

Mineral Resources of Cochise County, Arizona

Zoey C. Carey and Nathan J. Carey



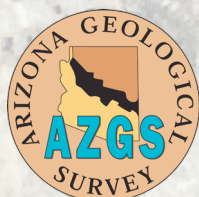
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Arizona Geological Survey University of Arizona

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Cover Image: Top Left: The Campbell Shaft at Bisbee, Arizona (Briggs, 2015). Top Right: Welcome to Tombstone sign. Bottom Left: Douglas Smelter in Douglas, Arizona. Bottom Right: The Lavender open pit mine at Bisbee, Arizona hosted on the AZGS photo gallery, <https://azgs.arizona.edu/lavender-pit-bisbee-arizona>.

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Introduction

Cochise County is situated in southeasternmost Arizona, sharing a border with New Mexico to the east and Mexico to the south (Plate 1). The county contains a rich history of metallic mining (e.g., the historic mines of Bisbee and Tombstone) but currently has only one active mining operation (i.e., the Johnson Camp mine operated by Gunnison Copper) (Gunnison Copper, 2026; Plonka and Richardson, 2025). Situated in the metal-rich Basin and Range Physiographic Province, Cochise County is host to numerous ore deposit types (e.g., porphyry, skarn, carbonate replacement, lode, epithermal, and more) and diverse associated commodities. Given the significant mineralization and potential for undiscovered critical and noncritical mineral resources in Cochise County, this region has a clear need for compilation and synthesis of geologic and mineral data into a single report to provide land users and policymakers with the requisite details to make informed decisions.

The purpose of this report is to provide a single review publication on the mineral resources of Cochise County to interested members of the general public and the geologic community. The sharing of past mining and exploration data, even in summarized form, is a significant factor in encouraging near-term exploration and bringing resource assessment forward in time to allow for careful consideration of all factors involving mining and resource extraction. This review publication contains brief summaries of each of the important mining districts of Cochise County and an associated map plate (Plate 1) with key mine/prospect locations that are addressed in the text and/or were important historic metal producers. Mining district summaries are generally organized into the following subsections: *Location and History*, *Geologic Setting*, *Mineral Deposits*, and *Exploration Overview*. Some of the less explored districts are summarized in a single *District Overview* section.

The reader should be aware of a few complementary resources that may aid in further understanding of the geology of Cochise County and its mineral resources. First, the U.S. Geological Survey recently published a new high resolution airborne magnetic and radiometric geophysical survey of the Arizona Porphyry Copper Belt, covering all of Cochise County (Scheirer et al., 2025). As many of the known resources in the county are exposed in uplifted mountain ranges, geophysical data will be important for moving exploration forward, especially in adjacent basins with sedimentary cover. Additionally, the Arizona Geological Survey Mining Info website hosts numerous historical mining reports, maps, drill logs, assays and more from donated mining collections that are not elsewhere available (AZGS Mining Files, 2026). The reader is encouraged to peruse this resource for additional information on each of the mining districts discussed.

California (Chiricahua) Mining District

Location and History

The California (also referred to as Chiricahua) mining district is located in southeastern Arizona on the eastern edge of Cochise County, proximal to the Arizona-New Mexico border within the Mexican Highland section of the greater Basin and Range province. The Chiricahua Mountains are situated between the San Simon Valley to the east and the Sulphur Spring Valley to the west (Brown, 1993).

The principal commodities produced in the district include lead, zinc, copper, silver, gold and minor amounts of tungsten (Keith, 1973). The California mining district was prospected before 1870, however, the area was not mined until after 1878 when the Chiricahua Indian Reservation was abolished (Keith, 1973). Intermittent mining activity in the district took place from 1881 through the 1970's, with peak productivity occurring first in the mid-1920's and again in the early 1950's (Brown, 1993; Keith 1973). The first large discovery occurred at Galeysville from 1881-1882, recovering primarily lead and silver ores (Keith, 1973; Table 1). The Hidden Treasure claim was the first claim on record with Cochise County and was filed in 1881 (Brittain, 1954). Hidden Treasure was later incorporated into the productive Hilltop Mine (Drewes and Williams, 1973). Early mining in the district exploited near surface, oxidized, and likely high-grade lead-silver ores which were sent to either Willcox, Arizona or Lordsburg, New Mexico (Brittain, 1954). As deposits were worked to depth, lead became scarce while copper ore increased in abundance (Badger, 1911). In 1884, a small smelter was erected and bullion from the smelter was sent to San Francisco, a journey that was long and expensive – implying extraction of high-grade ore (Brown, 1993). The mines were largely abandoned as they reached zones of copper mineralization due to low copper prices at the time (Badger, 1911). Mining in the early days of the district followed short-lived boom cycles followed by periods of quiescence driven by either land ownership conflict or depletion of accessible, economic resources (Brittain, 1954; Brown, 1993).

The Hilltop Mine was by far the greatest producer in the district, accounting for 68% of total production. In 1913, the Hilltop Metals Mining Company was created, and they operated the Hilltop Mine for 16 years (Drewes and Williams, 1973). In 1929, the mine closed due to a combination of low metal prices and exhaustion of ore reserves (Brittain, 1954). The California district experienced little activity from 1930-1949, although the United States Bureau of Mines reported minor production for the years 1938-1941 (Brittain, 1954; Brown, 1993). Piedmont Mines, Incorporated acquired the property from 1949-1951 and managed to ship out a few tons of ore while performing “rehabilitation work”, but new mining activity remained relatively quiet at this time (Brittain, 1954). The American Zinc, Lead, and Smelting Company leased Hilltop from 1951-1955 and produced copper, lead, zinc, and silver with the last record of production in 1954 (Brown, 1993).

Keith (1973) documented over 50 mines within the California Mining district, though many of them consisted of only small-scale workings with no recorded production data. Recorded production for the district is 338,000 pounds of copper, 8,263,000 pounds of lead, 1,132,000 pounds of zinc, 100 ounces of gold, and 137,500 ounces of silver from 1903-1970 (Keith et al., 1983), with production largely coming from the Hilltop and El Tigre mines (Brittain, 1954; Keith, 1973; Tsuji, 1984). The last recorded production from the California

district appears to come from the El Tigre mine, which was operated intermittently from 1941-1982 (Tsuji, 1984).

Geologic Setting

The California district is located in the northern extent of the Chiricahua Mountains. The Chiricahua Mountains are a north-northwest trending mountain range typical of the Basin and Range province. The range represents an uplifted fault block, tilted gently westward, and flanked by alluvial filled valleys. Pliocene to Pleistocene volcanic and sedimentary rocks fill the southeastern San Bernardino valley and sedimentary and lesser volcanic rocks fill the northeastern San Simon valley and the western Sulphur Springs Valley. This basin fill obscures most of the range-bounding faults of the Chiricahua Mountains (Drewes and Williams, 1973).

The bedrock geology of the California district is comprised of igneous, metamorphic, and sedimentary rocks that range in age from Proterozoic to Cenozoic (Brown, 1993). Precambrian basement rocks consist of sedimentary and volcanic rocks that have been intruded and subsequently metamorphosed by 1.7-1.45 Ga granitoid plutons (Drewes and Williams, 1973), and includes locally exposed Pinal Schist (Tsuji, 1984). Paleozoic sedimentary strata, including limestone, quartzite and other siliciclastic units and dolomite rest nonconformably on Precambrian basement rock (Tsuji, 1984; Chapman et al., 2025). Exposed Paleozoic units in the Hilltop area include the Cambrian Abrigo Limestone, Devonian Martin Formation, Lower Mississippian Escabrosa Limestone, Upper Mississippian Paradise Formation, and the Pennsylvanian Naco Group limestones (Brittain, 1954). Paleozoic strata strikes northwest and dips 40°-70° to the southwest and is variably faulted, folded, intruded and metamorphosed (Brittain, 1954). Early Cretaceous siltstones, shales, sandstones, and limestones of the Bisbee Group overlie the Paleozoic sedimentary rocks forming an angular unconformity (Tsuji, 1984) and are capped by Cenozoic andesite and basalt flows (Shafiqullah et al., 1978). Miocene-Oligocene volcanics dominate the geologic landscape of the northern Chiricahua Mountains and range from silicic to intermediate tuffs, welded tuffs, and lava flows (Marjaniemi, 1970; Tsuji, 1984). Rhyolitic ash-flow deposition is expressed as at least three “sheets,” each of which are greater than 1000 feet-thick and were deposited between 29-25 Ma (Marjaniemi, 1970). The youngest sheet is the Rhyolite Canyon unit which was sourced from the 13-mile diameter Turkey Creek Caldera. A coeval monzonite porphyry intrudes the Rhyolite Canyon unit, thought to be associated with the resurgence of the caldera (Marjaniemi, 1970). Mesozoic-Cenozoic volcanic units are generally intruded by rhyolite dikes whereas Paleozoic sedimentary rocks are generally intruded by quartz monzonite, granodiorite, and granite stocks (Tsuji, 1984). Drewes and others (1983) indicate three rock types in the California district which are potentially favorable hosts for mineral deposits: (1) Paleozoic-Mesozoic alternating beds of impure limestone and shale, (2) Lower Cretaceous to Oligocene andesitic rocks, and (3) Oligocene quartz-latitude porphyritic intrusive rocks.

Much of the mineralization in the California district occurs within a northwest-southeast trending belt of Paleozoic to Mesozoic sedimentary rocks (dominantly carbonates) from the town of Dos Cabezas to the Portal area (Brown, 1993). The Apache Pass fault zone is a 1- to 2-mile-wide zone of branching fault strands that have been mapped from the Dos Cabezas to the Chiricahua Mountains. The fault zone parallels the band of mineralization and has been suggested to be a reactivated, deeply penetrating crustal flaw that likely acted as a conduit for mineralizing fluids (Brown, 1993). The structural setting of the Chiricahua Mountains, and

greater southeastern Arizona, has been debated for many decades. The Apache Pass Fault Zone has been interpreted as a long-lived, reactivated normal fault (Drewes, 1981), a thick-skinned, moderate to high-angle reverse fault of the Laramide orogeny (Favorito and Seedorff, 2022), and as an originally low-angle thrust fault in a Sevier-type fold and thrust belt (Chapman et al., 2025). Regardless of the structural style, the Apache Pass Fault represents a zone of anisotropy that allowed for fluid movement that may have contributed to the formation of ore-deposits in the California district. A more thorough investigation of the structural complexity of the region is warranted to understand the distribution of mineralization and potential for concealed ore deposits in the California district.

Metallic Mineral Deposits

The known metallic mineral deposits of the California district include scattered and relatively small base metal occurrences largely hosted in Paleozoic to Mesozoic sedimentary rocks that have been strongly faulted, folded, and variably intruded by Laramide-Tertiary aged intrusions (Keith, 1973). Metal commodities include lead, zinc, copper, silver, and gold (Keith, 1973). Sparse tungsten mineralization, predominately described as fine, disseminated scheelite replacement lenses in limestone, occurs in the district as well (Dale et al., 1960). The deposit types can best be described as replacement, skarn, epithermal, and vein-hosted (Brown, 1993).

Pb-Ag(-Cu-Zn) deposits have been the most exploited commodities of the California district since the 1880s, largely at the previously described Hilltop Mine. Pb-Ag(-Cu-Zn) mineralization at the Hilltop Mine largely occurs as small, scattered replacement deposits (described as chimney, fissure-fill, and bed replacement) and vein deposits hosted in limestone and quartzite (Brittain, 1954). The main ore minerals at Hilltop are galena, sphalerite, pyrite, and chalcopyrite with quartz, calcite, and dolomite as primary gangue minerals. Garnet and epidote are noted to occur in moderate amounts, especially proximal to fault zones (e.g. the Blacksmith Fault). The main ore controls in the region are structural weaknesses which are controlled largely by differing lithology. These zones of anisotropy allowed for circulation of ore-bearing solutions and deposition of metals in brecciated/damaged zones (Brittain, 1954). Brittain (1954) reported the following ore grades: 2-5 oz. silver, 10-25% lead, 5-15% zinc, 0.1-5.61% copper, 10-12% iron, and 2-10% manganese.

The El Tigre mine produced gold, silver, and copper ore from 1941-1974, and while Keith (1973) reported lead and zinc production at the El Tigre Mine, detailed work by Tsuji (1984) notes no significant lead and only minor zinc mineralization in the area (Tsuji, 1984). Ore mineralization in the precious-metal epithermal deposit of El Tigre is hosted in multiple generations of stockwork and sheeted quartz-silica vein zones, locally up to 20 feet thick (Tsuji, 1984). Common vein assemblages include quartz, black-banded quartz, adularia, and black and white calcite with typical epithermal textures as described by Schmitt (1950) and Buchanan (1981) (Tsuji, 1984). The Ag-Au(-Cu) ore mineralogy consists of silver sulfides and sulfosalts with lesser amounts of disseminated gold, zinc, and copper minerals (Tsuji, 1984). Tsuji (1984) notes the occurrence of native gold, acanthite, proustite, cubanite, rosasite and pyrite in his mineral paragenesis.

While tungsten was first noted in the region in the 1940s, mineralization was described as “sporadic,” with little recorded production of tungsten ore in both the Chiricahua and northern Dos Cabeza Mountains (Dale et al., 1960). Tungsten in the Chiricahua Mountains, from Hilltop

to Paradise, occurs as scheelite in variably deformed and altered limestone beds and is associated with epidote, garnet, zoisite, wollastonite and calcite (Dale et al., 1960). The occurrences likely describe replacement or skarn-type deposits, although it is uncertain whether economic amounts of tungsten ore exist. There is apparently minor tungsten (WO_3) ore associated with the Pb-Ag mines within the Chiricahua mountains, and Dale et al. (1960) estimated non-compliant historic indicated reserves of 33,000 tons at 0.15% and 100 tons at $>0.75\% WO_3$.

Industrial Resources

There are two active marble quarries in the northern portion of the California district. The Arizona Marble Company and Cross Spear Marble are operating marble quarries located south of the Fort Bowie National Historic site and both operations produce limestone and marble (Plonka and Richardson, 2025). Limestone and marble resources form in the region due to widespread Paleozoic carbonate deposition and later intrusive igneous activity in the Chiricahua and Dos Cabeza Mountains.

Exploration Potential

Despite a relatively rich exploration and mining history throughout 1880-1970, the California mining district remains relatively underexplored over the past 50 years. There are four active claim blocks on record with the Bureau of Land Management (Mineral and Land Records System), with one claim near the Hilltop Mine and three other claims west of Paradise. According to a mineral investigation by Drewes and Williams (1973), areas within and adjacent to a northwest trending belt of mineralization were given moderate to high potential for likelihood of ore deposit(s) at depth (Drewes and Williams, 1973). Favorable rating is based on: (1) proximity to structural weaknesses/fault zones which may act as fluid conduits, (2) potentially favorable host lithologies, including Paleozoic limestone, Tertiary rhyolite, and a Tertiary granodiorite stock, and (3) extensive pyritization and oxidation of volcanic rocks with geochemical analyses confirming presence of barium, copper, lead, zinc, molybdenum, and silver (Drewes et al., 1983; Brown, 1993). Potential mineralization based on above criteria includes Pb-Ag-Zn vein or replacement deposits in sedimentary host rocks, W-(Mo) skarn deposits, and Cu(\pm Mo) porphyry-type mineralization at depth (Drewes et al., 1983).

Newmont Mining Corporation planned to drill four holes in the late 1980's to early 1990's near Portal to test mineralization at depth, but ultimately the holes were never drilled due to public opposition and legal issues (Brown 1993). Superior Oil Company conducted a small-scale drilling program in the Jhus Canyon area in 1967, and Duvall Corporation drilled two holes in 1968, however results were never made public. It appears unlikely that encouraging mineralization was encountered as the claims were dropped by the early 1990s (Chakarun, 1973). Dale et al. (1960) notes that the Chiricahua Mountains have been under-explored for scheelite mineralization, and that appears to remain true.

While the limited known exploration of the California district over the past few decades may appear unsuccessful, occurrences of disseminated tungsten mineralization, replacement and skarn Pb-Ag-Zn-Cu(\pm Au) mineralization, base metal Ag-Cu-Ag epithermal mineralization merit further attention. Surface expressions of skarn mineral assemblages as well as epithermal textures and mineralization at surface may be indicative of a porphyry Cu(\pm Mo) deposit at depth. A notable limiting factor to renewed exploration in the California district is land status and public opposition, with a large portion of the Chiricahua Mountains classified as the Chiricahua

National Monument and the Chiricahua Wilderness. The defined extents of the California mineral district are north and east of these two areas, however, proximity to protected lands likely poses obstacles to future exploration activities.

Cochise Mining District

Location and History

The Cochise mining district is located in northwestern Cochise County, about 25 miles north of the historic Tombstone district and immediately northwest of the Middle Pass district. The district makes up a large portion of the Little Dragoon Mountains and stretches to the south and east, straddling Interstate 10 (see Garcia and Richardson (2021) for district boundaries). Peaks in the rugged northern half of the Little Dragoon Mountains reach over 6,500 feet in elevation, with adjacent basins sitting around 4,500 feet. The eastern part of the district contains a series of low-lying hills, the Gunnison Hills and the Red Bird Hills, that get up to roughly 5,500 feet in elevation. The district has undergone considerable historic production of copper, zinc, silver, and tungsten principally from copper skarns and tungsten lode/vein type mineralization. The district is an active copper producer with the recent restart of mining at the historic Johnson Camp mine by Gunnison Copper (Gunnison Copper, 2026).

It is uncertain when exactly ore was first discovered in the Cochise district, but copper deposits were worked south of the Johnson Camp mine area prior to 1881 (Wilson et al., 1950; Cooper and Silver, 1964; Woodson et al., 2025). The Southern Pacific Railroad was completed in 1881, passing 4 miles south of the present-day Johnson Camp mine area. This railroad served as the catalyst for the growth of underground mining in the district (Woodson et al., 2025). Hence, the first recorded production numbers are from 1882, when the Russel Gold and Silver Mining Company of Philadelphia began smelting ores from the Peabody mine (Wilson et al., 1950; Cooper and Silver, 1964; Keith et al., 1983). Since 1882, deposits in the district have been mined intermittently by numerous different operators. The bulk of historic production came from the Republic, Moore, Mammoth, Peabody, and Copper Chief mines, most of which were small underground mines in and around the present-day Johnson Camp mine area on the eastern flank of the Little Dragoon Mountains (Wilson et al., 1950; Woodson et al., 2025).

Since 1975, copper oxide mineralization has been mined on and off from the two open pits that make up Johnson Camp mine, the Burro Pit and the Copper Chief Pit. Total production from these two open pits from 1975-2010 was 187 million pounds of copper (Zimmerman et al., 2017). Keith et al. (1983) reported district production from 1882-1981 totaling approximately 146 million pounds of copper, 94 million pounds of zinc, 1.3 million pounds of lead, 720,000 ounces of silver, and 3,300 ounces of gold. Woodson et al. (2025) reported nearly 68 million pounds of copper production from Johnson Camp between 1975 and 1981, so if that total (68 million) is included in the Keith et al (1983) total, then total district copper production is

approximately 265 million pounds. Additionally, the district produced tungsten from 1898 to 1953 with most tungsten ore coming from the Bluebird, Dividend, and Little Fanny mines at the southern end of the Little Dragoon Mountains and the Tungsten King mine on the western flank (Cooper and Silver, 1964). There is some inconsistency in reported tungsten production with Keith et al. (1983) reporting a total of 6,550 units of WO_3 , while Cooper and Silver (1964) estimated 75,000 units. A unit of WO_3 is equal to 20 pounds of WO_3 , which contains ~15.862 pounds of tungsten. This leaves estimates of total tungsten production from the district between 0.1 and 1.2 million pounds, from Keith et al. (1983) and Cooper and Silver (1964), respectively.

In August of 2025 Gunnison Copper restarted mining of copper oxides and began producing copper cathode from the historic Johnson Camp mine, which has measured and indicated mineral resources, as of March 2025, totaling over 101 million tons at 0.34% copper (Woodson et al., 2025; Gunnison Copper, 2026). This is the first mining in the Cochise district since 2010 (Woodson et al., 2025). The company is also working with Nuton LLC, a Rio Tinto venture, to test a new bioleaching technology for copper sulfide production. By December of 2025, Gunnison Copper began production from copper sulfide ore via Nuton™ technology (Gunnison Copper, 2026). Nuton™ technology is a bioleaching process using bacteria to extract copper from primary sulfide minerals, which historically have been difficult to leach (Nuton Tech, 2026). In addition to restarting production at the Johnson Camp mine, Gunnison Copper is conducting ongoing local exploration, highlighted by hopes to develop an open pit mine at the Gunnison deposit (also known as North Star), less than 2 miles southeast of Johnson Camp and just south of Interstate 10. The Gunnison deposit has measured and indicated mineral resources of 832 million tons at 0.31% copper. Their goal is to start producing copper from the Gunnison deposit in 2031 (Gunnison Copper, 2026).

Geologic Setting

The Cochise district is located in the larger regional Basin and Range Physiographic Province, known for its repeated episodes of mountain building, sedimentation, and magmatism. The local geology has been described in detail by various researchers, with key geologic maps produced by Cooper and Silver (1964), Johnson et al. (2017) and Fitzpatrick (2021). The eastern Gunnison Hills and the entire Red Bird Hills, in the eastern portion of the district, were mapped by Cooper (1960). A key aspect of the district's geology is a ~57 Ma two-mica granite, the Texas Canyon pluton (ages reported in Fitzpatrick (2021) and references therein), that intrudes complexly deformed units from Proterozoic to Cretaceous in age. The Texas Canyon pluton makes up most of the southern Little Dragoon Mountains. Local structures record three principal tectonic events: (1) northeast-southwest trending folds related to the Paleoproterozoic Mazatzal Orogeny, (2) northwest-southeast trending folds and thrusts due to compression during the Laramide Orogeny, and (3) northwest-southeast trending normal faults and northeast tilting related to mid- to late Cenozoic Basin and Range extension (Cooper and Silver, 1964; Fitzpatrick, 2021). Sedimentary units north of the Texas Canyon granite are part of a monocline that dips to the northeast, whereas the sedimentary rocks to the south of the pluton are folded,

steeply dipping, and incorporated into complex imbricate thrust systems in a similar style to the highly deformed rocks of the Dragoon Mountains directly to the southeast (Fitzpatrick, 2021). The monocline north of the pluton is locally modified by folds that become more abundant on the western margin of the Little Dragoon Mountains (Fitzpatrick, 2021).

The deformed strata generally go from oldest to youngest from southwest to northeast across the district, with exceptions related to thrust systems south of the Texas Canyon pluton. The key Proterozoic units include the various subunits of the Paleoproterozoic Pinal Schist, the ~1.4 Ga Tungsten King granite stock on the western flank of the Little Dragoon Mountains, and the Mesoproterozoic Apache Group (i.e., the Pioneer Shale and Dripping Spring Quartzite), which is intruded by 1.1 Ga diabase sills. Paleozoic carbonate-dominated sedimentary units and the largely Cretaceous Bisbee Group (i.e., Glance Conglomerate, Morita Formation, and Cintura Formation) make up much of the eastern flank of the Little Dragoon Mountains, as well as the Gunnison Hills and Red Bird Hills further east. Lastly, in terms of main lithologies present, sporadic small volume Tertiary lamprophyre dikes and plugs intrude older rocks including the Texas Canyon granite (Cooper and Silver, 1964).

Mineral Deposits

The historically mined mineral deposits of the Cochise district were primarily (1) copper skarns and carbonate replacement deposits with byproduct zinc, lead, silver, and tungsten and (2) tungsten lode/vein systems. Cooper and Silver (1964) also describe copper-zinc vein deposits spatially associated with the copper skarns and lead-silver vein deposits located further east in the Gunnison Hills (i.e., the Texas Arizona mine). Looking at the district from a broader mineral system perspective, the deposits are thought to be part of a larger porphyry copper system genetically related to the emplacement of the Texas Canyon pluton (Zimmerman et al., 2017; Fitzpatrick, 2021). Fitzpatrick (2021) suggests that the Texas Canyon pluton was tilted to the northeast during Cenozoic extension by a series of southwest-dipping normal faults. Due to this tilting, the paleo top of the pluton is interpreted to be represented by its easternmost extent. Thus, Fitzpatrick (2021) explained the distribution of mineralization in the district as occurring from two distinct pulses of fluids released from the Texas Canyon pluton. These two pulses of fluid release are responsible for (1) early shallow porphyry copper style alteration and mineralization that formed above (and now east of) the cooling magma chamber and (2) deep, late-stage greisen alteration and tungsten mineralization present in the entire exposed area of the pluton. Essentially, from west to east, observed mineralization represents deeper to shallower parts of the magmatic system, respectively. This trend is expressed as tungsten lode/vein mineralization making up much of the deeper (presently exposed portion) of the pluton, with the Bluebird and Little Fanny mines as examples, and shallow porphyry style mineralization to the east in areas like Johnson Camp and Gunnison. It is notable that significant sericitic alteration is not present in the district, in contrast with most porphyry copper systems (Fitzpatrick, 2021).

The porphyry-related skarn and carbonate replacement deposits, east of the Texas Canyon pluton, at Johnson Camp and the Gunnison deposit are similar but with slight differences in host rock and dominant ore mineralogy. The deposits at Johnson camp are primarily characterized by replacement of thin beds of the Abrigo Limestone by chalcopryrite, sphalerite, pyrite, bornite (\pm scheelite, magnetite, and molybdenite) with alteration minerals including garnet, epidote, vesuvianite, diopside, tremolite, wollastonite, orthoclase, chlorite, calcite and quartz (Wilson et al., 1950; Fitzpatrick, 2021). Mineralization also occurs, to a lesser extent, in the 1.1 Ga diabase sills and Bolsa Quartzite. The deposits are variably oxidized with copper oxide mineralization including chrysocolla, malachite, copper limonite, and manganiferous wad (Woodson et al., 2025). Some supergene chalcocite and native copper are present below the oxide mineralization (Woodson et al., 2025). At the Gunnison deposit, copper oxides dominate to depths near 1,600 feet, with mineralization consisting of primarily chrysocolla with minor tenorite and other copper oxides mixed with minor supergene chalcocite (Zimmerman et al., 2017). Here, the Abrigo Limestone and Martin Formation serve as the dominant host rocks. At depth, copper sulfide mineralization occurs in structurally complex zones as fracture coatings, quartz-orthoclase-carbonate (\pm magnetite, chalcopryrite) veins up to 10 cm wide, and disseminations. Skarn-type calc-silicate alteration at Gunnison is similar to what is observed at Johnson Camp and vein related alteration consists of haloes of chlorite, actinolite, and epidote (Zimmerman et al., 2017).

The tungsten lode/vein systems are primarily hosted within the main body of the Texas Canyon pluton and along faults cutting other units nearby (Fitzpatrick, 2021). Mineralization occurs as large quartz veins ranging from less than 2 feet wide up to 6 feet wide and extending 300-2,000 feet in length (Cooper and Silver, 1964). The typical mineralogy of the veins is quartz, muscovite, fluorite, hübnerite, scheelite, minor base metal sulfides, and traces of apatite and calcite. The vein zones are accompanied by greisen alteration extending a few inches to a few tens of feet from the veins (Cooper and Silver, 1964; Fitzpatrick, 2021).

Exploration Potential

Ongoing exploration efforts by Gunnison Copper are targeting deeper porphyry copper mineralization in and around the Johnson Camp and Gunnison deposits on the eastern flanks of the Little Dragoon Mountains. North of Johnson Camp, near the historic Peabody mine, the company has identified additional mineralization in an area they call Strong and Harris with an inferred resource of 76 million tons at 0.52% copper (Gunnison Copper, 2026). South of the Gunnison deposit is another target called South Star that is part of their ongoing exploration efforts. Tungsten mineralization in the western half of the district seems to be of little economic interest, at present. However, the recent shifted focus to domestic critical mineral production could warrant further examination of the remaining tungsten resources for small scale production.

Cottonwood Basin Mining District

Location and History

Cottonwood Basin is a very small mining district located in the southern extent of the Peloncillo Mountains of New Mexico-Arizona. The district lies on the border of Arizona and New Mexico, with the San Bernardino Valley to the west, and the Animas Valley to the east. There is one known historic mine in the district, the Silvertip gold mine. Remains of the Silvertip mine include a 240-ft-long adit and a 30-ft-deep shaft sunk on a mineralized fracture zone (Hayes et al., 1983). Waste piles around the workings contain up to 80 tons of rock but no ore minerals have been noted. There is no production data available for the Silvertip Mine (Hayes et al., 1983) and there are presently no active mines in or around the district (Plonka and Richardson, 2025).

Geologic Setting

The Cottonwood basin mining district encompasses a small portion of the Peloncillo Mountains which are a northeast-southwest trending mountain range predominately in New Mexico. The southwestern tip of the Peloncillo Mountains crosses the New Mexico-Arizona border. The geology of the greater Bunk Robinson Peak and Whitmire Canyon Roadless areas are described by Hayes et al. (1983). Outcropping rocks in the Cottonwood Basin mining district are dominated by Oligocene rhyolitic lavas and tuffs and related latite-dacite lavas and tuffs, volcanic and sedimentary breccias, and finer grained volcanoclastic rocks overlain by Miocene volcanic rocks, siliciclastic rocks, conglomerates, and Pleistocene-Pliocene basalt flows (Hayes et al., 1983). Faulting in the area is thought to be related to a volcanic cauldron responsible for the abundance of volcanic rocks in the region, possibly active in the Oligocene (Hayes et al., 1983).

Mineral Deposits and Exploration Insight

There are no known metallic mineral deposits in the Cottonwood Basin mining district. The historical Silvertip Mine reportedly targeted gold mineralization, but no production data is available to support such reports. Hayes et al. (1983) of the United States Geological Survey conducted a mineral resource potential report for the Bunk Robinson Peak and Whitmire Canyon Roadless areas in New Mexico and Arizona, which overlaps slightly with the Cottonwood Basin mining district. Geochemical results from their work identified anomalously high values of barium, lead, molybdenum, and arsenic near Bunk Robinson Peak (New Mexico) and anomalously high barium near the Baker Canyon fault (Arizona) along with field observations of hydrothermally altered rocks near the Silvertip Mine and throughout the roadless areas. These results alone do not indicate any mineral resource potential, but it is possible that it warrants more reconnaissance field work and geochemical studies. The position of this district on the border of Arizona and New Mexico may make permitting and exploration difficult, as alteration and geochemical anomalies occur on both sides of the state border. There are presently no active mining claims on file with the Bureau of Land Management's Mineral and Land Records System.

Dos Cabezas-Apache Pass Mining District

Location and History

The Dos Cabezas-Apache Pass mining district, also historically called the Teviston district, encompasses the Dos Cabezas Mountains in northeast Cochise County. Historically, the Teviston mining district referred to the northeast flank of the mountain range, and the Dos Cabezas mining district the southwest flank (Drewes et al., 1988). The southeastern extent of the mining district borders the California mining district of the Chiricahua Mountains. The Dos Cabezas and Chiricahua Mountains are separated by Apache Pass.

The Dos Cabezas district was prospected as early as the 1860's, but no appreciable mining activity occurred until the nearby Chiricahua Indian Reservation was abolished in 1878 (Keith, 1973). Major commodities of the district include Au, Ag, Pb, Zn, Cu, Fe, and minor W (Calder, 1984; Keith, 1973) found in sulfide-bearing veins commonly located in shear zones, sporadic replacement and/or skarn-type deposits in Paleozoic limestone, placer gold deposits in shallow alluvium, and gold lode deposits hosted in Precambrian granite (Calder, 1984; Drewes et al., 1988). Keith et al. (1983) broke out production for the Mascot, Apache Pass, and Teviston regions. Production from Apache Pass from 1904-1941 includes 150 pounds of copper, 29,000 pounds of lead, 600 ounces of gold, 600 ounces of silver, and 8 short ton units of tungsten. Production from Mascot between 1890-1953 includes 4,308,000 pounds of copper, 1,572,000 pounds of lead, 13,400 ounces of gold, and 427,000 ounces of silver. Production from the Teviston district between 1923-1940 includes 1,000 pounds of copper, 4,500 pounds of lead, 200 ounces of gold, and 800 ounces of silver (Keith et al., 1983). There are abundant small-scale mines and workings throughout the district. Keith (1973) documents 17 distinct mines or mine-groups in the Dos Cabezas (and Teviston) districts.

Major mines in the Dos Cabezas district include the Elma, Mascot, and Dives mines which were the largest base-metal producers of primarily chalcopyrite, bornite, and galena ores (Drewes et al., 1988). Production values are not available for each of these mines, however, Shields (1940) reports that the Dives property produced a total value of \$93,500 worth of ore from 1877-1940. The Gold Prince mine was the main producer of gold in the district with lesser gold production from the Mascot, Mineral Park, Leroy and Cottonwood mines. Minor gold was produced from placer deposits on the north and southwest flanks of the Dos Cabezas Mountains (Drewes et al., 1988). Minor tungsten was produced largely from the historic Teviston mining district. Many other small mines, prospects, and occurrences are scattered throughout the Dos Cabezas district, but most had little to no recorded production to report. Many of these prospects are distributed along the Apache Pass fault zone and within a dacitic breccia (Drewes et al., 1988).

Geologic Setting

The Dos Cabezas Mountains are composed of Precambrian metasedimentary rocks, Paleozoic limestone, Upper Cretaceous sandstone and slate, and Late Cretaceous to Cenozoic intrusive and extrusive igneous rocks (Shields, 1940; Erikson, 1968). Precambrian rocks include the Pinal Schist, which is locally characterized as phyllite, argillite, and amphibolite units, as well as five distinct gneissic quartz monzonite intrusions, two distinct weakly foliated quartz monzonite plutonic units and an undated dacite porphyry stock. The Precambrian "gneissic quartz monzonites" intrude the Pinal Schist. The oldest of the five Precambrian quartz-monzonite

intrusions in the Dos Cabeza Mountains has a reported age of 1440 ± 30 Ma (Rb-Sr isochron date) (Erikson, 1968). The foliated quartz monzonite intrusive rocks have reported ages of 1400-1450 Ma and 1375 ± 40 Ma (Rb-Sr isochron dates) (Erikson, 1968). Paleozoic units present in the Dos Cabezas Mountains include the Cambrian Bolsa quartzite, Ordovician El Paso Formation, Devonian Portal Formation, Mississippian Escabrosa Limestone, and the Pennsylvanian Horquilla Limestone of the Naco Group (Sabins, 1957). Mesozoic stratigraphy includes the Lower Cretaceous Bisbee Group Glance Conglomerate and a Cretaceous complex intrusive mass referred to as a welded volcanic breccia (Erikson, 1968).

Laramide tectonism resulted in at least two major west-northwest trending faults, including the Apache Pass Fault which is considered an important conduit for mineralizing fluids in the Dos Cabezas and Chiricahua Mountains (Erikson, 1968; Drewes et al., 1988). Laramide-related stocks, plugs, and dikes intruded into the central and western Dos Cabezas Mountains in the Paleocene and Eocene and range in composition from basalt and diabase plugs, fine-grained quartz diorite to porphyritic quartz monzonite stocks, and small olivine basalt dikes (Erikson, 1968). Erikson (1968) produced K-Ar dates for several of these Laramide stocks which range in age from 64.4 ± 1.9 Ma (the Silver Camp quartz diorite stock) to 55.9 ± 1.7 Ma (the Maverick porphyritic quartz monzonite stock). The olivine basalt dikes are the youngest of this series of intrusive activity, yielding an age of 47.6 ± 1.4 Ma. Following a brief period of quiescence, post Laramide-magmatism, Eocene to Oligocene porphyritic andesites (35.2 ± 3.1 Ma), dacite porphyry dikes and sills (33.9 ± 1.9 Ma), a large granodiorite stock (29.0 ± 1.7 Ma), and “quartz dikes” (< 29 Ma) intruded the Dos Cabezas Mountains, marking the youngest volcanic-magmatic events in the area (Erikson, 1968).

A majority of the ore deposits within the Dos Cabezas district are genetically related to Late Cretaceous to Paleocene magmatic-hydrothermal activity, while fewer deposits are associated with dikes and quartz veins that may be as young as Miocene (Drewes et al., 1988). The Apache Pass fault zone appears to be an important ore-controlling structure in both the Dos Cabezas and California mining districts and is especially favorable for mineralization when spatially associated with intrusive igneous rocks. Competing structural interpretations for the Apache Pass fault zone are discussed in the California mining district section. The dacitic breccia and breccia pipe structures are also considered important mineralization controls in the region. Skarn and carbonate replacement type ore mineralization occurs in sedimentary formations, namely dolomite of the El Paso Formation, the Horquilla Limestone, and the Bisbee Group (Drewes et al., 1988).

Mineral Deposits

Many of the ore deposits in the Dos Cabezas-Apache Pass mining district occur adjacent to the Apache Pass fault zone, especially where fault splays interact with stocks and dikes, while fewer deposits occur in dacitic breccia bodies at the base of the volcanic section (Drewes et al., 1988). Drewes et al. (1988) describe the mineralization in this mining district and draw on similarities to that of the nearby Peloncillo Mountains (25 miles east of the Dos Cabeza Mountains) and the Cochise and Turquoise mining districts (30-45 miles west and southwest, respectively).

Geochemical sampling conducted by Drewes et al. (1988) found that base and precious metals are widely dispersed in the Dos Cabezas mining district. High silver values were found to

occur in the north-central portion of the range, and along the southwest strand of the Apache Pass fault zone. Silver mineralization occurs with both copper and lead, appearing as argentiferous galena when associated with lead mineralization. Lead mineralization generally occurs more commonly in the northeast and northwestern parts of the volcanic field than the rest of the region. Gold commonly occurs in pyrite-bearing quartz veins or in argentiferous galena. Copper and zinc are widely distributed throughout the mining district, with copper being more prevalent. Quartz veinlets and propylitic alteration are seen throughout the district, and intense clay alteration occurs locally, indicative of hydrothermal fluids migrating through the sedimentary and volcanic rocks of the central Dos Cabezas Mountains (Drewes et al., 1988).

The Elma, Mascot, and Dives mines were the main producers of base metals in the district. The ore mineralogy primarily consists of chalcopyrite, bornite, and galena. The orebody at the Elma Mine is a “pyrometasomatic pipe-like body” that developed along a shear zone cutting the Upper Cretaceous or Paleocene volcanic rocks and within the Paleozoic limestone (Drewes et al., 1988). Ore bearing veins, replacement lenses, and disseminated ore at the Mascot Mine are also hosted in a sheared block of Paleozoic limestone and within a dacitic breccia near the Paleocene Mascot granitic stock (Drewes et al., 1988). Minor gold, tungsten, and beryllium was also produced at the Mascot Mine (Drewes, 1988). The Dives and Gold Ridge group mines targeted lode deposits hosted in quartz veins between Cretaceous siliciclastic rocks and Precambrian granitic rock along the southwest strand of the Apache Pass fault zone (Shields, 1940; Drewes et al., 1988). The paragenetic sequence of mineralization at the Dives ore-body is reported as: (1) siderite greater than calcite in veins and veinlets; (2) early barren quartz; (3) pyrite; (4) sphalerite; (5) chalcopyrite, galena (extensively altered to cerussite), and gold(?); (6) quartz and gold(?); (7) gold(?); and (8), cerussite, covellite, azurite and malachite. Shields (1940) notes that gold is free-milling at the surface, but he did not seem to encounter notable amounts in his studies.

Tungsten occurs in the Dos Cabeza mountains as low-grade scheelite ore in white quartz veins hosted in limestone and quartzite units (Dale et al., 1960). Sparse high-grade ore occurs in epidote and quartz veinlets (Dale et al., 1960). Tungsten mineralization occurs at the Silver Bell Claims, which consist of a shaft sunk on a quartz-wollastonite vein cut by tactite containing sparse scheelite mineralization. At the Austin mine, adits and shafts targeted a steeply-dipping quartz vein that cuts silicified limestone units. High-grade scheelite associated with galena and minor sphalerite, chalcopyrite, and pyrite is reported to occur in sheared and silicified limestone adjacent to the quartz vein (Dale et al., 1960).

Exploration Potential

The U.S. Borax and Chemical Corp. explored an area between Dos Cabezas Peaks, Cooper Peak, the Mascot mine, and the Elma mine from 1973-1975 and were reportedly targeting a deeply buried porphyry copper deposit. Targeting was based on surface exposure of copper-bearing massive sulfides, favorable alteration, mineral zoning, the presence of breccia pipes and proximity to regional structures. Drill results were not encouraging, and the project was cancelled (Drewes et al., 1986). In the mid-1980's Phelps Dodge reopened the Gold Prince mine and were reportedly mining high-purity vein quartz to use as smelter flux in their Douglas, Arizona copper smelter, but apparently did not explore for, or produce, any metal commodities (Drewes et al., 1986).

Drewes et al. (1988) highlights several geophysical surveys, including aeromagnetic and gravity studies, that identify several blind stocks or dikes along the Apache Pass fault zone or within the Dos Cabezas volcanic field, which could represent favorable sites for mineralizing fluid migration and deposit formation. Overall, the Dos Cabezas mining district encompasses a large area with evidence for favorable structures and Laramide age magmatic-hydrothermal systems, possibly including skarn and carbonate replacement mineralization – which could be indicative of a deeply buried porphyry system. Mundoro Capital is currently exploring areas within the Dos Cabezas mining district including Mescal Canyon, Mineral Park, Casey Copper Canyon, Elma, and Pediment areas. Mundoro highlights three target areas with potential for outcropping porphyry copper targets and two concealed target areas. Age dating by Mundoro has confirmed that the magmatic-hydrothermal system is “Laramide-aged” and they appear to have completed their “phase 1 drilling” and surface mapping campaigns (Mundoro, 2026). It seems likely that untapped resources remain in the Dos Cabezas mining district, and with advancing exploration techniques and ever-changing commodity needs and prices, this area seems to warrant current and future exploration activities.

Douglas Mining District

Location and History

The Douglas mining district (also referred to as Ash Peak) is located in southeastern Cochise County, Arizona – roughly 5 miles east of the town of Douglas. The district is situated on the Arizona-Mexico border, just south of the Parilla Mountains.

Historically, the Douglas district has only commercially produced industrial minerals such as gypsum, cinders, and aggregates (Keith, 1973). There are currently two active aggregate plants in the Douglas district, both of which produce sand and gravel commodities (Plonka and Richardson, 2025). There are two additional aggregate plants north and northwest of the town of Douglas. While the Douglas district has not historically produced metallic resources, it was the location of the Douglas smelter where ores from the nearby Warren (Bisbee) district were shipped and processed from 1903-1987 (Briggs, 2015). A thorough history of the Douglas smelter is provided by Briggs (2015). Prospecting efforts over the past century have identified numerous weak and spotty base and precious metal (Pb-Ag-Zn ± Cu-Au) occurrences and there are minor workings in the district, but no production data are known to exist (Keith, 1973).

Geologic Setting

The Douglas district is within the Mexican Highland of the greater Basin and Range province. The district is located just south of the Parilla (Perilla) Mountains, with the Sulphur Springs Valley to the west and the San Bernardino Valley to the east. The bedrock geology of the Douglas district is composed of limestone, shale, and sandstones of the Cretaceous Bisbee Group which have subsequently been intruded by Cretaceous to Paleocene porphyritic rocks (Cooper, 1959; AZGS Mining Files, 1960). The igneous intrusive rocks are described as relatively fine-grained porphyritic sills, dikes, and small stock-like masses of andesite and monzonite and are widely scattered throughout the region (AZGS Mining Files, 1960).

Metallic Mineral Deposits

A geologic report by John N. Faick on the lead-silver deposits of the Ellsworth Property in the Ash Peak (Douglas and Ash Spring) district appears to be the only literature that details the mineralization of the district (AZGS Mining Files, 1960). The area was reportedly extensively prospected in the early 1900s with 1,000 feet of workings which includes three shafts, a 42- by 65-foot-long tunnel and a 115-foot drift (AZGS Mining Files, 1960). There are noted occurrences of weak and spotty base metal sulfides, but no production has been recorded (Keith, 1973). According to Faick (AZGS Mining Files, 1960), the rocks are only mildly and locally moderately altered to clay and sericite, with much of the limestone remaining relatively unaltered. The principal ore mineral is galena, with lesser cerussite, anglesite, and copper-sulfides. Galena is closely associated with barite, quartz, and minor calcite and occurs primarily in limestone, with rarer mineralization in the intrusive units (AZGS Mining Files, 1960). Faick notes abundant pyrite in the intrusive unit but is unclear whether it is associated with Pb-Ag mineralization in the Douglas district.

Industrial Resources

The Douglas district is primarily known for producing gypsum, cinder, sand and gravel (Keith, 1973; Plonka and Richardson, 2025). Gypsum deposits are up to six feet thick, irregular lenses of white gypsum and gypsite overlying Cenozoic clay and shale beds (Keith, 1973). Gypsum grades in Douglas range from 91-95% and as of 1969 were described as, “largely mined out.” Modern industrial and aggregate mining in the region produces sand and gravel which is typically used for asphalt for roads, concrete when mixed with cement for building purposes, or gravel for various end-use applications (Plonka and Richardson, 2025).

Exploration Potential

While it appears that not much (published) work has been done on the metallic resources in the Douglas district over the last ten decades, there appears to be some interest in the area. Kennecott Exploration Company holds a roughly 6km by 2km block of mining claims on record with the Bureau of Land Management (Mineral & Land Records System). As with many metallic districts that were prospected in the 1800’s and early 1900’s, modern exploration techniques may lead to newfound interest in the Douglas district.

Hartford Mining District

Location and History

The Hartford mining district is in the southwest corner of Cochise County, encompassing the Huachuca Mountains approximately five miles southwest of the town of Sierra Vista. The Huachuca’s are a northwest-southeast trending range with it’s southeastern extent along the Arizona-Mexico border. The modern Hartford mining district boundary encompasses the once distinguished Reef district (Keith et al., 1983; Garcia and Richardson, 2021).

Little recorded mining activity occurred in the Hartford district prior to 1877 when Fort Huachuca was established, although it is speculated that earlier Spanish and Mexican settlers

likely prospected the area (Keith, 1973). Intermittent and minor lead-silver and gold ore was produced between 1880 and the early 1900's (Keith, 1973). In the 1880's, minor amounts of ore were shipped from Nelly James and other prospects to the lead smelters at Charleston and Benson (Wilson, 1951). Tungsten deposits were discovered and worked extensively during World War I, with the Reef Mine producing several thousand tons of tungsten ore (Keith, 1973). A majority of the mining activity in the Hartford district has occurred in the southern portion of the Huachuca Mountains (Alexis, 1949). Total reported base and precious metal production from the Hartford district includes 180,000 pounds of copper, 1,193,000 pounds of lead, 746,000 pounds of zinc, 400 ounces of gold, 60,000 ounces of silver, and 28,500 ounces of manganese from 1897-1963 (Keith et al., 1983). Accurate production records of tungsten are not available; however, Keith (1973) suggests 170 or more tons of 60-78% WO₃ (tungsten ore) concentrates may have been produced in the Hartford district. Keith (1973) documented 24 distinct mines and prospects in the Hartford district.

Geologic Setting

The Hartford district of the Huachuca Mountains is situated in the greater Basin and Range physiographic province. The Huachuca Mountains are a northwest trending range approximately 22 miles long and 8 miles across and are bound by the San Pedro valley to the east. The maximum altitude at Miller Peak is 9,446 feet.

Several geologic maps have been published for the Huachuca Mountains (e.g. Hayes and Raup, 1968; Drewes, 1981 – plate 6; Drewes and Bultman, 1996). Precambrian through Cenozoic rocks are exposed in the Huachuca Mountains. Precambrian units include coarse-grained to locally pegmatitic granitic rocks which are overlain by Paleozoic sedimentary rocks (Alexis, 1949; Tufton and Armstrong, 1994). Paleozoic stratigraphy in the Huachuca Mountains consists of the Cambrian Bolsa Quartzite, Abrigo Limestone, Devonian Martin Formation, Mississippian Escabrosa Limestone, and the Pennsylvanian Naco Group limestone. Locally, there are minor exposures of Permian limestone. The Jurassic Huachuca quartz monzonite pluton intrudes Paleozoic and Triassic to Jurassic age siliceous volcanic rocks (Tufton and Armstrong, 1994). K-Ar dating of biotite from the Jurassic Huachuca quartz monzonite produced an age of 167 ± 6 Ma (Marvin et al., 1973). Cretaceous sedimentary and volcanic rocks are exposed in the Huachuca Mountains, most notably on the western slopes of the northern portion of the range, which range from clastic sedimentary rocks, limestone, andesite flows, and a dacite porphyry unit (Alexis, 1949). The Cretaceous Bisbee Group is mapped quite extensively by Drewes (1996) although not mentioned specifically by previous authors. Cenozoic rocks include rhyolite porphyry flows, lesser tuffs to tuffaceous sandstone, and the Gila Conglomerate (Alexis, 1949). An exposure of Late Cretaceous to Eocene intrusive rock is mapped by Drewes (1996) on the western flank of the Huachuca Mountains and Ludington (1984) describes a Cretaceous aged, elongate granodiorite pluton and associated sills in the northwestern Huachuca Mountains. Drewes and Bultman (1996) indicate that small granitic stocks, ranging in age from 65 to 53 Ma, are spatially associated with mineralization and hydrothermal alteration in the Huachuca Mountains. Quaternary gravels and conglomerates infill the areas of low relief in the Huachuca Mountains (Alexis, 1949).

Generally, rocks in the Huachuca Mountains are cut by a variety of thrust faults, by northwest striking steep fault splays of the Sawmill Canyon-Kino Springs fault system, and by many other smaller localized faults (Drewes and Bultman, 1996). A majority of the deformation

in the Huachuca Mountains is inferred to have been post-Cretaceous, although several older thrust faults cut Precambrian granite, and are mineralized by tungsten and precious-metal bearing quartz veins (Tuftin and Armstrong, 1994). New geochronologic and structural investigations in the Huachuca Mountains may refine this geologic history and allow for a deeper understanding of potential for mineral deposits in the Hartford mining district.

Mineral Deposits

Weber (1950) describes four distinct types of ore deposits or mineral occurrences in the Hartford District; (1) scheelite-bearing quartz veins with trace gold, silver and base metals at the Tungsten Reef mine and the James mine, (2) Pyritic gold-quartz veins in prospects in Miller and Kelly Canyon, (3) “contact metamorphic zones with copper, lead, and zinc mineralization” at the Wisconsin group mines, which likely refers to carbonate-replacement type mineralization, and (4) Manganese oxide replacement mineralization in limestone.

Notable zinc and lead mines in the Hartford district include the State of Texas Mine, the Panama/Manila Mine, the Armistice Mine, the Cave Mine and the James Mine (Wilson, 1951). The State of Texas claim was initially staked by August Baron in 1898 and acquired by the Mitchell Development Company of Michigan several years later. A 1904 report describes the workings as three tunnels, a 250-ft-deep shaft, and one shallower shaft. The State of Texas Mine produced 1,791 tons of ore from 1943-1947 and ore is noted to contain 10 to 19.65% zinc, 1.0 to 6.65% lead, 0.2 to 1.12% copper, 2.75 to 11 oz of silver and negligible amounts of gold (Wilson, 1951). Ore minerals consist of sphalerite and galena together with local pyrite and minor chalcopyrite and mineralization is associated with garnet and other silicates, calcite and quartz. Ore mineralization replaces impure (Escabrosa or Naco) limestone within a northward-plunging anticline and appears to be strongest along two fissure zones. Detailed descriptions of the Panama/Manila mine are not available, but specimens of ore contained cerussite in a quartz-calcite gangue with minor malachite (Wilson, 1951).

Scheelite ore was mined in the Hartford district during World War I, typically from mines and prospects that had earlier been worked for gold and silver (Dale et al., 1960; Keith, 1973). Tungsten ore was primarily produced from localized concentrations of high-grade scheelite ore in quartz veins hosted in both Paleozoic sedimentary rocks and granitic rocks (Dale et al., 1960). At the Tungsten Reef mine, scheelite is straw-colored and occurs in milky-white quartz veins near the base of the Cambrian Abrigo Formation. Dale et al. (1960) describes two primary veins at Tungsten Reef, which parallel each other and individually range in thickness from a few inches to 6 feet-across. At the Emerald Group, scheelite-bearing quartz veins occur in deformed Paleozoic limestone. Shafiqullah et al. (1980) obtained a K-Ar age date of 47.8 ± 1.0 Ma on sericite in a massive quartz vein hosted in the Bolsa quartzite at the Reef Mine.

Exploration Potential

Drewes and Bultman (1996) highlight the following favorable geologic features for ore deposition in the Huachuca Mountains (and proximal Canelo Hills and Patagonia Mountains), including; (1) favorable host rocks, (2) extensively altered areas, (3) the presence of Late Cretaceous or early Tertiary stocks, (4) presence of fine-grained intrusive rocks coeval or slightly younger than the “Laramide” plutons, and (5) prevalence of steep, northwest-striking faults. A mineral appraisal of the Huachuca Mountains region by Tuftin and Armstrong (1994) rated the region with relatively low mineral resource potential, however the authors cite economic and

political factors as major deterrents to mineral exploration in the region – which are markedly different at this time. Mineralization in the Hartford district remains relatively poorly constrained and further work is likely warranted in the region, especially geochronologic and geochemical reconnaissance. Accessibility and social license may be limiting factors in the exploration or development of the Hartford district, as much of the region is national forest land intermixed with private land parcels and a large swath of military land near Fort Huachuca.

Middle Pass Mining District

Location and History

The Middle Pass mining district makes up the bulk of the central and northern Dragoon Mountains, in west-central Cochise County (see Garcia and Richardson (2021) for district boundaries). The district includes both the Golden Rule and Middle Pass mineral districts previously defined by Keith et al. (1983). Immediately to the north of the Middle Pass mining district is the Cochise mining district, in the Little Dragoon Mountains, and immediately to the south is the Turquoise mining district, at the very southern end of the Dragoon Mountains. The Dragoon Mountains are a roughly north-south trending rugged range with elevations between roughly 5,000 and 7,500 feet. Historic resources of the district were dominantly base metal (copper-zinc-lead) skarns and carbonate replacement deposits, with some gold-bearing quartz veins in the northeastern part of the district. Additionally, quarries at the northern end of the range produced marble for landscaping material and limited limestone quarries produced crushed stone for aggregate materials and to make cement.

The history of some of the important individual mines in the district is documented by Wilson et al. (1951) and detailed summaries of all mines and prospects are provided by Chatman (1993). According to Chatman (1993), gold mineralization was first discovered in 1849, in the area that would become the Golden Rule mine, by miners on their way to California during the famous U.S. gold rush. The district was generally ignored until the 1870s when discoveries at Tombstone sparked a local silver rush. Though silver was the targeted commodity early on, it has only been produced as a byproduct of base metal skarn mineralization. Early mining in the district began in 1883 with gold production from the Golden Rule mine (Wilson et al., 1951). Nearly all of the district's gold production and about a third of its lead production came from the Golden Rule mine, which was active until 1957 (Keith et al., 1983). Other than the Golden Rule mine, sporadic production of mainly copper and zinc occurred from the 1890s to the 1960s, predominantly from five key mines: Black Diamond, Middlemarch, Cobre Loma, Abril, and San Juan (Chatman, 1993). Total district production of metallic resources from 1883-1979 was 2.5 million pounds of copper, 8.4 million pounds of zinc, 0.6 million pounds of lead, 11,000 ounces of gold, and 146,000 ounces of silver (Keith et al., 1983). Minor molybdenum and tungsten production was also reported. Total estimated marble production from the mid-1950s to the early 1960s was 138 million pounds (Chatman, 1993).

No known production has occurred in the district since the late 1970s. Chatman (1993) reported that small-scale exploration took place from the 1970s to the early 1990s, including drilling by a couple companies in 1992, with one focused on skarn mineralization and the other on gold mineralization. As of early 2026, there are limited lode claims at the Abril, Middlemarch,

Muheim, and Golden Rule mines, and some placer claims in the northwestern part of the Dragoon range. Beyond that, no information regarding modern exploration could be found.

Geologic Setting

The complex geology of the Dragoon Mountains has been mapped by several authors, including some that have published more small-scale maps of specific areas within the range (e.g., Cederstrom, 1946; Rushing, 1978; Sousa, 1980; Trzinski and Chapman 2023) as well as more regional maps (e.g., Gilluly, 1956; Drewes, 1996). A map by Drewes (1987) perfectly covers the extent of the Middle Pass mining district at 1:24,000-scale. As with the other mining districts in Cochise County, the geologic complexity of Middle Pass largely results from its location in the Basin and Range Physiographic Province, an area affected by repeated episodes of mountain building, sedimentation, and magmatism. A key aspect of the district's geology is a large Oligocene-Miocene granitic batholith exposed at the center of the range, the Stronghold Granite, which intrudes heavily faulted strata of mostly Paleozoic and Cretaceous age (Drewes, 1987).

The key geologic units present in the Middle Pass district, from oldest to youngest, consist of the Paleoproterozoic Pinal Schist and amphibolites; a Mesoproterozoic granodiorite, which in some areas is referred to as the Cochise Peak Quartz Monzonite and is thought to be Triassic to Jurassic in age by Gilluly (1956); Paleozoic carbonate-dominated sedimentary rocks, sedimentary rocks of the Cretaceous Bisbee Group, some "Laramide" age (Late Cretaceous to early Paleogene) intermediate to felsic, variably porphyritic, dikes and plugs; an Oligocene granitic stock called the Jordan Canyon stock, the Oligocene-Miocene Stronghold Granite batholith; and numerous Miocene aphanitic to slightly porphyritic rhyolite dikes and plugs (Drewes, 1987). In general, the voluminous Stronghold Granite dominates the central part of the range with heavily faulted Paleozoic and Cretaceous sedimentary units exposed to both the north and south. The Mesoproterozoic granodiorite is exposed in various locations throughout the district with prominent exposures near the Pinal Schist in the northwestern part of the range and in the central part of the range, west of Middlemarch Canyon. Some intermediate to felsic Laramide dikes cut the Paleozoic and Cretaceous sedimentary rocks in the northeastern part of the range, with more voluminous Laramide plugs exposed in the vicinity of the Golden Rule mine. The Oligocene Jordan Canyon stock is exposed in the very northwestern part of the range and Miocene rhyolite dikes and plugs cut all older units throughout much of the district.

The complex structural geology of the district has been described by numerous authors (e.g., Cederstrom, 1946; Gilluly, 1956; Drewes, 1987). As with much of the region, the area underwent Mesozoic to early Cenozoic compression associated with subduction of the Farallon Plate and development of the western North American orogenic belt. Locally, this resulted in a strong northwest-southeast structural fabric characterized by numerous extensive thrust faults and folds (Drewes, 1987). Early work suggests Cenozoic extension was not too significant in the Dragoon Mountains (e.g., Cederstrom, 1946; Gilluly, 1956; Drewes, 1987), however, Trzinski and Chapman (2023) recently mapped laterally extensive normal faults in the Middlemarch Canyon area, possibly old thrust faults reactivated during Miocene Basin and Range extension.

Metallic Mineral Deposits

The metallic mineral deposits of the Middle Pass mining district can be broken into two distinct deposit types: (1) copper-zinc-lead skarns and carbonate replacement deposits, and (2)

gold-bearing quartz veins. The skarns and carbonate replacement deposits are present throughout the district, but the key historic producing mines are primarily located in the southern end of the district. The gold-bearing quartz veins are principally in the northeast, in the Golden Rule mine area.

The skarn and carbonate replacement ores throughout the district vary in terms of specific metal ratios. Deposits north of the large Stronghold Granite batholith are more zinc and lead-rich whereas the deposits south of the batholith are mostly copper and/or zinc-rich (Chatman, 1993). To the south, at the Middlemarch mine, metals were produced from a copper skarn with some zinc and silver mineralization and minor gold. Mineralization at the Rainbow mine, in the northern part of the district, is a lead-zinc skarn with no reported copper or precious metals. Despite this variability, controls on mineralization are similar for many of the skarn and carbonate replacement deposits. Chatman (1993) suggests that mineralization is both spatially and genetically related to intrusion of the Stronghold Granite and possibly the later Miocene rhyolite dikes, though Sousa (1980) reported that these dikes cut skarn mineralization and show no thermal effects on favorable host rocks in Middlemarch Canyon. In general, the deposits are hosted in carbonates and shales of the Cretaceous Bisbee Group and the Paleozoic limestones along northwest trending faults and occasionally fractures in north-northwest trending fold crests.

Alteration related to the skarn and carbonate replacement deposits consists of widespread isochemical-thermal alteration of limestone to marble and metasomatic skarn development. Sousa (1980) studied the mineralization and alteration in Middlemarch Canyon, where skarn-type alteration was most intense along northwest-trending faults occurring with ore mineralization primarily in Bisbee Group sedimentary rocks. Skarn alteration mineralogy consists of garnet (grossular and andradite), wollastonite, epidote, clinopyroxene (hedenbergite), biotite (phlogopite), chlorite, hematite, quartz and calcite. The dominant ore minerals are sphalerite, chalcopyrite, pyrite, galena, and pyrrhotite, with some minor scheelite. Sulfide ores formed in association with phlogopite and chlorite, both spatially and temporally. Supergene chalcocite, covellite, and copper oxides are present but relatively insignificant (Sousa, 1993). Rushing (1978) studied skarn alteration and mineralogy in Stronghold Canyon, about five miles north of Middlemarch Canyon where the host rock was Abrigo Limestone. Skarn alteration mineralogy here consists of fluorite, garnet, clinopyroxene (diopside), vesuvianite, scapolite, epidote, chlorite, calcite, quartz, and magnetite, and similar ore mineralogy to Middlemarch (Rushing, 1978).

The gold-bearing veins in and around the Golden Rule mine have not been well studied. Keith et al. (1983) reports the mineralization in this area to be "Laramide" (Late Cretaceous to early Paleogene) in age, in contrast to the younger Oligocene to Miocene mineralization in the rest of the district. This would suggest that mineralization was genetically related to the Laramide porphyry plugs that are spatially associated, as supported by Chatman (1993). Mineralization occurs both within the Abrigo Limestone and the porphyritic plugs. Wilson et al. (1951) described a couple 1- to 2-foot-wide quartz veins with weakly banded quartz, calcite, iron oxides, cerussite, anglesite, galena, pyrite, and minor copper and zinc oxides. The gold occurs within the quartz and is associated with iron oxides.

Industrial Resources

Chatman (1993) defined the remaining indicated marble resources in the district at over 5 billion pounds. Historic marble production occurred from eight quarries at the northern end of the Dragoon Mountains. The marble deposits formed from metamorphism of carbonates by the Stronghold Granite and possibly the Jordan Canyon stock. Very limited limestone has been produced from primarily the Escabrosa Limestone in the northern Dragoon Mountains. Chatman (1993) discusses the potential for future extraction of limestone for raw materials in cement production. Minor barite production was reported from the Standard Tungsten mine in the southern end of the district (Chatman, 1993). Barite occurs as a replacement mineral in Paleozoic and Mesozoic limestones (Cederstrom, 1946).

Exploration Potential

Previous post-mining mineral resource assessments of the Middle Pass mining district (Kreidler, 1982; Chatman, 1993) commented on the potential metallic resources in the region. Generally, the authors believe there is low potential for large economic deposits to be discovered in the future. Low potential is attributed to the small size of the existing skarn and carbonate replacement deposits. Perhaps the age of skarn mineralization, Oligocene to Miocene, discourages the hopes of finding a larger porphyry-type system in a region dominated by porphyry systems of “Laramide” age (Late Cretaceous to early Paleogene). Though mineralization in the northeastern part of the district, around the Golden Rule mine, may be genetically related to Laramide porphyritic rocks and further studies regarding the timing and genesis of this mineralization are warranted.

Pat Hills Mining District

District Overview

Pat Hills is a small mining district in the Sulphur Springs Valley about 20 miles east-southeast of the town of Cochise and 15 miles west of the Chiricahua National Monument. The district encompasses the small geologic feature called Pat Hills. Pat Hills is a past producing copper and silver underground mine. There were reportedly three mines in the district: the Pat Hills Mine, Pat Hills South #1 Mine, and the Pat Hills South #2 Mine (Rasmussen and Keith, 2023). There is no production data available for the Pat Hills mining District.

The Pat Hills are a small geologic feature in the Sulphur Springs Valley, roughly 15 miles west of the Chiricahua Mountains. The hills are composed of a volcanic sequence and related plutonic rocks including porphyritic andesite, laharic breccia, porphyritic dacite, and a fine-grained quartz diorite to granodiorite (Ettinger, 1962). Primary ore minerals in the Pat Hills district include pyrite and copper-oxides (Rasmussen and Keith, 2023). Ettinger (1962) reports chrysocolla filling fractures proximal to faults in the Pat Hills district. The chrysocolla is associated with quartz, calcite, siderite, and piemontite and is most commonly found in brecciated portions of the fault zone. The origin of the copper mineralization is unknown (Ettinger, 1962). Quartz-pyrite veins occur throughout the region. Drill core from the Cyprus Mining Corporation intercepted quartz-pyrite veins at 218 to 475-foot depths. Locally, limonite replaces pyrite (Ettinger, 1962). Evidence for local hydrothermal alteration comes from variable

levels of sericitization of most host rocks and moderate silicification and localized banded quartz veins.

Since Cyprus Mining Corporation drilled the Pat Hills in the 1950-1960s, it appears that little work has been done in the region. Ettinger (1962) suggests that it is unlikely that there is an economic mineral deposit in the Pat Hills, but if one exists it is likely hosted in Paleozoic carbonate units at depth, related to the minor chrysocolla found at surface. There are no active claims in the Pat Hills district.

Pearce Mining District

Location and History

The Pearce mining district is located just east of the Dragoon Mountains along highway 191, in the Sulphur Springs Valley. Historically, this district and its production data have been combined with the nearby Turquoise district (Keith, 1973) which is described separately in this report.

The Pearce district was initially prospected in the 1880's and produced 1,341,00 tons of ore through 1970, valuing approximately \$10 million worth of ore production (Howell, 1977). Keith et al. (1983) reported 79,000 pounds of copper, 12,000 pounds of lead, 1,000 pounds of zinc, 130,000 ounces of gold, and 12,739,000 ounces of silver produced in the Pearce district from 1895-1942. The Commonwealth Mine has been the largest producer of copper, lead, silver and gold in the district (Keith 1973). Smaller operations have targeted base and precious metals, fluorite, and minor uranium (Keith, 1973). The Commonwealth Mine is the largest mine among a group of small gold and silver mines/workings scattered among the Pearce hills. Commonwealth was discovered by John Pearce in 1895 (Keith, 1973; AZGS Mining Files, 1981). Underground workings in the vicinity of the Commonwealth mine and other small prospects consist of eight levels with the main shafts sunk on a 60°-70° incline into the footwall of the main vein system.

Geologic Setting

The Pearce district is relatively small and encompasses a series of isolated hills of Tertiary volcanic rock in the middle of Sulphur Springs Valley (Keith, 1973). The small set of hills near Pearce generally trend northwest and align with the northwestward extension of the Swisshelm Mountains and associated mining district (Howell, 1997). The Pearce volcanics generally consist of andesite porphyry, variably welded rhyolitic ash flow tuffs, and lenses of volcanoclastic-conglomerate rocks and overlie the Cretaceous Bisbee Group (Howell, 1997; Gilluly, 1956). The Pearce volcanics are overlain by Tertiary to Quaternary sedimentary rocks and volcanic flows within the Sulphur Spring Valley. Detailed lithologic and petrographic descriptions of the Pearce Volcanics are provided by Howell (1977) who warns that hydrothermal alteration near the Commonwealth veins makes it difficult to accurately assign compositional names.

The most prominent structural feature of the district is a fault zone that is speculated to control mineralization at the Commonwealth Mine, which consists of a series of faults and fault breccias striking west-northwest and dipping to the south-southwest (AZGS Mining Files, 1981).

This fault zone and related vein system ranges from 50-feet to 500-feet thick and the most intense brecciation and faulting occurs along the footwall (AZGS Mining Files, 1981).

Mineral Deposits

The Commonwealth mine of the Pearce district is a precious-metal (Ag-Au) epithermal vein hosted deposit within the Tertiary Pearce volcanics. The primary ore minerals include silver halides and native gold (Howell, 1977). Potassium feldspar and montmorillonite are the most abundant alteration minerals at the Commonwealth mine, with quartz, calcite, and sericite occurring less frequently, and chlorite and epidote rarely observed. Montmorillonite commonly occurs as an alteration product replacing pumice and filling vesicles in scoria. Sheeted or stockwork veins are common at the Commonwealth mine and a decrease in fracture intensity and ore grade is observed in the footwall of the main vein. Vein fill includes quartz, adularia, and black, clear, or white calcite with common epithermal-type textures including, drusy vugs, comb texture, and crustiform texture (Howell, 1977). A simple paragenesis is produced by Howell (1977) detailing an early quartz stage, followed by an adularia-black calcite stage, followed by a quartz-adularia-black calcite stage. Wall-rock alteration assemblages outboard of the veined system include potassium feldspar, quartz, calcite, montmorillonite, sericite, and iron oxides after pyrite. The known ore mineralogy, which is potentially biased to sampling of dumps and accessible workings in 1977, includes occurrence of native gold, native silver, argentite, embolite, cerargyrite, conichalcite and aurichalcite (Howell, 1977).

The Fluorine Hill deposit was included in a 1962 reconnaissance study of uranium deposits in Arizona by Granger and Raup (1962). The highest levels of radioactivity were detected in a prospect pit on the south side of the Fluorine Hill deposit. A carbonate vein containing minor dark purple fluorite and flecks of a yellow uranium-bearing mineral (possibly uranophane or autunite) was identified in the pit. The extent of the vein is less than 25 feet, and a grab-sample contained 0.11% uranium (Granger and Raup, 1962). No other prospect pits or mine dumps contained radioactive material. The rhyolite porphyry, of which the hill is composed of, showed a slightly abnormal radioactivity in all exposures in the region, containing 0.008% eU (equivalent uranium grade derived from a scintillometer). The rare secondary uranium minerals observed at Fluorine Hill are speculated to have replaced primary uranium-bearing minerals that were deposited in the vein, as fluorite and uranium-bearing minerals can be associated with hydrothermal deposits (Granger and Raup, 1962).

Exploration Potential

In 1975 Platoro Mines, Inc. conducted data compilation, geologic investigations, sampling, and metallurgical testing in the Pearce Mining district as detailed in a geologic report conducted by Paul Eimon (AZGS Mining Files, 1981), although no published work has been done in the region since. The Pearce Mining district is covered by primarily lode claims many of which are owned by the Commonwealth Silver and Gold Corp. There are no public reports or information available from this company. The Pearce district remains relatively understudied and would likely benefit from modern analytical techniques that could help better constrain the conditions of formation of epithermal mineralization.

Rucker Canyon Mining District

District Overview

Rucker Canyon is a small mining district located in the southern-central Chiricahua Mountains, roughly situated between the Swisshelm and California mining districts. There is only one historic operation in the district which appears under many names, including: Zardner, Gardner, and the Technocracy Mine Group. The Gardner/Zardner mine is described as a past-producing gold-silver underground mine. Production values for Rucker Canyon between 1935-1937 include 3,000 pounds of copper, 47,000 pounds of lead, 54,000 pounds of zinc, and 1,700 ounces of silver (Keith et al., 1983).

Rucker Canyon is a northeast to southwest trending canyon in the southern Chiricahua Mountains that drains westward into Whitewater Draw. The general geologic setting of this district is comparable to that of the previously described California district, in the northern Chiricahua Mountains. Lindberg (1987) describes the Cretaceous sedimentary geology of the canyon and highlights it as an important study area for Cretaceous sedimentary geology in southern Arizona due to complete exposure of the stratigraphic section. Cretaceous sedimentary rocks are exposed in a large horst block in Rucker Canyon and are in contact with Tertiary rhyolitic rocks from the nearby Turkey Creek Caldera (Lindberg, 1987). The north end of the Rucker Canyon “block” is a north-plunging syncline associated with Laramide compression which has been intruded by Oligocene dikes. Turkey Creek Caldera is roughly 15km north of Rucker Canyon, and as a result rhyolitic flows and related intrusions decrease from the northern to southern end of the Rucker Canyon block (Lindberg, 1987).

The Gardner/Zardner mine was a silver-gold underground mine with minor open “cuts and shafts.” The mineralization is described as relatively weak and oxidized, exposed along fault zones and hosted in the Cretaceous Bisbee Group (Mindat, 2026). The ore mineralogy is not described. Keith (1973) states that the mineralized occurrence is not itself of economic value, however its existence may indicate that precious-metal deposits may occur under thick, post mineral volcanics.

Spike “E” Hills Mining District

District Overview

The Spike “E” Hills mining district is located within the Spike E/Circle Hills of northern Cochise County. The district lies roughly 5 miles north of Wilcox, AZ (Garcia and Richardson, 2021). At present, there are no active mines operating within the Spike E Hills mining district (Plonka and Richardson, 2025). Spike “E” Hills is a small copper prospect with notable exploration efforts by Conoco and Bear Creek (now a part of Rio Tinto-Kennecott) in the 1970s. Extensive drilling by Conoco estimated a resource of 228,000 metric tons of copper, however seemingly no mining activity occurred, and as such, no production data is available (Rasmussen and Keith, 2023).

The Spike “E” Hills mining district consists solely of the Spike “E” Hills prospect which is described as a surface copper prospect with a suspected porphyry copper deposit present at

depth. The deposit is speculated to be spatially related to the Circle Hills granite pluton which has been dated at 28.43 Ma (Shafiqullah et al., 1978; Rasmussen and Keith, 2023). If this age and genetic association is valid, then Spike “E” Hills could represent less common Oligocene copper mineralization in the otherwise “Laramide” aged porphyry copper belt. Elemental Royalty maps refer to the granitic rock simply as, “Tertiary Granite.”

While the Spike “E” Hills prospect has gained little attention over the last 50 years, Elemental Royalty currently holds the project. Historic drilling at Spike “E” Hills intercepted sparse supergene copper mineralization near outcropping advanced argillic alteration, while deeper drilling encountered less intense alteration at depth. Elemental Royalty states that a new structural model identified “extreme post-mineral extension that was poorly understood previously,” suggesting that the prospect consists of a dismembered porphyry system that may merit further exploration efforts (Elemental Royalty, 2026).

Swisshelm Mining District

Location and History

The Swisshelm mining district is located in the northern Swisshelm Mountains, which are a 15-mile-long north-northwest trending mountain range. Principle commodities in the district include lead, silver, zinc, gold, silver, minor tungsten, and fluorspar (Keith, 1973; Dale et al., 1960). The district is roughly 30 miles north of the town of Douglas. Pb-Au-Ag(\pm Cu) deposits were first discovered in the Swisshelm district in the 1880’s and it has intermittently produced ore through the 1970s (Keith, 1973). The area has also been prospected for fluorspar. There is currently no active mining in the Swisshelm district (Plonka and Richardson, 2025).

Major mines in the Swisshelm district include the Mountain Queen, Chance, and Mammoth and Whale mines, with lesser production from the Great American, March, Apex, and Colford Copper mines (Gillette, 1983). Most of the production in the district has come from the Mountain Queen mine (Loring, 1947), which was discovered in 1885 (Galbraith and Loring, 1951). The Mountain Queen mine produced minor oxidized Ag-Pb ore through 1913; however, no production values are available for this period (Galbraith and Loring, 1951). The property was leased by an unknown operator in 1913 and \$5,807 of Au, \$35,365 of silver and \$41,754 of lead was produced (Galbraith and Loring, 1951). In 1935, a 25-foot interval of ore was intercepted while drilling a water well, a shaft was sunk, and \$80,000 of ore was produced. The discovery was named the Chance No. 1 claim, but mining ceased in 1941 when the shaft caved in (Galbraith and Loring, 1951). Mountain Queen was leased by another operator in 1945 and continued to produce ore through at least 1947. The Chance mine is located only several hundred feet away from Mountain Queen and seems to consist of claims enveloped by the Mountain Queen operations, seeing as no production data is available specific to the Chance Mine (Galbraith and Loring, 1951). One mile northeast of the Mountain Queen mine is the Swisshelm Mountain Gold and Silver Company property which contains the Mammoth and Whale claims (Galbraith and Loring, 1951). The Swisshelm Mountain Gold and Silver Company acquired the claims, complete with a 300 ft inclined shaft and several hundred feet of drifting, in 1947 from the Swisshelm Development Company (Galbraith and Loring, 1947). Production from these claims is unknown. Keith et al. (1983) reports production values from the entire Swisshelm

district from 1911-1981 including, 98,000 pounds of copper, 11,998,000 pounds of lead, 5,900 ounces of gold, and 364,000 ounces of silver.

Geologic Setting

The Swisshelm district covers most of the Swisshelm Mountains, which is a north-northwest trending range that branches off of the Pedregosa Mountains. To the west of the Swisshelm Mountains is the Sulphur Springs Valley and to the east is the greater Chiricahua-Pedregosa mountain range. The bedrock geology of the district consists of Proterozoic granite, Paleozoic sedimentary rocks, Mesozoic sedimentary and volcanic units, and a sequence of Oligocene and younger volcanic and sedimentary rocks, gravel deposits, and a basalt flow (Gillette, 1983; Drewes, 1991). Precambrian granite in the Swisshelm Mountains, termed the “Swisshelm Mountain Granite,” by Gillette (1983) is described as a leucogranite in thrust contact with the Cambrian Bolsa Quartzite and has been correlated to the 1.5-1.4 Ga Tungsten King Granite of the Little Dragoon Mountains (Silver, 1978; Gillette, 1983). Paleozoic-Mesozoic sedimentary rocks range from siliciclastic units (sandstones, shales, and siltstones) to limestone and dolomite units of Cambrian to Cretaceous age (Gillette, 1983). Tertiary igneous rocks in the Swisshelm Mountains include andesite dikes, quartz latite dikes, and a rhyolite tuff (Gillette, 1983). Based on cross-cutting relationships, the Tertiary igneous rocks post-date thrust-faulting in the region. The andesite has a K-Ar date of 37.2 ± 0.8 Ma and a felsic quartz latite dike yields K-Ar ages of 36.6 ± 0.8 Ma and 35.4 ± 0.8 (Gillette (1983) citing Shafiqullah personal communication). The rhyolite tuff flows have been dated between 35-34 Ma and therefore predate the 29-24 Ma rhyolite flows in the adjacent Chiricahua Mountains (Gillette, 1983; Marjaniemi, 1970).

Gillette (1983) identifies at least four periods of faulting in the Swisshelm Mountains. Mesozoic and older rocks have been thrust faulted, folded, and locally metamorphosed (Drewes, 1981). Oligocene and younger rocks have been substantially less deformed and affected by extensional (rather than compressional) stresses (Drewes, 1991). In general, the Swisshelm Mountains are an uplifted fault block of Precambrian granite, Paleozoic-Cretaceous carbonate and clastic units, and Tertiary felsic to intermediate intrusive rocks and rhyolite tuff flows (Gillette, 1983).

Mineral Deposits and Exploration Potential

Small irregular massive sulfide replacement bodies containing 70% argentiferous galena, 25% cerussite and 5% pyrite occur in the Swisshelm district (Gillette, 1983; Loring, 1947). The deposits are largely recognized as carbonate replacement deposits, with ore-replacement lenses occurring primarily in the Escabrosa and Horquilla Limestone units (Gillette, 1983). Occurrence of hydrothermal quartz veins and jasperoid lenses in the southeastern Swisshelm Mountains suggests the potential for other ore-deposit types (Gillette, 1983). Gillette (1983) identified anomalous precious-metal values within quartz veins and anomalous base-metal values in the jasperoid units, both of which appear to be associated with oxidized pyrite. The carbonate replacement type mineralization is proposed to be genetically related to a proximal granodiorite stock, which was dated at 34-30 Ma (Gillette, 1983; Drewes, 1981).

Dale et al. (1960) describes the Big Four and Valley View tungsten claims in the Swisshelm Mountains, however notes that in his investigation – the claims were not found. Original claimants sought copper in the 1890s, but after being re-discovered in 1942, tungsten

was identified (Dale et al., 1960). Tungsten is reported to occur as scheelite in contact zones between a monzonite intrusive body and limestone in a “hard, siliceous, garnet-bearing host rock” (Dale et al., 1960).

There are currently no active claims on file with the Bureau of Land Management’s Mineral and Land Records System. Land accessibility may pose difficulties in exploration efforts of the Swisshelm Mountains. Roughly half of the district is covered by private land, while the other half is a combination of public (BLM) and state-trust land. However, renewed interest in Pb-Zn-Ag deposits elsewhere in the state may encourage exploration efforts of similar carbonate-replacement deposits in the Swisshelm district, as in the Turquoise district just 20 miles to the west.

Tombstone Mining District

Location and History

The Tombstone mining district is located in western Cochise County, about 70 miles by road, southeast of Tucson. Historic mines and prospects in the area are within the Tombstone mining district (see Garcia and Richardson (2021) for district boundaries), extending southwest from the town of Tombstone toward the San Pedro River, flanking both sides of South Charleston Road. The mining district is situated in a set of low-lying hills roughly averaging 5,000 feet of elevation. Mineralization in the area is predominantly related to the intrusion of Late Cretaceous to early Tertiary granitic and porphyritic rocks, which produced structurally controlled carbonate replacement deposits and some low-grade porphyry style mineralization (Guilbert, 1993). The district is famous for its significant historic silver production but also produced considerable amounts of gold, lead, manganese, and some copper and zinc.

The Tombstone district has an immense amount of published and unpublished literature regarding its history, dating back to the mid-1800s. The Arizona Geological Survey’s Mining Info website contains numerous files from historic mining collections containing maps, reports, drill logs, communications, and more that are useful for anyone who is interested in learning more about the district’s long and complex history (AZGS Mining Files, 2026). Ore in the district is said to have been first discovered by Ed Schieffelin in 1877 (Butler et al., 1938). A few years later, in 1880, a mill was built along the San Pedro River and silver production had commenced (Butler et al., 1938). In 1881, Tombstone was the largest city in Arizona (Butler et al., 1938), and by 1882, there were over 1,000 mining claims and significant development and production was underway (Blake, 1882). Most of the district’s production occurred from 1877-1915 (Rasmussen, 2012), with about one half of that produced during the initial boom, from 1877-1886 (Butler et al. 1938). Production was slow but steady from 1915 to the mid-1930s, with considerable production of manganese occurring during this time (Butler et al., 1938). Intermittent production continued through the mid-1980s, when Tombstone Exploration, Inc. developed an open pit operation mining the Contention vein for approximately 2 million ounces of silver and 10,000 ounces of gold from 1980-1985 (Guilbert, 1993).

Total district production from 1879-1981 (not including the bulk of the production just mentioned from the open pit operation on the Contention vein) was approximately 8 million pounds of copper, 54 million pounds of lead, 0.65 million pounds of zinc, 14 million pounds of

manganese, 132,000 ounces of gold, and 32 million ounces of silver (Keith et al., 1983). Of the total production value, silver was 81% and gold 14% during the district's major producing period from 1879 to 1933 (Butler et al., 1938). Some of the major historically productive mines in the district include Bunker Hill, Contention, Good Enough, Grand Central, Toughnut, Empire, and the Oregon-Prompter Mines. Mineral exploration in the district continues to the present day. Notably, drilling in the early 1970s identified a porphyry copper alteration zone with low grade mineralization (Guilbert, 1993). In the early 1990s, JABA Inc. exploration identified multiple zoned porphyry copper centers from geochemical data, geologic mapping, aeromagnetic surveys, and drilling (Guilbert, 1993), however, no known development or related production ensued. At present, Intrepid Metals Corp. holds 50 unpatented federal mining claims and 6 Arizona State Prospecting Permits in an area that makes up approximately 3,500 acres southwest of the town site (Intrepid Metals Corp., 2026). The company recently conducted a large dipole induced polarization ("IP") ground-based geophysical survey and are planning a drill program targeting silver-lead-zinc carbonate replacement and skarn deposits.

Geologic Setting

The Tombstone district is located in the greater regional Basin and Range Physiographic Province, known for its repeated episodes of mountain building, sedimentation, and magmatism. Locally, the geology of the district is structurally complex, resulting primarily from different periods of compressional folding and thrust faulting and extensional faulting. Southwest-northeast to south-north compression related to the Laramide orogeny resulted in folding and thrust faulting prior to the Late Cretaceous igneous activity (Butler et al., 1938). During this compressional event northeast-trending fissures opened, at right angles to the folds and faults, and were intruded by northeast trending Late Cretaceous dikes (Butler et al., 1938; Moore, 1993). Many of the mineralized fissure veins also follow this trend indicating that the fissures served as optimal fluid conduits (Devere, 1978). Following late Cretaceous and early Tertiary magmatism, north-northwest striking normal faults cut and tilted the district to the northeast (Butler et al., 1938; Newell, 1974), likely associated with regional Miocene Basin and Range extension.

Several geologic maps have been published in the Tombstone district (e.g., Jones and Ransome, 1920; Gilluly, 1956; Moore, 1993). Generally, the key geologic units present, from oldest to youngest, consist of Proterozoic schist and granite; Paleozoic carbonate-rich sedimentary units, Cretaceous sedimentary units, Late Cretaceous intermediate to felsic volcanic rocks, granitic stocks, and porphyritic rocks, and early Tertiary andesite and rhyolite porphyritic dikes. The basement rocks include the Paleoproterozoic Pinal Schist and a younger Proterozoic equigranular granitic rock which both have limited exposure on the western side of Ajax Hill, about 3 miles south of the Tombstone town site (Butler et al., 1938; Gilluly, 1956). Paleozoic sedimentary units exposed at the surface or in mine workings in the Tombstone area altogether make up a nearly 5,000-foot stratigraphic section consisting of the Cambrian Bolsa Quartzite and Abrigo Formation, Devonian Martin Formation, Mississippian Escabrosa Limestone, Pennsylvanian Horquilla Limestone, Pennsylvanian to Permian Earp Formation, Permian Colina Limestone and Epitaph Dolomite (Butler et al., 1938). The oldest Paleozoic units are exposed at the surface near Ajax Hill and exposures progress up section moving to the east for about 3 miles at the surface. Unconformably overlying the Paleozoic section is the Cretaceous Bisbee Group, which is made up of over 3,000 feet of shale, sandstone, quartzite, conglomerate, and limestone

(Butler et al., 1938). Outcropping Bisbee Group is present between the town site and Ajax Hill and west of Ajax Hill extending roughly north to south.

The two main Late Cretaceous units are the Uncle Sam Tuff and the Schieffelin Granodiorite which make up the majority of exposed bedrock in the western and northern parts of the district, respectively. Two smaller exposures of granitic rock occur in the southwestern part of the district near the San Pedro River and were originally mapped as Schieffelin Granodiorite (Gilluly, 1956; Moore, 1993). However, these two exposures have recently been broken out into distinct intrusive units, Quartz Monzonite of Brunckow Hill and Quartz Monzonite of Government Draw, based on slight petrographic differences (Pearthree et al., 2018). Age determinations from K-Ar on biotite are 76.0 ± 3.0 Ma for the Schieffelin Granodiorite, 76.3 ± 1.8 Ma for the Quartz Monzonite of Brunckow Hill and 73.5 ± 2.8 Ma for the Uncle Sam Tuff (Reynolds et al., 1986 and references therein). In addition to these main Late Cretaceous units are a variety of intermediate to felsic lava flows, plugs, and tuffs, of similar age to the Schieffelin Granodiorite and Quartz Monzonite of Brunckow Hill (Reynolds et al., 1986), which are scattered throughout the southern and western parts of the district, mostly near the San Pedro River (Moore, 1993). Lastly, andesite and rhyolite porphyry dikes of early Tertiary age crop out throughout the district, with seemingly highest abundance in the northern portion (Moore, 1993).

The prominent structural features of the district are the Prompter reverse fault, the Horquilla Peak normal fault, and the Ajax Hill normal fault (Gilluly, 1956; Newell, 1974). The east-west trending Prompter reverse fault is located north of Ajax Hill and is reported to dip 60° - 80° to the south (Gilluly, 1956). The Oregon-Prompter and Bunker Hill mines, some of the larger producing mines in the district (Mason and Arndt, 1996; Rasmussen and Keith, 2023), are situated along this fault system. The roughly east-west trending Horquilla Peak normal fault is located south of Ajax Hill and dips 60° to the southeast (Gilluly, 1956). The Ajax Hill fault, just west of Ajax Hill, is a north-northwest trending normal fault that dips to the east (Butler et al., 1938). Together, these faults mark the northern, southern, and western boundaries of an uplifted block, consisting predominantly of the Paleozoic carbonate-rich sedimentary section, that has been referred to as the Ajax Hill Horst (Butler et al., 1938). Many of the historic producing mines in the district are located within the Ajax Hill Horst or are spatially related to these three prominent faults.

Mineral Deposits

Historic production in the Tombstone district focused principally on silver-lead-zinc fissure veins and carbonate replacement deposits (CRDs) in the northeastern part of the district (Devere, 1978). The northeastern portion of the district is the area of most intense mineralization (Butler et al., 1938), at least near the surface. After the bulk of the district's production had ceased, some low-grade porphyry style copper-molybdenite mineralization was identified in the western part of the district, in the 1970s (Guilbert, 1993). Historically, the spatial relationship between the major ore bodies and structural features have been important guides for exploration and discovery. A large majority of the deposits are localized at the intersection of northeast striking fissures and another structure, be it a fold or a fault (Butler et al., 1938). Favorable host units for mineralization, where these structural features intersect, are the sedimentary rocks of the Cretaceous Bisbee Group and the thick carbonate-rich sedimentary rocks of the Paleozoic section (Butler et al., 1938).

The exact genesis and timing of mineralization are questions that remain for the Tombstone district. Newell (1974) first proposed the timing of two distinct periods of mineralization for the main northeastern part of the district; the first being silver and base metal mineralization associated with intrusion of the Late Cretaceous Schieffelin Granodiorite and Uncle Sam Tuff and the second being manganese-rich mineralization assumed to be related to the early Tertiary rhyolite porphyry dikes. Additionally, Newell (1974) suggested the existence of a second mineralization center to the southwest near the Charleston Lead mine and that the age of this mineralization was indistinguishable from that of the Schieffelin Granodiorite and Uncle Sam Tuff. It is reasonable, given the possibility of multiple porphyry centers as suggested by Guilbert (1993), that there is even more complexity in terms of the timing and genesis of mineralization throughout the district.

Rasor (1937) produced the first comprehensive mineralogical study of the wide range of minerals present in the main northeastern part of the district and reported a hydrothermal vein paragenesis to sort out at least the relative ages between styles of mineralization. Generally, the major ore minerals related to the first period of mineralization include masses of argentiferous pyrite, galena, tetrahedrite, as well as sphalerite, and minor chalcopyrite whereas ores related to the second period of mineralization are principally made up of psilomelane (Devere, 1978). Sulfide ore associated with silver and base metal mineralization is in some places oxidized with resulting cerussite (PbCO_3) and minor smithsonite (ZnCO_3), malachite, and native gold and silver. Typically, the manganese ore contained less silver and lead but more copper (Devere, 1978).

Alteration in the historic northeastern part of the district is dominated by skarn minerals replacing limestone or limestone that has been metamorphosed to marble. Rasor (1937) reported that the most abundant replacement minerals observed are calcium-aluminum silicates (grossular, vesuvianite and occasional clinozoisite). Pyroxenes, diopside and pigeonite, are also common and are observed in layers that alternate with grossular-vesuvianite layers at Comstock Hill, just west of the Tombstone townsite (Rasor, 1937). Notably, Rasor (1937) mentions a lack of iron-bearing silicates such as epidote, andradite and hedenbergite.

In the western part of the district sericitization, or phyllic alteration, has been described within the Uncle Sam Tuff (Butler et al., 1938; Guilbert, 1993). Additionally, Guilbert (1993) described breccia pipes with extensive phyllic alteration in the southwestern part of the district in an area referred to as Robbers Roost. The author also mentions that drilling in the Robbers Roost area by ASARCO in 1973 and 1974 identified previously unmapped deep granodiorite to quartz monzonite porphyries and breccias that grade into secondary potassium feldspar and biotite with purple anhydrite and low-grade chalcopyrite-molybdenite mineralization.

Exploration Potential

Some district-scale metal zoning was documented by Butler et al. (1938), but this type of work could be a focus of further research, incorporating more recent exploration results. Silver and manganese mineralization is widespread and relatively uniform whereas the distribution of gold and lead are less common in the western part of the district (Butler et al., 1938). Ongoing exploration in the district is targeting silver-lead-zinc carbonate replacement and skarn deposits (Intrepid Metals Corp., 2026). The bulk of historic mining in the district has been on the skarn, vein, and CRD mineralization but there is potential for additional deeper porphyry style

mineralization. Guilbert (1993) discusses the potential for multiple porphyry centers and suggests the possibility of deeper porphyry copper mineralization in the western and southern portions of the district. Altogether, the mineralization and alteration styles observed by previous researchers are typical of porphyry mineral systems and the range of deposit types associated with them (e.g., skarn, vein, and CRD; see Hofstra and Kreiner (2020) for mineral systems and related deposits). Further research and drilling, as well as a better knowledge of more recent drilling and exploration efforts, could help define the multiple potential porphyry centers through gaining a better understanding of the metal and alteration zoning throughout the district.

Turquoise Mining District

Location and History

The Turquoise mining district, also known as Courtland-Gleeson, is located at the southeastern end of the Dragoon Mountains, about 15 miles east of Tombstone and 20 miles north of Bisbee. The district got its name from the gem quality turquoise that was produced early in the district's history from shallow mines in the northwestern part of the district. The historical base and precious metal mines are primarily situated in the ridges and hills stretching from Gleeson to several miles north of Courtland, at elevations of about 5000 feet. Copper, lead, and silver carbonate replacement ores have been the focus of past production, but the district also contains some zinc, manganese, and gold mineralization. Modern exploration is targeting the potential for a larger porphyry copper-gold system. This district is most well-known for its complex structural geology and distinctive Jurassic magmatism that exists in a broader region that is dominated by "Laramide" (Late Cretaceous to early Paleogene) magmatism and porphyry copper mineralization.

The Turquoise district was the focus of some early 20th century publications (e.g., Platt, 1909; Ransome, 1913; and Crawford and Johnson, 1937), with Wilson (1927) producing the most comprehensive study of the geology and ore deposits in the area. Gilluly (1956) described the principal lithologies and provided an early interpretation of the complex structural geology. McRae (1966) added further structural interpretations and assumptions of the timing of mineralization based on an exploratory drill program from 1960-1962. Since 1966, the district has not been the focus of scientific study beyond inclusion in more regional studies with brief interpretations of the structural history (Lipman and Sawyer, 1985; Lipman and Hagstrum, 1992) and updated geochronology and geochemistry (Lang, 2001). Richardson (2020) published historic drill data for 113 drill holes in the district including updated geologic maps, drill logs, assays, and a comprehensive interactive webmap hosting all of this data. Additionally, the Arizona Geological Survey's Mining Info website (AZGS Mining Files, 2026) hosts historic mining files which include reports, maps and other data on the district.

The first claim in the district was staked by John Collins in 1877 (Wilson, 1927), although copper, lead, and silver mineralization was previously known. Turquoise, in particular, was highly esteemed by Native Americans and several deposits were known and worked on the western flank of Turquoise Ridge in the northwestern part of the district prior to 1877 (Ransome, 1913; Crawford and Johnson, 1937). Beginning in 1883, a few small mines near Gleeson (e.g., Silver Bill, Gleeson, and Tom Scott) were producing high grade oxidized silver-lead ores with

minor gold and copper. By 1900, numerous deposits had been identified and were in production, including those to the north near the settlement of Courtland (Wilson, 1927). Base and precious metal mining in the district occurred almost continuously until 1978 (Rasmussen and Keith, 2023). Today, there is ongoing exploration targeting both the carbonate replacement deposits and ultimately the potential for a porphyry copper-gold system (Intrepid Metals Corp., 2026). Total district production from 1883 to 1978 was approximately 53,000,000 pounds of copper, 5,750,000 pounds of lead, and 1,169,000 ounces of silver, with lesser production of zinc, manganese, and gold, totaling 800,000 pounds, 78,400 pounds, and 21,600 ounces, respectively (Keith et al., 1983; Rasmussen and Keith, 2023).

Geologic Setting

The complex geology of the Turquoise mining district is due to the long history of orogenesis and magmatism, overprinted by intense extension in the Basin and Range province. Similar to many of the mining districts in Cochise County, rocks in the Turquoise district range in age from Proterozoic to Cenozoic. Existing geologic maps of the district include those produced by Ransome (1913), Wilson (1927), Gilluly (1956), and McRae (1966). Richardson (2020) digitized a more modern map solely based on a compilation of pre-existing maps. The only Precambrian rocks exposed are the muscovite-chlorite-quartz schists and quartzites of the Paleoproterozoic Pinal Schist. Significant Paleozoic units include the Cambrian Bolsa Quartzite and Abrigo Limestone, Devonian Martin Limestone, Mississippian Escabrosa Limestone, Pennsylvanian Horquilla Limestone, and the Permian Colina Limestone. Conglomerates, sandstones, and shales of the Cretaceous Bisbee Group are the only other significant sedimentary rocks in the area. The structural complexity of the Courtland-Gleeson area is described in Gilluly (1956), McRae (1966), Lipman and Hagstrum (1992), with interpretations ranging widely from a extensive imbricate thrust zone to a large caldera system, with tilting, normal and reverse faulting, and folding recognized in many areas.

There are three prominent plutonic igneous units that have most recently been characterized as Jurassic in age: the Gleeson Quartz Monzonite, Turquoise Granite, and Copper Belle Monzonite Porphyry (Richardson, 2020). However, there is some uncertainty in the published literature regarding their ages. The three igneous rocks were originally constrained as younger than Paleozoic and older than Cretaceous in age (Triassic-Jurassic) based on cross-cutting relationships (Wilson, 1927; Gilluly, 1956; McRae, 1966). Lang (2001) published ages of 201.3 ± 0.7 Ma for the Copper Belle Monzonite Porphyry and 191.3 ± 0.3 Ma for the Gleeson Quartz Monzonite, in agreement with the previous suggestions. However, Lang (2001) also published an age of 1659.2 ± 3.7 Ma for the Turquoise Granite, suggesting the pluton is older than previously mapped. The analytical methods for these ages are not well reported and the maps produced recently by Richardson (2020) suggest that all three units are Jurassic in age, but with no new geochronology. In addition to the three main “Jurassic” igneous units, younger igneous rocks of Laramide (Late Cretaceous to early Tertiary) age are present and are mapped as the Sugarloaf Volcanics (Richardson, 2020), consisting of a quartz latite and andesitic members (Gilluly, 1956). Finally, numerous Tertiary dikes, porphyritic rocks, and volcanic rocks are also reported, including dikes of the Stronghold Granite, a prominent unit further north in the Dragoon Mountains (Wilson et al., 1951; Gilluly, 1956; McRae, 1966).

The complex structural history of the Turquoise district was documented as early as 1913 (Ransome, 1913). Regionally, the Laramide orogeny produced Late Cretaceous to early Tertiary

compressional thrusting and Miocene Basin and Range extension resulted in significant normal faulting and dismemberment of preexisting geologic features. Locally, the major structural feature of the area is a proposed west dipping, north-south striking thrust fault called the Dragoon Fault (Gilluly, 1956). This proposed fault separates a massive block of Gleeson Quartz Monzonite to the west and a heavily faulted block of essentially all other rock units to the east. In the eastern block, there are repeated sequences of older to younger stratigraphy as one traverses eastward. The complexity has led to two quite distinct genetic interpretations proposed in the literature. First, Gilluly (1956) suggested that east of the Dragoon Fault is a series of imbricate thrusts which resulted in a “gigantic thrust breccia.” Gilluly (1956) described the thrust breccia as follows; “rocks of Paleozoic age and small local bodies of Pinal schist and other rocks are jumbled in almost random stratigraphic order in a gigantic breccia overlying the Sugarloaf Quartz Latite, Copper Belle Monzonite Porphyry, and Turquoise Granite.” He suggests that the thrust breccia and the Dragoon Fault are related to the same orogenic event but that the Dragoon Fault is slightly younger and its eastward thrusting caused the originally west dipping faults of the thrust breccia to overturn and now dip to the east. In contrast, Lipman and Hagstrum (1992) argue that the large exposure of the Gleeson Quartz Monzonite represents a large Jurassic intracaldera intrusion and that the complex eastern portion of the district represents “voluminous collapse-megablocks of Paleozoic rocks in ash-flow matrix.” The authors define this rhyolitic ash-flow tuff that encloses megablocks of Paleozoic rocks as the Tuff of Courtland. Other researchers also have their interpretations of the geology and structural history (McRae, 1966; Drewes, 1981; Lipman and Sawyer, 1985). Clearly, the genetic and structural interpretations of the geology are wildly distinct and perhaps merit more detailed structural research that is paired with a modern understanding of the regional geologic history.

Mineral Deposits

Historically, the Turquoise district has been mined for near-surface copper-lead-silver carbonate replacement deposits, consisting of both hypogene and supergene ores. However, recent exploration has also demonstrated the potential for one or more porphyry centers in the district (Intrepid Metals Corp., 2026). Important historically productive mines include Copper Belle, Defiance, Germania, Mary (Mame), Maid of Sunshine, Leadville, Tejon, Tom Scott, and Silver Bill (Rasmussen and Keith, 2023). Wilson (1927) broke out the deposits into the three primary commodity types: (1) copper, (2) lead-silver, and (3) turquoise. The copper ores occur as principally oxide deposits associated with faults, chalcocite enrichment zones, or hypogene mineralization present as disseminations, stringer veins, and massive replacement lenses. Copper mineralization occurs throughout the district with ores consisting of malachite, azurite, cuprite tenorite, chalcocite, chalcopyrite, bornite, and native copper. Lead-silver deposits that were the source of early production, as described by Wilson (1927), were principally limited to oxidized replacement ores near Gleeson with the main ore minerals consisting of cerussite, anglesite, wulfenite, and cerargyrite, associated with some zinc, manganese, and copper oxides. Favorable host rocks for copper, lead, and silver replacement mineralization are the Abrigo Limestone, Escabrosa Limestone, and Horquilla Limestone, with some mineralization hosted in the local intrusive bodies. Alteration in the district is not well reported beyond brief descriptions of garnet, epidote, quartz, calcite, limonite, and sericite in the metamorphosed Abrigo Limestone and sericite and clay replacement of feldspars in some of the intrusive units (Wilson, 1927). Based on field evidence, Wilson (1927) suggested that much of the copper, lead, and zinc ores are genetically related to the intrusion of a quartz monzonite porphyry (the Copper Belle Porphyry)

and that quartz monzonite (the Gleeson Quartz Monzonite) and limestone contacts served as fluid conduits for the later mineralizing fluids. However, he did not discount the potential for other intrusions to have played a role in the resulting mineralization. Turquoise is primarily located in the northwest corner of the district, west of Turquoise Ridge, as thin stringers up to a few inches wide and lenses occupying fractures in the Bolsa Quartzite and Turquoise Granite.

McRae (1966) suggested that there were two distinct periods of mineralization in the Turquoise district: the first occurring pre-Cretaceous and the second after emplacement of the Sugarloaf quartz latite, based on crosscutting relationships and alteration/mineralization of certain units. However, more recent literature describes this area as a productive Jurassic district (Lang, 2001; Barton et al., 2011) and does not say anything about a second period of mineralization. Lang (2001) reported that the Copper Belle Porphyry was a “productive” intrusion which would place, at least one period of mineralization at ~201 Ma, according to his geochronologic ages. Wilson (1927) described a “felsite” he mapped as having anhedral quartz phenocrysts and feldspar phenocrysts that were completely altered to sericite. This unit was later mapped as the Sugarloaf quartz latite and was said to have experienced more significant silicification and sericitic alteration in highly mineralized areas (Gilluly, 1956). Reynolds et al. (1986) reported an age of 74.5 ± 2.9 Ma for this unit, but Wilson (1927) concluded that it appeared to have no significant economic importance. Whether both Jurassic and “Laramide” (Late Cretaceous to early Paleogene) age mineralization occurred in the district, as suggested by McRae (1966), is still uncertain and requires further study.

Exploration Potential

Recent exploration by Intrepid Metals Corp. has revived significant interest in the Turquoise mining district. Rio Tinto, Ivanhoe Electric, and Intrepid Metals Corp. all have large claim blocks in the area (Intrepid Metals Corp., 2026). Intrepid’s recent drilling confirmed historic assays, and new drilling has attracted Teck Resources, a company that is investing in the project’s future. The recent drilling identified porphyry-style mineralization including widespread quartz-sericite-pyrite veins and breccia clasts containing chalcopyrite-molybdenite veins. This, along with a recent resistivity survey suggests there are several untested porphyry targets, according to the company (Intrepid Metals Corp., 2026). Intrepid, with the help of Teck, hopes to discover porphyry copper-gold targets at 500-700m depths, deeper than any previous drilling, in addition to identifying carbonate replacement deposits.

Warren (Bisbee) Mining District

Location and History

The Warren (Bisbee) mining district is centered around the mines immediately southeast of the historic mining town of Bisbee, in south-central Cochise County. The district extends about 10 miles to both the northwest and southeast of the town of Bisbee along State Route 80 (Garcia and Richardson, 2021). The mines and prospects are situated in semi-arid canyons at over 5,000 feet of elevation within the rugged Mule Mountains. The major metallic commodities produced in the district include copper, lead, zinc, manganese, gold, and silver (Stegen et al.,

2005). The bulk of historic ore production was from carbonate replacement deposits and porphyry copper related breccias (Lewis, 2021).

The presence of metallic ore at Warren was first discovered in 1876 when U.S. army scouts spotted an outcrop of gold-silver mineralization southeast of present-day Bisbee, while searching for water (Ransome, 1904; Nye, 1968). By August of 1877, the first mining claims had been staked (Graeme, 2013) and minor lead-carbonate ore was being produced from the Hendricks mine immediately south of Bisbee (Ransome, 1904). Initially, silver-lead ores were sought by prospectors and copper ore, which was first discovered in the district in 1877, was ignored due to its low value (Nye, 1968; Graeme, 2013). The district was an insignificant mining camp until 1880, when increased prospecting activity resulted from construction of local railroads and a rise in copper prices (Ransome, 1904). In late 1880, production began on the large, unusually rich copper oxide orebody (ore averaging 23% copper) at the Copper Queen mine (Ransome, 1904). Success at the Copper Queen mine resulted in increased interest and exploration near the quickly developing town of Bisbee (Ransome, 1904).

Near-surface copper oxide ores were produced from the Copper Queen and other nearby mines until the 1890s when copper sulfide minerals were discovered at depth and became the dominant ore mined (Stegen, 2005). These early-mined high-grade oxide and sulfide ores were primarily hosted in limestones that were mined by underground mining methods (Briggs, 2015). In 1911, the Sacramento deposit was discovered less than a mile east-southeast of the Copper Queen mine, and from 1923-1929, disseminated sulfide ore (containing up to 3.5% copper) hosted by an intrusive porphyry was produced from a large open pit that came to be known as the Sacramento Pit (Francaviglia, 1982; Briggs, 2015). Then, in 1929, one of the district's largest and highest-grade deposits, the Campbell orebody (over one million tons of ore with 8-10% copper), was discovered about a mile southeast of the Sacramento deposit (Briggs, 2015). In the midst of the Great Depression, the Warren district was urbanized and industrialized, and successful discovery and production led to it being known as "one of the world's greatest copper producers" (Francaviglia, 1982). During the late 1940s, a low-grade (less than 1% copper) orebody was defined between the Sacramento and Campbell mines which resulted in the development of a large open pit called the Lavendar pit, which eventually enveloped the original Sacramento Pit (Briggs, 2015). The Lavendar pit was in production from 1954-1974 but closed due to low copper prices and increased labor costs. Major production from underground mines in the district ceased by 1975 but minor processing and leaching continued until 2013 (Graeme, 2013; Francaviglia, 1982; Briggs, 2015).

The Cochise deposit, located immediately northwest of the Lavendar and Sacramento pits, was originally discovered in the 1890s but additional drilling and exploration since 1975 has further delineated a significant chalcocite blanket overlying a low-grade porphyry copper system (Lewis, 2021; Lewis and Seedorff, 2022). Mineralization consists of chalcocite and covellite which replaced chalcopyrite and pyrite (Stegen et al., 2005). Freeport-McMoRan currently owns the Cochise porphyry copper system which has an estimated resource of 289 Mt averaging 0.45% copper, as of December 2023 (Lewis, 2021; Freeport-McMoRan, Inc., 2024).

Total district production, from 1880-2013, was 7,922,958,000 pounds of copper, 324,256,000 pounds of lead, 355,048,000 pounds of zinc, 28,000,000 pounds of manganese, 2,792,000 ounces of gold, and 102,215,000 ounces of silver (Briggs, 2015), making Warren one of the most significant producers of both base and precious metals in the state. As of 2015, the

Warren district was Arizona's seventh largest producer of copper, fourth largest producer of manganese, second largest producer of zinc and silver, and the state's largest producer of lead and gold (Briggs, 2015).

Geologic Setting

The Warren district is located in the Basin and Range Physiographic Province, a region with repeated episodes of mountain building, sedimentation, magmatism, and extension. Recent research has summarized the local geologic setting, rock types, and major structures in detail (Stegan et al., 2005; Lewis and Seedorff, 2022). In general, the geologic units present in the district include the basement Paleoproterozoic Pinal Schist, roughly 5,000 feet of Paleozoic carbonate-rich sedimentary units, a variety of intermediate to felsic Jurassic intrusive and volcanic rocks ranging in age from approximately 201-170 Ma, and nearly 5,000 feet of the Cretaceous Bisbee Group composed of conglomerate, mudstone, sandstone, and limestone. The Jurassic (~201-199 Ma) Sacramento Hill Intrusive Complex (SHIC), consisting of quartz monzonite to granodiorite intrusions and hydrothermal breccias, is at the center of the district's base and precious metal mineralization (Lewis and Seedorff, 2022). The ~175 Ma Juniper Flat granite, a large elongate, stock northwest of the SHIC is the largest intrusion in the area and contains minor hydrothermal alteration (Lang et al., 2001). Additionally, some Tertiary quartz latite porphyry intrusions have been mapped in the southern and western portions of the district (Hayes and Landis, 1964) but are not spatially associated with historic mines and prospects.

The principal structure of the district is a northwest striking, south dipping, post-mineral normal fault called the Dividend fault (Stegan et al., 2005). The Dividend fault dissects the SHIC, with intrusive rocks of the SHIC existing on both sides of the fault. Northeast of the fault is the Pinal Schist overlain by Bisbee Group and southwest of the fault is primarily Paleozoic rocks and Jurassic dikes (Lewis and Seedorff, 2022). In the hanging wall to the southwest are a series of northeast striking faults that are truncated by the Dividend fault. These faults formed prior to mineralization and served as an important control for some of the carbonate replacement deposits and dikes in the Cole, Dallas, Junction and Campbell mines (Nye, 1968; Stegen et al., 2005). In addition to the major role that faults play in the district's structure, numerous small amplitude folds are present, evident through variable degrees of generally east dipping Paleozoic rocks exposed in different mines (Stegan et al., 2005).

Mineral Deposits

The deposits of the historic Warren mining district are predominantly related to a Jurassic porphyry copper system associated with intrusion of the Sacramento Hill Intrusive Complex. It is one of the few Jurassic porphyry systems in southwestern North America, a region dominated by "Laramide" (Late Cretaceous to early Paleogene) porphyry copper systems. The four main deposit types are (1) copper-gold-zinc-lead-silver carbonate replacement deposits, (2) intrusive breccias containing copper-rich fragments enriched in chalcocite, (3) supergene chalcocite blankets, and (4) manganese veins and carbonate replacement deposits (Stegan et al., 2005).

The carbonate hosted massive sulfide replacement bodies were the principal source of metals produced in the district: nearly 70% of the total copper production and almost all of its lead, zinc, gold, and silver (Lewis, 2021). The Cambrian Abrigo Limestone, Devonian Martin Formation, and Mississippian Escabrosa Limestone served as the most important host rocks for the carbonate replacement deposits (Nye, 1968). Within these limestone units, the major control

of ore formation was the intersection of strong local fracturing or faulting and porphyritic intrusions, where ore grades were commonly over 3.5% copper (Bryant, 1964; Stegen et al., 2005). The carbonate hosted orebodies have been described as mantos (generally conformable to bedding) and chimneys (not conformable to bedding) with mineralization including primarily chalcopyrite, bornite, sphalerite, and galena. As for the manganese deposits, the principal ore mineral was braunite ($\text{Mn}^{2+}\text{Mn}^{3+}_6(\text{SiO}_4)_8\text{O}_8$) which occurred in shallow fractures and as limestone replacement with quartz, hematite, and calcite gangue. Manganese mineralization is primarily hosted in the Mississippian Escabrosa Limestone and limestones of the Pennsylvanian to Permian Naco Group (Stegen et al., 2005).

Principal alteration types in the Warren district include abundant quartz-sericite-pyrite and intense clay alteration of the intrusive bodies of the SHIC and quartz-sericite alteration and silicification of the limestones. Nye (1968) reported the presence of some pre-mining calc-silicate alteration in the Naco Group limestones on the southern margin of the SHIC, consisting of quartz, epidote, chlorite, serpentine, garnet, tremolite, diopside, idocrase, and wollastonite. The calc-silicate alteration was not as pervasive in older Paleozoic units (i.e., Escabrosa, Martin, and Abrigo), though some talc-serpentine alteration was reported in the Martin Formation (Nye, 1968). Not only is the quartz-sericite alteration more widespread in the district but it also appears to have occurred paragenetically later and overprinted some calc-silicate alteration (Nye, 1968). Overall, the Warren district is known for its exceptional mineralogical diversity. Graeme et al. (2020) published a list of all known minerals that have been recognized in the area (over 300 different mineral species), including specific lists of all the rock-forming minerals, hydrothermal alteration minerals, and hypogene and supergene ore minerals.

Exploration Potential

Freeport-McMoRan currently owns the Cochise porphyry copper deposit, just north of the historical Lavendar Pit, which has an estimated resource of 289 Mt averaging 0.45% copper (Freeport-McMoRan, Inc., 2024). Ore grades of the chalcocite blanket range from 0.2-1.0% copper, whereas the known hypogene mineralization below averages 0.14% copper (Stegen et al., 2005). As always, commodity prices will influence whether production occurs or not. Overall, there seems to be lack of modern interest in the district, at least in terms of active exploration. With the Warren district being Arizona's seventh largest producer of copper, fourth largest producer of manganese, second largest producer of zinc and silver, and the state's largest producer of lead and gold (Briggs, 2015), it could be that much of the potential has already been realized. Though, commodities of national interest have changed since the bulk of mining occurred and the district's incredible mineralogical diversity implies there could be some remaining critical mineral potential.

Whetstone and Mine Canyon Mining Districts

Location and History

The Whetstone mining district encompasses the northeastern half of the Whetstone Mountains, approximately 10 miles southwest of Benson, Arizona. The Mine Canyon district is in the southwestern portion of the Whetstone Mountains and is roughly a third of the size of the Whetstone district. Due to their proximity and similar geologic histories, both districts are discussed together. Small mines and prospects of copper, minor gold and silver, tungsten, fluorite, uranium and silica flux have been explored and exploited in the Whetstone and Mine Canyon districts. Mining operations consisted of small shallow pits with limited quantities of ore being produced from these two districts (Keith, 1973). Keith et al. (1983) reported 500 pounds of copper, <1,000 short ton units of tungsten, and 215 pounds of uranium (U_3O_8) produced in the Whetstone district from 1955-1957. In the Mine Canyon district, 76,000 pounds of copper and 1,600 ounces of silver were produced from 1915-1959 (Keith et al., 1983).

McColly and Scott (1982) divide the districts into four mineralized zones: Mine Canyon, the Copper Plate mine area, the Middle and Guindani Canyons area, and the Cottonwood Canyon area. The Nevada-Mascot and Two Peaks Cu-Au-Ag deposits were discovered in 1870 in the Mine Canyon district, and were intermittently mined, prospected and explored for many years. Adits, shafts, and shallow pits appear to have been sunk on shear zones and quartz veins within a Laramide age granodiorite stock (Creasy, 1967). No production data is known for the early period of mining and total production is unknown, however, 36,048 pounds of copper, 8 ounces of gold, and 611 ounces of silver were produced between 1955-1961 from Nevada-Mascot, Two Peaks, and other small mines in Mine Canyon (McColly and Scott, 1982). The Copper Plate mine produced copper and silver which was hosted in sandstone, shale and marl of the Cretaceous Bisbee Group (McColly and Scott, 1982). Mine workings at Copper Plate consist of a 70 foot long, 30-50 foot wide, and 15-30 ft deep open pit which exposes a fault zone containing copper carbonates and iron-magnesium oxides (McColly and Scott, 1982). 1,600 tons of ore averaging 1.2% copper and 0.6 oz/ton silver were produced from 1957-1958 at Copper Plate (McColly and Scott, 1982).

Within the Middle and Guindani Canyons area are the Lone Star fluorite mine, the Gold Crystal (also Gold Cristle) gold prospect, the Ricketts quartz mine, and the Star No. 1 (a.k.a. Bluestone) uranium mine (McColly and Scott, 1982). The Lone Star fluorite may have been the largest fluorite producer in Arizona (Elevatorski, 1971) with peak production occurring between 1946-1967. The headframe and shaft opening at Lone Star were bulldozed in 1980 (McColly and Scott, 1982). Two miles west of Lone Star fluorite mine is the Gold Crystal mine, which produced gold-bearing ore in an oxidized, brecciated fault contact between the Cambrian Bolsa Quartzite and Abrigo Limestone. No production data is available (McColly and Scott, 1982). Phelps Dodge operated the Ricketts Mine during the 1950s to produce flux for use at their Douglas smelter. Tungsten was produced from the Chadwick and James mines in the southern portion of the Whetstone district, which consist of short adits and scattered pits diving on quartz veins in alaskite (Creasy, 1967; McColly and Scott, 1982). Tungsten ore occurs as scheelite and wolframite in the quartz veins. Lastly, in the Cottonwood Canyon area, prospects centered on uranium ore. Uranium exploration in Cottonwood canyon targeted quartz veins, shear zones, faults, and dikes in a Precambrian quartz monzonite stock and were found due to radiometric anomalies in the area. Kerr-McGee and the Rocky Mountain Energy Corporations filed nearly

600 claims in the late 1970's and drilled out the area. Results were never made public (McColly and Scott, 1982).

Geologic Setting

The Whetstone Mountains consist of Proterozoic to Mesozoic sedimentary, metamorphic, and igneous rocks. The Proterozoic basement rock is made up of the early Proterozoic Pinal Schist, which locally consists of muscovite-biotite-quartz schists that have been subsequently metamorphosed by a 1.45-1.4 Ga quartz monzonite (Wrucke et al., 1983; Silver, 1978). Paleozoic sedimentary formations in the Whetstone Mountains range from sandstone, limestone, dolomite, and gypsum units, each reflecting changes in relative sea level. The Paleozoic sedimentary sequence is remarkably continuous and unaltered in the Whetstone Mountains, making it an ideal reference section for Paleozoic strata in southeastern Arizona (Wrucke and Armstrong, 1987). Paleozoic sediments exposed in the Whetstone Mountains include the Bolsa Quartzite, Abrigo Limestone, Martin Formation, Black Prince Limestone, Horquilla Limestone, Earp Formation, Colina Limestone, Epitaph Formation, Scherrer Formation, Concha Limestone, and the Rainvalley Formation (Wrucke and Armstrong, 1987). There are limited outcrops of sedimentary and volcanic Triassic and Jurassic rocks near the southern end of the Whetstones. Early Cretaceous rocks of the Bisbee Group rest unconformably on Permian sedimentary rocks (Wrucke and Armstrong, 1987). Late Cretaceous igneous rocks intruded into Paleozoic and Mesozoic strata and are composed of granodiorite plutons, dikes and sills and an intrusive rhyodacite unit (Wrucke et al., 1983; Creasy, 1967). The granodiorite pluton yields an age of 74 ± 4 Ma (Marvin et al., 1978), coeval with much of the porphyry copper mineralization in southeastern Arizona (Creasy, 1980). The granodiorite is locally sericitically altered and contains secondary potassium feldspar in the central portion of the stock. Cenozoic sedimentary and volcanic rocks cover and intrude into the existing rocks (Wrucke et al., 1983).

The Whetstone Mountains are structurally relatively simple, which allows for complete exposure of the Paleozoic stratigraphy, which is not often found in southeastern Arizona. Paleozoic and Mesozoic strata dip approximately 25° to the southwest (Wrucke et al., 1983). Presence of steeply dipping normal faults and southwest dipping thrust faults can only be traced a few miles and do not significantly disturb the strata. The main tilting, folding, and faulting event in the Whetstone Mountains is speculated to have occurred during the Laramide Orogeny (Wrucke et al., 1983; Drewes, 1980). While some debate exists about the timing and structural style of deformation in the Whetstone Mountains, the relatively undisturbed stratigraphic sequence implies that large-scale thrusting likely did not occur. Basin and Range bounding faults are buried beneath Tertiary and Quaternary gravels (Wrucke et al., 1983).

Mineral Deposits

Wrucke and others (1983) conclude that regions within the Whetstone and Mine Canyon districts that are underlain by Proterozoic quartz monzonite and alaskite units host uranium, fluorite, and tungsten ore deposits. This is juxtaposed by copper deposits in the Whetstone Mountains which tend to be concentrated in and around the Cretaceous granodiorite unit, which crops out near the southern portion of the range (Wrucke et al., 1983). Copper mineralization is often hosted within the granodiorite unit but also occurs in skarn deposits developed in the adjacent carbonate units (Wrucke et al., 1983). Disseminated Cu-Au-Ag mineralization at the Nevada-Mascot and Two Peaks mines is hosted in quartz veins and shear zones along seams in

the Laramide porphyry dikes and as replacement lenses near contacts with Cretaceous Bisbee and Permian Naco Group limestone units (McColly and Scott, 1982). DeRuyter (1979) calculated a resource of 29 million metric tons of 0.3% copper and 0.01% molybdenum from 4,400 feet of assayed drill core south of the Nevada-Mascot workings. The Copper Plate mine targeted copper carbonates that pervasively stain the host rock (McColly and Scott, 1982), mapped as sandstone of the Cretaceous Bisbee Group by Creasey (1967). McColly and Scott (1982) speculate a 2,000-4,000-ton resource of low-grade copper in the old Copper Plate mine workings.

Tungsten in the Whetstone mining district was sporadically in production as early as 1900 at the James and Chadwick Mines. Tungsten occurs as black tungsten-bearing minerals with small amounts of scheelite in narrow quartz veins within granitic rocks, especially proximal to contacts of the granite with Pinal Schist and Paleozoic sediments (Dale et al., 1960) and within the Proterozoic alaskite-schist contact (McColly and Scott, 1982). There is no production data available for tungsten mining in the Whetstone district, however Dale et al. (1960) speculates that no more than 1,000 units of WO_3 were likely produced.

Fluorite of the Lone Star mine in Middle Canyon is hosted in veins within the Proterozoic Pinal Schist and is speculated to be genetically related to a Precambrian granite stock mapped north of the mine (Burnette, 1957; McColly and Scott, 1982). Mined fluorite was pale green to white, crystalline, and high-grade, averaging 75-85% CaF_2 (McColly and Scott, 1982). All of the ore production of came from a single vein.

Exploration Potential

Wrucke et al. (1983) evaluated the resource potential for the Whetstone Roadless Area including the Mine Canyon area, the Copper Plate area (within the Mine Canyon district), and the Guindani Canyon and Middle Canyon area (within the Whetstone district). The Mine Canyon region appears to have the highest potential, specifically for a porphyry copper deposit and/or skarn deposit (beyond the limits of known porphyry mineralization) at depth (DeRuyter, 1979; McColly and Scott 1982). Exploration and targeting would benefit from geophysical data collection and surface geochemistry to inform a potential drilling campaign. It is unclear at what depth a potential deposit may be located. Mineral resource potential in the Copper Plate area is rated as low based on presence of only low-grade, disseminated, and/or surface staining copper carbonate minerals. Guindani and Middle Canyon were given low-moderate resource potential for tungsten mineralization. Areas where the Proterozoic alaskite unit is in contact with the Pinal Schist are considered of moderate potential.

There are several claim blocks located in both the Whetstone and Mine Canyon districts, on record with the Bureau of Land Management Mineral and Land Management System. No further evidence of current exploration activities was found. Based on historical mining activity and estimated copper \pm molybdenum and tungsten resources, these areas would benefit from modern analytical and exploration techniques.

Willcox Mining District

District Overview

The Willcox mining district is a small district located southeast of the town of Willcox. The Willcox district boundary is just outboard of the Willcox playa, which is situated between the intersection of I-10 with highways 191 and 186 south. The Willcox Playa and the Willcox mining district are within the Sulphur Springs Valley, with the Dragoon Mountains to the west and the Dos Cabezas-Chiricahua Mountains to the east. The only notable metals exploration appears to be in the nearby Spike “E” Hills mining district, approximately 10 miles north of the Willcox district, which is discussed separately in this report.

The main geologic feature of interest near the Willcox mining district is the Willcox Playa. The geology of the Dos Cabezas Mountains and the Dragoon Mountains are described in other sections of this report. Willcox Playa is the remnant of pluvial Lake Cochise which was present during the late Pleistocene (Shreiber, 1978). Willcox basin deposits consist of moderately consolidated conglomerate, Tertiary siliciclastic rocks, poorly consolidated Tertiary to Quaternary gravel, sand, silt and clay and Quaternary lake sediments. Wells drilled in the basin record at least 300m of basin fill, however, it may be as thick as 900-1500m based on other valleys in the region with similar geologic histories (Schreiber, 1978).

There is not much evidence for current exploration for any metallic mineral deposits in the Willcox mining district. Due to the proximity to the Willcox Playa, mining opportunities are likely to focus on evaporite type minerals like gypsum or the potential for lithium-rich sediments. MAX Power Mining Corp holds a 6-mile-long land package in the Willcox Playa where they are exploring for lithium. A 2024 press release announced discovery of near-surface lithium clays and describes the mineralization as a hectorite-saponite mix of lithium within clays and sediments of the Willcox Playa. Samples analyzed by the Lawrence Berkely National Laboratory in California from the “discovery zone” averaged 1,243 ppm Li. (Max Power, 2024). A majority of the playa is leased by the US Department of Defense from the Bureau of Land Management. MAX Power is the first company to initiate a diamond drilling campaign in the Willcox Playa.

Winchester Mining District

Location and History

The Winchester mining district is situated at the southern tip of the Winchester Mountains in northwestern Cochise County. The district lies roughly 15 miles northwest of Wilcox, Arizona and centers in Severin Canyon (Cooper and Silver, 1964). At present, there are no active mines operating within the Winchester District (Plonka and Richardson, 2025).

The Winchester district is best known for producing silver ore, however minor reports of gold and various base metals (Cu-Pb-Zn) in irregular quartz veins and jasperoid replacement lenses occur as well (Keith, 1973). The primary operating mine in the district appears to have been the Hearst Mine (also referred to as the Winchester Mine and the old Hagggen-Hearst mine), but reported production was limited. In the 1890s, underground workings were developed in a

jasperoid mass and “some silver ore was shipped out” (Cooper and Silver, 1964 – citing oral communications). Keith et al. (1983) reports production values of 500 pounds of copper and 400 pounds of lead between 1941-1949 in the Winchester district.

Geologic Background

The Winchester Mountains are the southern continuation of the Galiuro Mountains and are a typical basin and range uplifted fault block in southeastern Arizona. The Winchester Mountains are bound on the east and northeast by the Sulphur Springs Valley and by Pedro Valley to the west.

Tertiary volcanics dominate the outcropping rocks in the Winchester Mountains. The two lower members are part of the Galiuro Volcanic group and consist of the lower latite member and the overlying rhyolite member. These two units are capped by black, vesicular lava flows that can be up to 1,200 feet thick. Tertiary volcanics are overlain by weakly consolidated Tertiary to Quaternary alluvium (including the Gila Conglomerate). In the southern portion of the Winchester Mountains (where the mining district is located) there are outcrops of variably altered Paleozoic carbonate rocks (Keith et al., 1982; Armstrong and Brown, 1993).

Mineral Deposits and Exploration Potential

Paleozoic limestone in the Winchester mining district has been locally replaced by lenses of jasperoid that can be up to 100 feet wide and 1,000 feet long. Shear zones in Precambrian granite have been silicified, indicating some degree of hydrothermal alteration in the region. Minor limonite is noted in the silicified shear zones, but no ore minerals are present (Cooper and Silver, 1964). The Paleozoic limestone is said to contain erratic concentrations of silver with the highest assay-values coming from yellow-stained jasperoid. The limited production in the Winchester district is thought to come from base-metal sulfide veins that cut the limestone in the northern portion of the district (Cooper and Silver, 1964).

Keith and others (1982) sampled from 28 sites representative of the drainage basins in and around the Winchester Roadless Area (approximately 4 miles north of the mining district), and found high concentrations of lanthanum, niobium, lead, and tin. The anomalous concentrations are interpreted to be derived from minerals weathering out of the Galiuro Volcanic rocks and from localized human contamination (Keith et al., 1982). Armstrong and Brown (1993) followed up on the 1982 study on the mineral resource potential of the Winchester Roadless Area, examining the portion of the Winchester Mountains that lies within the Coronado National Forest boundary. Armstrong and Brown (1993) generally agreed with the conclusion that the Winchester Mountains unit has low potential for mineral resources – but do note that silicified structures (northwest-southeast trending) in the southern portion of the unit contain trace gold. Further work in the region could aim to follow up on studying these silicified gold-bearing structures. There are no active claims on file with the Bureau of Land Management Mineral and Land Records System in the Winchester mining district.

Yellowstone Mining District

District Overview

The Yellowstone Mining district is located in northwest Cochise County, approximately 12 miles north of the town of Benson. The district surrounds the Johnny Lyon Hills and is proximal to the larger Cochise district of the Little Dragoon Mountains, which is described earlier in this report. Yellowstone was first prospected in the 1880's and there are unconfirmed reports of gold production (Keith, 1973). The main commodities of the Yellowstone district include copper, lead, zinc, silver and gold plus minor amounts of fluorspar and barite. There are currently no active mining operations in the Yellowstone district (Plonka and Richardson, 2025).

There are minor workings in Yellowstone that target sulfide and gold-quartz mineralization, but it is speculated that no more than 125-150 tons of ore has been shipped out from the Yellowstone district (Keith, 1973). The primary operator in the region was the La Vantia Mining Company (Cooper and Silver, 1964). La Vantia developed a 225-foot incline shaft with 800-feet of drifts and owned a 5-stamp mill that was equipped for amalgamation and concentration; however, no production was reported from this district (Cooper and Silver, 1964). The La Vantia workings were never confirmed and are speculated to have been incorporated into the American mine (Cooper and Silver, 1964). The American Mine (also referred to as War Eagle and La Vantia) consists of the aforementioned shaft workings and was likely the only producing mine in the district. Keith et al. (1983) report production values for the Yellowstone district from 1906-1930 as 700 pounds of copper, 6,000 pounds of lead, 100 ounces of gold, and 200 ounces of silver.

The Yellowstone district encompasses the Johnny Lyon Hills, which is dominated by the Proterozoic Johnny Lyon granodiorite, but also includes outcrops of the Pinal Schist, and Paleozoic sedimentary rocks (Cooper and Silver, 1964). Cooper and Silver (1964) describe the Johnny Lyon granodiorite in detail, but generally it is a medium- to coarse-grained, somewhat porphyritic, gray to green-grey hornblende-biotite granodiorite. The Johnny Lyon granodiorite includes several phases, including local pegmatite and aplite phases and zones of hydrothermal alteration. Paleozoic units exposed in the Yellowstone district include the Bolsa Quartzite, Abrigo Limestone, Martin Formation, Escabrosa Limestone, the Black Prince Limestone, and the Horquilla Limestone (Cooper and Silver, 1964). Minor Tertiary lamprophyre dikes cut the Paleozoic sedimentary units.

Mineralization within the Yellowstone district consists primarily of polymetallic veins. Ore mineralogy at the American Mine includes sparse pyrite, galena, chalcopyrite, and oxidized sulfides hosted in quartz-carbonate veins located in the thrust plane of the Precambrian Johnny Lyon granodiorite. Fluorite and barite are reported to occur alongside ore minerals (Keith, 1973). The San Jose/Gold Mine Ridge prospect contains brown carbonate, quartz and limonite boxwork/veins with spotty malachite, chrysocolla, and chalcocite, along with minor chalcopyrite, galena, sphalerite, and pyrite (Cooper and Silver, 1964; Keith, 1973). Veins of this assemblage cut the Johnny Lyon granodiorite, lamprophyre dikes, and the thrust fault on the north side of Gold Mine Ridge, and as such are speculated to be of Tertiary age (Cooper and Silver, 1964; Keith, 1973). Another common vein type within the Johnny Lyon granodiorite contains massive milky quartz, vugs and open fractures, and traces of galena, chalcopyrite, pyrite, specularite, malachite, chalcocite, and limonite (Cooper and Silver, 1964). The Paleozoic sedimentary units in the Yellowstone district contain traces of base metals. Within the Escabrosa Limestone are thin

quartz veinlets with traces of pyrite, galena, and chalcopyrite. At the Tip Top No. 1 prospect, copper-oxide minerals occur alongside minor chalcopyrite, bornite, and pyrite. In general, polymetallic veins exposed in the district range from a few centimeters to several feet thick but tend to be short and contain only sparse ore minerals (Cooper and Silver, 1964).

There are currently no active claim blocks in the Yellowstone district on file with the Bureau of Land Management's Mineral and Land Resources System and the region has received little attention over the past 50+ years. Updated geologic mapping, geochemical and geochronologic analyses, and geophysical surveys would be critical for further work in the Yellowstone district, but based on available information, exploration potential appears low.

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