues

through a variety of changes to Sec. 14, and it is notable that the whole series begins and ends with the vertical stope A standing alone, though it has frequently disappeared entirely in intermediate sections, and in Sec. 15 looks like a flat stope. In Sec. 10 a new ore-body, F, comes in, which is the beginning of the Hoodoo ore-body along the Quarry anticlinal, Figs. 5 and 6.

A study of these sections shows that there is nothing like a vertical vein in this place. There is verticality in certain stopes along one line for a short distance; but as an ore-body it is fully as irregular as the most variable of the flat stopes, and it is less persistent than one of the latter. It is entirely probable that the vertical arrangement which the flat stopes assume when they coalesce is due to the existence of other cracks in their path. The deposition of ore may have changed from one crack to another, limiting itself to a certain width, within which lie the flat stopes which show by their dip that their shape and position have been determined by the anticlinal folds.

This is well shown in Fig. 5, which is a plan and section of the Hoodoo stope, in the same Northwest mine. Its beginning is the stope F of Secs. 10 and 11, Fig. 9. The position of Sec. 10 is shown on Fig. 5 at F. The strike of these two series of ore-bodies is nearly at right angles. On the lower edge of the plan Fig. 5, beginning at F, narrow stopes will be noticed following one general horizontal position. This is the line of the Hoodoo crack, which is ore-bearing only at isolated points. Whether it is one continuous crevice or a series of nearly parallel cracks crossed or touched in slight echelon by the flat stopes cannot be determined. The general conditions of the creviced area incline me to believe that the ore is not always in the same crack. As in Fig. 9, the vertical deposition of ore is very limited. Besides the Hoodoo crack, there are several others at various angles that show vertical deposition for small heights.

The silicified fossiliferous blue limestone already mentioned is another product of this fissuring, and also of replacement. It is found on the surface and underground in lines of limited length, appearing like veins, and in the mines areas 100 ft. wide have been passed through. They consist of this silicified

rock, with scores of open crevices several inches wide. Nothing like this is known in the white limestone. This replacement was not accompanied by metalliferous deposition, except to a feeble extent. Assays of 1 to 3 ounces of silver are sometimes had from the rock, but not always. There is no recognizable relation of this rock to the ore-bodies. It is found both near to and distant from them, and is, perhaps, the only rock in the district that shows no sign of yielding to the influence of secondary deposition. This may be due to the filling of the pores in the original rock by silica before the replacement began.

Some of the thin limestones lying in the shale have been ore-carriers in the vertical veins and anticlines, and the richly mineralized layer which was called the East body of the Contention was probably one of these shale limestones.

Of the mines in the lower measures, the Lucky Cuss, Fig. 10, is the most interesting. It lies within 400 ft. of the granodiorite, and outcrops about 350 ft. from a dike which Prof. A. A. Julien determined to be a minette, and which lies in the granodiorite close to the contact with limestone. A mass of this rock, 15 ft. thick, encountered below the 350-ft. level, is attributable to an apophyse from the dike. A section from it showed some chlorite, which seems to be absent from the dike. Similar occurrences are found in the Combination ore-body and elsewhere, but none so far from a dike as this.

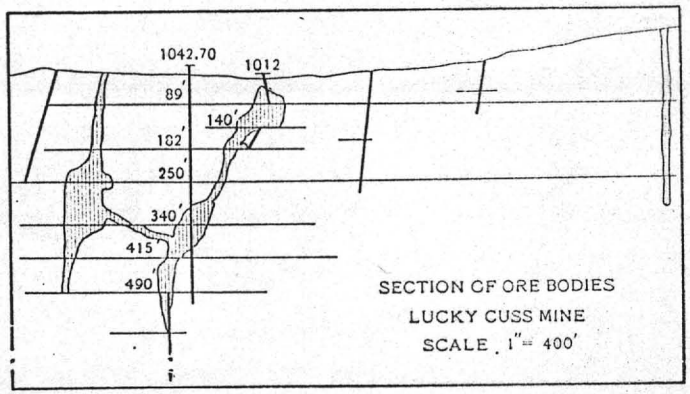
The Lucky Cuss has had two principal ore-bodies, connected by a cross-shoot at about the fourth level, and several pipes of manganese ore, of which only one is shown in Fig. 10. Most of them are of limited depth; but this one, though otherwise of small dimensions, had a vertical depth of 350 ft.

The origin of the manganese in this mine, and also in the Knoxville and others, is a question of great interest, and was discussed by C. W. Goodale in a paper before the Institute.* The subject received enlightenment when, under the tongue of minette on the 350-ft. level of the Lucky Cuss, a mass of rock was found which was rich in alabandite, or manganese sulphide, mingled with galena and pyrite. In this position, protected by the dike-rock from the infiltration of surface-waters, the original form of the manganese seems to have been

* *Trans.*, xvii., 767, and xviii., 910, with section of ore-bodies.

preserved. It is difficult to believe, however, that all the manganese-oxide deposits, which usually form pipes disposed in an erratic manner over the surface of the limestone, represent old deposits of alabandite in place. I am disposed to regard some or all of them as secondary depositions derived from masses or impregnations of the sulphide in the limestone, and probably, in part, from its eroded portion. There is some manganese-oxide in all or most of the Tombstone mines, but the quantity is small in the strata above the Lucky Cuss limestone. This and the Emerald limestone produce basic ores wherever opened; but, as Mr. Goodale has pointed out, the true manganese-ores are confined to two localities. The first comprises a series of mines, the Knoxville, Wedge, Lucksure and Lucky

FIG. 10.

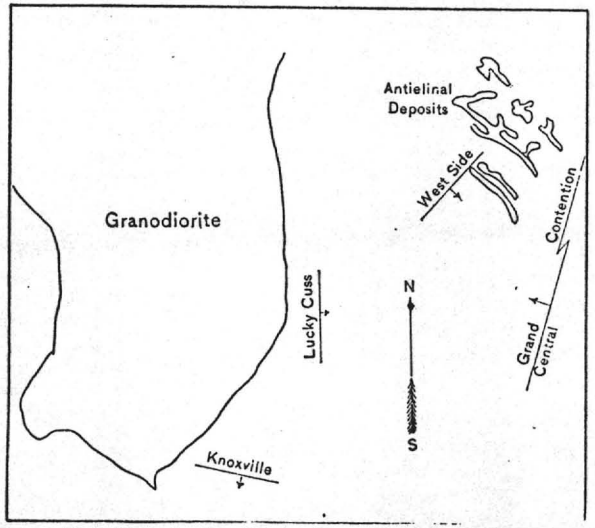


Cuss, lying very near the contact of the granodiorite. The second group, containing the Emerald, Bunker Hill, Rattlesnake and Mammoth, is about a mile S. of E. from the contact, and the Comet is still farther. This group yields basic ore, but the proportion of iron and lime is greater, and of manganese much less, than in the mines near the granodiorite. In both groups the manganese seems to decrease with depth.

The most extensive deposits of manganese are those of the Lucky Cuss and Knoxville. The Lucky Cuss has a fissure with chamber deposits of small extent reaching from it into the limestone walls. The Knoxville is described by Mr. Goodale as a series of four ore-shoots lying in the line of a continuous closed crack. The relation of these two mines to the granodiorite is shown in Fig. 11.

The distinctive manganese deposits are the only ones in the district that indicate by their position an intimate connection with the granodiorite. The mines in the Randolph limestone, which also yield a basic and somewhat manganiferous ore, are about 3000 ft. from the contact. The presence of alabandite under an apophyse which is derived from a dike in the granodiorite, and the occurrence of the Comet ore under a granophyre dike, are indications that the entrance of manganese did not follow immediately upon the intrusion of granodiorite. It must therefore be ascribed to aqueous deposition. There is

FIG. 11.



Plan, Showing Relation of the Contention and West Side Fissures to the Anticlinal Deposits, and of the Lucky Cuss and Knoxville Mines to the Granodiorite.

strong evidence that the bodies of oxide are depositions from solutions, but it cannot be determined whether they always occupy the position of original sulphide bodies, which they have enlarged, or have sometimes entered barren cracks and replaced the limestone walls. The Lucky Cuss ore, which was so rich at the surface that slags made from it contained 43 per cent. MnO, gradually lost manganese and gained silica and lead. This vein undoubtedly received large accessions of oxide as a secondary deposition. Something of the same kind seems to have taken place in the Knoxville, where, Mr. Goodale says,

the ore-pipes had a siliceous center, surrounded by a richly manganiferous shell next the limestone.

All the manganese-ores were very poor in gold at the surface, and I believe the Knoxville did not change; but the Lucky Cuss improved so much that the ore below the water-level contained $12 per ton of this metal. The alabandite of the Lucky Cuss was not a solid mass of that mineral, but a local enrichment of the sulphides of manganese, lead and iron, the greater portion of the mass being silica and limestone, though there were masses of the manganese sulphide several hundred pounds in weight.

The Comet mine, the largest of the manganese deposits, is an instance of the wide extent of ore-deposition in the district, lying 2200 ft. east of the Grand Central. Active deposition has taken place over an area in the Tombstone basin about 10,000 ft. long from north to south and 7500 ft. from east to west. This does not include the mines on the Charleston slope.

The Comet vein lies under and in contact with a granophyre dike 60 ft. thick, and has been mined for a length of 2000 ft., and to the 400-ft. level. Its ore is valuable for its fluxing quality, besides the silver.

A mine of great interest from its position in the rhyolite is the State of Maine. The rhyolite on the side nearest Tombstone is poured out on the Ajax quartzite. In the State of Maine there are two nearly parallel veins in the rhyolite which reach down to the underlying quartzite, 375 ft. deep on the inclination of the shaft and 240 ft. vertically. The quartzite has been cracked by the heat to a shaly condition, or at this point one of those changes of composition which are frequent and sudden in this district may have occurred.

The sedimentary rocks are folded, and at one point appear to be broken. It is possible that the rhyolite takes the form of a dike there, about 60 ft. thick, but the question cannot be determined until greater depth is reached or the rhyolite is crosscut. The veins are from 2 to 7 ft. thick, and quite irregular in strike, so that they come to a junction with an angle between them of 20°. When parallel they are about 50 ft. apart, and both dip NW. 45°. These interesting veins have been very profitable for the amount of metal they have yielded, which was probably $600,000. The mine is not now in condition for

proper examination, but the stopes resemble strongly those in limestone. The hanging is a smooth continuous wall of rhyolite, the veins very soft and decomposed, and apparently they carried ore in individual ore-bodies rather than a continuous vein. Their average strike is N. 35° E., and dip of the incline 40° N. 55° W. The dip varies from about 33° to 48°, with

rhyolite. It is the oldest mine in all this region, having been a developed property before the outcrops of Tombstone were found. It has had a most checkered history, and is now worked with more vigor than ever before. In general, I believe the veins in the rhyolite have had rich ore, but have been small and irregular.

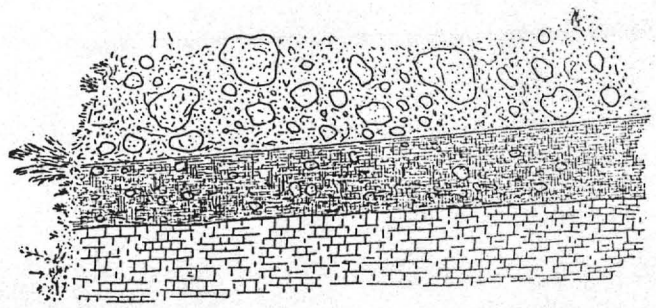
One of the curiosities of Tombstone is a fault in Emerald gulch with shale on one side and caliche on the other. Its strike is N. 32° E., dip E. 80°. A shaft in it is 20 ft. deep, without disclosing the full extent of the throw. This interesting fault is shown in Fig. 12. It is marked by the usual zone of laminated or crushed material, which contains both caliche and shale fragments. As the caliche is entirely a product of local erosion and modern calcareous cementing, and must have been formed since the time of powerful erosion, this fault, which seems to be equal in throw to others in the district, must be quite recent.

On the hill back of the Grand Central mine there is an open crevice which is said to have opened, or at least enlarged, within recent years. It is therefore commonly attributed to the caving of the stopes in that mine, its strike, N. 32° E., being about the same as that of the ore-bodies. This explanation is not satisfactory, for the thickness of rock between it and the stopes would, in this locality of shaly quartzites, be sufficient to fill the widest stopes of the Grand Central without producing any effect upon the surface. The parallelism between this open

fissure and the caliche fault is suggestive. They are about 3000 ft. apart, the crack being nearly due north from the fault.

There are several faults in the district, but none of moment. The largest vertical fault known is in the Empire part of No. 6 anticlinal, 50 ft. The Quarry anticlinal is faulted 35 ft. Of cross-faults, the best known is on the Contention-Head Center line, where the dike and vein have been shifted 120 ft. horizontally. There is also a small horizontal throw of 20 ft. in the Empire dike, and others noticeable in the outcrops of the shale limestones. The anticlinal faulting preceded the deposition of ore. In the Empire there is ore under the shale on the upthrow side, but none on the downthrow side. In the Quarry fault there is ore on both sides, but here we have not only one of the strongest anticlinals in the district, but a dike just through the outcrop. There is no sign of an ore-body faulted after its

FIG. 12.



Fault between Shale and Caliche in Emerald Gulch.

deposition. The dikes do not seem to have caused faulting, no instance of it being known. The torsion-crevices, on the contrary, frequently faulted the ground. In the Hoodoo stopes there is occasionally a jumble of limestone and quartzite blocks, but with small throw. The Head-Center fault is interesting because it is closely parallel to the West Side compression-fissure and crosses the Contention vein at an angle of 30°.

With this example of faulting in a crevice, it is somewhat remarkable that the West Side fissure shows no faulting, but abundant disproof of it. There is some slipping of slabs on each other, but very little, and the bedding-lines across the drifts prove that there has been no general movement. The West Side and Contention represent the strong lines of compression-fissuring, and no faulting along their lines is known.

proper examination, but the stopes resemble strongly those in limestone. The hanging is a smooth continuous wall of rhyolite, the veins very soft and decomposed, and apparently they carried ore in individual ore-bodies rather than a continuous vein. Their average strike is N. 35° E., and dip of the incline 40° N. 55° W. The dip varies from about 33° to 48°, with much larger variations for short distances. The ore was manganiferous and rich in silver.

There are many other openings in the rhyolite, and the mineralization of this rock appears to have been quite extensive, though the number of profitable mines was small. The Maine was the most successful, and the San Pedro, near it, probably stands next in productiveness. The Bronco, near Charleston, 7 miles away, is in siliceous schists, entirely surrounded by rhyolite. It is the oldest mine in all this region, having been a developed property before the outcrops of Tombstone were found. It has had a most checkered history, and is now worked with more vigor than ever before. In general, I believe the veins in the rhyolite have had rich ore, but have been small and irregular.

One of the curiosities of Tombstone is a fault in Emerald gulch with shale on one side and caliche on the other. Its strike is N. 32° E., dip E. 80°. A shaft in it is 20 ft. deep, without disclosing the full extent of the throw. This interesting fault is shown in Fig. 12. It is marked by the usual zone of laminated or crushed material, which contains both caliche and shale fragments. As the caliche is entirely a product of local erosion and modern calcareous cementing, and must have been formed since the time of powerful erosion, this fault, which seems to be equal in throw to others in the district, must be quite recent.

On the hill back of the Grand Central mine there is an open crevice which is said to have opened, or at least enlarged, within recent years. It is therefore commonly attributed to the caving of the stopes in that mine, its strike, N. 32° E., being about the same as that of the ore-bodies. This explanation is not satisfactory, for the thickness of rock between it and the stopes would, in this locality of shaly quartzites, be sufficient to fill the widest stopes of the Grand Central without producing any effect upon the surface. The parallelism between this open

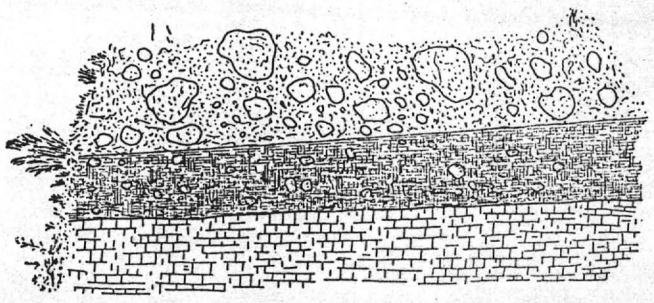
fissure and the caliche fault is suggestive. They are about 3000 ft. apart, the crack being nearly due north from the fault.

There are several faults in the district, but none of moment. The largest vertical fault known is in the Empire part of No. 6 anticlinal, 50 ft. The Quarry anticlinal is faulted 35 ft. Of cross-faults, the best known is on the Contention-Head Center

SECRETARY'S NOTE:—Fig. 12 is a vertical cross-section, and should have been placed with the present left-hand end at the top.—R. W. R.

the outcrop. There is no sign of an ore-body faulted after its

FIG. 12.



Fault between Shale and Caliche in Emerald Gulch.

deposition. The dikes do not seem to have caused faulting, no instance of it being known. The torsion-crevices, on the contrary, frequently faulted the ground. In the Hoodoo stopes there is occasionally a jumble of limestone and quartzite blocks, but with small throw. The Head-Center fault is interesting because it is closely parallel to the West Side compression-fissure and crosses the Contention vein at an angle of 30°.

With this example of faulting in a crevice, it is somewhat remarkable that the West Side fissure shows no faulting, but abundant disproof of it. There is some slipping of slabs on each other, but very little, and the bedding-lines across the drifts prove that there has been no general movement. The West Side and Contention represent the strong lines of compression-fissuring, and no faulting along their lines is known.

The entire yield of Tombstone is estimated at 163,000 ounces of gold, 21,500,000 ounces of silver, and 5000 tons of lead. The losses by pan-amalgamation, which was the method by which most of the product was obtained, would require an addition of 15 per cent. to the gold and silver to obtain the gross total of these metals, making somewhat more that 187,000 oz. gold, and 22,500,000 oz. silver. The proportion of gold was, therefore, only 0.0827 per cent., by weight, of the precious metals.

The total value of all products as marketed was about $25,000,000, to which about $4,000,000 must be added for losses, and somewhat for unreported product. Some mines report only their net returns, leaving the expenses of marketing to be surmised, though they belong to the net yield.

The mines varied extremely in their proportions of gold and silver. The Contention and Grand Central produced about 20 gold to 80 silver, by value, which corresponds to about 1 ounce gold to 80 ounces silver, as the latter metal was worth about $1 at that time. Other mines show a much smaller proportion, the Tombstone Mill and Mining Company having 1 gold to 180 silver, and in mines which were confined entirely to superficial deposits in limestone the proportions may have fallen to 1 : 400 by weight.

The relative proportions of gold and silver in the ore forms one of the most interesting and important problems of the district, and there are indications that a favorable change is taking place with depth. The gold value was greater in the fissure-veins than in the anticlinal deposits, and it improved in both going downward.

In the Contention, a drift run for a length of 140 ft. about 00 ft. below the water-level gave an average assay of more than $100 per ton in gold, and this was in an anticlinal deposit. The condition in the vertical bodies is not reported. In the West Side the ore found at the lowest points mined in the anticlinal, 1150 ft. from the vertical vein, yielded $17.20 per ton as the average of 55 shipments, which is probably four times the average of the West Side vein near the surface.

The same increase is found in both vertical and flat deposits. The Lucky Cuss, which had little more than a trace at the surface, produced ore worth $12 a ton below the water-level, and

the last two shipments contained 1.7 ounces, or $35 a ton. The lowest ore of No. 6 anticlinal yielded 1.63 ounces, or $33.58 per ton, as the average of 71 shipments. The ore now mined in the Tranquility is also rich in gold.

While these are merely specific instances, we obtain from the books of the Tombstone Mill and Mining Company a comparison of the product by periods which is more exact, and also more instructive. From June, 1879, to March, 1884, inclusive, that company produced 10,931 ounces of gold and 3,459,555 ounces of silver, or 1 : 317. From March, 1884, to December, 1893, the product was 26,745 ounces gold and 3,247,603 ounces silver, or 1 : 121, the proportion being 2.6 times as high in the second period as in the first. The only mine opened from the grass roots in the second period was the Lucky Cuss. All others were opened in the first period, and had their deep mining in the second period. This company mined two fissures and nearly all the anticlinals in the camp, and its results must be received as representative of the true conditions in the district. This increase of gold with depth is as interesting in a scientific sense as it is important to the future prosperity of the district.

If I understand Prof. Comstock* correctly, he ascribes this increase in gold tenure to impregnation following an ancient uplift and folding, which was succeeded by a later uplift that brought in silver, the latter being geologically higher than the ores of the first deposition.

Confining myself to this district, without considering evidence to be obtained from other districts in Arizona, I do not find facts at Tombstone to sustain his view. There have been two well-marked periods of folding there. One preceded the intrusion of the granodiorite; the other came after the intrusion, and crowded the strata against the eruptive mass, producing effects strongly marked in its neighborhood; but I see no evidence of different ore-depositions after these events. The entrance of all the ore was later than the second folding. The difference of level in the Goodenough incline between the poorer gold-ores of the surface and the richer of the Empire is less than 300 ft., the continuity of the ore is complete, and

* *Trans.*, Canadian Meeting, August, 1900.

the ore itself is as uniform in character as oxidized ores ever are.

Roughly speaking, about half the gold and silver produced in Tombstone has been taken from the upper shales, about a third from the blue and white limes, and most of the remainder from the Lucky Cuss limestone at various points of its extensive outcrop. The quartzites over and under the white lime have carried the least ore, but neither of them has been reached in the larger fissure-veins which have had richly paying ground in the quartzite included in the upper shale. The Toughnut quartzite was ore-bearing in the West Side mine.

The town of Tombstone occupies a flat gravel mesa, or table, quite level for a width of a third of a mile from north to south, and sloping gently to the west for a mile and a half. The gravel lies on the anticlinal shown on the extreme left of Fig. 4, and the white limestone of Combination and No. 6 anticlinals outcrops on the southern side of the town. Toughnut gulch is a natural boundary on that side, and, with the exception of Comstock hill, the rock exposures stop at the gulch. Some do not reach it, being covered by gravel. To the north is a waste of gravel, which a shaft near the town penetrated for 300 ft. without reaching rock.

After lying idle for several years, the reopening of the Tombstone mines has been undertaken by gentlemen who were prominent in the early mining of the district. A new shaft, with two hoisting compartments 4 x 7 ft. and two pump compartments 5 ft. 9 in. x 7 ft., has been sunk near the Contention fissure, and has reached the water-level at a depth of 569 ft. This work was done and the shaft strongly timbered in less than five months. Pumps to throw 1750 gallons a minute will be installed. It may seem remarkable that pumps of such capacity should be needed in a region that is not only arid, but one where the underlying rocks receive an unusually small part of the rain that falls. The caliche which Prof. Blake described in a recent paper* covers a large part of the district and sheds the surface-water, and the run-off is abnormally large. The calculations are made on the results of pumping done in 1884, when about 1,500,000 gallons a day

* *Trans.*

were thrown out. The water has never returned to its old level by 6 or more feet; and, though there is a great body of water in the ground, it is believed that, when once removed, the rocks will be permanently dry.

The water-level on the west side of the granodiorite is about 250 ft. higher than on the Tombstone side, which may indicate a great depth of rhyolite between the mines there and the San Pedro river, 6 miles distant and 400 ft. lower.

One of the principal objects of my examination of the Tombstone district was to ascertain what measures are likely to be encountered below the water-level. The presence of the "granite" formerly led to the supposition that it underlaid the town and ore-bearing rocks; but the evidence contradicts that impression. The mines still have about 2000 ft. of known sedimentary rocks under them, and perhaps much more.

The revival of these mines is a matter of more than usual interest, for it is based upon convictions derived from a knowledge of the structural geology of the district, and this knowledge is in no sense a theory nor an ordinary scientific explanation of facts. The mines in the anticlinals were managed for years in the light of this knowledge, and thousands of feet of drifting was done to reach anticlinals at the contacts of their rocks. The work began on a theory of Mr. Staunton's, but repeated successes soon lifted it from the plane of reasoning to the solid basis of experience.

It is this experience which will guide operations in future, and the projectors have the greatest faith in their successful outcome. All the fissure-veins, all the most productive mines in anticlinals, and many of second importance, have been consolidated in one ownership, as was necessary before a company could be found to pay for draining the entire district.