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THE TOMBSTONE MINING DISTRICT HISTORY, GEOLOGY AND ORE DEPOSITS

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INTRODUCTION

The Tombstone mining district, located in a small group of hills 6 mi north of the San Pedro River and 65 mi southeast of Tucson, Arizona, was one of the rich "bonanza" silver districts of the late 1800's. Mining commenced in 1878, escalated rapidly until 1882, and then slowly declined until the last mine closed in the late 1930's. The total production from 1878-1957 amounted to approximately one million tons of ore worth about $39,000,000; of that total value, half was derived from the production during the seven-year period 1879-1886 (Wilson, 1962).

The district has been described in the literature by Blake (1882), Church (1903), Ransome (1920), Butler and others (1938), Gilluly (1956) and Newell (1974). Of these works, that by Butler and others was the most extensive and detailed. The accompanying geologic map and section (figs. 4, 5) are from their publication and have been reproduced without modification.

HISTORY

Ed Schieffelin discovered silver chlorides and lead carbonates in a quartz vein in the southwestern part of what became the Tombstone mining district in the late summer of 1877. On the third of September, 1877, he recorded his "Tumbstone Mine" and "Graveyard" claims in Tucson, County of Pima, Arizona Territory (Devere, 1960). After recording his claims, it took Schieffelin almost a year before he could raise sufficient money and convince his brother Al, and Richard Gird, a mining engineer, to join him in developing his discovery. The vein proved to be small and poorly mineralized, so while the disgruntled Al Schieffelin and Richard Gird attempted to mine, the ever-optimistic Ed Schieffelin prospected further to the north and east, and in two successive days, discovered the large, rich lodes of the Lucky Cuss and Toughnut silver deposits (Butler and others, 1938).

With the discovery of the Lucky Cuss and Toughnut lodes, the Tombstone silver boom was born. In rapid succession, the lodes of the Goodenough, Grand Central, Contention, Vizna, Empire and Tranquility mines were discovered. A town, named after Schieffelin's original claim, the Tombstone (fig. 1), was established and mills were built on the San Pedro River at what became the towns of Charleston, Contention and Fairbank. The "Arizona Weekly Star" of November 2, 1879, reported that Tombstones' petition for incorporation had been granted by the Pima County Board of Supervisors. The town boasted a population of 1000-1500, while Charleston, a mill town on the San Pedro River claimed 600-800 inhabitants (Devere, 1960).

The silver-lead ores were high grade, near surface and easily extractable. The only problem was the lack of local water for milling; therefore mills were built along the San Pedro River and ore was transported the 9 mi at a cost of $3.50 per ton (Blake, 1882). That problem was solved in 1881 when water was encountered at a depth of 520 ft in the Sulphuret mine. With water, the future for mining seemed bright, but the water that was thought to be the mines' savior, turned into their executioner. In 1886, the pumps at the Grand Central mine burned, leaving only the Contention mine pumps to handle the water. Those pumps were inadequate, forcing the suspension of all mining below the water table. From 1886-1901, mining was at a low ebb, being carried on largely by lessees.

In 1901, the Grand Central Company, the Tombstone Mill and Mining Company and the Contention Company were joined to form the Tombstone Consolidated Mines Company. With the joining of the three companies, the majority of the larger mines in the district were consolidated and the decision was made to once again pump the water and develop the deeper ores. The company sunk the four compartment Boom shaft, constructed a new 125 ton per day cyanide mill and reconditioned the old levels in the Grand Central, Contention, Empire, Lucky Cuss, Silver Thread, Toughnut and West Side mines. By 1906, the Boom shaft had reached the 1000-ft level and water was being pumped at the rate of 3000 gpm (fig. 2).

The deeper ores were only partially oxidized, so in the same year the cyanide mill was converted and expanded. Using stamps, slime cones, Wilfley tables and cyanide tanks, the mill operated at a capacity of 225 tons per day (Butler and others, 1938). Independent mines reopened and mining at Tombstone regained some of its old vigor. Silver was selling for 67 cents per ounce, lead at 5.6 cents per pound and gold at the fixed price of $20.67 per ounce.

In June 1909 water again dealt Tombstone mining a serious blow. Due to defective fuel for the boilers, the steam pumps on the 1000-ft level (fig. 3) of the Boom shaft seized and stopped. Eight large steam sinking-pumps were installed, but they were incapable of handling the water and it rose to the 900-ft level. As the water rose the overtaxed boilers ruptured

Figure 1. Grand Central mine surface plant in 1884, with the town of Tombstone in the background (Macia-Devere collection).

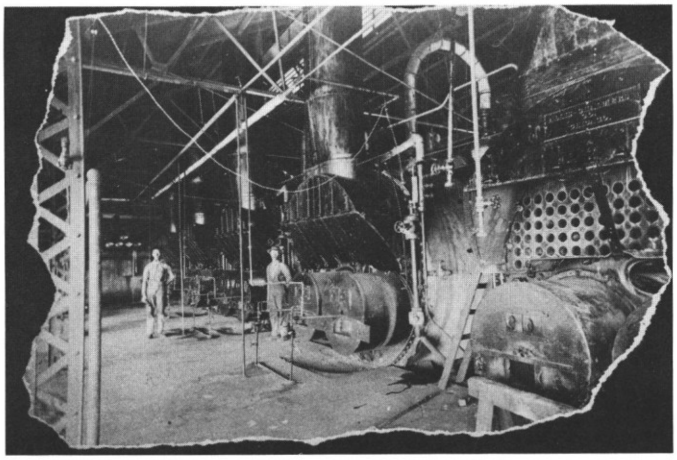

Figure 2. Surface boilers for the steam pumps in the Boom shaft near Tombstone about 1904 (Macia-Devere collection).

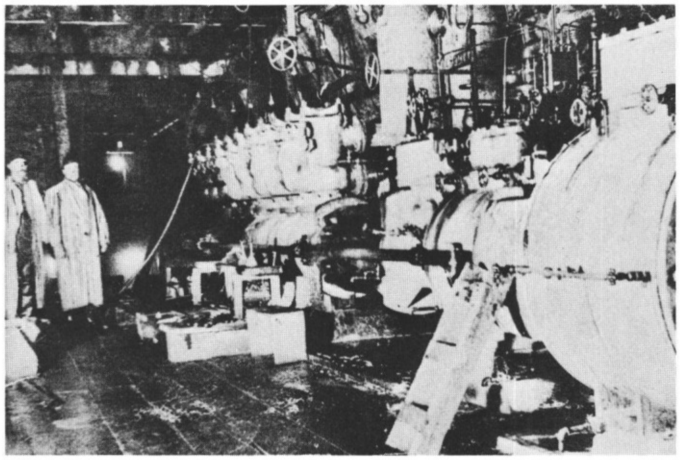

Figure 3. Steam pumps on the 1,000-ft level of the Boom shaft near Tombstone about 1906 (Macia-Devere collection).

almost simultaneously, stopping all pumping. In 1910, a 4,000 cubic-foot compressor was installed and the sinking pumps were run by air. With the air pumps and the installation of new boilers, the submerged pumps were finally recovered and development on the 1,000-ft level was resumed by the end of the year (Butler and others, 1938).

The cost of defeating the water, pumping 3,500 gpm, the decreasing silver price and the lack of sufficiently large, high-grade orebodies at depth, finally took their toll. On January 11, 1911, pumping stopped and the pumps on the 600, 700, 800 and 1,000-ft levels of the Boom shaft were allowed to flood (Butler and others, 1938). With the flooding of the lower levels, mining by the Tombstone Consolidated Mines Company ceased, though lessees continued to work the dumps and search for ore above the water table.

In 1914, Phelps Dodge Corporation, one of the principal creditors of Tombstone Consolidated Mines Company, acquired all the company's holdings and started mining under the name of Bunker Hill Mines Company. That company made no attempt to recover the lost pumps or reopen the lower workings. Rather, they concentrated on mining the shallower, lower grade manganese-silver ores in the southern and western part of the district. They mined until 1918, when they turned their operations over to lessees.

In 1933, the properties of Bunker Hill Mines Company were taken over by the Tombstone Development Company, which attempted to operate the mines via lessees; their operations continued sporadically into the late 1930's.

The Tombstone Extension, a lead-carbonate vein mine located in the eastern part of the district, opened in 1930. During 1932-33, the mine was the largest lead producer in Arizona (Asarco files). That mine was turned over to lessees in the mid-1930's and closed in the late 1930's.

Since the Second World War, the Anaconda Company and Newmont Mining Corporation have both examined the district in some detail; however, neither company was successful in discovering sufficient ore to justify reopening the mines.

Two mining operations are being conducted in the district at present. The Escapule Brothers, Charles and Louis, are leaching the dumps from the State of Maine mine and plan to commence mining and leaching of low-grade underground ores in the near future. The other operation is that of Sierra Min erals, which has during the last few years, been reworking the old mine dumps and recovering silver and gold via a cyanide leach process. The large dump east of Tombstone is the site of their current operation.

REGIONAL GEOLOGIC SETTING

The Tombstone mining district lies along the axis and just west of the deepest part of the Sonoran geosyncline. It also lies within a belt of north-northwest trending mountain ranges that are separated by broad alluvial-filled valleys and extend from the Colorado Plateau in central Arizona, to Sonora, Mexico. The region is underlain by a relatively thick blanket of Paleozoic and Mesozoic sediments.

GEOLOGY

Rocks of the Tombstone mining district consist of schist, granite, limestone, dolomite, shale, sandstone and conglomerate of Precambrian through Mesozoic age, and younger granodiorite, tuff, rhyolite sills, plugs and dikes, andesite dikes, valley fill and a basalt plug.

Precambrian rocks, Pinal Schist and granite, are exposed in a north-south elongate window in younger sediments and volcanic rocks in the south-central part of the district (fig. 4).

Overlying Precambrian rocks are 440 ft of Cambrian Bolsa Quartzite (Ransome, 1916) and 844 ft of Cambrian Abrigo Limestone (Gilluly, 1956). Devonian Martin Limestone, 230 ft of alternating limestone and shale, unconformably overlies the Abrigo Limestone (Gilluly, 1956). The Mississippian is represented by 786 ft of Escabrosa Limestone and dolomite (Gilluly, 1956).

The Pennsylvanian-Permian Naco Group, first described by Ransome during his early work in the Bisbee district, 20 mi to the southeast (Ransome, 1904), is well exposed in the Tombstone Hills. Due to the excellent exposures, Gilluly and his co-workers (Gilluly, 1956) were able to subdivide the Naco into 999 ft of Horquilla Limestone, 584 ft of limestone, sandstone and shale in the Earp Formation, 633 ft of Colina Limestone and 783 ft of limestone and dolomite in the Epitaph Dolomite.

Unconformably above the Naco Group is the Cretaceous Bisbee Formation (Gilluly, 1956). The Bisbee Formation at Tombstone is not to be confused with the Bisbee Group

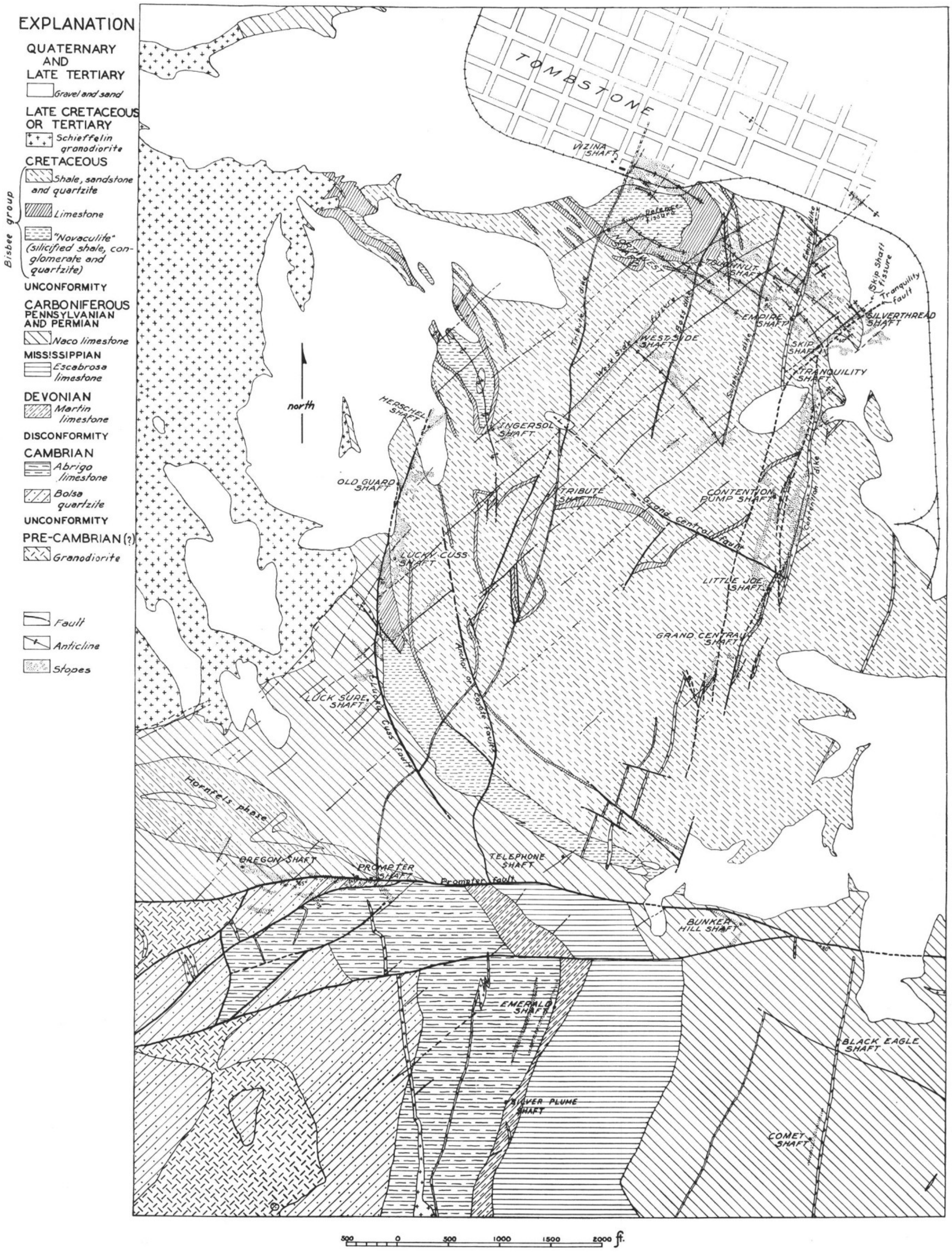

Figure 4. Geologic map of Tombstone district, Arizona (from Butler and others, 1938).

(Ransome, 1904) in the Mule Mountains to the southeast, as the Glance Conglomerate, Morita Formation, Mural Limestone and Cintura Formation do not occur, but their stratigraphic equivalents may be present. It has been suggested that Cretaceous beds at Tombstone are all younger than the Mural Limestone and "possibly even post-Cintura Formation" (Stoyanow, 1949, p. 30). However, Reeside has noted that "although the fossils of the Blue limestone (in the Bisbee Formation) at Tombstone are not precisely identifiable, they resemble those of the Mural closely" (Gilluly, 1956, p. 77). While there is little doubt of the Cretaceous age of the Bisbee Formation at Tombstone, direct correlation of stratigraphic units of the Bisbee Group, as they occur in their type locality, cannot be made. The formation exposed at Tombstone is a much faulted and metamorphosed sequence of sandstone, shale and limestone that is 3,079 ft thick (Gilluly, 1956). Of considerable importance as far as mineral deposition is concerned is the lower 128 ft of the formation, which consists of the "Novaculite" unit which contains 60 ft of basal shale and limey sandstone with localized limestone conglomerate, the "Blue limestone" which is 34 ft thick, 24 ft of shale and a 10-ft thick bed of limestone (Gilluly, 1956).

Late Cretaceous igneous rocks, the Schieffelin Granodiorite and the Uncle Sam quartz latite tuffs (Butler and others, 1938), are exposed in the western and southern part of the district, and dikes of granodiorite are found throughout its central part. The granodiorite is a holocrystalline rock with a hypidiomorphic granular texture. It is light gray to grayish-pink and medium-grained, consisting of 35-40% plagioclase, 15-20% orthoclase, 5-10% quartz, 5-10% green hornblende, 3-5% biotite and 1-5% augite with minor amounts of clinozoisite, zircon, magnetite, sphene and apatite (Newell, 1974).

Newell (1974) describes the Uncle Sam quartz latite tuff as a hypocrystalline rock that is slightly welded and contains ash-phenoclasts that are embayed and set in a devitrified matrix. The light yellowish-brown to gray-brown lithic tuff, with moderately well-defined flow structures, contains 40-50% plagioclase, 20-25% quartz, 15-20% orthoclase, and 1-5% biotite with traces of magnetite and apatite.

The tuffs have been dated at 71.9±2.4 m.y. (Newell, 1974), whereas the granodiorite is 72 m.y. old (Creasey and Kistler, 1962). The close relationship of the two rock types, both spatially and temporally, and the tendency for the tuff to be less mafic and more siliceous than the granodiorite, suggest that they are differentiates from the same magma.

The granodiorite and tuffs are cut by dikes of hornblende andesite that are bluish gray to light olive-gray in color. They consist of medium to coarse-grained hornblende phenocrysts and fine-grained plagioclase in a microcrystalline groundmass (Newell, 1974).

Rhyolite porphyry, dated at 63 m.y. (Creasey and Kistler, 1962) occurs as sills, plugs and dikes south and east of the main part of the district. The rock is pinkish gray and made up of medium- to fine-grained phenocrysts in devitrified ground- mass. The texture is hypocrystalline, being typically porphyritic aphanitic.

To the north and east of the district, the pediment of the Tombstone Hills is covered by Gila Conglomerate. The rock unit, which is probably a fanglomerate, is several hundreds of feet thick, contains boulders up to 3 ft in diameter, as well as cobbles and pebbles, all of which are set in a fine sand matrix. The unit is generally poorly sorted, becoming finer grained and vaguely bedded in its upper part.

The youngest rock in the area is a basalt plug which intrudes the Gila Conglomerate on the east side of Walnut Gulch, north of the central part of the district. The elliptically shaped plug is dark gray to greenish black in color, being made up of fine-grained olivine, diopside and enstatite that occur in the interstices between felted plagioclase laths (Newell, 1974).

STRUCTURE

The Tombstone mining district is structurally complex. Several periods of faulting, with movement along the same structure, sometimes in different directions, has complicated the unravelling of the tectonic history.

Two structural features predominate: the Ajax Hill horst and the Tombstone basin (Butler and others, 1938). The Ajax Hill horse, located mostly south and east of Figure 4, is a 6 mi¹ area that is bounded on the west by the north-south trending Ajax Hill fault, on the north by the east-west trending Prompter reverse fault, and on the south by the northeast-southwest trending Horquilla Peak fault (Gilluly, 1956). To the east, the boundary is concealed by alluvium. Displacement along the boundary faults has been significant; the Ajax Hill fault has brought rocks of the Bisbee Formation, on the west, into contact with Bolsa Quartzite, on the east; the Prompter fault separates the northern Naco Group limestones from southern Pinal Schist; while the Horquilla Peak fault has brought upper Naco Group limestones on the south to rest against the Abrigo Limestone on the north.

North of the Ajax Hill horst is the Tombstone basin, which is shown by the large area of Cretaceous sediments on Figure 4. The basin is a broad synclinal warp, the axis of which trends east-west and plunges gently to the east. The syncline is complicated by a series of smaller west-northwest trending, anticlinal and synclinal folds that were called "rolls" by the early miners. To the west the broad syncline and its associated tighter folds abut and are truncated by the Schieffelin Granodiorite which is clearly younger than the folding.

Prior to the intrusion of the Schieffelin Granodiorite the Tombstone basin was subject to east-west and north-south faulting. Following the intrusion of the granodiorite, dikes of similar composition were emplaced along many of the pre-existing faults. The basin was then faulted along north-northeast trends, and there was renewed movement along the east-west and north-south faults which brought about the development of a series of northeast tension fractures. Thereafter, the faults and the tension fractures were mineralized, with the tension fractures becoming the northeast fissure veins. Following mineralization, the basin was again disrupted by faulting along west-northwest and north-northwest trends. Movement along the newly created and pre-existing faults tilted the basin to the north and northeast.

METAMORPHISM

The intrusion of the Schieffelin Granodiorite and its accompanying dikes metamorphosed the rocks in the Tombstone mining district prior to mineralization. Shale and sandstone of the Bisbee Formation were converted to hornfels and quartzite which fractured well and helped develop the long continuous tension fractures during the many periods of faulting. Limestone of the Bisbee Formation and upper Naco Group were recrystallized, while the "Novaculite," the basal member of the Bisbee Formation, altered to a jasperoid.

ORE DEPOSITION

The hornfelsic shales played a dual role: they fractured well, thus providing excellent, confined channel ways for ascending mineralizing solutions; and, because they were unshattered and competent except in the immediate vicinity of the fissure veins, they formed impermeable caps under which the solutions could spread and replace favorable limestone horizons. Since the Bisbee Formation is mostly shale and sandstone that altered to hornfels and quartzite, much of the ore was confined to fissure veins and faults. However, the largest orebodies occurred as limestone replacement deposits. Favorable horizons for replacement deposits were the "10-foot limestone," the "Blue limestone" and the "Novaculite," of the lower Bisbee Formation and the uppermost beds of the Naco Group.

The most favorable loci for ore deposition were where a northeast fissure vein, dike or premineral fault cut a favorable horizon that had been folded by one of the west-northwest-trending anticlinal flexures. In most cases, the "10-foot" and "Blue" limestones were more tightly folded and fractured than were the underlying Naco limestones. These features, together with the fact that the "10-foot" and "Blue" limestones were capped and bottomed by impermeable hornfelsic shales, made them the most receptive hosts in the district. Fracturing and permeability are the greatest where the bends are the sharpest. The folds are not symmetrical, and the sharpest bends may or may not be at the crest of a fold. In some folds, slip along beds produced permeable zones on the limb of the fold, and mineralization often extended for some distance down a limb.

The Silver Thread fold has a flat crest that bends sharply into a nearly vertical northeast limb. The bend has intensely fractured the "Novaculite," and it is continuously mineralized for 600 ft between a dike and a northeast fissure vein. The "Blue limestone" on the same roll was replaced by sulfides for 400 to 500 ft from the dike (Butler and others, 1938). The "Blue limestone," where it is cut by a large fissure vein along the Sulphuret fold, produced an orebody that was stoped for 300 ft; the stope varies in width from 25 to 100 ft and from 3 to 8 ft in height. The ore averaged $70 per ton when it was mined in 1904-05 (Butler and others, 1938). Figure 5, taken along the West Side fissure between the Boss and Sulphuret dikes is a good example of the complexity of folding and localization of replacement ores within the district.

Several ore shoots occur in the fisure veins. The Skip-Shaft fissure was mineralized for about 900 ft along strike and for more than 600 ft below the surface. Stratigraphically, the fissure made ore from the Naco Group to about 400 ft above the "Blue limestone" in the Bisbee Formation. The fissure was most productive along its intersection with the "Blue limestone," where the limestone was replaced for some distance away from the fissure. Maps of the old workings indicate the fissure was stoped over a width of several feet regardless of the rock type. The Arizona Queen fissure on the surface is a shear zone 4 to 5 ft wide. Like the Skip-Shaft fissure, the Arizona Queen has been most productive where it crossed the "Blue limestone." However, in the altered shales the fissure was well mineralized over a width of 10 to 12 ft, reaching a maximum width of 20 ft (Butler and others, 1938).

In addition to the replacement and fissure vein deposits, several orebodies were formed within the larger faults. These deposits generally occurred at the intersections of faults and fissure veins, particularly where a fissure vein hooked into and paralleled the fault for some distance before continuing in a northeasterly direction. Orebodies so formed were usually irregular, erratic and pipelike in shape. The Prompter fault contained irregular pipelike and tabular orebodies from the surface to the water level, where mining stopped. In one stope on the third level of the Prompter mine, approximately 180 ft below the surface, the entire fault zone, a width of 30 ft, was ore (Buchard, 1884).

The bulk of the Tombstone ores have been silver chlorides and lead, zinc and copper carbonates, with the majority occurring above the water table that stands at 4,120 ft above sea level, 450 to 600 ft below the surface. At some time in the past, the water table must have been lower, as oxidized ores have been mined from below the water table in the Grand Central, Lucky Cuss, Bunker Hill and Emerald mines.

There appear to have been at least two phases of mineralization: an earlier iron, lead, zinc, copper sulfide phase that was rich in silver and contained significant gold and a later manganese-silver phase. The ore related to the sulfide phase of mineralization contains little manganese and occurred as masses of pyrite, galena, tetrahedrite and sphalerite with minor amounts of chalcopyrite. The galena is later than the other sulfides as it replaces them, but it does not appear to be associated with the later manganese-silver mineralization. Galena and tetrahedrite are both argentiferous as is some of the pyrite. A sample of massive pyrite from the Sulphuret mine assayed 4.18 ounces per ton silver (Butler and others, 1938).

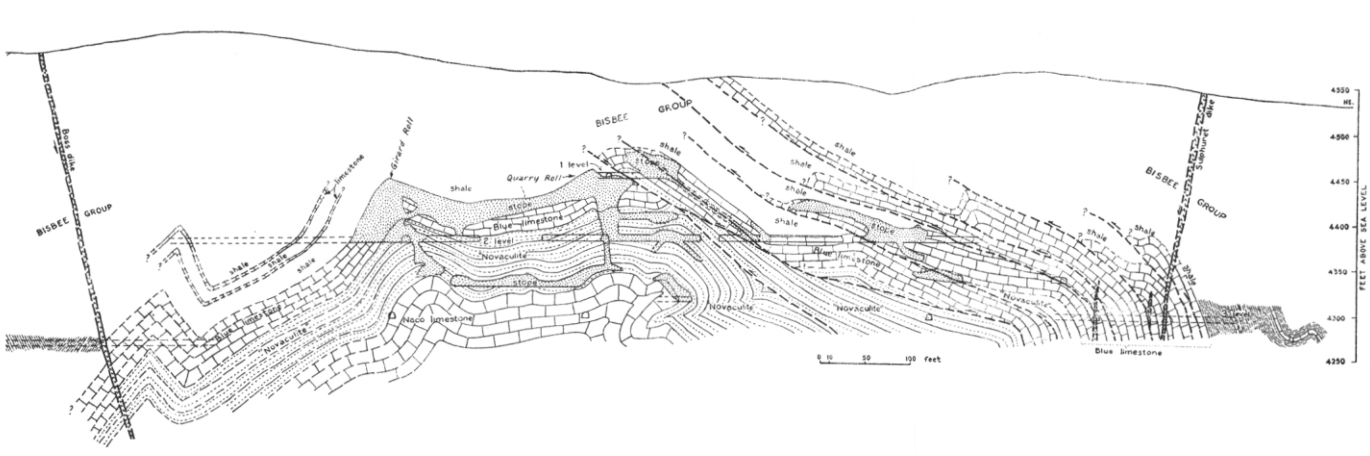

Figure 5. Cross-section along West Side fissure, looking northwest (from Butler and others, 1938).

The sulfide ore oxidized to limonite and cerussite that contained considerable bromyrite and cerargyrite with minor amounts of smithsonite, malachite, native gold and silver. In a few phases, chalcocite and argentite were found with the oxides.

The later manganese-silver ores occur mostly in the southern and western parts of the district principally in orebodies associated with the Prompter and Lucky Cuss faults. Most of the manganese occurs as psilomelane; however, a mass of alabandite was mined from the 350-ft level of the Lucky Cuss mine. The alabandite occurred in a replacement deposit in crystalline Naco limestone adjacent to the Lucky Cuss fault and was surrounded by pyrite, galena and sphalerite, which it in part replaced (Butler and others, 1938). The manganese ore generally contained less silver and lead and more copper than the oxidized sulfide ores, with the silver content usually being less than 20 ounces per ton. Typical manganese ore from the Dry Hill mine assayed 17 ounces per ton silver, 0.04 ounces per ton gold and 0.17% copper (Butler and others, 1938). However, some of the manganese ores from the Prompter mine averaged 35 ounces per ton silver from production in 1883 (Buchard, 1884). Ransome (1920) concluded that there was little doubt that the manganese-silver deposits occurred, at least in part, due to the reaction between the carbonate host rocks and the oxidizing sulfide deposits. However, the much lower silver and lead, and the higher copper content of the manganese-rich ores compared to the low-manganese sulfide ores suggests a separate, distinct phase of mineralization.

Silver was the most economically important metal produced, but gold and lead were also significant. The silver to gold ratio for ores produced was 6:1 in dollar value. The district has produced 45,000,000 pounds of lead (Keith, 1973, p. 13), an average of approximately 45 pounds of lead per ton of ore mined.

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