THE ECONOMIC GEOLOGY OF PORTIONS OF THE TOMBSTONE-CHARLESTON DISTRICT, COCHISE COUNTY, ARIZONA,
IN LIGHT OF 1967 SILVER ECONOMICS

by

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STATEMENT BY AUTHOR

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ABSTRACT

Economic conditions existing in the early part of 1967 are favorable for an historic price rise in silver. The supply of silver in the United States in 1967 is becoming critical in view of the existing high demand caused by a growing population and a rapid increase in industrial applications of silver. Silver supply is governed by new mine production and secondary, or recovered, silver flow. New mine production largely occurs as a by-product in base-metal mining under present economic conditions of the last few years. Presently large amounts of secondary silver also exist in the world. China and other countries are presumed to have large hoards to be released as the price goes up. Our government is slowly removing controls on the silver market, a factor which has resulted in an upward price adjustment of silver and which will draw new silver supplies into the world market.

On the premise that historically productive but currently inactive domestic silver districts may again be called upon for their potential in supplying new silver, two small portions of the Tombstone-Charleston district, several miles southwest of Tombstone, Cochise County, Arizona, were mapped.

Silver values in these two areas occur in fissure zones in Cretaceous sediments and intrusives. The fissures themselves
developed after the emplacement of the major intrusives because of a gentle tensional movement parallel to a pre-fissure regional joint pattern.

Andesite porphyry dike material is often found in the fissure zones associated with ore mineralization. The ore fluids and the andesite porphyry dike were controlled by structural planes of weakness in the fissure zones. Ore textures and mineral assemblages suggest epithermal mineralization in the areas studied in contrast to the mesothermal deposits of the Tombstone basin just south of Tombstone.

Silver-bearing manganese mineralization associated with calcite forms the primary low temperature mineralization in the mines of the studied areas. Subsequently, silver was concentrated in well-developed oxide zones where the only economic silver ore has been found to date. Higher temperature mineralization in the Tombstone basin with replacement of limestones by base metal minerals, however, does not eliminate the possibility of ore grade mineralization below the water table in this area.

With an increase in silver price to $1.75-$2.50 per ounce, small operations will be profitable in the areas studied and similar areas throughout the Tombstone district. It is possible that a total of several hundred thousand ounces of silver could be produced per year in these operations. The future possibility of large operations exists but would be limited to the more intensely mineralized areas.
CHAPTER I

INTRODUCTION

Purpose of Investigation

It is the purpose of this paper to examine and to consider together both the economics of silver and the occurrence of silver in the Tombstone-Charleston district.

If portions of the Tombstone-Charleston district can be closely examined in regard to general geology, structure, mineralogy, and regional distributions of ore (particularly in relation to the silver ores), an accurate picture of its economic geology can be produced. This geologic picture will supply information as to where the silver mineralization is in the district, what minerals, rock types, and structures it is associated with, and finally an estimate of how much mineable silver might be present.

"Silver ore" is an economic term and to determine what is actually ore, as opposed to mere occurrence, involves a careful examination of the value of the metal to be produced. It is again the purpose of this paper to examine the supply, demand, and governmental controls on silver and show that the economic conditions in 1967 are favorable for a considerable increase in the price of silver. The nature of the mineral deposits in the Tombstone-Charleston district
will determine the extent to which the favorable changing economics of silver are capable of increasing or initiating production of silver in this district.

Plan of Treatment

The course of this investigation involved two parts. First, the detailed study of the economics of silver was undertaken with the data available in the spring of 1967. This study included an examination of the supply and demand situation as well as examination of historical price movements and factors involving governmental control of silver. The second involved a detailed examination in the field of two square-mile portions of the Tombstone-Charleston district. These two chosen areas contained the two most recently productive and accessible mines to the district, the Charleston Lead mine and the Escapule mine. Preparation for this work was begun in late 1966 and was completed in May, 1967. The topographic map used for the two areas is the United States Geological Survey Tombstone Quadrangle Map, portions of which were enlarged from a scale of 1:24,000 to a scale of 1:7,920 or one inch to 660 feet. The latter enlarged portions served as a base for the geologic mapping. Distances were paced from obvious landmarks on the base map and exact locations when needed were triangulated from prominent cultural and physical features.

Some of the mineral identification was done by X-ray diffraction methods, and suites of minerals collected by numerous
people at the University of Arizona were also helpful in identification. Chemical analyses and assay values were obtained from companies previously working in the area. A detailed structural analysis of the jointing, its relation to the dikes, fissures, and to the ore controls was carried out and based to a limited extent on previous work by Butler (1938) and Gilluly (1956), neither of which covered in detail the two areas given close study in this paper.

In the interest of clarity and purpose, the geologic studies precede the economic studies in the organization of this paper.

Previous Work

The geology of the Tombstone district including the Escapule mine area was mapped at a scale of 1:24,360 by B. S. Butler (1938). A geologic map of central Cochise County which includes both areas studied was done at a scale of 1:62,500 by James Gilluly (1956). Both Butler's (1938) work on the geology, mineralogy, structure, and ore occurrences of the Tombstone district and Gilluly's work on the geology of central Cochise County were of invaluable help in this study. A geologic study of the Uncle Sam porphyry was also done by Gilluly (1945) and incorporated in his later work.

A Ph.D. dissertation on the mineralogy of the Tombstone district by C. A. Rasor (1938) was followed by subsequent articles on the manganese mineralization at Tombstone (Moore, 1965). No published work exists on the mineralization at the Charleston Lead mine. Numerous references to unusual mineralization as well as
other features of the Tombstone basin are listed in Moore and Wilson's (1965) Bibliography of the Geology and Mineral Resources of Arizona (1848-1964). Two articles by D. F. Hewett (1967a,b) described the silver-bearing manganese minerals and the nature of black calcite as they relate to this district.

Work on the economics of silver is extensive and has been profuse in 1967. Numerous newspaper clippings, augmented with financial reviews by Indicator Digest (1967), Standard and Poor's Industrial Survey (1967), Harris, Upham and Company Research (1967), and the Value Line Investment Survey (1967), as well as several annual reports of silver mining companies were given detailed study in formulating the economic analysis of silver presented in this paper. An article by Paul Jeanty (1967) involves international aspects of silver economics giving special consideration to the hoards of silver in India and China. The 1966 E & MJ Market Guide for silver deals in fair detail with production and demand aspects of silver economics, and a paper by Robert Dreyer (1967) describes the economics of silver in relation to exploration in the southwestern United States. A very recent publication edited by Allison Butts, 1967, is a thorough and exhaustive study of the economics, metallurgy, and uses of silver with particular emphasis on the last.
CHAPTER II

GENERAL GEOLOGY OF PORTIONS OF THE TOMBSTONE-CHARLESTON
DISTRICT, COCHISE COUNTY, ARIZONA

Introduction

Location

The Tombstone district and the western extension of that district towards Charleston are located in western Cochise County approximately 25 miles north of the Mexico-United States border. Two areas of one square mile each were selected for detailed study in this district for the purpose of determining the economic potential of those areas and relating them to the entire district. Both square mile areas are west of Tombstone (see figure 1). One, the Escapule mine area, is approximately two miles directly southwest of the town of Tombstone and is located in Township 20 south, Range 22 east, covering portions of sections 9, 10, 15, 16. It is for the most part east of Uncle Sam Hill but includes some of the easternmost portion of that hill and the portion of the valley lying east of Uncle Sam Hill and west of the Tombstone Hills. Several producing mines have been located in this square mile area. The largest to date, the State of Maine, produced amounts of silver and gold estimated at from $200,000 (Butler, 1938) to four million dollars claimed by
FIGURE 1
INDEX MAP

General geologic map including both the Tombstone area and the Charleston area, Gilluly (1956) and a generalized geologic section of Tombstone, Arizona, Butler (1938).
FIGURE 1. INDEX MAP
Ernie Escapule, whose relatives owned it (personal communication). Exact records were seldom kept and most of those that were kept have been destroyed. The State of Maine mine is at the west edge of the area and on the eastern slope of Uncle Sam Hill. In the northern portion is the Merrimac mine. In the eastern central and southern portions of the area, there are the Bonanza, Mamie, Escapule, Sailor, and Randolf mines, all small high grade silver and gold producers. Only the Escapule mine was productive in 1967 although several dumps of the older mines which were in production around the turn of the century have recently been reworked. This area will continually be referred to as the Escapule mine area. The second square mile area studied, the Charleston Lead mine area, lies six miles directly southwest of the town of Tombstone, in line with and four miles southwest of the center of the first square mile area. The center of this area lies approximately 2.5 miles northwest of the abandoned town of Charleston. The San Pedro river parallels its western edge 1.5 miles to the west. The area comprises the eastern portions of sections 25 and 36, Township 20 south, Range 21 east; and western portions of sections 30 and 31, Township 20 south, Range 22 east. The Charleston Lead mine, a recent small producer of sericite with values in lead, zinc, and silver, is in the southwest corner of this square mile area and the Mustang mine, a very small and erratic producer of high grade silver and gold, is in the northwest corner. This area will be referred to as the Charleston mine area.
FIGURE 2
A VIEW OF THE STUDIED AREAS

View from the west-central edge of the Escapule mine area with dumps from the State of Maine mine on Uncle Sam Hill in the foreground looking southwest four miles to the Charleston Lead mine (Ch). Located in unnamed conical hills of Uncle Sam porphyry. The Huachuca Mountains are in the background.
Transportation

There is easy access to both of the areas studied by light duty roads and unimproved dirt roads which abound in the area. The district is served by a standard gauge branch line from Fairbank, seven miles west of the town of Tombstone along the San Pedro river and a station on the Douglas loop of the Southern Pacific Railway.

Climate

The climate is semi-arid and typical of intermediate altitudes of southern Arizona. In winter the average high daily temperature is about 75° and the average low about 25°, whereas in the summer the average high is near 100° and the low near 55°. Average annual rainfall is over 14 inches, and July to September is the rainy season. Desert shrubs, mostly creosote bush, predominate and no timber suitable for mining use grows in the area.

Physical Features

Topographically, the Tombstone-Charleston district is one of predominantly low scattered hills with the highest elevation of 4320 feet on Ajax Hill and the lowest, about 3900 feet, along the San Pedro river. The highest elevation in the Escapule mine area is 4750 feet along Uncle Sam Hill and the lowest elevation in this square mile is 4425 feet along the north edge. The highest elevation in the Charleston Lead mine area is nearly 4350 feet in the southwest, and the lowest about 4050 feet in the west center. There are no perennial streams in the area studied. Most water in the district
has a high fluorine content which makes it unsuitable for drinking. Water encountered in deep excavations and shafts has been a major problem in mining throughout the district. Extensive jointing and fracturing allow the ground water to flow easily and make lowering of the water table difficult. Water is encountered about 250 feet below the surface at an elevation of 4225 feet in a valley in the Escapule mine area; however, the quarry of the Charleston Lead mine in the Charleston Lead mine area contains a few feet of water indicating a water table of less than 100 feet in depth exists there. It is quite likely that this shallow water table persists throughout this area. Duval Corporation, which explored the southwestern portion of the Tombstone district in the Spring of 1967, claimed that one of their major reasons for not starting mining operations near Tombstone was the enormous amount of underground water that would have to be pumped out for any large scale operations in the district. Presumably the ore they were interested in was below the existing water table.

**General Geology of the Tombstone-Charleston District**

The general geology of this district is covered in considerable detail by Butler and Rasor (1938), and Gilluly (1956). For more detailed information concerning the district and its regional relations, particularly for geology and rock types around the Tombstone district not covered by this author in the two areas he studied, a reference to these works may be made.
The rocks composing the Tombstone district range from pre-Cambrian to Quaternary in age. A generalized geologic column (Butler, 1938) and a geologic map (Gilluly, 1956) of the district as a whole are shown together in Figure 1. The following statement of the general geology of the Tombstone district is quoted from Butler (1938, page 11-12).

The oldest rock is fine-grained, greenish-gray schist, evidently pre-Cambrian and correlated with the Pinal schist of Bisbee. It is invaded by granitic and porphyritic rocks that have been tentatively regarded as pre-Cambrian, but may be younger.

Unconformably overlying the pre-Cambrian rocks is the Cambrian Bolsa quartzite, here about 440 feet thick. This is succeeded by the Cambrian Abrigo Limestone, approximately 700 feet thick. Overlying the Abrigo with apparent conformity is the Devonian Martin limestone, about 340 feet thick, followed by the Mississippian Escabrosa limestone, estimated to be about 500 feet thick. It is not very distinctly separable from the overlying Naco limestone of Pennsylvanian and Permian age. As the upper limit of the Naco is a surface of erosion, the original thickness of this formation is unknown; its present maximum thickness exceeds 3,250 feet. The Naco limestone is intruded by a few dikes and sheets of quartzose porphyry, generally rather decomposed, that were erupted prior to the deposition of the Mesozoic sedimentary rocks.

Unconformably overlying the Naco is the Bisbee group, a series of conglomerate, sandstone, quartzite, shale, and limestone. These beds, as shown by fossils in the limestone layers, are of Mesozoic, probably Comanche, age. The thickness of the Bisbee group is unknown, as no measurable section of the whole is available; it probably exceeds 3,000 feet.

After the deposition of the Tombstone formation, the rocks of the district were folded and faulted and, probably at the same time, were invaded by the mass of Uncle Sam quartz latite porphyry that crops out in the western part of the district. About the same time, but probably slightly later, they were intruded by an irregular body of granitic rock, the Schieffelin granodiorite. Southwest of the mapped
area, near Charleston, the quartz latite porphyry is intruded into andesitic and rhyolitic extrusive rocks. It seems likely that the earliest volcanic activity was extrusion of lavas, followed by intrusion of quartz latite porphyry near the then existing surface, and this in turn was followed by intrusions of granodiorite.

After the intrusions, the district appears to have been subject to long-continued erosion. Probably in late Tertiary time the lowlying parts of the district were covered by a fluvial deposit of crudely stratified, more or less firmly consolidated angular rock detritus with some layers of sand and silt. This material which appears to be analogous in age and made of deposition to the Gila conglomerate of central Arizona, occupies large areas in the broad valleys that separate the hills of the Tombstone district from the Huachuca, Whetstone, and Dragoon ranges. In most places it is overlain by a few feet of Quaternary gravel, sand, and silt. At least one basaltic eruption occurred during or after the accumulation of the valley fill, as shown in Walnut Gulch, about a mile northeast of Tombstone. Some faulting has taken place since the deposition of the valley fill, which has been deeply trenched by arroyos of the present erosion cycle.

These paragraphs are a brief but accurate summary of the general geology of the whole region, much of which this author did not examine. However, a more detailed description of the geologic formations, structure, and mineralogy of the two individual areas studied both updates and improves the accuracy of the geology just described.

Specific Description of the Geology of the
Escapule and Charleston Mine Areas Mapped

No rock unit observed in the two areas studied is older than the Cretaceous and only southeast of the Escapule mine area are there outcropping Paleozoic and pre-Cambrian rocks.

The oldest of the Cretaceous rocks consists of a series of sandstones, shales, quartzites, hornfels, and limestones called the
Bisbee group. These rocks occur only in the Escapule mine area where Bisbee outcrops could be found over nearly all of its eastern half, especially in prospect pits. Small, steeply dipping (60°-90°) outcrops of this formation were found along the road up toward the State of Maine shaft, and in the northeast corner a large Bisbee block with a dip of 35°-85° to the northeast angles into Uncle Sam porphyry. This porphyry also pokes up through Bisbee group sediments near the Sailor mine (see figure 4). On a regional scale these exposures of the Bisbee formation are part of a roughly crescent shaped body, concave to the west, the southern tip of which extends westward until it lies just south of the Charleston Lead mine area (figure 1).

The Bisbee formation, in general, is lighter in color than the Uncle Sam porphyry and shows metamorphism probably caused by the injection of the later intrusives. Hornfels, limestones, and baked sandstones with aggregates of epidote, and quartzites are common, and they all show the shattered appearance of brittle rocks. Commonly, many small blocks will break between two closely spaced, parallel strong joint planes. It is little wonder with such propensity to shattering that small pieces of bedrock cover most of the outcrop area. A very hard quartzite was found at the edge of the Bisbee group in the north central part of the Escapule mine area. Again this quartzite had been fractured into small sharp blocks, and a stream channel had been cut on the contact between this quartzite and the Uncle Sam porphyry.
FIGURE 3

THE ESCAPULE MINE AREA

A geologic map of the Escapule mine area.
GEOLOGIC MAP OF THE TOMBSTONE AREA COCHISE COUNTY, ARIZONA

FIGURE 3. THE ESCAPULE MINE AREA
FIGURE 4

THE CHARLESTON LEAD MINE AREA

A geologic map of the Charleston Lead mine area.
GEOLOGIC MAP OF THE CHARLESTON AREA, COCHISE COUNTY, ARIZONA

FIGURE 4. THE CHARLESTON LEAD MINE AREA
Butler gives a generalized description of the Bisbee exposures directly south of the town of Tombstone although he states that a complete section of this rock unit cannot be determined. Gilluly (1956) also gives a composite section of the Bisbee formation, at the base of which the novaculite number, composed of a quartzite-like material with calcite, lies unconformably on Paleozoic limestones. Above the novaculite lies the blue limestone, an important ore producing bed near the town of Tombstone. Above the blue limestone are nearly 3000 feet of shales, sandstones, and limestones, all somewhat metamorphosed. This author was unable to distinguish the various members, although Butler reported lenses of limestone similar to the blue limestone member outcropping near the Randolph mine. As seen near the Sailor mine, ore was found in the fissure zones in both the Bisbee sediments and the Uncle Sam porphyry and it did not appear that the ore minerals in this area replaced the Bisbee group preferentially with respect to the Uncle Sam porphyry. The Mamie, Bonanza, and Randolph mines are a few of the small turn-of-the-century silver and gold producers located in the Bisbee group. In 1967, the Escapule mine produced ore from the Bisbee group.

Bronco Volcanics

Slightly younger than the Bisbee group, but older than the later intrusives, are the Bronco volcanics. Supposedly at the outset of Laramide activity, extrusive volcanics were laid down, before the subsequent intrusives. These flows appear as the Bronco volcanics
and are quite extensive around Charleston and the western Tombstone district. The southern portion of the Charleston Lead mine area is largely covered by these volcanics. Two distinct members exist. The lower and older is a dark gray, almost purplish andesite flow breccia which is well shattered in all its exposures around the Charleston Lead mine. Small phenocrysts of plagioclase can be observed in hand specimens, along with sparse phenocrysts of hornblende of nearly the same 1-4 millimeter size. Over 70% of the rock is dark aphanitic groundmass. This unit was too shattered to determine any accurate flow directions. The dike containing the vein of mineralization which supported the Charleston Lead mine is surrounded by this andesite.

Directly above and younger than the andesite is the quartz latite member which in some areas is a quartz latite tuff. Almost white or light gray, it is easily distinguished from the darker andesite. Small phenocrysts of quartz with a little red-brown biotite exist in a white devitrified microcrystalline groundmass. In the stream north of the Charleston Lead mine boulders of what appear to be Bisbee group sediments occur as blocks in the latite, indicating at least it is post Bisbee. The only mineralization that occurs in the quartz latite in the Charleston Lead mine area is a small vein of black calcite.

Uncle Sam Porphyry

The Uncle Sam porphyry is exposed in large portions of both of the mapped areas. It is probably genetically related to the
Schieffelin granodiorite although it is a little older. The Schieffelin granodiorite was dated as 72 million years old by Creasy (1962), placing it in the Laramide or late Cretaceous. The rock is considered an intrusive quartz latite porphyry (Gilluly, 1956) and invades both the Bisbee group and the Bronco volcanics. Where it lies in contact with the Bronco volcanics in the stream north of the Charleston Lead mine it is itself altered by contact with pre-existing rock from a few feet to tens of feet and becomes soft and crumbly when eroded. It is gray in the Escapule mine area to pinkish gray near the Charleston Lead mine. Upon weathering it changes color to a rusty brown. Plagioclase, being 1-8 millimeters long, biotite, and less common hornblende phenocrysts are most diagnostic in a fine grained groundmass. Some small quartz phenocrysts can be seen. Inclusions make up 3-5% of the mass. Gilluly (1945) believes the intrusive to be a roughly laccolithic sill which extended laterally along either a thrust fault or an erosional surface. As evidence he cites two factors; first, the enormous size of the intrusive and its unusually fine grained nature; second, the abundant and evenly distributed inclusions. He also notes that the State of Maine shaft penetrated a considerable body of shale on the 600 foot level, but several large rafted sedimentary bodies were noted by this author to be isolated in Uncle Sam porphyry on the surface near this mine. Gilluly (1945) attributes the relatively mild contacts of the intrusive to an inherent lack of volatiles.
The contact between the dark Uncle Sam Porphyry and the lighter Bronco volcanics quartz latite member in the stream bed one-fourth mile north of the Charleston Lead mine. The darker Uncle Sam porphyry has been altered by intrusions into the older volcanics and in this spot is about two feet wide.
The mass of Uncle Sam porphyry near Charleston appears to be a laccolith, first by the physical expression of the hills at Charleston, made up of the porphyry, and secondly, by the quartz latite member of the Bronco volcanics which north of the Charleston Lead mine dips away from the hill of Uncle Sam porphyry. Throughout this porphyry strong cleavage planes are well developed, so the intrusive erodes into shoe-box and larger sized blocks. A predominant joint direction of north 30-60 degrees east was observed in the areas studied, as is discussed later.

Some silver and gold precious metal production has come from mines in the Uncle Sam porphyry. The State of Maine, Merrimac, Sailor, and Mustang were a few in the two areas studied.

Andesite Porphyry Dikes

A rock unit younger than the Uncle Sam and most likely older than the Schieffelin granodiorite is the dike-forming andesite porphyry. In the two areas studied, parallel andesite porphyry dikes cut across both the older Bisbee group and the Uncle Sam porphyry, not varying in strike much from north 35° east in the Escapule mine area, and north 55° east in the Charleston Lead mine area. They appear to have, at least in the two areas studied, more importance in controlling ore fluids than has been previously indicated. Gilluly in 1956 states that there are at least two ages of andesite porphyry present, but his casual study did not lead to a separate discussion. He states that one andesite porphyry dike is cut off by the Schieffelin
FIGURE 6

ANDESITE PORPHYRY DIKE ROCK

A weathered specimen of the andesite porphyry dike rock, showing the white plagioclase phenocrysts.
granodiorite (K-AR dated 72 million years old by Creasy, 1962) although they are present in the Uncle Sam porphyry, indicating the Schieffelin granodiorite to be younger than the Uncle Sam. He also mentions that north of Comstock Hill, just west of the town of Tombstone, a few badly altered dikes composed of hornblende andesite porphyry cut the Schieffelin granodiorite. These possibly are the same dikes seen in the areas studied, although he states that they were so altered he could not compare them satisfactorily with other andesite porphyry units and that their relation to the Schieffelin is not well understood. Finally, he mentions several narrow dikes and pipe-like masses exist that cut the Bronco volcanics, and which are possibly related to the Schieffelin granodiorite but younger.

All the dikes in both the areas studied by this author had the same petrographic appearance. They are composed of a grayish rock which turns almost green when exposed to extensive weathering. The dike rock has distinctive phenocrysts of plagioclase up to six millimeters, and hornblende altering to chloritic aggregates. The plagioclase phenocrysts become chalky white when exposed to weathering. Gilluly (1956) states that the texture is pilotaxitic and the andesite porphyry has been hydrothermally altered, and in thin section is composed of epidote, sericite, chlorite, and calcite with only relicts of original minerals including andesite-labradorite and magnetite. Structurally, in both square mile areas, dikes of this andesite cut across the Uncle Sam porphyry, Bronco volcanics, and the Bisbee group. All the dikes strike in a similar direction,
are commonly associated with a hydrothermally altered zone, and are not uncommonly mineralized. The vein of the Charleston Lead mine is in hydrothermally altered andesite dike material. These dikes are pre ore and definitely an ore control. They are not to be confused with the north-south striking granodiorite dikes, also pre ore, which establishes a strong ore control in the Tombstone basin district just south of the town of Tombstone. The andesite porphyry dikes were most likely intruded into planes of weakness caused by structural deformation after the intrusion of at least the Uncle Sam porphyry. A plug of this andesite porphyry outcropping over about 1000 feet square is said to exist (Gilluly, 1956) some 2.5 miles south of the Charleston Lead mine; it is referred to by local miners as the "Blow-out."

The dike at the Charleston Lead mine is definitely an ore control, and the fluids forming the vein have largely replaced the dike material with sericite. Outcroppings of dike material are also found along the State of Maine vein, as well as in the Bonanza and Escapule workings. Possibly dike material also occurs in other mines in the district, as local miners insist, but the dikes show no topographical relief and the outcrops that exist are altered and non-resistant. Except where erosion or mine workings have recently exposed the dikes, identification is difficult.

Quaternary Alluvium

Quaternary alluvium covers large areas in the Charleston Lead mine area; and in the northwestern portion of that area it is
perhaps 50 to 100 feet thick. Only in the north part of the Escapule mine, however, does one find even a few feet of alluvium. An area of alluvial material was mapped as alluvium only if there were many different rock types present on the surface in order to differentiate it from Bisbee float, for instance. Usually there is a change in vegetation marking the onlap of alluvium. The lighter colored alluvium on the Uncle Sam porphyry was quite distinctive. In the western part of the Charleston Lead mine area recent stream alluvium was mapped where it obscured the Uncle Sam porphyry and Bronco volcanic contact.

Structure in the Square Mile Areas Studied

General

An important structure in the Tombstone district is the Tombstone basin, the most productive portion of the district consisting of a syncline-like mass of Mesozoic and Paleozoic sediments located just south of the town of Tombstone (see figure 1). Another large structure is an upthrown block of Paleozoic sediments southeast of the Escapule mine area called the Ajax Hill horst. Separating the downdropped synclinal group of sediments forming the Tombstone basin and the Ajax Hill horst, striking roughly east-west, is the Prompter fault. The south side of the Ajax Hill horst is formed by the Horquilla Peak normal fault. These structures, and other important structures of the Tombstone district, are dealt with in considerable detail by Butler (1938) and Gilluly (1956) and will not be dealt with here since none of them projects into the specific areas studied.
Layered Rocks - Bisbee Formation

There are no outstanding structural features in the Bisbee formation in the Escapule mine area like those in the more productive part of the district. The synclines and anticlines (rolls) so favorable to ore fluids in the Tombstone basin appear to be absent here although the size of the Escapule mine area precluded the noting of such large scale structures. The hill of Bisbee group sediments in the east portion of the Escapule mine area dip northeast and most other Bisbee sediments seem to show an easterly dip. The large block in the northwest of this district clearly dips in a northeastward direction. It might be noted that in several areas the highly fractured Bisbee group sediments were covered with float and blocks of Bisbee which often made an accurate dip reading impossible. Strong joints also led to ambiguity, but more resistant members and members of obviously different composition were occasionally observed which permitted reasonably accurate dip recordings. Both Butler (1938) and Gilluly (1956) mentioned that Bisbee sediments encountered at depth in the State of Maine mine exist at the same level as those one-half mile farther north. If, indeed, they are the same Bisbee sediments, they should continue under the outcropping Uncle Sam porphyry. Northeast fissure zones cut the Bisbee as well as all other consolidated rocks in both of the areas studied.
Bronco Volcanics

Very little structure was seen in the Bronco volcanics. The andesite member is inclined to shatter into pieces around an inch in size in several places. It was also difficult to find mappable structure even in the latite which did not fracture as easily but was largely covered by blocks of latite rubble. In several outcrops along streams, cleavage, and rarely flow direction, could be discerned. The contact between the two members is clear in the stream north of the Charleston Lead mine where the quartz latite member dips north, away from the hill of Uncle Sam porphyry. Several dikes and mineralized fissures, all of which were striking nearly north 55 degrees east, were observed in these volcanic units. The dike with this N55°E strike at the Charleston Lead mine has been both altered and mineralized.

Emplacement of Igneous Bodies

Uncle Sam Porphyry

As discussed above, the Uncle Sam porphyry is believed by Gilluly (1956) to be a sill-like igneous intrusion, injected along a thrust fault plane or an erosion surface. Butler (1938) believed that in eastern exposures of Uncle Sam, including that in the Escapule mine area, the underlying porphyry is a series of injected sills or laccolithic bodies and in western exposures, which would include the Charleston area, the Uncle Sam was probably intruded as a stock-like body. The author's observations tend to confirm
Butler's. Although it contained numerous inclusions and its texture appeared relatively, but not extremely, fine grained for the size of the igneous body, it did not contain large sharp xenoliths in the Charleston area like those of Bisbee group blocks incorporated in the Uncle Sam porphyry in the Escapule mine area. However, small xenoliths, on the order of a few inches or less, at the porphyry contact with the Bronco volcanics were noted which leave six inch spherical blocks of hybridized Uncle Sam around them. Bisbee formation or volcanic blocks were seen in the Uncle Sam away from this contact area in the Charleston Lead mine area, a relationship which would lead to the belief that the porphyry in that area was rather massive and probably a large stock-like body.

A pervasive northeast jointing exists with almost all the planes dipping at steep angles. Commonly, altered "fissure zones," not necessarily mineralized but displaying an altered and bleached appearance due to some sericitization of the Uncle Sam by hydrothermal fluids, cut through the porphyry along the same strike as the joints. Andesite dikes, usually only a few feet in width, also cut the porphyry in several locations on a northeast-southwest strike and small patches of this dike material could almost always be found near one of these altered and northeasterly striking fissure zones in the Uncle Sam. Prospect pits were common in these altered zones but only a few produced any precious metal, for instance the small Mustang mine in the Charleston Lead mine area.
Andesite Porphyry Dikes

The only other intrusives seen in the area were the andesite porphyry dikes. The outstanding structural feature of these dikes is the northeast-southwest strike of the individual dikes. Most surface outcrops are weathered rubble. Directly east of the Charleston Lead mine one of these dikes strikes north 55° east, is about 10 feet wide and appears to be largely unaltered by weathering. Some indications of hydrothermal activity are present, however. No strong direction of cleavage was noted in this dike parallel to its direction of strike, perhaps indicating that it was injected after regional forces had formed the pervasive northeast-southwest steeply dipping joints. Miners in the area state that these dikes can be followed along strike for miles, although this author could only trace outcrops of andesite porphyry material along strike for hundreds of feet in several places. Often a particular dike seemed to disappear under the surface debris and could not be picked up again along the strike a few hundred feet beyond. These dikes are pre ore, and in places altered by hydrothermal solutions as observed at both the Charleston Lead mine and in a trench west of the Escapule mine. These two areas were drawn up in the schematic diagrams shown in Figure 7.

Lead, zinc, and copper mineralization occurs in the altered dike at the Charleston Lead mine, but negligible ore value is recorded in the dikes near the Escapule mine. Apparently, the dikes have been offset at depth by later faulting as described by miners in the area.

Particular zones of dikes seen at the surface are composed of individual
FIGURE 7

A) DRAWING OF THE CHARLESTON LEAD MINE

Schematic diagram of the west face of the Charleston Lead mine in the Charleston area.

B) DRAWING OF A TRENCH NEAR THE ESCAPULE MINE

Schematic diagram of the west face of a trench near the Escapule mine in the Tombstone area.
Altered Iron oxide (oxidation of pyrite)
Pb(Anglesite) / Bronco volcanic andesite
Andesite porphyry dike
Pods of chalcocite (Secondary Enrichment)
Sericite
Altered andesite porphyry dike
Iron oxide (oxidation of pyrite)
Pb(Anglesite)
Altered dike
Andesite porphyry dike
High metal values
Bronco volcanic andesite
Uncle Sam porphyry
Altered zone
Ore fluids

FIGURE 7. A) DRAWING OF THE CHARLESTON LEAD MINE
B) DRAWING OF A TRENCH NEAR THE ESCAPULE MINE
parallel striking dikes of random spacing over a small area. This can be observed both at the Charleston Lead mine and the Escapule mine. This random spacing of the individual dikes does not mean, however, that there is no uniformity in the spacing of the stronger zones themselves. With the exception of the hundred-foot-wide dike at the Charleston Lead mine, all those observed were less than thirty feet wide.

Northeast Ore Fissures

Butler (1938) described the northeast ore fissures as existing in both the Tombstone basin and in the western part of the district. The fissures in the eastern part of the district dip to the east and those in the western part of the district, which here includes the Escapule mine area, dip to the west.

Several points are made by Butler about these fissures. First, they cut all rock units older than the Cenozoic. Second, they show very little displacement. Third, they seem to be made up of fissure zones rather than compression. He also mentions that they trend nearly at right angles to the folds in the Tombstone basin and that these fissures tend to work into the strike of the granodiorite dike and follow them along this strike a short way before resuming their normal northeastward strike at an acute angle to the strike of the granodiorite dikes. These last two observations concerned the Tombstone basin which was not studied by this author, but the other observations made by Butler were confirmed in the
mapped areas. In addition, a regional jointing parallel to these fissure zones, particularly noticeable on large outcrops of Uncle Sam porphyry, was determined in both areas studied. Several rock slabs on the dump of the northernmost shift along the Bonanza fissure showed slippage along parallel cracks an inch or so apart. Small blocks of breccia were also noticed on the dump. Both these specimens consisted of Bisbee limestones and hornfels. In the State of Maine mine, the ore is reported by Butler (1938) to have occurred as replacement of Uncle Sam porphyry along a northeasterly trending fissure zone which dips $40^\circ$ northwestward at the surface. Quite possibly the Charleston Lead mine vein becomes a fissure type vein deposit in the Uncle Sam porphyry underlying the volcanics, the fluids being concentrated in the andesite porphyry dike rock near the surface due to the generally unfavorable ore controls in the Bronco volcanics on both sides of the dike near the surface of this area. Some ore fluids have extended laterally from similar fissures to replace favorable sedimentary beds in the Tombstone basin. Throughout the Tombstone district, structure has had tremendous controlling influence on the ore fluids and to date has been the major guide for exploration.

Joint Pattern Study

Both the two square mile areas were covered taking the dip and strike of prominent joint planes. The data was plotted up on Rose diagrams and pole plot diagrams (figures 10 and 11). Only planes persistent through several outcropping blocks were measured.
FIGURE 8

SLIP ALONG THE FISSURE VEINS

A specimen taken from dumps in the northeast Bonanza fissure vein showing small amounts of slip along closely spaced plane in a hornfelsic member of the Bisbee group.
FIGURE 9

OPEN SPACE FILLING IN THE FISSURE VEINS

A specimen taken from dumps in the northeast Bonanza fissure vein showing open space filling with white calcite in a breccia of Bisbee group sediments.
FIGURE 10

STRUCTURAL DIAGRAMS OF THE CHARLESTON LEAD MINE AREA

A) A Rose diagram showing trends of the azimuths of joint planes in the Charleston Lead mine area.

B) This diagram shows the joint planes in the Charleston Lead mine area on a pole plot.
FIGURE 10. STRUCTURAL DIAGRAMS OF THE CHARLESTON LEAD MINE AREA
FIGURE 11
STRUCTURAL DIAGRAM OF THE ESCAPULE MINE AREA

A) A Rose diagram showing the regional trends of the azimuths of joint planes taken in the Tombstone area.

B) This diagram shows the joint planes taken in the Charleston area or a pole plot diagram.
FIGURE 11. STRUCTURAL DIAGRAM OF THE ESCAPELE MINE AREA
FIGURE 12

JOINTING IN THE UNCLE SAM PORPHYRY

The view of the Uncle Sam porphyry looking northeast a few feet from the contact with the Bronco volcanics. These strong joints are probably related to the original intrusion of the Uncle Sam and the later northeast-southwest jointing is less obvious at this spot being so close to the contact. It does, however, show the inclination for jointing in the Uncle Sam porphyry. The two strong directions here are north 80° east and north 75° west, both vertical.
Where two or more equally persistent planes existed, they all were recorded. Locations for measurements were chosen on the quality of outcrop. Extremely fractured rock was not measured unless an obvious joint direction existed. Ingerson (1939) states that the joints in the Uncle Sam are nearly random in orientation of azimuth but they all seem to dip steeply. After taking 61 dip and strike measurements on the joints in the Charleston Lead mine area and 82 in the Escapule area, a definite preferred orientation of azimuth in the jointing pattern and direction of dip is revealed. The pattern is not obvious in the field without close examination. In the Escapule mine area the strongest direction is north 30-40° east and in the Charleston Lead mine area north 50-60° east. The joints of the Escapule mine area show a general steep dip to the northwest and there is a slight preference for steep dips to the southeast in the Charleston area. It is important to note that the fissures in the Escapule mine area dip steeply to the northwest and those in Charleston area dip to the southeast. These structural similarities would seem to indicate that the joints and fissures are genetically related, both formed by gentle regional tension. The majority of these readings were taken in Uncle Sam porphyry, which occupied the majority of the outcrop area, although a number were taken in the Bronco volcanics and the Bisbee sediments with no apparent change in orientation other than perhaps a slight refraction.
Possible Relations of Observed Structural Features

It seems likely that regional forces resulted in uniformly spaced slips or fissures along a preferred jointing orientation. The joints were observed to cut all the rock units in the area studied, including the Schieffelin granodiorite (Butler, 1938). The one exception, however, is possibly the andesite porphyry dikes where they were not observed. It is possible that regional tectonic forces occurred after the major intrusions and after the regional preferred jointing. Slip along these preferred joints caused the fissures. Subsequent dikes of andesite porphyry were injected into the fissures and were followed by hydrothermal fluids in certain favorable areas. The age of the andesite porphyry dikes is somewhat questionable. As noted above, Gilluly (1956) states that several dike ages are present, one earlier than the Schieffelin granodiorite and one possibly later than the granodiorite. A detailed investigation over a larger area would probably resolve this question, but it appears to this author that the andesite dikes in the areas studied represent only one age. They are younger than all the other consolidated rock types.

Mineralogy of the Areas Studied

General

The mineralogy of the various rock units in the area is discussed under the geology of those rock units and a complete list of all minerals in the Tombstone district is given by Butler (1938).
This section will primarily deal with the observed ore minerals and related gangue. Many of the workings in the area were not safe and therefore were not investigated. Two workings, however, were accessible, the Escapule mine in the Escapule mine area, and the Charleston Lead mine in the Charleston Lead mine area. A few others such as the Mustang mine northeast of the Charleston Lead mine and records on the State of Maine mine yielded some additional information.

The Escapule mine is typical of the older workings in the area and is a good representative of the numerous small precious metal mines once producing there. The Charleston Lead mine, on the other hand, is primarily a non-metallic sericite producer, also producing lead, zinc, some copper, and silver.

Assuming the lead-zinc mineralization at the Charleston Lead mine to be the ore, there is a difference between ore in the Escapule mine and the Charleston Lead mine ore, although it is quite likely that these two workings, four miles apart, are genetically related.

The Escapule Mine and the Tombstone Area

The Escapule mine was a producer of silver and small amounts of gold in 1967. Exact figures were not obtainable, but approximately ten pounds of precious metal precipitate can be produced by the cyanide process per working day. The ore is chiefly what the miners call horn silver or cerargyrite but determination with X-ray diffraction methods proved it to be bromyrite, the only difference
being in the halide ion in ionic bonding with the silver ions. Bromyrite is a characteristic oxide zone mineral. The greenish bromyrite, which turns black on exposure to light, occurs above the water table associated with chalcedony, native silver, quartz, hydrous manganese oxides, calcite, limonite, and sericite in, for the most part, open space fillings. In high grade specimens, wires of moss-like bromyrite would spread out into the open cavities. An analysis of the bromyrite (Butler, 1938) showed that it also has small amounts of iodine substituting for chlorine. The results given were 0.6% Cl, 38.9% Br, 2.6% I, and 56.7% silver. Small nuggets and vein fillings of native silver are occasionally found in the mines. Hydrous manganese oxides in calcite (black calcite) found in the Escapule mine contain some silver, but it is apparently subeconomic. Hessite (Ag₂Te) is found in the Tombstone basin mines but was not seen here. Neither was the supergene silver-bearing stromeyerite or primary silver-bearing tetrahedrite, although they have been reported in the Tombstone basin. The Escapule mine yielded one small cube of galena with a surrounding layer of anglesite and some associated chrysocolla, but sulfides are rare. Several vanadium minerals were present. Incrustations of mottramite $\sum Pb' (Ca,Fe)OH \cdot (VO₄)_3^{-}$ of a dull greenish color were present. Some green-blue stains resembling copper stains were also determined by X-ray to be a vanadium oxide mineral and small black prismatic crystals on the mottramite appeared to be vanadinite. The above mineral assemblage is unquestionably an oxide
zone assemblage and the ore values, as in all the other mines, are reported to drop off at the water table. The most common gangue mineral is silica, either in colloform crustifications or as crystalline quartz lining open cavities and forming vein fillings. Iron oxides, calcite, sericite, and hydrous manganese oxides appear as gangue material along with the altered rock units. Dumps at other mines in the Escapule mine area indicated a similar mineral assemblage as the Escapule and State of Maine mines.

The high bromine and iodine content of the silver halides is difficult to explain as resulting simply from meteoric waters. Vinogradov (1959) states that the basic source of all halogens is volcanic gases. The average Cl:Br ratio is about 300 in natural waters, meteoric precipitations, and rocks and 200 in crystalline rocks, while the Br:I ratio ranges between 10 and 20. The Cl:Br ratio in the bromyrite from the Tombstone district is 0.015 and the Br:I ratio is 150. Vinogradov furthermore states that solubility has no effect on the Cl:Br ratios under natural conditions. However, a process of sorption of Br and I by organic material in muds, soils, and especially peat, can concentrate Br and I, although it does not effect the Cl. Ratios associated with organic matter can reach 10-20 for Cl:Br and 1-0.01 for Br:I. Since there is not an abundance of organic material in the Tombstone district, the exceptionally high Br:I ratio can possibly be explained by relatively large amounts of Br and I in the original hydrothermal solutions, remobilized by meteoric waters.
The absence of evidence for large amounts of primary sulfide mineralization, and the presence of chlorite in the altered dike rock (Gilluly, 1956), indicate a low temperature environment compared to a higher temperature sulfide assemblage characteristic of the more productive mines in the Tombstone basin. Gold appears in the ores of the State of Maine mine at about a 184:1 silver-gold ratio which compares to a nearly 180:1 ratio over the entire district. The State of Maine values were calculated from assay values taken in 1915 by Phelps-Dodge (see Table I). Most of the gold elsewhere in the district is apparently associated more with the late sulfides than with the earlier ones (Butler, 1938) and most gold production over the entire district has come from a few mines about one-half mile southwest of Tombstone. Silver production, on the other hand, has been fairly uniform over the Tombstone district.

Charleston Area Black Calcite

Mineralization in outcropping Uncle Sam porphyry as seen at Mustang mine and other insignificant altered vein showings in the Uncle Sam porphyry in the Charleston area contained approximately the same mineral assemblage and high grade silver halide ore as the Escapule mine. One particular polished vein filling from the Mustang mine dump showed a 1.5 inch vein of chalcedony with vugs of crystalline quartz in the center. Sericite alteration in the porphyry was present but less manganese staining was present here than in most mines in the Escapule mine area. One old shaft at the southern edge of the
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<td>3rd</td>
<td>--</td>
<td>196</td>
<td>2.06</td>
<td>0.023</td>
<td>3.50</td>
<td>152/1</td>
</tr>
<tr>
<td>4th</td>
<td>--</td>
<td>199</td>
<td>1.80</td>
<td>0.019</td>
<td>4.35</td>
<td>229/1</td>
</tr>
<tr>
<td>7th</td>
<td>325</td>
<td>178</td>
<td>1.29</td>
<td>0.012</td>
<td>3.27</td>
<td>273/1</td>
</tr>
<tr>
<td>3rd (high grade samples)</td>
<td>4</td>
<td>465.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Charleston Lead mine was on a vein which occurred in the outcropping quartz latite member of the Bronco volcanics. Barite, siderite, quartz, black calcite, white calcite, hydrous manganese oxides and serite alteration were observed on the dump. Observations of the paragenesis of the black calcite agree with those made by Hewett and Radtke (1967) on their silver bearing black calcite specimens where the earliest mineral is quartz, forming small crystals, second is manganese oxide, and finally white calcite, forming consecutively layered encrustations on the initial quartz crystals. Open space filling predominates. A second article by Radtke (1967) describes three silver-bearing hypogene manganese oxides in black calcite: aaurorite, argentian todorokite, and hydrous silver-bearing lead manganese oxide. This article describes them as being regionally associated with cerargyrite, native silver, calcite, pyrolusite, and several other minerals in layered volcanic or intrusive igneous rocks of Laramide to mid-Tertiary age. The point to be made here is that this black calcite is most likely a hypogene black calcite mineral assemblage of the type described by Hewett and Radtke and quite possibly the black calcite is originally responsible for much of the silver values in all these small high grade precious metal mines of both the Escapule and Charleston Lead mine areas. Up until this recent work, the mineral source for all the silver, where sulfide mineralization is rare in these areas, has been a perplexing problem. Oxidized hydrothermal silver-bearing black
FIGURE 13

THE MUSTANG MINE

A view of the silver producing Mustang mine looking southwest nearly a mile to the Charleston Lead mine (Ch). This vein strikes N 55° E and dips to the southwest in Uncle Sam porphyry.
calcite veins would certainly explain why the values drop off rapidly at the water table in the precious metal mines as the deeper unoxidized primary silver-bearing black calcite is encountered since concentration of silver by leaching and oxidizing of gangue minerals prevalent in the oxide zone would no longer exist beneath the water table. Black calcite itself can contain as much as one percent silver and the black residue remaining after solution of the calcite can concentrate the silver up to 1,500 ounces to the ton (4.7%). Usually black calcite contains less than one ounce per ton and has been associated with lead-zinc mineralization (Hewett, 1967). Throughout both areas studied, black manganese oxides could be recognized on the dumps of the small precious metal mines. Black calcite was noticed particularly with veins in outcropping Bisbee group sediments and with small veins in the Bronco volcanics. Dumps at mines in outcropping Uncle Sam porphyry showed abundant staining by manganese oxide minerals although black calcite was rarely seen. Referring to the Tombstone basin, silver occurs in ores high in manganese, but some ores high in manganese contain little silver. High lead contents may or may not be accompanied by high silver values (Butler, 1938).

Charleston Lead Mine

Mineralization at the Charleston Lead mine consists of galena, sphalerite, and pyrite with lesser amounts of chalcopyrite and secondary chalcocite. Silver, apparently in solid solution in the galena, amounts to at most 2.6 ounces per ton and averages
FIGURE 14

THE CHARLESTON LEAD MINE

A view looking nearly due west of the quarry of the Charleston Lead mine. The vein is in altered andesite porphyry dike, strikes N 55° E and dips to the southwest. A continuation of the vein can be seen at the right or north wall and the darker andesite member of the Bronco volcanic at the lower left.
somewhat less than an ounce per ton with 0.01 ounces of gold. The sulfides are fine grained, small, often euhedral crystals with open spaces present in ore specimens. Anglesite is common near the surface and chalcocite pods are encountered at less than 50 feet from the surface. Little copper staining is observed, and oxidized iron staining observed alongside the altered vein is not extensive.

The most outstanding feature at the Charleston Lead mine is the alteration of the andesite porphyry dike to a commercial grade of sericite in a zone up to 50 feet wide in places. Analysis of this sericite showed a sample to be 97% sericite and the remainder composed of minor amounts of sphene, tremolite, hematite, and calcite with traces of the elements lithium and titanium. Chemical analysis of the sericite, courtesy of the James Stewart Company, shows the following:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO$_2$</td>
<td>45%</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>38.4%</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>0.56%</td>
</tr>
<tr>
<td>CaO</td>
<td>0.13%</td>
</tr>
<tr>
<td>MgO</td>
<td>0.18%</td>
</tr>
<tr>
<td>Na and K oxides</td>
<td>9.92%</td>
</tr>
</tbody>
</table>

The intense sericitization here is a replacement of andesite porphyry dike rock, and second to more abundant mineralizing fluids.

Values of the ore in dollars per ton, projected with increased silver prices, are given in Figure 15. An assayed sample by the
FIGURE 15

VALUES IN THE CHARLESTON LEAD MINE

This table represents assay values in dollars per ton for lead, zinc, and silver values at the Charleston Lead mine where the silver values are given at the present price and several projected prices. The samples were taken from a hole that was cut diagonally across the vein.
(Pb + Zn) + Ag at $2.50/oz.
(Pb + Zn) + Ag at $1.75/oz.
(Pb + Zn) + Ag at current $1.30/oz.

Zn at 14.5¢/lb., New York
Pb at 14¢/lb., New York

Prices for May, 1967 quoted.

**Figure 15. Values in the Charleston Lead Mine**
James Stewart Company ran as follows:

<table>
<thead>
<tr>
<th>Sulfide</th>
<th>Non-Sulfide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>0.018%</td>
</tr>
<tr>
<td>Lead</td>
<td>0.44%</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.13%</td>
</tr>
<tr>
<td>Iron</td>
<td>0.43%</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.41%</td>
</tr>
</tbody>
</table>

A schematic drawing across the vein (Figure 15) indicates higher metal values close to the hanging wall and the foot wall of the vein.

The mineral assemblage here is different than that of the surrounding deposits which are entirely silver-gold producers. Alteration is pervasive in the andesite porphyry dike wall rock along the vein. Few metal values are recovered from the altered dike rock at the Escapule mine whereas here the mineralization is in the altered dike material. The Charleston vein strikes north 55° east and dips southeastward, values consistent with all the other nearby fissure veins and indicating that they are structurally related.

On the east face of the quarry a large block of sericite gives the impression that the vein continues east-west, as mapped by Gilluly (1956). Actually the block of sericite dips to the northwest and apparently represents an area where the rising solutions have moved along a zone of weakness or fracture toward the hanging wall. The block is a small feature and does not continue for any length
along strike. The pyrite-lead-zinc mineral assemblage, intensive sericitization, association with the large dike, and an almost complete lack of an oxide zone development, make it possible to consider this vein genetically different than the surrounding veins. However, its conformity to the regional structure, the sericite alteration with some pyrite, and limited open space lead-zinc mineralization led this author to the opinion that the Charleston Lead mine and the other northeast striking veins are genetically related. Andesite porphyry dike rock at the Escapule mine is also altered and sericitized, but to a lesser degree. Here the andesite volcanics, being unfavorable to these solutions themselves, may have channeled the rising solutions into the dike rock or post dike movement in the dike itself may have created a favorable zone. The size of the dike could indicate a larger structure and a tapping of slightly higher temperature lead-zinc bearing fluids perhaps earlier but of the same basic regional mineralizing period. Subsequent cooler mineralizing solutions deposited the silver-rich black calcite, quartz, colloidal silica, primary manganese minerals and other low temperature minerals in less prominent zones of weakness.

Regional Distribution and Relations of the Ores

After looking rather specifically at the geology, structure, and mineralogy of the specific areas studied, it would follow that a broader look at certain geologic features might relate the specific areas studied to the entire district which can then be classified and
related to other districts for an appraisal of the silver producing capabilities of the Tombstone-Charleston district.

Ore Control

Over the entire Tombstone-Charleston district the chief ore control is structure. Only in the Tombstone basin is lateral replacement of favorable beds important. Limited replacement of structural zones of weakness occurs along, and occasionally in, the andesite porphyry dike rock, in the Uncle Sam porphyry, and in the Bisbee group, but open space filling generally seems to predominate in the two areas given detailed study.

Fissure zones formed where small amounts of slip occurred along closely spaced parallel joint planes. The formation of the zones was accompanied by some brecciation, especially in the brittle, somewhat metamorphosed limestones and hornfels of the Bisbee group. Occasionally, intrusion of small andesite porphyry dikes along these joint planes, which incidently are parallel to the regional joint pattern, also accompanied the formation of these zones. The fissure zones themselves seem to be uniformly spaced enough to represent gentle tensional movement over a rather large area. The rising ore-bearing solutions frequently found the more permeable zones along the dikes a favorable environment, filling open spaces and replacing a limited amount of brecciated wall rock. It might be noted that the dikes themselves seem to have found these zones of weakness to be favorable intrusion planes prior to the advent of ore solutions.
Therefore, in summary, pervasive alteration, brecciated zones, general lack of base metals, and low temperature mineral assemblages characterize these areas. Much of the economic ore has been concentrated by meteoric waters in the oxide zone above the water table. The silver halides are very stable under a wide range of near surface Eh-pH conditions. Stronger planes of structural weakness as at the Charleston Lead mine appear to have tapped a higher temperature mineral assemblage where low silver values are apparently only present in solid solution in galena. In the lower temperature veins throughout the two areas studied, mineralizing fluids with silver bearing manganese minerals in calcite account for one possible source of primary silver. Minor amounts of lead mineralization, with pervasive alteration, open space filling, chalcedony, calcite, and uncommon barite, indicate epithermal mineralization. The Tombstone basin district to the east of the areas studied has abundant replacement and sulfide mineralization which is indicative of higher temperature mesothermal ore fluids. The andesite porphyry dikes, fissure zones, and the predominant north 30-60° east jointing suggest a strong regional structural control in the areas studied. Structural control along north-south granodiorite dikes and large fault zones of the Tombstone basin also represent similar strong structural control but in a higher temperature mineralizing environment.

Zoning

By examining the mineralogy and gold-silver ratios perhaps a crude zoning exists in the Tombstone district which can be extended
several miles westward to include the area near Charleston. A general lack of accurate records and quantitative data for the mines in the district make a completely accurate picture impossible. Butler (1938) describes the highest gold values as occurring near the Lucky Cuss-Herschel zone about one mile due southwest of the center of the town of Tombstone and almost two miles due east of the Merrimac mine in the Escapule mine area. Here the silver-gold ratios reach nearly 100:1, as recorded near the shaft on the fourth level of the Lucky Cuss. This ratio compares with an overall district figure of about 180:1 calculated from the total ore values 1930-1936. A systematic silver:gold ratio analysis as carried out by Nolan (1935) for Tonopah, Nevada, has not been performed at this district and would be useful. Assay values in ounces of gold per ton are rare and the more common dollar per ton total gold production records are also spurious due to both incompleteness and reliance on complete metallurgical extraction of gold. The fact that most of the gold production came from a few mines on the west side of the Tombstone basin, including the Lucky Cuss-Herschel district, does, however, indicate that there is a lower silver:gold ratio there than in the surrounding districts, and it can be considered a high gold zone. Butler reports that in this gold bearing zone the highest values are near the northeast fissure zones and the gold values drop off in the replaced sedimentary units.

The only obtainable silver-gold ratios in the two areas studied was the 184:1 silver-gold assay reported for five levels
in the State of Maine mine and a channel sample taken across 145 feet in an open pit adjacent to the mill at the Charleston Lead mine which reported 0.01 ounces of gold and 0.20 ounces of silver per ton. The high 20:1 silver-gold ratio here is due to a lack of silver rather than an abundance of gold since the gold per ton is just a little less than 0.018 ounces per ton at the State of Maine mine.

In a review of Butler's work, Tenney (1938) noted a crude zoning of the entire Tombstone district. A central high gold-fluorite-silica-molybdenum zone existed in the Tombstone basin at the northeast part of the district. This zone was surrounded by a predominantly silver zone (including most of the Escapule mine area) and a manganese, silver and copper zone to the south and southwest of the district.

Observations by this author were incomplete since they were restricted to the two square mile areas. Little variation was noticed in the mineralogy of the mapped Escapule mine square mile that could be attributed to zoning. However, the San Pedro mine, in Uncle Sam porphyry one-half mile northwest of the State of Maine mine, is reported to have more manganese and quartz than the State of Maine (Butler, 1938). Suites of sulfides were examined from the Tombstone basin and evidence of similar massive sulfides did not exist in the areas studied but neither were the favorable anticlinal or synclinal structures present in the sedimentary beds. Several small fissures in the Bronco latite, filled with chalcedony, black and white calcite, with quartz, did differ markedly from the Charleston
Lead mine mineralization and the large dike associated with it. Just south of the Charleston Lead mine area a small six inch vein with malachite and crysocolla was observed but it apparently did not continue to any depth as the prospect pit is shallow and abandoned. In summary, there appears to be a crude zoning in the Tombstone district with the most intense mineralization in the northeast portion of that district around the Tombstone basin with roughly lower temperature zones consecutively outward placing the Escapule mine area in the predominantly silver zone. In the Charleston Lead mine area some six miles southwest of the most intense mineralization we find some very low temperature black-calcite veins but we also find higher temperature lead-zinc mineralization at the Charleston Lead mine. The latter may or may not represent another but much smaller zone of intense, locally anomalous mineralization. The low temperature black calcite veins are consistent with a zoning pattern extending outward from the Tombstone basin.

Depth and Persistency

In the two areas studied, precious metal ore values drop off rapidly below the water table. The predominant ore mineral above the water table consists of silver halide which is stable under normal ground water conditions and concentrated in the oxide zone. If it is assumed that the water table was not once considerably below the present table and that further oxide zone development does not exist below the present water table, then the rich high grade oxide ores
will drop off at, for example, an elevation of about 4225 feet near the Merrimac mine. The values in the State of Maine mine drop off at the fifth level or approximately 170 feet vertical depth from the collar where the vein, dipping 40° at the surface, steepens to a dip of 55° or 60° although no mention is made of encountering the water table. All the values in the other mines are reported to drop off at what is now the water table, presumably as the fissure zone passes below the oxide zone development. It is reasonable to assume that the primary silver mineralization and black calcite, continues beneath this oxide zone development. Reaction of these silver-bearing manganese minerals (Hewett, 1967) in the oxide zone frees some of the silver for precipitation with halogens, with some of the silver concentrated as native silver.

Evidence exists that some oxide zone development continues below the present water table (Butler, 1938). If this be the case, then supergene ores with high precious metal values like those in the Pachuca-Real del Monte district, Mexico (Park, 1964), could lie below the base of this previous oxide zone development and perhaps supply a small amount of extremely high grade precious metal values.

The ore is often limited along strike of the favorable structures; for instance, the State of Maine mine was most productive along only 500 feet of strike. Alteration zones also exist along strike usually less than several hundred feet. The width of the veins is difficult to measure. Rather than remaining in one single ore
vein, mineralization in the high grade oxide zones commonly branches out along several planes in a fissure zone which might be only a few feet wide at the Escapule mine, for example, at a depth of fifty feet. Extreme high grade ores may be concentrated in small planes or pods only a few inches wide. All the old workings in the areas studied consist of one inclined shaft down the dip of the vein and single drifts out along strike.

The above description of depth and persistency is restricted to the precious metal deposits along fissure zones in the areas studied. In consideration of the capacity of the district to produce silver as a whole, it is worth noting that different ore controls exist in the Tombstone basin. This basin and the immediately surrounding areas are characterized by both more intense mineralization and by conditions favorable to replacement along sedimentary beds. The silver bearing primary ore here would not likely be the black calcite assemblage, but rather an assemblage involving hessite and argentiferous tetrahedrite (Butler, 1938). Therefore, in the Tombstone basin metal values with accompanying silver values probably persist below the oxide zone in more economic quantities.

Although Butler (1938) mentions that in several places oxidation is known to extend well below the present water table, generally alteration is less intense and the ore values drop off. Oxidation throughout the district has generally improved the value of the ore. To what extent the present water tables are perched water tables or represent higher water tables than have existed in the past, can only be determined by more extensive research.
In summary, the silver mines in the areas studied were mostly in oxide zones of narrow veins extending along the strike of fissures up to 500 feet and little ore grade mineralization can be expected below this oxide zone where silver ions have not been concentrated. In the Tombstone basin deeper mineralization with silver values undoubtedly exists and there is also greater probability of replacement in favorable beds. However, since oxidation generally has improved the value of the ore, a lower grade would be expected.

Classification

In relating the Tombstone district to other districts, it would, of course, be necessary to classify it according to one or more characteristic features. The mineralization in and immediately around the Tombstone basin has been classified as mesothermal by McKnight (1933) using Lindgren's scheme of classification. This assignment would give it an environment of formation of moderate pressure temperatures in the range of 175-300°C, with ore fluids typically at some distance from their genetically related intrusive source. Six categories exist for Silver-Lead-Zinc deposits according to this classification. 1) quartz-tetrahedrite galena veins, 2) tetrahedrite-galena-siderite veins, 3) galena siderite veins, 4) silver-lead-calcite-siderite-barite mesothermal veins (not found in western United States, 5) pyrite-galena-quartz veins, and 6) silver-lead-zinc replacements in limestones.
McKnight (1933) places Tombstone in the last category of silver-lead-zinc replacement deposits. The mineralogy in this case should be of the following assemblage: pyrite, galena, sphalerite, chalcopyrite, tetrahedrite, tennantite, wolframite, molybdenite, and stibnite. Gangue would consist of cherty quartz, dolomitized or silicified limestone, calcite, barite, fluorite, siderite and rarely rhodochrosite. Structure would consist of simple fissure veins, lode or replacement deposits, or a combination of these. Also, the vicinity of dikes and intrusive sheets is favorable although with dikes the ore body is likely to be crosscutting parallel to dikes rather than forming bedding blankets. Therefore, McKnight (1933) concludes that Tombstone, among other examples, localized as it is along the axes of sharp folds where the latter are crossed by ore-bearing fissures, is a mesothermal deposit characterized by features of a mesothermal deposit. Mesothermal mineral assemblages, structural relations, and ore controls seem to predominate in and immediately around the Tombstone basin.

Two miles west in the Escapule mine area, however, shallow lower temperature mineralizing characteristics were observed to be abundant. Open space filling in tension cracks or vug fillings in breccia predominated over replacement in the fissure zones. Cryptocrystalline quartz or chalcedony seemingly from colloidal solutions is present near the surface, as well as pervasive alteration and a general lack of base metals. Veins are restricted to zones of
shearing or brecciation and although most major intrusives are Cretaceous-Laramide, early Tertiary rhyolite intrusives, often associated with epithermal deposits, exist south of Tombstone (dated 63 million years old, K-Ar; Creasy, 1962) and the age of the andesite porphyry dikes may be Tertiary. Therefore, this area would be classified according to Lindgren as typically epithermal. With the possible exception of the Charleston Lead mine, discussed earlier, the Charleston Lead mine area, which also is characterized by most of the above features, would be classified epithermal or even low temperature epithermal due to the barite, calcite, manganiferous siderite and/or black calcite, quartz, and chalcedony mineral assemblage, and small vein occurrences. Deposits intermediate between Lindgren's mesothermal and epithermal have been classified as leptothermal by L. C. Graton (1933). Perhaps this district might fit into this classification whereby the Charleston Lead mine may represent the type of mineral assemblage to be expected underneath the Escapule mine, Mustang mine, State of Maine mine, and the other precious metal mines in the studied areas at depths in excess of 1000 feet.

Another possible classification was presented by Nolan (1933). Since he classified the deposits according to whether a silver-gold ratio or a gold-silver ratio predominates, Tombstone, with a silver-gold ratio of approximately 180:1, would be classified with those deposits with silver to gold ratios of from 1:1 at Oatman, Arizona,
to 100:1 as at Tonopah, Nevada. In the gold-silver deposits, on the other hand, the gold must exceed the silver by weight.

Nolan (1933) states that these silver-gold deposits are characterized by the following: 1) Well-defined fissures of good horizontal and vertical distance exist and often branch out near the surface. The tectonic faulting is not associated with the volcanics in the area. 2) Mineralogy consists of electrum, argentite, silver sulfosalts, selenides, but no telurides, pyrite, galena, chalcopryite, and sphalerite. Gangue mineralization is mostly quartz, calcite later replaced by quartz, adularia, barite, and black calcite (considered secondary). 3) Propylitic alteration is widespread in the wall rock next to the vein. Less widespread alteration consists of quartz, sericite, and adularia.

Agreement with the classification in the areas studied is good. The predominant alteration seems to be sericite and quartz with epidote and chlorite reported in the altered andesite dike rock (Gilluly, 1956). The structure is confined to strong fissures and finally the mineral assemblage, except possibly silver tellurides in the Tombstone basin, agrees with the above generalized silver-gold deposit assemblage.

Summary

There appears to be a difference in environment between the mesothermal ores deposited in and immediately around the Tombstone basin as contrasted with the lower temperature epithermal environmental
deposits a few miles west of the Tombstone basin in the areas studied. This possibly reflects a zoning outward from the most intense mineralization in the Tombstone basin to the least intense mineralization near Charleston. Although the ore controls for the mesothermal deposits show considerable replacement, observed ore controls in the epithermal areas were confined to planes of structural weakness where open-space and fissure filling predominated over replacement. Both deposits have been limited to higher grade oxide zone ores. Depth and persistency in the areas studied were largely limited to this oxide zone environment, although in the Tombstone basin considerable mineralization may extend below the present water table.
CHAPTER III

SILVER ECONOMICS

A discussion of the economic geology of Tombstone and Charleston would not be complete, especially where we are concerned with silver, without giving careful consideration to the present highly volatile economics of that element.

Never before in history has silver been in the academic limelight as it has been in 1966 and 1967. A rapidly rising demand, coupled with a slowly rising supply, has put upward pressure on the price of silver. Until recently, the government has countered the pressure by selling silver out of its treasury stocks at the current price. But since it is running out of silver, it will not, by 1968, be able to restrain the price as it seeks its natural equilibrium between supply and demand (figure 16). The government is trying to maintain the price of silver below $1.38, above which point melting those silver coins minted prior to 1965 will be profitable. During the period of price stabilizing at about $1.38, the government plans to remove most of these silver coins and replace them with the copper-nickel variety. Then it will certainly withdraw from its historic control of the silver market, and the price of silver will probably adjust upward to somewhat less than
FIGURE 16

SILVER SUPPLY, DEMAND AND PRICE

Revised from R.M. Dreyer paper, Mineral Yearbook, 1967

FIGURE 16. SILVER SUPPLY, DEMAND AND PRICE
$2.00 an ounce in 1968, and perhaps further to $2.50-$3.00 per ounce by 1970.

A deeper understanding of the 1967 silver situation involves an analysis of four factors. First, the major factors that have influenced past silver price trends should be considered; secondly, the current silver supply situation; thirdly, the current demand situation, and finally the presently effective and probable future United States governmental policies concerning silver.

**Major Factors Influencing Past Silver Price Trends**

Since 1900 the price of silver has shown considerable fluctuation. From a high of $1.37 per troy ounce in 1919 at New York, it dropped to a low of $0.24 per ounce in 1932. This drop, was, however, characteristic of most metal markets except gold which was stabilized by governmental policy. Since 1932 the price of silver has steadily risen, with a few fluctuations, to the present $1.30 per ounce (June 1967).

If we examine the price and production statistics since 1900 for both the United States and the world markets (figures 17 and 18), a trend is noticeable in that the price is inversely proportional to the amount of silver produced. This complies with standard laws of supply and demand since if we assume a near constant consumption rate (not graphed in figure 17 due to the difficulty in accurate determination), then as large amounts of silver are produced, the price falls or if small amounts of silver are produced, the price...
FIGURE 17
UNITED STATES PRODUCTION AND SILVER PRICE (1900-1965)
Figure 17. United States Production and Silver Price (1900-1965)
FIGURE 18
WORLD PRODUCTION AND SILVER
PRICE (1900-1965)
FIGURE 18. WORLD PRODUCTION AND SILVER PRICE (1900-1965)
rises. The United States production and price statistics by themselves show little direct relation to this because the domestic production represents only a small portion of world production which basically controls the price in New York and elsewhere. In 1965, world production was 210 million ounces. This is relatively small compared with the 270 million ounces produced in 1940 and the 230 in 1910, yet demand is rising because of new industrial uses of silver and a growing population.

In examining the price fluctuations in the United States over the last fifty years, say from 1915 to 1965, several cycles can be noticed before 1940.

The First Cycle: 1913-1932

The first cycle began in 1915 with a silver price of about $0.48 per ounce and charts indicate a rise to $1.37 per ounce in 1919, then a fall-back to about $0.65 per ounce in 1922 where it remained stationary. Here the sudden rise in price was attributed to strong silver demand for coinage by the allies in World War I. In 1917, about 300 million ounces were sent to India for the account of the British Government with the price established for a year at about $1.00 an ounce by the United States Government. Following this action the United States lifted its restrictions and heavy Chinese buying sent silver prices soaring to $1.37 per ounce. A general deflation, demonetization, and debasement of foreign coinages followed World War I and resulted in dropping the price to
about $0.65 per ounce by mid 1920. From 1920 to 1923, under provisions of the Pittman Act of 1918, the United States Government was authorized to purchase 200 million ounces of silver. At this time, Europe, which had melted its silver coins during World War I, began to mint silver again but the West was unable to absorb increased silver sales from the Orient. This imbalance led to a depressing report in 1926 by the Royal Commission on Indian Currency and from 1927 to 1933 heavy sales from Indian Government silver reserves resulting in depressing the price to an all time low of 24 cents per ounce in 1932. In 1933 Britain followed by the United States abandoned the existing gold standard.

The Second Cycle: 1932-1934

A second cycle began with the withdrawal from the gold standard by Britain and the United States. Although this cycle is much smaller, in point of time, it is similar to the first major price cycle in several respects; first, the government interfered in the silver market; second, the price was driven up by speculation; and finally, a rapid price drop occurred, caused by withdrawal of government support in the face of heavy selling pressure. No further cycles in silver price have been observed since the United States passed the Silver Purchase Act in June 1924, which firmly established our government in the world market as a large price controlling buyer.
During the years following this act, the United States acquired 2.5 billion ounces of silver by draining large quantities of silver from the East, particularly China. At the start of World War II, industry began to exploit the unique properties of silver and a substantial industrial demand developed which has continued to grow. In 1947, the Far East disappeared from the silver market as consumer and speculator resulting in a smaller but more stable market deeply involving the United States. Not until 1961 did the United States take its first step toward withdrawal of price control when it suspended its free market sales to domestic industry. Subsequently, in the fall of 1963, the first large scale redemption of silver certificates took place and again in 1965 the Coinage Act nearly removed silver as a coinage metal. The final withdrawal will most likely occur within the next year.

Before the United States became seriously involved and experienced in the silver market, prior to 1936, there had been considerable price fluctuation. While the government was in the market, some fluctuation existed, but basically the New York silver prices were stabilized, except for a gentle increase over a fairly long period of time. In the event of complete governmental withdrawal, the silver markets will again become occasionally unstable, and cyclical price trends as well as short, sharp fluctuations will develop.

In summary, the influences on the price of silver over the last fifty years have been controlled by three variables. First is
supply. Mine production, although important, has not been the major factor in large price shifts. The real controlling factor has been the large amounts of silver dumped on the market by countries such as China and India, and the speculation involved with trying to anticipate sudden changes in supply. A second influence has been rather sudden shifts in demand, either by countries buying up silver for coinage, or stockpiling it to back currency. Industrial demand has only become an important factor in the last twenty years and has increased steadily without the benefit of large governmental buying policies. Finally, the largest historical influence on silver price has been governmental policy. Although directly related to the prior mentioned influences of supply and demand, governmental policy of one country or another has been the major cause of price fluctuations.

The 1967 Silver Supply Situation

The supply of silver involves both mine production, which places newly produced metal on the market, and secondary production, which makes scrap or already produced silver available to supply the buyer.

New Mine Production

Most of the world's newly produced silver is obtained as a by-product from base metal mining of lead, zinc, and copper. As a consequence, the production of silver assumes secondary importance to the production of these base metals. In the United States 60%
of the new silver is produced as by-product; about 30% as a copper ore by-product; 20% from complex zinc-lead, zinc-copper, or lead-zinc-copper ores; and 10% from lead-zinc bodies, with a negligible amount from placer deposits. Less than 40% of the silver produced in the United States comes from ore where silver is the major ore metal. It is unlikely that large base metal deposits will come into production just due to an increase in the price of silver. United States silver mine production in 1965 was 39.8 million ounces while over 220 million ounces were produced by all the free world (figure 18).

In 1965, Mexico just edged out the United States as the world's largest silver producer with production of 40 million ounces of silver. Peru was third (35 million ounces), Canada was fourth (32 million ounces), U.S.S.R. fifth (27 million ounces), Australia sixth (16.7 million ounces), and Japan seventh with nearly 10 million ounces. In analyzing the top ten producing mines in the United States, the by-product nature of silver production becomes evident as the mine, its rank in production, state and major ore are listed below. Of the 25 mines which produced 84 percent of United States silver in 1964, only four were principally mined for silver. The world production picture follows the same pattern.

An exact dollar per ton analysis (figure 15) was made on the Charleston Lead mine, Cochise County, Arizona, to illustrate the effect on a lead-zinc and minor silver producer when the price of silver is increased. Little increased production in this case would be initiated even if silver reached $2.50 per ounce.
### TABLE II

**TOP TEN U. S. SILVER PRODUCING MINES**

<table>
<thead>
<tr>
<th>RANK</th>
<th>MINE</th>
<th>STATE</th>
<th>MAJOR ORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sunshine</td>
<td>Idaho</td>
<td>Silver</td>
</tr>
<tr>
<td>2</td>
<td>Galena</td>
<td>Idaho</td>
<td>Silver</td>
</tr>
<tr>
<td>3</td>
<td>Lucky Friday</td>
<td>Idaho</td>
<td>Lead</td>
</tr>
<tr>
<td>4</td>
<td>Utah Copper</td>
<td>Utah</td>
<td>Copper, Gold</td>
</tr>
<tr>
<td>5</td>
<td>Butte, underground</td>
<td>Montana</td>
<td>Copper</td>
</tr>
<tr>
<td>6</td>
<td>Bunker Hill</td>
<td>Idaho</td>
<td>Lead-Zinc-Silver</td>
</tr>
<tr>
<td>7</td>
<td>Butte</td>
<td>Montana</td>
<td>Zinc</td>
</tr>
<tr>
<td>8</td>
<td>Butte, Berkeley open pit</td>
<td>Montana</td>
<td>Copper</td>
</tr>
<tr>
<td>9</td>
<td>Mission</td>
<td>Arizona</td>
<td>Copper</td>
</tr>
<tr>
<td>10</td>
<td>Copper Queen-Lavender Pit</td>
<td>Arizona</td>
<td>Copper-Silver</td>
</tr>
</tbody>
</table>

The fact that most newly produced silver is a by-product metal therefore limits the effect of price increases on its production, but favorable prices in the future may lead to the development of large low grade silver properties presently sub-economic. Increases in mined silver are expected from Canada, United States, Australia, Europe, Peru, and Mexico, particularly, but other areas indicate possibilities and all are dependent on silver price behavior.

Secondary Production

Secondary silver is important in considering the future of this precious metal's economics. Although scrap silver, largely in the form of photographic and electroplating wastes, and discarded silverware and jewelry, accounts for perhaps 10% of the 1967 silver supply in the United States, speculators with hoarded silver on the individual, group, or national level could create a very volatile situation. Demonetization has rarely yielded much silver directly to the market. Britain over a program of 20 years recovered some 60% of the silver coins in circulation or stock, but France, on a similar program, recovered as little as 5-12%, and India only 5%

In 1967, both South Africa and Australia are withdrawing their silver coinage, which may yield some 50 million ounces to the world market (Jeanty, 1967). Another secondary source in this respect is the Far East. The largest amount of silver in the world today, an estimated 5.5 billion ounces is held by the people of India. If the price of silver rises relative to the price of gold, large amounts
of silver could flow out of India. Since in India gold and to a lesser degree silver have religious significance, the people there will trade silver for gold at a price ratio favorable for acquiring gold. Although China produced little silver at the last reported production, she sold 100 million ounces to the West between 1959 and 1961 and also sold a large amount to Russia. Silver was for centuries the monetary base in China. Perhaps, then, China could also be a supplier to the world silver market in the future. Russia supplied about 10 million ounces in both 1965 and 1966 which probably represents surplus primary production and is not, like China and India, a country where large amounts of secondary silver exist. Demonetization by the United States is not likely to bring much silver to the market because of Gresham’s law which states that when two coins of equal face value, but one of different intrinsic value, are circulated together, the coin of greater intrinsic value disappears from circulation. Even more unlikely is a continued supply from United States Treasury stocks which were depleted to 485 million ounces in mid May 1967, compared with two billion available in 1960 (figure 16). By law, 430 million ounces have been frozen to back United States currency, but Congress in 1967 will probably have to free this reserve now kept to cover silver certificates in circulation.

Summary of the Silver Supply Situation

It can be concluded, therefore, that in a free market a price will be established that is high enough to bring to the silver
market the supply of silver required for world consumption. Some of this silver will come from new mine production (delayed somewhat by the time necessary to start production), unprofitable at a lower silver price, profitable at a higher silver price. Large amounts will come from speculators and hoarders if the price is high enough. This could conceivably drain some large amounts of silver now in possession of countries and people of the East. Some supply could come from demonetization by the United States, South Africa, and Australia. Continued supply from the United States treasury's stocks, which have been sacrificed to maintain an artificially low silver price of about $1.30 per ounce during removal of circulating silver coins, is unlikely by 1968 since there is simply no more silver in the treasury to be spared. The need for a larger supply of silver will be met along with a growing demand. The timing and size of new supplies to the market will be a function of increased silver price. This price increase will influence secondary sources of supply first, and if substantial, will also influence over a longer period of time new mine production from low grade, predominantly silver ores.

The 1967 Silver Demand Situation

Demand for silver involves consumption for coinage, jewelry, speculation and consumption for growing industrial usage.
Coinage

Silver for coinage in the United States is not causing the strong demand it once did due to Washington's recent demonetization policies. In 1964, 203 million ounces of silver were consumed for coin; in 1965, 320.3 million ounces; in 1966, only 53.6 million ounces will be consumed for this purpose. The change in silver content by the coinage act of 1965 is presented below:

| TABLE III |
| AMOUNT OF SILVER IN U. S. COINS\(^a\) |

<table>
<thead>
<tr>
<th></th>
<th>Pre 1965</th>
<th>Post 1965</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Silver Dollar</td>
<td>371.25 grains(^b)</td>
<td>(suspended)</td>
</tr>
<tr>
<td>Half Dollar (90% Ag)</td>
<td>173.61 grains</td>
<td>(40% Ag) 77.16 grains</td>
</tr>
<tr>
<td>Quarter (90% Ag)</td>
<td>86.80 grains</td>
<td>0</td>
</tr>
<tr>
<td>Dime (90% Ag)</td>
<td>34.72 grains</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^a\) From Harris, Upham & Co., 1965.

\(^b\) 480 grains to a troy ounce.

There are in circulation United States coins containing 1.9 billion ounces of silver. These coins can only be profitably melted down when the price exceeds $1.38 an ounce. Only minor amounts of this silver are likely to reach the market according to Gresham's law.
Looking at coinage on the free world level, some 800 million ounces have been consumed for coins in the last 20 years. Most European countries are still minting silver coins. France recently used 80 million ounces and will probably use another 30 million by 1970, Belgium used 13 million ounces in the early 1960's and Italy has recently issued new silver 500-lire coins. In both Italy and Belgium the silver coins disappeared nearly as fast as they were minted. Japan has used some 45 million ounces of its stocks for silver coinage, and 75 million ounces were minted in Saudi Arabian coins. Most of this foreign silver coinage is an attempt to increase public confidence in their governments and their currency. Demand for silver in United States coinage has dropped sharply, but free world demand for this purpose still remains relatively strong.

Silverware and Jewelry

Use of silver in sterling tableware and jewelry is second only to photographic and coinage uses in the United States. In 1964, 225 million ounces and again in 1965 an estimated 225 million ounces were used for this purpose (Congressional Record, 1965). Stainless steel and other substitutes have captured some of this market but the demand continues to grow with a growing and more affluent population. In India, particularly, demand for silver to be used for jewelry is very strong due not only to its beauty and ductility, but also for religious and mystical reasons.
Speculation

Perhaps the most difficult consumer market to measure and yet the one with the most dramatic and unstable effect on demand is that of the speculator. Heavy Chinese speculation in 1919 and 1920 raised the price of silver by nearly a third of its value, and again heavy speculation in 1934 caused a large demand for silver and a subsequent price rise only to be followed by a rapid price decline. Since the speculative demand lasts only as long as the speculator thinks a profit can be made, it may be ephemeral. Speculation therefore remains like the sword of Damocles over the head of the 1967 silver price outlook.

Industry

Finally and most important is the rising demand for silver by industry. Our domestic industry used about 40 million ounces of silver in 1940, required 137 million ounces in 1965, and jumped its needs by 10% to 150 million ounces in 1966. Properties such as high electrical and heat conductivity or unique light sensitive properties of silver salts make them increasingly essential to specialized industry. In 1965 the free world industrial consumption alone at 330 million ounces exceeded the free world mine production of 230 million ounces (figure 16).

As electrical miniaturization becomes increasingly important, silver will be demanded for its electrical properties. New chargeable silver-zinc and silver-cadmium batteries hold great promise.
Photography is booming and consumed 43 million ounces in 1965. New chemicals and sensitizing paper have to date failed to replace silver in photography especially in areas of work requiring fine reproduction. Further demand for silver brazing alloys, solders, dental uses and mirrors remains high. New ideas are constantly appearing; for instance, high temperature conductive paint, catalysts for refining oil, and even conductive caulking compounds. The following table illustrates the rising industrial consumption of silver in the United States (Table IV).

Industrially, the United States used 140 million ounces of silver amounting to 42% of the free world silver industrially consumed in 1965. West Germany was second with 55 million ounces of 17%, and Japan third with 35 million ounces or 11% of the free world industrial consumption.

An important consideration for the future price of silver is that in many cases only a small portion of the total cost of the final products is attributable to the cost of silver. For instance, if the price of silver quadruples to $5.20 per ounce, the price of film would increase only ten percent. This is also true for electrical products using silver.

Summary of the Demand Situation

Silver is enjoying a rising demand in 1967. Cutbacks of silver usage in the United States coins are offset by other free world coinage demands and a steadily rising industrial demand which
TABLE IV

SILVER USES IN THE UNITED STATES (1959-1965)\textsuperscript{a}

<table>
<thead>
<tr>
<th>SILVER IN MILLION OUNCES</th>
<th>1959</th>
<th>1960</th>
<th>1961</th>
<th>1962</th>
<th>1963</th>
<th>1964</th>
<th>1965\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batteries</td>
<td>3.5</td>
<td>3.5</td>
<td>5.0</td>
<td>6.0</td>
<td>6.2</td>
<td>9.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Brazing alloys, solders</td>
<td>10.5</td>
<td>10.5</td>
<td>11.0</td>
<td>13.0</td>
<td>13.0</td>
<td>13.8</td>
<td>17.0</td>
</tr>
<tr>
<td>Dental, Medical</td>
<td>4.8</td>
<td>4.8</td>
<td>4.9</td>
<td>5.0</td>
<td>5.1</td>
<td>5.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Electrical contracts, components</td>
<td>20.5</td>
<td>19.5</td>
<td>24.0</td>
<td>25.0</td>
<td>26.0</td>
<td>30.3</td>
<td>35.0</td>
</tr>
<tr>
<td>Mirrors</td>
<td>3.0</td>
<td>3.0</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Missiles</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>0.2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Photographic</td>
<td>30.8</td>
<td>31.7</td>
<td>32.3</td>
<td>33.3</td>
<td>33.3</td>
<td>40.3</td>
<td>43.0</td>
</tr>
<tr>
<td>Silverware, Jewelry</td>
<td>28.0</td>
<td>29.0</td>
<td>25.0</td>
<td>22.0</td>
<td>22.0</td>
<td>22.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>-</td>
<td>-</td>
<td>0.2</td>
<td>2.0</td>
<td>1.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Net Industrial Usage</td>
<td>101.2</td>
<td>102.0</td>
<td>105.5</td>
<td>110.4</td>
<td>110.0</td>
<td>127.1</td>
<td>140.0</td>
</tr>
</tbody>
</table>

\textsuperscript{a.} From U. S. Department of Commerce, 1965.

\textsuperscript{b.} Estimated.
mostly requires silver as an essential but not a cost governing ingredient. Demand for silver is likely to increase heavily over the next decades as the need for the metal, one of the first known to man, assumes its space age role.

Effective Governmental Legislation Concerning Silver

In 1967 and Future Projections

By closely examining price trends over the last fifty years, governmental control has been the strongest single influence. So important are governmental policies to silver economics that a brief look at recent legislation is imperative.

Before late 1961, the United States was a major stabilizing influence on free world silver markets. When prices rose above official selling prices, industrial consumers in the United States purchased silver from the treasury instead of on the open market. Conversely, when prices fell below the official price, almost all domestic production was sold to the treasury. But due both to expanded industrial usage and relatively stable mine production, the treasury's stocks were generally depleted until 1961 when the United States suspended sales of silver to domestic industry. Subsequently, the price of silver jumped to $1.29 per ounce by mid 1963 from $0.91 in 1960. On June 4, 1963, Public Law 88-36 repealed all silver purchase legislation and allowed the gradual retirement of silver-backed one and two dollar bills to be replaced by Federal Reserve notes. In September, 1963, the first large scale redemption
of silver certificates took place and a new ceiling price of $1.293 per ounce was established. The above legislation was not sufficient to stop the drain on the treasury stocks and on July 23, 1965, the Coinage Act of 1965 became law, only after extensive hearings in Congress. The principal provisions are as follows:

1) The creation of a new half dollar, a copper silver layered coin with a total of 40% silver to replace the previous 90% silver half dollars.

2) Provision for new silverless dimes and quarters of a cupro-nickel composition.

3) Although the silver dollar remained unchanged, no more are to be minted for five years from the date of the act.

4) Provisions for the treasury to buy newly mined domestic silver, if offered, at $1.25 per ounce.

5) The Secretary of the Treasury is authorized at his discretion to prohibit the export or melting of any coin minted by the United States government.

6) The President is authorized to establish a joint commission on coinage to study the progress made in introducing the new coins and to review and make recommendations on all aspects of the coinage system.

7) The Secretary of the Treasury is authorized to sell silver not needed to back silver certificates for at least $1.29 per ounce.
Also in 1965, the Office of Emergency Planning established a silver stockpile objective of 165 million ounces earmarked from the treasury stock.

In May, 1967, the fifth article referred to above was invoked when the Treasury Department discontinued sales to any buyers except for legitimate domestic firms which require silver in their business and banned the melting, treatment, and export of silver coins. The action was a necessity caused by heavy speculative buying and hoarding of silver coins.

A bill which should be law by 1968 will set up a one year deadline for redemption of all silver certificates and permit the Secretary of the Treasury to declare some silver certificates lost or destroyed, and thereby free the silver held to cover these silver certificates to the open industrial market. This will help the treasury maintain a price of silver below $1.38 per ounce long enough to remove as much circulating silver coinage as possible.

In the spring of 1967, India limited exports severely; however, silver will leave India if the economics are right, law or no law. As for the non-free world countries and France, who knows what they will do? It is quite likely, though, that none of these governments will be able to prevent exports of precious metals by their nationals if the world price is attractive enough.

Conclusion

Post 1967 legislation, therefore, will probably be designed to ease the United States out of silver price controls and eventually
out of the silver market altogether. After a free market is estab-
lished, speculation should cause fluctuating upward prices for a
short time, but vast hoards of silver located throughout Europe, the
Middle East, India, and perhaps China, should ease the 1967 supply-
demand gap, and the price of silver will probably settle somewhat
below $2.00 per ounce in 1968. Over the slightly longer period of
time that is required for new silver mine production, the supply
will also be augmented by sub-economic ores at $1.30 per ounce and
economic ores at $1.75-$2.00 an ounce. Perhaps portions of the
Tombstone-Charleston mining district, once a silver producer, can
again become a supplier of new silver under different economic
conditions than prevailed when mining operations closed down and
the price of silver was held well below $1.38 per ounce.
CHAPTER IV

ECONOMIC IMPLICATIONS FOR THE TOMBSTONE-CHARLESTON DISTRICT

History of Silver Production

The Tombstone district was discovered in 1877 by Ed Schieffelin and the first silver ore with some gold values was supplied to the national market in 1879. The last recorded production records (Butler, 1938) state that at the close of 1936, 37 million dollars worth of metal had been produced from the area. Production tapered off shortly after this date and at the present time small quantities are produced by fewer than a dozen one-, two-, and three-man operations. Over half the total value of the district production was produced from 1879-1886 and in 1881 and 1882 over five million dollars worth of ore were produced each year. These early values came from the high grade, near surface, oxide ores. Production from 1886 to 1936 varied with the price of silver, with minor influence by the price of manganese and gold, which account for nearly one-sixth the value of silver production. Exact figures on the various ores prior to 1908 are not available, but during the 29 year period (1908-1936) the following quantities were produced from 630,537 tons of ore (Butler, 1938) and yielded over 8.5 million dollars.
If we calculate the values of these metals at 1967 metal prices, silver would account for roughly $9.0 million dollars, whereas, the by product metals (exclusive of manganese, iron and lime, and similar non-recorded products) total $6.4 million.

These figures show that Tombstone between 1908 and 1936 was predominantly a silver producer and this can be extrapolated back to earlier days of production with reasonable reliance. The mines of the Escapule area were predominantly silver producers although no records have been kept. The few small mines in the square mile area near Charleston, exclusive of the Charleston Lead mine, were also predominantly silver producers.

**Estimation of the 1967 Silver Ore Types of Reserves**

Examination of the economic geology of the two square mile areas closely studied in the western part of the district makes it possible to make several broad generalizations concerning the amount of silver which would be produced in this district although insufficient data are on hand to present exact figures. The more intensely mineralized area surrounding the Tombstone basin has produced large amounts of silver from shallow workings in the oxide zone which

<table>
<thead>
<tr>
<th>Gold ($)</th>
<th>Silver (ounces)</th>
<th>Copper (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,514,295</td>
<td>7,049,997</td>
<td>2,516,040</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lead (pounds)</th>
<th>Zinc (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26,955,138</td>
<td>1,058,234</td>
</tr>
</tbody>
</table>
occurs generally less than 600 feet in depth in fissure zones, fault zones, and replacement zones. Here mineralization most likely continues below the oxide zone, where with depth the predominant ore control will become replacement of either favorable sedimentary beds, or fissure and fault zones with the silver occurring as ions in solid solution with the base metal sulfides. Little likelihood of oxidized silver-bearing manganate minerals associated with calcite and low temperature mineralization would exist at these depths. A substantial economic reliance at depth, on by-product base-metal production should become a factor, even to the point where silver itself would probably become a by-product of copper, lead or zinc.

In the outlying lower temperature deposits, the primary mineralization is largely void of base metal sulfides. The ore values are almost entirely limited to concentration of silver and some gold by meteoric processes in the relatively shallow oxide zones of narrow fissure veins rather uniformly spaced in distance. Many of these fissures have been worked in the past and several are being worked in 1967, and future workings to be economical, will also be limited to these oxide zones.

**Future Potential as a Silver Supplier**

During 1967 renewed interest in the Tombstone basin area was shown by Duval Corporation just southwest of the town of Tombstone. This, along with indications of deeper mineralization by geologic studies, indicates production could be resumed in the Tombstone
basin possibly on a large scale basis. However, land ownership problems, and mining problems associated with a high water table may forestall activity. If the oxide zone development in the Tombstone basin is extensive and if silver values persist throughout this zone, then a shallow open pit silver mine would not be out of the question. Demand for silver looks exceptionally bright in 1967, but demand for lead and zinc is not as high would would definitely inhibit extensive development below the oxide zone where the ore would largely consist of lead and zinc. The lower temperature deposits to the west as shown by the assay values taken in the State of Maine mine, and graphed with possible future price changes on Figure 19, are, with exceptions, sub-economic and will remain so until the price of silver reaches over at least $3.00-$4.00 per ounce. Freight rates from the State of Maine mine to El Paso, the nearest smelter, run $2.00 per ton for trucking to Fairbank and $10.70 per ton basic rate to El Paso with a grade charge, where the smelter pays for 70% silica plus four or more ounces per ton of silver. Penalties exist for aluminum and iron oxides. Profitably, then, it would only pay to ship 10 ounces of silver per ton plus 70% silica. The State of Maine assays indicate a lower grade than this (Figure 19) which apparently eliminates future large scale mining at the State of Maine. This is not to say that small high grade operations, however, cannot be profitable. High grade specimens from the State of Maine veins for instance ran over 260 ounces per ton. Although the quantity of such ore is limited, it could be
This shows assay values for several levels in the State of Maine mine, in the Tombstone area with in value in dollars per ton at a present price of silver and several projected prices of silver.
FIGURE 19. PROJECTED VALUES AT THE STATE OF MAINE MINE
profitable in 1967 and with an increase in silver prices, the profitability could also increase. The Escapule mine is a fine example of how a small miner, without the use of expensive massive industrial machinery, can profitably produce perhaps 160 ounces per day in a small oxide zone vein deposit avoiding high transportation costs by building a cyanide processing plant with only a small capital investment. There is evidence of numerous old small cyaniding plants for rich silver oxide ore throughout the Tombstone district. In the event of higher silver prices such small operations could become highly profitable for the skilled small operator. But these small reserves would not begin to attract the expensive administrative, legal, and mechanical machinery of a large enterprise. Making the assumption that land-title problems could be solved and an increase in silver price to several dollars per ounce, numerous profitable small operations with a yearly output of several hundred thousand ounces of new silver could be initiated here. In 1934, when silver was only $0.48 an ounce, the Tombstone Mining Company reports from the Hasselgren and Carper leases alone, production of silver amounting to 42.8 thousand ounces presumably from such small operations in the Tombstone basin.

The Charleston Lead mine, however, will not be likely to increase production due simply to a rise in silver prices as shown on Figure 15. Predominant values of lead and zinc determine what is ore and what is not ore, regardless of whether silver is $1.30 an
ounce or $2.50 an ounce, and therefore production from the mine will be geared to these base metals. This is not the case in the precious metal deposits previously discussed wherein the high grade ore, some of which is economical at silver prices of $1.30 per ounce, simply will not be mined until the price of the predominant ore, silver, increases to the point where the small miner finds it profitable to establish a small silver producing operation.
CHAPTER V

CONCLUSIONS

Several conclusions can be drawn concerning the economics of silver in mid 1967 and its relation to the economic geology of the Tombstone-Charleston district, particularly the two areas given detailed study.

First, most past silver production has come from oxide zone development in the entire Tombstone-Charleston district. Higher temperature mesothermal mineralization characterizes the Tombstone basin area. Considerable base metal sulfides are found here, but the high silver values are concentrated in the well-developed oxide zone. Several miles west, however, epithermal, lower temperature, mineralization persists where primary mineralization consists of silver-bearing manganate minerals associated with "black calcite." Here, the silver values are also concentrated in the well-developed oxide zone of mineralized fissure veins and it is unlikely that economic mineralization exists much below this oxide zone. Although deeper mineralization is likely in the Tombstone basin area, silver values will also diminish with depth.

Secondly, as the need for silver production increases and the gap between relatively stable new silver production and a growing
industrial demand widens, certainly economic pressures will result in higher silver prices. For the few years immediately preceding 1967, the United States government has been able to withstand pressures for increased prices by selling silver out of its large treasury stocks. These stocks are now depleted, and the government will no longer be able to maintain silver price controls. Therefore, silver prices will rise and eventually level off at somewhat less than $2.00 per ounce, $1.75 being a reasonable figure.

Thirdly, in close examination of the economic geology of portions of the Tombstone-Charleston district, and relating it to the district as a whole, it can be said that with a change in silver prices certain new silver production may come from this old district. One possible source of production which may be influenced by a higher silver price is the deep suboxide zone ore of the Tombstone basin. Here substantial values must come from base metals to make up for a lower grade silver ore. Possibly open pitting of the well-developed oxide zone will eventually be profitable. Any such operations should be large and would involve solving ownership and mining problems. A pre-production interval of several years would be likely. Finally, rapid, although limited, increase in production could come from numerous, small, high grade operations in the area; economic only to the small miner and feasible only if silver prices increase enough to motivate him. Although this district will by no means eliminate the silver supply-demand gap, increased production will, eventually,
be brought about as economic pressures demand new silver and establish stronger incentive to initiate this new production.
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