Southern Spring Mountains (a.k.a. Goodsprings) Mining District, Clark County, Nevada and San Bernardino County, California

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Introduction
This paper summarizes what is known about the stratigraphy, geology, tectonics and mineral deposits of the Southern Spring Mountains. It is the fifth in a series of papers that has been compiled for the Desert Symposium focusing on mining geology and history in the Mojave Desert:
• 2015: Cronese, Cave and Northern Cady Mountains
• 2016: Ivanpah Mountains, Mescal Rane, Clark Mountains
• 2017: Bristol and Old Dad Mountains
• 2018: Old Mojave Road
For 2019 compilations have been made for the Northern Halloran Springs and Southern Spring Mountains Mining Districts.

The Southern Spring Mountains Mining District includes the previously described Goodsprings, Yellow Pine and Potosi mining districts. Development and production in the district were influenced by world economics for lead and zinc, the development of railroads, improvements in mining and beneficiation technologies, and metallurgical understanding of the ores.

This paper summarizes a more comprehensive compilation of data about the geology and mineral deposits of the Southern Spring Mountains found at: http://www.greggwilkerson.com/southern-spring-mountains-goodsprings-mining-district.html or https://www.academia.edu/38194204/SPRING_MOUNTAINS_SOUTHERN_MINING_DISTRICT_CLARK_COUNTY_NEVADA_TEXT

Location
The Goodsprings (Yellow Pine, Potosi) district is in the southern part of the Spring Mountains. It is bounded on the west by the Pahrump and Mesquite Valleys, on the south by the California...
State line, on the east by Goodsprings Valley, and on the north by Potosi Mountain. Elevations above sea level range from just under 3,000 feet in the south to 8,504 feet at Potosi Mountain in the north (Longwell and others, 1965, p. 101).

This report is for an area larger than the “Goodsprings District” of Longwell and others (1965) or of earlier (Yellow Pine, Potosi) district descriptions (Wheeler, 1871; Keely, 1893; Longwell, 1926; Heiks, 1931; Hewett, 1931, Secor, 1963, Carr and Pinkston, 1987). The southern Spring Mountain mining district is defined herein as an area with:

Lovell wash and the Old Spanish Trail (Highway 160) to the north
Cottonwood Valley, Goodsprings Valley and the Lincoln and Ireland mines to the east
Ivanpah Valley to the southeast
Mesquite Valley between the southern tip of the Spring Mountains and the west end of Black Butte to the southwest.

Thusly defined this study area embraces 227, 156 acres in the southern Spring Mountains. Within this area there are 186 mineral deposits inventoried in the USGS Mineral Resource Data System (MRDS, 2011). Of these, 143 are classified as producers, past producers or plants. Individual reports for 91 of the most important producing or past producing mines and deposits of special interest were prepared. The most important mines and deposits are summarized in table 1.

### History

Some of the minerals in the district were known to Native Americans and Spanish explorers. In 1856, the district was explored by Nathaniel V. Jones under direction of the Church of Jesus Christ of Latter-Day Saints. Early efforts at smelting were unsuccessful. In 1861 the Potosi mine was developed and sporadic attempts were made between 1861 and 1893 to produce lead. From 1893 to 1898 interest centered largely in the gold-bearing deposits in the district. In 1898 the Yellow Pine mill began processing copper ores. In 1905 the railroad between Los Angeles and Salt Lake City was completed and in that year oxidized zinc minerals (hydrozincite), herefore ignored, were identified by T.C. Brown. The district’s proximity to the railroad connecting Mojave to Las Vegas in Ivanpah Valley at Jean facilitated mine developments as did the re-evaluation of zinc resources. A narrow-gauge railroad from Jean to Goodsprings and the Yellow Pine mine was built in 1910. More lead, zinc and copper zinc mines were opened during WWI. Between 1902 and 1930, cyanidation extracted more gold and silver from the ores. There was some renewal of activity during WWII, but by 1964 most of the mines were dormant (Hewett, 1931, Longwell and others, 1965).

### Stratigraphy

The stratigraphy of the Spring Mountains (Hewett, 1931) ranges from Pre-Cambrian granite gneiss to Jurassic Aztec sandstone. Mines are only hosted by the Pennsylvanian Bird Springs and Mississippian Monte Carlo formations.

### Structure

The geologic structure of the Goodsprings district is dominated by three major Mesozoic thrust faults. From east to west, these are the Contact, Keystone, and Green Monster thrust faults. Thrusting began on the Contact thrust by Late Jurassic time and ended with the Keystone thrust overriding the Contact in the Late Cretaceous. Parts of the Contact and Keystone thrust plates appear to have moved over erosional surfaces. The
Green Monster thrust plate is the structurally highest and westernmost structural unit in the Goodsprings district. The age of the Green Monster thrust can only be limited to the time between post-Kaibab (Late Permian) and pre-Keystone thrusting (Late Cretaceous?). Thrusting in the Spring Mountains produced a minimum shortening estimated from the décollement model to be between 22 and 45 mi (36.6 to 75 km). Some deformation occurred during Late Cretaceous time, but part of the deformation could be early or middle Mesozoic in age. The major Mesozoic thrust plates in the southern Cordillera were emplaced eastward over autochthonous rocks at the same time as the autochthon underwent high-angle faulting. Granite porphyry dikes were intruded, some following fault planes, between earliest Cretaceous and Quaternary time. Various extrusive flows, tuffs and breccias erupted during the Tertiary (Burchfiel and others, 1974; Burchfiel and Davis, 1977; Carr, 1978, 1983, Carr and Pinkston, 1987). Gravity-slide blocks of Paleozoic rocks derived from the uplifted thrust-plate terrane are present at the head of Lavinia Wash and at the east end of the Ironside fault zone, a tear fault in the Keystone thrust plate. The gravity-slide blocks in Lavinia Wash overlie a buried pediment surface cut into deformed Lavinia Wash sequence and are overlapped by Pleistocene alluvium (Carr and Pinkston, 1987).

Mineral deposits
Ores are typically found in brittle, brecciated carbonate beds of the Bird Springs and Monte Carlo Formations. The ore bodies are generally bounded on either side by more plastic shales. Some deposits are partly hosted by granite porphyry or sandstone. The ore bodies are found along bedding plane faults and at the junctions of the low angle faults with high angle faults. Dolomitization of limestone preceded sulfide mineralization and sometimes the sulfides are encaised in dolomite (Hewett, 1931). The district has mineral deposits for the following commodities:

- Mine grades, host rock and ore mineralogy for major mines are summarized in Table 1.
- The magnesia in the host rocks ores seems to have been brought to an upper zone in the crust by circulation along fractures, but a large part of the actual process of replacement of limestone seems to have been accomplished by diffusion. The metallic sulphides rose along similar major channels but appreciably later than the magnesia and were deposited in part by replacement of the carbonate wall rock and in part by precipitation in open spaces (Hewett, 1931, p. 102).
- The places of deposition of the metallic sulphides were determined in a broad way by the distribution of bodies of intrusive granite porphyry and locally by the structure. The principal channels by which the metals were brought to their sites of deposition were steeply dipping crosscutting fractures. Some of the bodies of sulphides were deposited in these fractures, but the largest bodies were formed in bedded breccias along flat thrust faults near their intersection with crosscutting fractures (Hewett, 1931, p. 102).
- The shape of the ore bodies is controlled by the dip of the bedding. Where the bedding is flat, the ore bodies are generally tabular and parallel the bedding. Where the bedding is inclined, the ore bodies are generally in flattish pipes that parallel bedding or cut across it at low angles. A few ore bodies follow steep fault zones that cut the beds. The ore bodies range in size from a few tons to more than 20,000 tons (Longwell and others, 1963, p. 104, 105).
- Among the zinc minerals, which have been the principal product of the district thus far, hydrozincite is the most abundant, but considerable smithsonite and a little calamine have been produced by some mines.

### Table 2. Primary mines of the Southern Spring Mountains listed by commodity

<table>
<thead>
<tr>
<th>Commodity and (number of deposits)</th>
<th>Primary deposit or mine names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony (1)</td>
<td>Antimony Prospect</td>
</tr>
<tr>
<td>Cobalt (3)</td>
<td>Highline, Columbia, Copper Chief,</td>
</tr>
<tr>
<td>Copper (37)</td>
<td>Azurite, Belle (Maybelle), Blue Jay, Boss, Columbia, Copper Chief, Copperside, Doubleup, Fitzhugh Lee, Green Copper, Highline, Ironside, Keystone, Lincoln, Ninety-nine, Oro Amigo, Rose, Snowstorm</td>
</tr>
<tr>
<td>Flagstone (1)</td>
<td>Flagstone Quarry</td>
</tr>
<tr>
<td>Gold (19)</td>
<td>Chagua, Clementina, Keystone, Lavinia, Red Cloud</td>
</tr>
<tr>
<td>Lead (41)</td>
<td>Kirby, Ruth, Silver Gem (Christmas Group)</td>
</tr>
<tr>
<td>Perlite (1)</td>
<td>U.S. Perlite</td>
</tr>
<tr>
<td>Platinum (2)</td>
<td>Little Tommy G No. 9, Boss</td>
</tr>
<tr>
<td>Radium (1)</td>
<td>Radium Deposit</td>
</tr>
<tr>
<td>Silver (4)</td>
<td>Crystal Pass, Lavinia, Lincoln, Valley View</td>
</tr>
<tr>
<td>Stone (2)</td>
<td>Unnamed quarries No. 1 and No. 2</td>
</tr>
<tr>
<td>Uranium (7)</td>
<td>Rosetta No. 1 and No. 2, Jean-Slone, Uranium Locality 27</td>
</tr>
<tr>
<td>Vanadium (2)</td>
<td>Akron, Valley Forge</td>
</tr>
<tr>
<td>Zinc (60)</td>
<td>Akron, Houton, Combination (Nob Hill Area), Little Betty, Monte Cristo (Combination Lode), Van Henry (Hoosier)</td>
</tr>
<tr>
<td>Zinc or Lead (97)</td>
<td>Accident, Addison (Milford), Alice (Yellow Pine Extension), Anchor, Bullion, Christmas (Silver Gem and Eureka), Contact, Dawn, Eureka Silver Gem, Fredrickson, Hermosa (Hoosier), Hoodoo, Kirby, Lookout (Annex, Mountain Top), Middlesex, Milford, Milford No. 2, Mobile, Mountain Top (Lookout, Annex), New Year, Palace-Porter, Pilgrim, Potosi, Prairie Flower, Pauline., Root, Ruth, Shenandoah, Sultan, Surprise, Spelter, Tam o-Shanter, Tiffin, Valentine, Whale, Yellowpine</td>
</tr>
</tbody>
</table>
These minerals represent zinc once deposited as sphalerite, oxidized to the sulphate, and reprecipitated nearby but at lower levels under the influence of weathering. The original lead sulphide is largely unaffected by weathering, but the shallow zones of many mines yield some carbonate and sulphate of lead. Under weathering numerous vanadates of zinc, lead, and copper have been formed. Only traces of copper sulphide minerals are exposed in the mine workings, as most of them have been weathered to form the carbonates and silicates. Minerals of the jarosite group--hydrous sulphates of iron with the alkalies and other metals--are common (Hewett, 1931, p. 102).

Many deposits show displacements along fractures that have been formed since the metallic sulphides were deposited. There is little if any record of movement along these fractures since the oxidized minerals were formed, and it seems that most of the weathering has taken place since the formation of the fractures (Hewett, 1931, p. 102).

Lead-zinc ore of the Goodsprings district typically occurs as flattened pipes and tabular bodies replacing dolomitized limestone in zones of fracturing and brecciation. 98% of lead-zinc ores came were hosted by the Mississippian Monte Carlo Formation. The other 2% are hosted by the lower 500 feet of the Pennsylvanian Bird Springs Formation (Alberton and others, 1954, p. 1).

Beneath some of these impermeable caps the ore remains unaltered and consists principally of galena and sphalerite. In most places, however, the ore is oxidized to undetermined depths below present mine workings. Sphalerite has been altered to hydrozincite and calamine. Locally the galena has also been altered--to cerussite or less commonly to anglesite--but mostly it remains as scattered pods and lentils in the oxidized ore. This common association of the primary lead sulfide with the secondary zinc carbonate and silicate indicates that the oxidation of primary ore was accomplished without significant change in position or shape of the ore bodies (Albritton and others, 1954, p. 1-2).

Gold ± silver deposits appear to be restricted to one of four textural and modal varieties of Late Triassic porphyritic intrusions, all of which are highly altered feldspar porphyry (Vikre and others, 2011, p. 409).

The lead in the present deposits was derived from 1.7 Ga crystalline basement or from Late Proterozoic siliciclastic sedimentary rocks derived from 1.7 Ga crystalline basement (Vikre and others, 2011, p.381).
Figure 3. Metal zones of the southern Spring Mountains.

Vikre and others studied the district and compared K-Ar, Pb-Pb, and Rb-Sr geochronometers. They stated:

Data are not adequate to identify true differences in age between intrusion subtypes or between emplacement and hydrothermal activity. The range in ages by all techniques suggests that a period of intrusion and hydrothermal activity occurred at about 217 Ma and fluid systems continued well beyond the range indicated by analytical errors. (Vikre and others, 2011, p. 398)

The Lead-Zinc carbonate replacement deposits originally formed in the late Paleozoic from leaching of the base metals from Pre-Cambrian crust. Then in the Late Triassic, igneous activity produced the gold-silver and other types of deposits (Vikre and others, 2011, p. 382).

These Triassic intrusions also remobilized the older lead-zinc replacement deposits and some of them contain components deposited in them by the Late Triassic hydrothermal systems (Vikre and others, 2011, p. 408).

There is a crude pattern of concentric mineral zoning in the district that is consistent with mineralization produced by porphyry copper intrusions. This model (Cox and Singer, 1992, p. 76) can be applied to the southern Spring Mountains Mining District. In this model, mineral deposits formed by differentiating ore solutions from a cooling magma of dioritic or granitic composition. In the ideal case, porphyry copper style mineralization would produce concentric rings of minerals. From center to the periphery, these mineral zones are:

- Tungsten-Molybdenum
- Lead-Zinc
- Copper
- Gold
- Silver
- Mercury

In the Southern Spring Mountains, Lead-Zinc, Copper, Gold, and Silver zones are recognized. In addition, the distribution of uranium deposits is concentric around the porphyry systems. There are incomplete generalized
copper porphyry style concentric zoning patterns in four areas:

**Northwestern system:**
This area is between the Desert Valley Prospect and the Rainbow Quarries.

It is on a western spur of the southern Spring Mountains. The east-west trending zone is 4 miles long and 2 miles wide. The system has a central lead-zinc zone (Green Monster, Hatchet and Daniel Boon Mines) with copper zone outward from it to the east and west (Desert Valley Prospect, Mohawk No. 7, Rainbow Quarries).

**Northeast system**
This area trends W-NW to E-SE between the Paradise Prospect and the Red Cloud Mine. It is 3.8 miles long and 2.3 miles wide. The central lead-zinc zone is on the west end (Bluejay, Snowstorm, Pilgrim mines) with a large copper zone to the W-NW and a gold zone to the south (Red Cloud Mine).

**Central system**
This area is southeast and southwest of Shenandoah peak. It is 5.2 miles long and 2 miles wide. It extends from the Boss mine in the southeast to the Prairie Flower mine in the northeast. It has a central lead-zinc zone, a southern copper zone, and a northern gold zone. Most of the gold deposits are associated with porphyritic intrusive rocks.

**Southern system**
This is the largest porphyry system, covering an area of 47 square miles. The northern boundary of this zone is the Sand Valley Road in Kirby Wash. The west side extends to the townsite of Ripley. The southern boundary extends to Devil Peak. The eastern side is marked by the Lincoln and Ireland mines. It has a lead-zinc core with copper zones to the north and east. There is also a silver zone outward of the copper zone in the southeast part of the porphyry system. In addition, there is a western gold zone.

**Ore formation**
The foregoing review of the stratigraphy, structure and mineral deposits in the Southern Spring Mountains suggests that the lead in the polymetallic replacement deposits originated from the leaching of 1.7 billion year old Precambrian crustal units. Those Paleozoic Lead-Zinc replacement deposits became parts of differentiating porphyry systems in the Late Triassic. This partly
remobilized and mixed mineral assemblage was included in subsequent thrusting, normal faulting and detachment events involving Paleozoic and Mesozoic formations from Triassic to Late Cretaceous time.

The ore solutions from the differentiating porphyry systems dolomitized limestones and replaced favorable carbonate units with remobilized sulfide minerals. Weathering and supergene enrichment of the sulfide replacement deposits have produced the present mineral assemblages.

If the relic porphyry mineral zonation (Maps 3 and 4) is from the Late Triassic intrusive hydrothermal events, then the lower parts of that system must be below the thrusts and west of the Spring Range due to post-Cretaceous extension. Alternatively, the zonation could be the product of a 3rd overprinting and remobilizing igneous-hydrothermal event in Tertiary time.

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