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Arizona Bureau of Mines
G. M. Butler, Director

THE MINERAL INDUSTRIES
OF
ARIZONA

By J. B. Tenney

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68. What To Do With the Other Eight Hours, by S. C. Dickinson.
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122. Quicksilver (Mercury) Resources of Arizona, by Carl Lausen and E. D. Gardner.
123. Geology and Ore Deposits of the Courtland-Gleeson Region, by Eldred D. Wilson.
(The following voluminous, beautifully illustrated Bulletin is sold for $1.00)
PREFACE

From the time the Arizona Bureau of Mines was created it has been flooded with requests for a bulletin that would give a fairly accurate idea of the importance and magnitude of the mineral industries in the State, but nothing purporting to cover this subject has been written for many years, and the desired information was scattered through scores of books, bulletins, and magazine articles.

When Mr. J. B. Tenney was added to the staff of the Bureau as Assistant Geologist, two tasks were specifically allotted to him: First, and most important, he was made responsible for the preparation of an annual report upon the mineral industries of the State together with much briefer quarterly progress reports on the same subject. His second responsibility was the preparation of a history of mining in Arizona for which a strong demand existed. This volume constitutes the first annual report issued by the Bureau. It was written almost entirely by Mr. Tenney, although Dr. E. P. Mathewson obtained and arranged much of the data relating to smelters and mills. Subsequent issues will doubtless differ materially from the first, since the detailed data contained therein will not be repeated, and only changes in practice or personnel and new developments will be mentioned. Furthermore, it is hoped and planned to make subsequent annual reports more statistical, and to discuss generally the condition and probable future of the mineral industries in various parts of the State.

While the Bureau may be criticised for not including descriptions of or references to scores of smaller developing properties in Arizona, it was felt best to include only properties that are productive or promise to become productive in the not distant future. To have made the report a complete reference manual on mining in Arizona would have been impossible, as small properties are starting up or closing down so frequently that descriptions of many of them are obsolete by the time they are in print. Weed's “Mines Handbook” which is now issued annually, contains much data relative to practically all the operating mines, and may be consulted in most libraries or stock brokers' offices. The report issued annually by the State Mine Inspector, at Phoenix, contains some information concerning all properties employing six men or more. Furthermore, the Bureau clips all references to Arizona mines that appear in newspapers and periodicals, and is always willing to give inquirers concerning mining properties as much information as may be thus available.
Recognizing the limitations of the present volume, it is hoped that it will serve to give some idea of the magnitude of the mineral industries in the State, which has a larger annual production of metals than any other in the Union, and may be the means of attracting increased attention to the State's mineral industries.

G. M. Butler,
Director, Arizona Bureau of Mines.

February 15, 1928.
## CONTENTS

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>COPPER MINING</td>
<td></td>
</tr>
<tr>
<td>General Introduction</td>
<td>9</td>
</tr>
<tr>
<td>Bisbee-Douglas District</td>
<td>9</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>9</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>10</td>
</tr>
<tr>
<td>Mining Methods</td>
<td>10</td>
</tr>
<tr>
<td>Ore and Material Transportation</td>
<td>11</td>
</tr>
<tr>
<td>Concentrator</td>
<td>12</td>
</tr>
<tr>
<td>Leaching</td>
<td>14</td>
</tr>
<tr>
<td>Pumping</td>
<td>14</td>
</tr>
<tr>
<td>Copper Reduction Works</td>
<td>15</td>
</tr>
<tr>
<td>Copper Queen Reduction Works</td>
<td>15</td>
</tr>
<tr>
<td>Calumet and Arizona Smelter</td>
<td>16</td>
</tr>
<tr>
<td>Chamber Acid Plant</td>
<td>18</td>
</tr>
<tr>
<td>Apache Powder Works Contact Acid Plant</td>
<td>18</td>
</tr>
<tr>
<td>Power Plants</td>
<td>19</td>
</tr>
<tr>
<td>Labor</td>
<td>20</td>
</tr>
<tr>
<td>Personnel of Operating Companies</td>
<td>21</td>
</tr>
<tr>
<td>Globe-Miami District</td>
<td>23</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>23</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>24</td>
</tr>
<tr>
<td>Mining Methods</td>
<td>24</td>
</tr>
<tr>
<td>Ore and Material Transportation</td>
<td>28</td>
</tr>
<tr>
<td>Concentrators</td>
<td>29</td>
</tr>
<tr>
<td>Old Dominion Company Concentrator</td>
<td>30</td>
</tr>
<tr>
<td>Miami Mill</td>
<td>31</td>
</tr>
<tr>
<td>Inspiration Mill</td>
<td>32</td>
</tr>
<tr>
<td>Leaching Plant</td>
<td>33</td>
</tr>
<tr>
<td>Smelter</td>
<td>34</td>
</tr>
<tr>
<td>Power Plants</td>
<td>35</td>
</tr>
<tr>
<td>Pumping and Water Supply</td>
<td>36</td>
</tr>
<tr>
<td>Labor</td>
<td>36</td>
</tr>
<tr>
<td>Personnel of Operating Companies</td>
<td>38</td>
</tr>
<tr>
<td>Ray-Hayden District</td>
<td>40</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>40</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>41</td>
</tr>
<tr>
<td>Mining Methods</td>
<td>41</td>
</tr>
<tr>
<td>Ore and Material Transportation</td>
<td>42</td>
</tr>
<tr>
<td>Concentrator</td>
<td>43</td>
</tr>
<tr>
<td>Reduction Plant</td>
<td>43</td>
</tr>
<tr>
<td>Pumping</td>
<td>43</td>
</tr>
<tr>
<td>Power Plant</td>
<td>44</td>
</tr>
<tr>
<td>Labor</td>
<td>44</td>
</tr>
<tr>
<td>Personnel of Operating Companies</td>
<td>44</td>
</tr>
<tr>
<td>Jerome District</td>
<td>44</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>45</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>46</td>
</tr>
<tr>
<td>Mining Methods</td>
<td>46</td>
</tr>
<tr>
<td>Ore and Material Transportation</td>
<td>47</td>
</tr>
<tr>
<td>Concentrator</td>
<td>48</td>
</tr>
<tr>
<td>Smelters</td>
<td>48</td>
</tr>
<tr>
<td>United Verde Smelter</td>
<td>48</td>
</tr>
<tr>
<td>United Verde Extension Smelter</td>
<td>48</td>
</tr>
</tbody>
</table>

(3)
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel of Operating Companies</td>
<td>71</td>
</tr>
<tr>
<td>Dos Cabezas District</td>
<td>72</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>72</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>72</td>
</tr>
<tr>
<td>Development</td>
<td>72</td>
</tr>
<tr>
<td>Concentrator</td>
<td>73</td>
</tr>
<tr>
<td>Power</td>
<td>73</td>
</tr>
<tr>
<td>Water Supply</td>
<td>73</td>
</tr>
<tr>
<td>Present Activity</td>
<td>73</td>
</tr>
<tr>
<td>Personnel of Central Copper Co</td>
<td>73</td>
</tr>
<tr>
<td>Swansea District</td>
<td>73</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>73</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>74</td>
</tr>
<tr>
<td>Mining Operations</td>
<td>74</td>
</tr>
<tr>
<td>Silverbell District</td>
<td>74</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>74</td>
</tr>
<tr>
<td>Mining Activity</td>
<td>74</td>
</tr>
<tr>
<td>Labor</td>
<td>74</td>
</tr>
<tr>
<td>Personnel of Operating Companies</td>
<td>74</td>
</tr>
<tr>
<td>Miscellaneous Copper Districts</td>
<td>75</td>
</tr>
<tr>
<td>Bagdad Deposit</td>
<td>75</td>
</tr>
<tr>
<td>Patagonia District</td>
<td>75</td>
</tr>
<tr>
<td>Gunsight District</td>
<td>76</td>
</tr>
<tr>
<td>Cerbat Mountains</td>
<td>76</td>
</tr>
<tr>
<td>Old Hat District</td>
<td>76</td>
</tr>
<tr>
<td>White Mesa Sandstone Deposits</td>
<td>76</td>
</tr>
<tr>
<td>Tucson Mountains Deposits</td>
<td>76</td>
</tr>
<tr>
<td>Copper Creek District</td>
<td>76</td>
</tr>
<tr>
<td>Lone Star District</td>
<td>77</td>
</tr>
<tr>
<td>Cunningham Pass District</td>
<td>77</td>
</tr>
<tr>
<td>Grand Gulch Mine</td>
<td>77</td>
</tr>
<tr>
<td>LEAD MINING</td>
<td>78</td>
</tr>
<tr>
<td>General Introduction</td>
<td>78</td>
</tr>
<tr>
<td>Bisbee District</td>
<td>78</td>
</tr>
<tr>
<td>Mining Methods</td>
<td>78</td>
</tr>
<tr>
<td>Concentrator</td>
<td>78</td>
</tr>
<tr>
<td>Copper Queen Lead Smelter</td>
<td>80</td>
</tr>
<tr>
<td>Tonopah Belmont Development Company</td>
<td>83</td>
</tr>
<tr>
<td>Mining</td>
<td>83</td>
</tr>
<tr>
<td>Milling</td>
<td>83</td>
</tr>
<tr>
<td>Power</td>
<td>83</td>
</tr>
<tr>
<td>Labor</td>
<td>84</td>
</tr>
<tr>
<td>Personnel of Company</td>
<td>84</td>
</tr>
<tr>
<td>Empire Mountains</td>
<td>84</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>84</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>84</td>
</tr>
<tr>
<td>Mining</td>
<td>84</td>
</tr>
<tr>
<td>Labor</td>
<td>84</td>
</tr>
<tr>
<td>Personnel of Operating Company</td>
<td>84</td>
</tr>
<tr>
<td>Miscellaneous Mining</td>
<td>85</td>
</tr>
<tr>
<td>COMPLEX ORE DEPOSITS</td>
<td>86</td>
</tr>
<tr>
<td>General Introduction</td>
<td>86</td>
</tr>
<tr>
<td>Cerbat Mountains District</td>
<td>87</td>
</tr>
<tr>
<td>Mining Activities</td>
<td>87</td>
</tr>
</tbody>
</table>

(5)
<table>
<thead>
<tr>
<th>District</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oro Blanco</td>
<td>88</td>
</tr>
<tr>
<td>Mining Activities</td>
<td>88</td>
</tr>
<tr>
<td>Concentrator</td>
<td>89</td>
</tr>
<tr>
<td>Power</td>
<td>89</td>
</tr>
<tr>
<td>Labor</td>
<td>89</td>
</tr>
<tr>
<td>Personnel of Montana Mines Operations</td>
<td>90</td>
</tr>
<tr>
<td>Sierrita Range</td>
<td>90</td>
</tr>
<tr>
<td>Mining Activity</td>
<td>90</td>
</tr>
<tr>
<td>Concentrator</td>
<td>90</td>
</tr>
<tr>
<td>Inactive Properties</td>
<td>90</td>
</tr>
<tr>
<td>Labor</td>
<td>90</td>
</tr>
<tr>
<td>Patagonia District</td>
<td>91</td>
</tr>
<tr>
<td>Bradshaw Mountains</td>
<td>91</td>
</tr>
<tr>
<td>Dragoon and Little Dragoon Mountains</td>
<td>91</td>
</tr>
<tr>
<td>Superior District</td>
<td>92</td>
</tr>
<tr>
<td>Arivaipa District</td>
<td>92</td>
</tr>
<tr>
<td>Miscellaneous Deposits</td>
<td>92</td>
</tr>
</tbody>
</table>

**GOLD AND SILVER MINING**

<table>
<thead>
<tr>
<th>District</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oatman-Katherine District</td>
<td>93</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>93</td>
</tr>
<tr>
<td>Mining Methods</td>
<td>93</td>
</tr>
<tr>
<td>Ore and Material Transportation</td>
<td>94</td>
</tr>
<tr>
<td>Mills</td>
<td>94</td>
</tr>
<tr>
<td>Tom Reed Mill</td>
<td>94</td>
</tr>
<tr>
<td>Katherine Mill</td>
<td>94</td>
</tr>
<tr>
<td>Power Plants</td>
<td>95</td>
</tr>
<tr>
<td>Labor</td>
<td>96</td>
</tr>
<tr>
<td>Development Work</td>
<td>96</td>
</tr>
<tr>
<td>Personnel of Operating Companies</td>
<td>96</td>
</tr>
<tr>
<td>White Hills District</td>
<td>97</td>
</tr>
<tr>
<td>Tombstone District</td>
<td>97</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>97</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>97</td>
</tr>
<tr>
<td>Mining Operations</td>
<td>97</td>
</tr>
<tr>
<td>Labor</td>
<td>98</td>
</tr>
<tr>
<td>Wickenburg-Congress District</td>
<td>98</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>98</td>
</tr>
<tr>
<td>Mining Activity</td>
<td>98</td>
</tr>
<tr>
<td>Vulture Mine</td>
<td>98</td>
</tr>
<tr>
<td>Congress Mine</td>
<td>98</td>
</tr>
<tr>
<td>Winifred District</td>
<td>98</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>98</td>
</tr>
<tr>
<td>Mining Activity</td>
<td>98</td>
</tr>
<tr>
<td>Pearce District</td>
<td>99</td>
</tr>
<tr>
<td>Baboquivari Mountains</td>
<td>99</td>
</tr>
<tr>
<td>Mining Activity</td>
<td>99</td>
</tr>
<tr>
<td>Miscellaneous Districts</td>
<td>99</td>
</tr>
</tbody>
</table>

**ASBESTOS MINING**

<table>
<thead>
<tr>
<th>District</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>101</td>
</tr>
<tr>
<td>Salt River Basin Deposits</td>
<td>101</td>
</tr>
<tr>
<td>Location and General Geology</td>
<td>101</td>
</tr>
<tr>
<td>Mining Properties</td>
<td>101</td>
</tr>
<tr>
<td>Mining</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CINNABAR (MERCURY) MINING
Introduction
Mazatzal Mountains Deposits
Operating Companies

MOLYBDENUM AND TUNGSTEN MINING
Introduction
Patagonia Mountains
Huachuca Mountains
Little Dragoon Mountains
Miscellaneous Deposits

FELDSPAR MINING

GYPSUM MINING

ONYX MINING
Operating Properties
Mayer Operations
Camp Creek Operations
Personnel of Operating Companies

LIMESTONE QUARRYING

OIL PROSPECTING
Holbrook Area
Inter-mountain Valleys

COAL MINING

MANGANESE MINING

SALT AND THENARDITE (SODIUM SULPHATE) MINING
Introduction
Mining Methods
Treatment
Labor
Production
Personnel of Sodium Products Corporation

APPENDIX
Ore Markets
Copper Ores
Lead Ores
Zinc Ores and Concentrates
Molybdenum and Tungsten Ores
Manganese Ores
Feldspar
Thenardite
Asbestos
Mercury
Onyx

EXPLORATION COMPANIES AND DEPARTMENTS
Model Report on Mining Property
Exploration Companies

APACHE POWDER COMPANY PLANT
COPPER MINING

GENERAL INTRODUCTION

For many years, Arizona has led all other states in the production of copper. Ores of this metal are found in nearly every mining district in the State, and her largest mines are her copper mines. A general review of the occurrences, mines, and reduction plants, is given in the following pages. In some of the copper districts, ores of other metals are mined, which will be reviewed under separate headings.

BISBEE-DOUGLAS DISTRICT

LOCATION AND GENERAL GEOLOGY

This district, one of the earliest to be discovered and exploited, is situated in Cochise County, in the southeast corner of the State, near the Mexican boundary. The deposits are found in the southeastern end of the Mule Pass Mountains. The principal mining community is the city of Bisbee. The towns of Lowell, Upper Lowell, Warren, and Don Luis are near by. The ores of the district are smelted at the city of Douglas, 20 miles east, situated in the Sulphur Springs Valley just north of the Mexican line. The district is served by the Southwestern Branch of the Southern Pacific Railroad.

The Mule Pass Mountains are carved from pre-Cambrian schists and granite; overlying Paleozoic sediments, mostly limestones; and Cenozoic sediments, mostly sandstones and shales. This series of metamorphics and sediments has been intricately faulted and extensively intruded by granite porphyry. The ore bodies occur at the southeast end of the range, and are essentially replacements of the Paleozoic limestones and of the intruding porphyry. The ore bodies are tabular in form, and have generally small vertical dimensions. There are two types of ore; that in which the limestone is replaced, and that in which replacement is of the porphyry. The limestone replacement ore bodies are massive and high grade, as contrasted to the porphyry ore which is of the relatively low grade disseminated type. The ore has a proved distribution of about 3 miles square, the outer limits constantly expanding with developments.

The grade of limestone replacement ore varies greatly depending both on the degree of secondary enrichment and oxidation, and of primary
metallization. The primary ore, although lower in grade than the enriched and oxidized ore, is sufficiently high grade to constitute good direct smelting ore, and some primary ore occurs of bonanza grade.

The ore replacing porphyry consists of the usual network of veinlets carrying pyrite and chalcocite in a silica and sericite gangue. The grade varies from 0.5 percent to over 15 percent, with an average of about 2 percent.

In certain parts of the district, the limestone has been replaced by silver-bearing lead ores. This ore is all highly oxidized. Large reserves have been developed, and are being mined.

The geology of the district has been described in the following articles and publications:


MINING PROPERTIES

There are five producing mining companies in the district: Phelps Dodge Corporation, Copper Queen Branch; The Calument and Arizona Mining Company; The Shattuck-Denn Mining Corporation; The Wolverine and Arizona Mining Company; and the Night Hawk Leasing Company. One company is developing: The Bisbee Queen Development Company, a subsidiary of the United Verde Extension Mining Company.

MINING METHODS

A great variety of mining methods is employed in the camp, depending on the grade of ore, firmness of the walls, shape and size of ore bodies, etc. In the limestone replacement ore bodies, more expensive methods are used than in the porphyry ore bodies.

In the limestone replacement ore bodies, where they are oxidized or enriched, and where the ground is as a consequence heavy, the following mining methods are used:

1. Overhead square-setting and fill (small irregular ore bodies).
2. Underhand square-setting and fill (large thicker ore bodies).
3. Horizontal panel top slicing, using drag scrapers. (Applicable for very heavy ground and where the back is thoroughly prospected and will follow readily).

In limestone replacement primary ore bodies where the ore and walls are firm, some modification of the incline cut and fill method is used.
In the porphyry ore bodies, two methods are used:

1. Steam shovel pit mining (west ore body Sacramento Hill).
2. Modified Morenci system of block caving (on a portion of an ore body lying too deep to steam shovel.)

These mining methods have been described in the following articles:

Dickson, Robert H., Mining by Briggs Underhand Square-Setting. E. & M. J., Jan. 6, 1923.

ORE AND MATERIAL TRANSPORTATION

The greater bulk of limestone replacement ore is hoisted through shafts. A part of the Copper Queen ore is taken out through a tunnel. Hand tramming is used to transfer the ore to main chutes where it is dropped to haulage levels. At the haulage levels, the ore is transported in trains by electric locomotives to pockets at main hoisting shafts, and from there hoisted in skips.

At the Shattuck Mine of the Shattuck-Denn Mining Corporation, the ore is hand trammed and hoisted in cages, and from there dumped into bins. It is from there transferred to buckets and carried over a 3,500-foot aerial tramway to the railroad at the base.

Ore mined on the southern slopes of the range by the Wolverine and Arizona Mining Company, the Night Hawk Leasing Company, and the White Tailed Deer Mine of the Phelps Dodge Corporation is hoisted and hauled by motor truck, a distance of about a mile, to the railroad.

Men and supplies are lowered in cages, both at the main hoisting shafts and others. At the Queen Tunnel of the Phelps Dodge Corporation men walk to a shaft connecting with the tunnel, and supplies are hauled to this shaft, where they are hoisted to levels above.

The Phelps Dodge Corporation maintains four shafts and a long tunnel. Besides these extraction openings, it is sinking a deep prospect shaft in the town of Warren, and is developing from another shaft, also in the town of Warren, maintained primarily for the water supply for its concentrators. A number of other shafts and openings are maintained by lessees.

The Calumet and Arizona Mining Company maintains four shafts, and lessees maintain one.

The Shattuck-Denn Mining Corporation is operating two mines, the Shattuck and the Denn, about 3 miles apart, with a shaft on each.
The Wolverine and Arizona Mining Company operates from a shaft on the southern slopes of the range, and is prospecting from a tunnel and winze.

The Night Hawk Leasing Company extracts its ore from a shaft on the southern slope of the range, on ground adjoining the White Tailed Deer Mine, owned by Phelps Dodge Corporation, and operated by lessees from a vertical shaft.

The Bisbee Queen Development Company is prospecting ground about a mile east of Warren from an 800-foot shaft sunk in 1926.

The Ivanhoe Copper Company has sunk a shaft on ground adjoining the town of Warren to the south and east, and has done considerable drifting. More work is contemplated in the near future.

**CONCENTRATOR**

To handle the large reserves of porphyry ore developed on Copper Queen ground, the Phelps Dodge Corporation is operating a 4,000-ton concentrator on the southern slope of the range, about a mile south of Warren. Ore is treated from the Sacramento Hill steam shovel pit and from the southeast extension of the east ore body, being mined underground.

The ore from the pit and from underground, is transported in 40-ton side-dump cars to the coarse crushing plant. Here the ore is delivered to an 84 by 66-inch jaw crusher through an 8-inch grizzly. The crusher runs at 120 r.p.m. and is driven through twelve, 1¼-inch rope drives by a 250-h.p. motor, and crushes to 8-inch size. The grizzly undersize and crushed ore drop onto two 54-inch pan conveyors discharging into a 1,000-ton surge bin, which absorbs intervals between trains and allows continuous operation of the following crushing equipment. Ore from the surge bin is delivered over 2½-inch ring grizzlies to two No. 9 gyratories. Grizzly and gyratory products are delivered over 1½-inch ring grizzlies to four disc crushers, the finished product passing 1¼-inch ring. It is either delivered to the 12,000-ton concentrator storage bin over a shuttle conveyor, or to the smelter ore bins, for shipment to Douglas. A Lynch dust collecting system is installed, insuring healthful working conditions.

The concentrator is built in four 1,000-ton units. The ore from the storage bins is drawn by twenty-four 20-inch apron feeders and is delivered to the primary 6'6"x12'3" Marcy Rod Mills, two to each section, eight in all, loaded with 22 tons of 3¼-inch steel rods. The discharge material, about 11 percent plus 48 mesh and 44 percent minus 200 mesh, goes to Dorr bowl classifiers, (in one unit, two of these
classifiers are 8"x28'10"x15', and in the other three units are six, 6'x28'4"x15' classifiers.) The sands in all units go to eight secondary 6'6"x12'3" Marcy rod mills charged with 22 tons of 3-inch rods run in closed circuit with Dorr duplex circulating classifiers, in one unit of 8'x23'4" size, and in the other three units 6'x23'4" in size. The overflow from the bowl classifiers and from the circulating classifiers delivers a product 0.7 percent plus 65 mesh 73.2 percent minus 200 mesh, is delivered to a mixing box (except that from the one experimental unit), and is taken from there to eight 54-foot double spitz Forrester type flotation machines, with air furnished at 1½ pounds pressure by two Root blowers. Finished concentrate is obtained from the first 12 to 16 feet of the machine, the remaining middlings being pumped back to the mixing box for retreatment.

Flotation reagents consist of 0.1 pound of Xanthate per ton of ore, added in solution to the classifier overflow pulp before it enters the mixing box; 6 pounds of lime per ton of ore added to the ore dry as it is conveyed to the primary grinding machines; and 0.05 pounds per ton of steam-distilled pine oil added in the mixing boxes.

The concentrates are delivered to one or more Dorr Duplex classifiers, as required, delivering slime concentrates and sand concentrates. The slime concentrates go to two 75-foot Dorr tray thickeners, the spigot product being elevated to a 14 by 14-foot Oliver drum filter; delivering a cake containing 11.6 percent moisture direct to railroad cars. Sand concentrates are delivered through air lifts to four Blaisdell dewatering tanks equipped with vacuum bottoms. The overflow is elevated to the slime concentrate thickeners. Each tank holds 600 dry tons, and is unloaded by disc excavators, the dewatered concentrates dropping direct into railroad cars. The moisture content of the sand concentrates is 7.87 percent.

Tailings are thickened in one 200-foot Dorr thickener and two 75-foot Dorr tray thickeners, and the spigot product delivered by launders to the tailings pond.

The mill heads vary from 1.28 to 2.50 percent copper, contain a small amount of gold and silver, about 60 percent SiO₂, 13 percent Al₂O₃, 9 percent Fe, 0.5 percent CaO and 10 percent S.

The ratio of concentration is about 9.3 to one, an increase over 1926 results which were 6.33 to one.

The extraction is 87.5 percent total copper and 92.2 percent sulphide copper. Concentrates contain 42 percent S and 40 percent Fe and from 12 to 17.5 percent copper, depending on the heads.

The descriptions of the concentrator and metallurgical data were
furnished the Bureau by the management of the Phelps Dodge Corporation, Copper Queen Branch.

LEACHING

Low grade material between 0.51 and 0.9 percent copper is sent to special piles west of the concentrator, and is then spread and irrigated by a mixture of acid mine water and fresh water, and the dissolved copper precipitated on scrap iron. The experimental work and plant have been described in the following articles:


PUMPING

The pumping of the operating mines of the camp is done at one shaft, the Junction shaft of the Calumet and Arizona Mining Company, the deepest shaft in the district. The pumps are located at a special concreted station on the 2,200 foot level, and raise the water to the surface in one lift. The installation consists of two, 1,000-g.p.m., one 1,500-g.p.m., and one 1,250-g.p.m. electrically-driven horizontal, duplex, 4-plunger pumps. The 1,000-g.p.m. pumps are each connected through flexible couplings and single reduction herring bone gears to 750-h.p. 514-r.p.m. synchronous motors. The 1,500-g.p.m. pump is connected with a 1,050-h.p. motor and the 1,250-g.p.m. pump with a 900-h.p. motor. All motors are 2,200 volt, 60-cycle, 3-phase motors with special impregnation winding. The total capacity of the plant is 4,750 g.p.m. The amount of water normally handled is from 2,500 to 3,000 g.p.m. and not over 3,750 g.p.m. is anticipated as possible future normal flow.

Sump capacity is 165,000 gallons allowing for rise of water during power shut-offs.

Power is conducted through 3,250,000 C.M., 3-conductor stranded cables insulated for 4,000 volts.

There are two 12-inch pipe water columns, varying in thickness with the depth from the surface. They are 1 inch thick below the sweep tees and have 24-inch diameter flanges. The whole weight of the columns (amounting to 370 tons when full of water) is borne on a box section girder concreted in place 50 feet below the 2,200-foot
station level. The plant has been described in the following articles:

The water for the Phelps Dodge Corporation concentrator is pumped in two lifts from the 1,800-foot level of the Calumet and Cochise shaft in Warren. These pumps are also electrically driven.

COPPER REDUCTION WORKS

There are two copper smelting plants, both situated at the city of Douglas, 20 miles east of the mines. A lead smelter is also situated there which will be described under a separate heading.

Copper Queen Reduction Works. This plant was originally a blast furnace plant. Later three reverberatories and 20 roasters were installed, but from three to four blast furnaces were continued in service. To obtain the maximum benefits of the cheaper reverberatory practice, two new reverberatories with Copper Queen Type superimposed roasters were added in 1926. The lead smelter was not completed until June 1927, and will be described under Lead Mining.

The copper smelter treats crushed ore from Bisbee, concentrates from Bisbee and Nacozari, and miscellaneous customs ores, and has a capacity of 2,700 tons a day, without using any blast furnaces. The ores and concentrates as received are sampled by tenth shovel samples, the sample transferred to the sample mill, and the reject ore and concentrates bedded. The ore is reclaimed from the beds by steam shovel, and transferred to the roasters by belt conveyor.

The roasters and reverberatories are arranged in two units, each of which contains one reverberatory and six superimposed Copper Queen type roasters. The roasters have 11 hearths. The moving parts are aircooled and radiating surfaces are insulated. Each roaster has a capacity of 300 tons per day. The gas goes to pipe type Cottrell dust treaters, one for each two roasters, the precipitated dust returning immediately to the calcine bins from which it is fed to the furnace by screw feeders to prevent dusting. The hot calcines drop through insulated pipes into insulated hoppers. These hoppers are on either side of the reverberatories. The roasters can be oil fired, but usually run without fuel.

The reverberatories are 95'x23'9" at the skewback. Each reverberatory has four Erie 550-h.p. boilers set two at the end and one on each side to generate steam from waste heat. The whole installation is designed to have gravity flow throughout. The Cottrell Plant is
135 feet above ground, roasters directly beneath, followed by the reverberatories and the matte and slag disposal tracks at the bottom. They are all housed in one steel frame building with concrete and lattice steel flooring.

The matte is handled by cranes to nine 12-foot Great Falls type converters, the slag from which is poured molten into the reverberatories and the blister cast into bars for shipment to an eastern refining plant.

_Calumet and Arizona Smelter._ This smelter receives run of mine ore from Bisbee, concentrates from New Cornelia, siliceous ore from the 85 Mine, and miscellaneous customs ore.

The plant consists of a crushing and sampling unit, ore beds, roasters, reverberatories, converters, Cottrell dust precipitators, and two acid plants, one for chamber acid for New Cornelia and the general market, and one for the production of concentrated "fuming" acid made, by the contact process, for the Apache Powder Company.

All run of mine ore received is discharged into two 7,000-ton steel bins, one of them of the suspended type. Ore is taken from these bins through arc gates by traveling pan feeders, one for each bin, discharging onto belt conveyors, arranged to discharge a mixed charge from each bin to duplicate No. 8 gyratories after passing over grizzlies. Each grizzly and gyratory delivers to its own sampling unit over 24-inch belt conveyors. The belt conveying arrangement allows for sampling each bin separately or together as desired. In each sampling unit the discharge from the 24-inch belt is cut by 1, 2, 3, or 4, steel plate sample buckets attached to horizontal arms driven by motor, revolving a vertical shaft. Any of the buckets can be swung aside if desired. The reject is received in a hopper discharging upon a 30-inch belt conveyor and delivering to a 120-ton steel surge bin. The sampling buckets discharge into a cast iron receiving hopper. A feeder of the shaking pan type delivers the contents of the hopper to a No. 3 Telsmith crusher. The discharge hopper feeds a vertical ore stream cut by a second set of two to four sampling buckets carried on the same shaft as the first pair. The second reject is delivered to a cast iron hopper attached to a 10-inch pipe which delivers to a conveyor in a tunnel beneath the first floor of the sampler, delivering to a bucket elevator, discharging upon the conveyor carrying the first reject. The second sample cut is received in a cast iron hopper discharged by a shaking pan feeder to a set of Allis-Chalmers 42 by 12-inch rolls. The vertical stream of ore is cut by a third set of two to
four sample buckets, the sample being received in a cast iron hopper and
the reject spouted to the conveyor in the tunnel. The sample receiving
hopper is discharged when desired into a mixer like a concrete mixer,
discharging into a Jones splitter, the reject being spouted to the con-
veyor belt and the sample being received in iron boxes.

The 120-ton surge bin discharges the reject by means of roll feeders
over four hummer screens, the oversize being sent by conveyor to the
rolls in a separate building. The conveyor delivers to either of two
165-ton surge bins provided with roll feeders, the feeder discharge
being sent to a 78 by 24-inch set of Traylor rolls. The roll product
bin discharges to eight Hummer screens, the oversize going back to the
rolls bin and the undersize being discharged over short conveyors to a
30-inch belt conveyor and tripper to the bedding piles. The finished
product is crushed to ½-inch size. Each unit of the plant is equipped
with separate motor drive, eliminating the hazard of long belts. The
sampling mill is all in one building of three stories. The description
of this plant is taken from the following article:

Young, George J., A Model Crushing Plant at Douglas, Arizona. E. & M. J.,

New Cornelia concentrates, and any customs ore not needing crush-
ing are received in separate bins, discharging by feeders onto conveyor
distributing belts delivering to the ore beds. There are six of these
beds of 9,000 tons each. The ore is reclaimed and conveyed by
Messiter conveying system to 24 21½-foot Herreshoff oil-fired 6-hearth
roasters, removing 61 percent of the sulphur as gas. The gas from
5 roasters, run on special high sulphur ore after passing through a
dust chamber, is split, part being used for making 200 tons daily of
60° Baumé Chamber sulphuric acid, and part diverted to an acid
plant using the contact method for producing “fuming” sulphuric
acid for use in the Apache Powder Works. The gas from the other
19 roasters goes to waste up the stack, after passing through a Cottrell
Plant.

The calcines and recovered dust are transferred to four oil-fired re-
verberatories, 19 by 100 feet of 700 tons capacity, each eliminating 34.5
percent sulphur. Attached to the reverberatories are ten 712-h.p.
Sterling waste heat boilers generating power for the mines and smelter.

The matte from the reverberatories is transferred by a traveling
crane to six stands and nine shells of basic lined Great Falls type up-
right converters using 14 pounds per square inch air pressure. Sec-
ondaries from the reverberatories are transferred to the ore beds, gas
from the roasters to the Cottrell plant, and slag to the slag dump.
The converters produce blister copper and slag. The blister copper is cast into bars, and the slag is transferred to the reverberatories and poured in molten. This slag runs about 2.5 percent copper.

Chamber Acid Plant. The gas from five of the Herreshoff roasters, containing about 5 percent SO$_2$ is used to furnish acid for this plant. This gas after dust removal, goes by a flue to a double compartment chamber containing 12 cast iron “nitre pots,” charged with Chilean nitrate and sulphuric acid. The hot SO$_2$ gas is circulated in this chamber over and beneath the pots, mixing with the NO$_2$ fumes generated in the pots. The contents of the pots become liquid and the reaction takes about 2 hours, the resulting NaHSO$_4$ going to waste. The mixed gases are conducted through a lead flue to the bottom of a Glover tower 22’2” in diameter, 56 feet high, of steel frame construction, lined with Duro brick, laid in Duro cement, and packed with a checker board of Duro chemical tile. The entire block of towers is enclosed in lead sheeting hung upon a steel frame. The gases from the Glover tower are conducted through a 6 by 10-foot lead flue to a set of five cooling towers, lead lined, 17½ feet in diameter, 41 feet high, the gases entering the bottom and leaving the top of each tower. A lead blower 4 feet wide, 8 feet in diameter running at from 150-200 r.p.m. draws the gas through the Glover tower and cooling towers, and into the first acid chamber, thence to three cooling towers, and five more acid chambers with cooling towers between. Chamber acid is here generated by the action of NO$_2$ on SO$_2$, oxidizing the SO$_2$ to SO$_3$, which combined with water gives sulphuric acid. The strength of this chamber acid is about 53° Baumé.

The acid chambers are each lead lined and 143½ feet by 51 feet by 41 feet high. Water is sprayed in the cooling towers and chambers by Schutte and Koerting platinum tipped jets. After passing through the chambers and cooling towers the weak SO$_2$ strong NO gas is forced by a second lead blower through the Gay Lussac towers, where the downward percolating strong acid absorbs the NO to form nitrous vitriol and is pumped back to the Glover tower. The acid from the chambers is elevated to the Glover tower by an adaptation of the Pohle air lift in stages of 15 feet, the total lift being 90 feet. A description of the plant is given in the following article:


Apache Powder Works Contact Acid Plant. This plant is run by the Apache Powder Company, to manufacture fuming sulphuric acid for use in the making of nitroglycerine and guncotton at their plant at
Curtis. The ground is leased from the Calumet and Arizona Mining Company and the SO₂ gas is bought from that company’s smelter.

In the manufacture of this strong acid, the contact process is used whereby SO₃ gas is generated by the oxidation of SO₂ gas in contact with sponge platinum, and the SO₃ gas is combined with enough water to give 100-percent sulphuric acid and then charged with SO₃ gas to give fuming sulphuric acid which contains 105 percent SO₃.

Five of the roasters at the smelter are charged with high sulphur ore from Bisbee, and the gases used for both acid plants. This gas containing about 5 percent SO₂ passes first to a dust chamber, and from there it is split, part going to the chamber acid plant and part to the contact acid plant. That going to the contact acid plant is first cooled to air temperature by water sprays and bath and then passes through four sets of filters, consisting of three boxes each. In the boxes the gas is forced up through a bed of sawdust and quartz in the first box, quartz, sawdust, and asbestos in the second, and quartz and mineral wool in the third box. The object of this filtering is to eliminate all dust and also such impurities as chlorine and arsenic. From the filter boxes, the gas is forced through a dryer, then through a pre-heater, where it is heated by an oil burner. From there it is forced through a converter, where the weak, hot SO₂ gas comes in contact with roasted epsom salts charged with 0.15-percent platinum. From the converters, the SO₃ gas passes up through oleum towers, against downward percolating weak sulphuric acid. The resulting 100-percent sulphuric acid then passes through an absorber tower against a counter current of SO₃ gas, and the resulting product is fuming sulphuric acid 105-percent SO₃ which is stored in a wrought iron tank and shipped in special tank cars to Curtis.

The capacity of the plant is 20 tons a day. It is built in two units of 10 tons each.

POWER PLANTS

Electric power for the mines and concentrators of the Phelps Dodge Corporation is furnished from two sources. Power is generated from waste gases from the reverberatories, the total installation being 7,000 h.p., and transmitted over a high tension line from Douglas to Bisbee. At the concentrator, power is generated by a 6,000-h.p. Diesel plant, direct connected with compressor and turbo generator set, and tied in with the turbo generators at Douglas by a transmission line.

Electric power for the Calumet and Arizona Mining Company is generated at the smelter at Douglas by 7,000-h.p. boilers running three
ARIZONA BUREAU OF MINES

turbo generator sets of 3,000, 2,500, and 500 kw. each. It is transmitted to Bisbee over a high tension line.

All power in the district can be hooked together if necessary.

LABOR

The underground forces of the Phelps Dodge Corporation, of the Calumet and Arizona Mining Company, and of the Bisbee Queen Development Company are preponderantly American. Those of the other operating companies and of all lessees are preponderantly Mexican.

The common labor in the steam shovel pit and most of the surface labor is Mexican. Steam shovel runners and locomotive engineers are American.

In the mines of the Phelps Dodge Corporation most work is done on individual bonus basis. An elaborate system has been worked out based on standards for a number of variants such as hardness of ground, ventilation and temperature conditions, etc. Some work is done on gang-bonus basis.

In the Calumet and Arizona mines, a considerable amount of development work is done on an elastic bonus system with no set standards.

In the other properties and in lessee’s openings work is generally done on day’s pay.

The Phelps Dodge Corporation employees have established an organization based on our federal institutions, with a lower house made up of representatives of the rank and file, an upper house or senate made up of representatives of the shift bosses, an executive branch headed by the manager, and a supreme court appointed by the manager from local business and professional men, the appointments subject to the approval of the senate. The two houses meet regularly once a month, and elections are held each year by secret ballot. The organization has been described in the following article:


Both the Calumet and Arizona and Phelps Dodge Corporation help to maintain benefit associations, subscribed to voluntarily by their employees. Sick benefits and death benefits sustained off duty are paid.

The Phelps Dodge Corporation has instituted a regular pension scheme. Men are retired on pension after 22 years service, the pension varying with the age and years of service of the applicant and pay received. Employees may or may not be pensioned at the end of the 22 years at the option of the employee.

The average number of men employed in the mines of the district is as follows:
<table>
<thead>
<tr>
<th>Company</th>
<th>Kind of Work</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phelps Dodge Corporation—C. Q. Branch</td>
<td>Underground</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>Steam Shovel</td>
<td>209</td>
</tr>
<tr>
<td></td>
<td>Copper Concentrator</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>Surface</td>
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</tr>
<tr>
<td></td>
<td>Lessees and men</td>
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</tr>
<tr>
<td>Calumet &amp; Arizona Mining Co.</td>
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</tr>
<tr>
<td></td>
<td>Surface</td>
<td>187</td>
</tr>
<tr>
<td></td>
<td>Office</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Lessees and Men</td>
<td>15</td>
</tr>
<tr>
<td>Wolverine &amp; Arizona</td>
<td>Underground</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Office</td>
<td>15</td>
</tr>
<tr>
<td>Shattuck-Denn Mining Corporation</td>
<td>Underground</td>
<td>207</td>
</tr>
<tr>
<td></td>
<td>Office</td>
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</tr>
<tr>
<td></td>
<td>Surface</td>
<td>81</td>
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<tr>
<td>Night Hawk Leasing Company</td>
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<tr>
<td></td>
<td>Surface</td>
<td></td>
</tr>
<tr>
<td>Bisbee Queen Development Company</td>
<td>Underground</td>
<td>40-45</td>
</tr>
<tr>
<td></td>
<td>Surface</td>
<td></td>
</tr>
</tbody>
</table>

PERSONNEL OF OPERATING COMPANIES

**Phelps Dodge Corporation**

General Manager: P. G. Beckett — Douglas
Purchasing Agent: J. L. Hastings — Douglas
Consulting Mining Engineer: Gerald Sherman — Douglas
Consulting Metallurgist: H. H. Stout — New York
Consulting Concen. Engineer: W. B. Cramer — Warren
Chief Engineer: H. H. Pratt — Douglas
Auditor: Geo. R. Drysdale — Douglas

**Copper Queen Branch**

Manager: J. P. Hodgson — Bisbee
General Superintendent: D. D. Irwin — Bisbee
Mine Department:
Superintendent.............................. F. H. Hayes.............................. Bisbee
General Mine Foreman.............................. J. W. Scott.............................. Bisbee
Chief Engineer..................................... G. C. Pidgeon.............................. Bisbee
Chief Geologist..................................... Carl Trischka.............................. Bisbee
Sacramento Hill:
Superintendent..................................... S. G. Plummer.............................. Bisbee
Chief Engineer..................................... H. M. Ziesemer.............................. Bisbee
Mechanical Department:
Master Mechanic..................................... A. C. Reifsnider.............................. Bisbee
Chief Electrician..................................... H. J. Clemmer.............................. Bisbee
Concentrator Department:
Superintendent..................................... Ernest Wittenau.............................. Bisbee
Metallurgical Department:
Chief Metallurgist..................................... C. H. Compton.............................. Bisbee
Clerical Department:
Chief Clerk......................................... L. T. Buell.............................. Bisbee
Manager Supply Dept..................................... F. S. Davenport.............................. Bisbee
Labor Department:
Manager............................................... H. C. Henrie.............................. Bisbee
Reduction Plant:
Smelter Superintendent.............................. J. O. Ambler.............................. Douglas
Asst. Superintendent............................... Curtis Pigott.............................. Douglas
Ore Buyer.............................................. H. J. Bishop.............................. Douglas
Head of Investigation Dept............................. J. M. Samuel.............................. Douglas

CALUMET AND ARIZONA MINING COMPANY
General Manager.................................... H. A. Clark.............................. Warren
Assistant Manager.................................. E. E. Whiteley.............................. Warren
Mine Superintendent.............................. D. M. Rait.............................. Warren
Chief Engineer...................................... H. M. Lavender.............................. Warren
Chief Master Mechanic.............................. E. F. Irving.............................. Warren
Purchasing Agent..................................... George Jay.............................. Warren
Chief Clerk........................................... Arthur Engelder.............................. Warren
Smelter Superintendent.............................. George Dawe.............................. Douglas
Superintendent Acid Works............................. M. E. Jacks.............................. Douglas
Metallurgist......................................... Carl Cole.............................. Douglas

SHATTUCK-DENN MINING CORPORATION
Manager.............................................. T. McGrath.............................. Bisbee
Mine Superintendent.............................. Joseph Walker.............................. Bisbee
Chief Clerk........................................... R. H. Cochran, Jr.............................. Bisbee
LOCATION AND GENERAL GEOLOGY

This district is situated in the central part of the State in the Globe Hills and Pinal Mountains, between the valleys of the Salt and Gila rivers. It is connected to the main line of the Southern Pacific Railroad by a branch line from Bowie.

The hills are carved from a basement of pre-Cambrian schist and granite, overlain by a sedimentary series, the lower members of which are predominantly quartzites and shales and the upper members limestones. This series of formations was first intruded by large dikes and sills of diabase, and later extensively faulted, and intruded by monzonites and granites, after which occurred a long period of erosion. Following this erosion period was a period of volcanism during which thick flows of dacite were poured out. The extrusions were followed by the deposition, during late Tertiary or early Quaternary, of thick, poorly consolidated conglomerates. Further faulting, uplift, and erosion to the present time have resulted in an intricate patchwork of faulted blocks in which formations of all ages are exposed.

The ore occurrences are of two general types: replacement veins cutting the sediments and schist; and disseminated copper deposits in the schist and intruding granites. The predominant metal of both types is copper. The ore of the vein deposits occurs as pyrite, chalcopyrite, and bornite, when primary, pyrite and chalcocite when enriched, and carbonates and oxides of copper, when oxidized, in a gangue of silica, sericite and specularite. The grade is high as compared to the grade of the disseminated ore. Part of the ore is smelted direct and part is concentrated. The ore varies in tenor and gangue depending on the walls. The lower limits have not yet been reached.

The ore of the disseminated type occurs as large tabular bodies of enriched ore in metallized schist and granite. The primary material consists of veinlets of cupriferous pyrite of too low a grade to consti-
tute ore. The ore itself owes its value to the process of secondary enrichment, whereby the copper in the original primary material has been dissolved and reprecipitated on the pyrite below. The grade of the ore varies from 0.7 percent to 5 percent copper. Most of the better grade material has been exhausted, and the ore now being mined averages about 1 percent copper. The ore bodies of this type are very large, running into millions of tons.

To the west of Miami there occurs a series of veins cutting diabase and schist in which the ore minerals are galena and zinc blende. These veins are now being developed.

MINING PROPERTIES

There are five producing mines in the district: The Old Dominion Company, the Arizona Commercial Mining Company, the Iron Cap Copper Company, the Inspiration Consolidated Copper Company, and the Miami Copper Company. Two companies are developing: The Pinto Valley Company and the Black Bess Mining Company.

MINING METHODS

In the vein deposits of the Old Dominion, and Arizona Commercial, the mining methods vary with the conditions met. Where the ore is soft, in the more oxidized portions of the veins, the following methods are used:

- Rill stoping and fill.
- Overhand square-setting and fill (for irregular lenses).
- Top slicing, inclined and horizontal.

In the deeper portions of the veins, where the values are largely primary and the walls hard quartzite and diabase, the principal mining methods in use are:

- Incline cut and fill.
- Shrinkage stoping.
- Morenci Block Caving by inclined slides.

The disseminated ore bodies are mined by block caving methods. At the Inspiration Mines, an adaptation of the Ohio Copper Company method is used. After considerable experimenting the following system described by Felix McDonald and J. L. Johnson has been found best adapted to the requirements. Haulage level drifts are spaced 100 feet apart. The undercutting horizon is about 65 feet above the haulage level, varying with local conditions. Raises from the haulage level

\[^{1}\text{McDonald, Felix, and Johnson, J. L., History of the Development of the Undercut Caving Method of Mining. The American Mining Congress, Globe-Miami Meeting of the Arizona Chapter, pp. 5-8, 1927.}\]
are spaced 25 feet apart and are run at a 54° inclination in planes at right angles to the haulage drifts, off a pony set above the regular drift set. The grizzly level is driven 30 feet above the back of the haulage drifts, the grizzly drifts being 50 feet apart, and grizzlies on 25 by 50-foot centers. From each grizzly, the raises are continued to a point about 15 feet below the undercut level. Here framed square-sets are put in, and four finger raises at angles of 60° to the square-sets driven to the undercut level, insuring better spacing of the finger raises. The entire height of the ore body is mined in one operation. The caving and drawing is operated to keep the waste angle between 30° and 60° from the horizontal. The ore body is mined in large regular sized blocks across the ore body, one or two sides of the block being in contact with the waste from old stopes. To insure regularity in caving, slice drifts are driven off raises at the boundaries of the block to be caved, and slice drifts driven on the boundaries, spaced at 30-foot vertical intervals, on three sides of the block to a point 60 feet from the back, and from these drifts small shrinkage stopes carried up to within 30 feet of the back. Leaving the last 30 feet is found to insure the center of the block caving first, and prevents arching and settling of large blocks without the necessary crushing.

At the Miami Mine, the system used has been described by McDermid. Haulage level drifts are spaced 150 feet apart. Inclined transfer raises are driven to a height of 30 feet below the undercutting level in planes at right angles to the haulage drifts, at 50-foot intervals, and grizzly drifts driven at the tops of the raises, at right angles to the haulage drifts. Inclined wing raises are driven from the main transfer raises, so spaced that the tops at the grizzly levels are 25 feet apart. Grizzlies are put in at each of these raises. From each grizzly, two raises are driven at right angles to the grizzly drifts, 14 feet at a 44° incline and 9 feet vertical. Framed square-sets are put in at the top of the vertical part of the raises and from these, four inclined finger raises driven to the undercut level, the tops being at regular 12½-foot centers. The square-sets are placed at a 45° angle with the grizzly drifts. Much skill is required correctly to set and block these sets. The tops of the finger raises are connected with longitudinal drifts parallel with the grizzly drifts. A very careful sequence of operations is carried on for each stope or block.

The ore body is laid out in regular blocks 300 feet long and 150 feet wide, with a 15-foot pillar between blocks. The size of blocks is fixed.

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by the maximum size for soft ground and the minimum necessary to insure caving in hard ground. Each block is caved vertically, and the sequence in caving blocks so arranged that an interval of at least a year is allowed for a block to settle completely before the adjacent block is caved. To insure vertical caving, vertical raises are driven at each corner and boundary caving drifts driven 30 feet apart vertically, carried to within 30 feet of the back. The backs of these fringe drifts are blasted and the corner raises enlarged when found necessary. Inspection of the caving is made by observation from adjacent boundary caving drifts at the various levels.

Undercutting is started at one end of the block by enlarging one of the end crosscuts into a chamber 8 feet wide by 22 feet high. This is followed by rooms 8 feet wide and 25 feet long 6 feet high at right angles to the longitudinal drifts, each room connecting with six finger raises. The pillars between rooms are then blasted. The rooms are cut out and the pillars blasted starting at the end of the stope in such a way as to keep the line of caving diagonally across the block. When the far end of the block is reached, a room 8 feet wide and 22 feet high is cut similarly to that at the beginning end.

On the completion of undercutting, drawing is carried on systematically under the supervision of trained engineers, great care being taken to draw as evenly as possible, and to draw vertically above each square-set. Detailed daily reports are made, and the schedule of chutes to be drawn, to keep the drawing even, are sent out each day by the management. To keep the required tonnage coming constantly, three blocks are worked simultaneously. To insure this condition a very careful development schedule is held to, and crews trained for each type of work. All work is done on contract.

The total costs for three completed blocks is given below.

<table>
<thead>
<tr>
<th>Total tonnage produced</th>
<th>3,450,260</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per ton</td>
<td></td>
</tr>
<tr>
<td>Haulage level drifts</td>
<td>$ 0.0099</td>
</tr>
<tr>
<td>Haulage level tracks</td>
<td>0.0010</td>
</tr>
<tr>
<td>Haulage level trolley and bonds</td>
<td>0.0004</td>
</tr>
<tr>
<td>Haulage level loading chutes</td>
<td>0.0018</td>
</tr>
<tr>
<td>Transfer raises</td>
<td>0.0173</td>
</tr>
<tr>
<td>Grizzly level drifts and grizzles</td>
<td>0.0121</td>
</tr>
<tr>
<td>Grizzly raises to square-sets and square-sets</td>
<td>0.0282</td>
</tr>
<tr>
<td>Total Development</td>
<td>0.0707</td>
</tr>
</tbody>
</table>
Finger raises to undercutting level ........................................ 0.0111
Undercutting level drifts .................................................. 0.0062
Sub-level boundary caving drifts ....................................... 0.0369
Undercutting on undercutting level ................................... 0.0137

Total stoping ..................................................................... 0.0679
Drawing ............................................................................ 0.0477
Maintenance of square-sets, grizzly level and raises ............ 0.0214

Total drawing ..................................................................... 0.0691
Total cost of ore delivered to haulage level ......................... 0.2077
Electric haulage ................................................................. 0.0587
Hoisting ........................................................................... 0.0375
Pumping ........................................................................... 0.0020
Ventilation and sanitation .................................................. 0.0190
Lighting ............................................................................ 0.0028
General underground expense ............................................ 0.0124
Engineering and sampling .................................................. 0.0135
Mine surface ...................................................................... 0.0226
Mine accident ..................................................................... 0.0097  0.1782

Total mining cost ................................................................ 0.3859

For the three finished blocks, the extraction data were as follows:

Estimated tonnage undercut ............................................ 2,861,995
Tonnage produced ............................................................. 3,450,260
Percentage of estimated tonnage recovered ....................... 120.554 %
Estimated grade of ore undercut ....................................... 1.1142% Cu.
Grade of ore produced ...................................................... 1.0097% Cu.
Percentage grade extraction .............................................. 90.621 %
Percentage copper extraction .......................................... 109.243 %

The total height of ore undercut was about 250 feet. A chart prepared for one of the blocks shows the total cost for different heights undercut. This chart shows a cost starting at 25 feet of $1.56. For 50 feet, $0.96, for 75 feet, $0.73, for 100 feet, $0.62, for 200 feet, $0.42, for 300 feet, $0.35, for 400 feet, $0.32, for 500 feet, $0.31.

Ventilation is effected by forcing air through the grizzly level center drift, and exhausting through the side drifts. Unused transfer raises are used for air ways, and doors in the drifts for air regulation. From 3,000 to 4,000 cubic feet of air per minute is required for each stope.
ORE AND MATERIAL TRANSPORTATION

At the Old Dominion Mine, all ore and material is handled through a central shaft, the five compartment A shaft, equipped with two skips for ore and waste handling, two cages for material and men, and a compartment for pipe lines and ladderway. Ore is dropped in chutes to main haulage levels, and hauled by electric trains to pockets at the shaft for hoisting. Two other shafts are maintained as airways and emergency exits. The mine is developed to a depth of 2,000 feet.

At the Arizona Commercial, the mine is worked from one central shaft, the Copper Hill No. 1, 2,228 feet deep, with the deepest level the 2,200-foot level. All ore, material, and men are handled through the shaft. Connections are maintained for ventilation and safety with the Old Dominion Mine.

The Miami Copper Company ore is hoisted from a four compartment concrete lined shaft, 1,000 feet deep. The ore is hoisted in two 10-ton skips run in counterbalance. One ore haulage level is in use at present and the ore is hauled by two 6-ton electric locomotives run in tandem, in 4-ton side-dump cars, and dumped direct into a 750-ton storage pocket at the shaft. Supplies and men are lowered in a large cage in a separate compartment of the shaft. Timber and supplies enter the mine through a long tunnel connecting the supply yard with the shaft.

At the Inspiration Consolidated Copper Company mines there are two main divisions, the Inspiration and Live Oak. The concentrating ore from the Inspiration and the oxide ore from the Live Oak are hoisted at twin shafts, 107 feet apart, each 692 feet deep. Both shafts are concrete lined. The ore is hoisted in 12-ton skips running in counterbalance, by automatically controlled electric hoists, the skips dumping into a 2,000-ton ore bin at each shaft. From the coarse ore bins the ore is transferred by apron feeders to 3-inch grizzlies, at the head of the coarse crushing plant of four units, each unit consisting of a No. 8 gyratory crusher followed by 48-inch disc crushers, making a product passing a 1½-inch ring. This is transferred by 36-inch inclined belts to horizontal distributing belts equipped with trippers at the top of a 25,000-ton storage bin. An automatic weighing machine is situated on the incline belt, and an automatic sampler at the horizontal belts.

Ore from the Main Live Oak shaft, 7,000 feet distant, is hauled by the company's railroad to a supplementary coarse ore bin, and is crushed in the coarse crushing plant, and transferred to the 25,000-ton bin with the ore hoisted at the Inspiration shafts. Oxide ore from Live Oak and Keystone is handled separately from a special underground pocket
and is crushed and transferred to a special 10,000-ton bin to the south of the concentrating ore bin.

The Main Live Oak shaft, 1,400 feet deep, 7,000 feet west of the Inspiration shafts, serves the Live Oak ore body. This shaft is equipped with two skip compartments, a large cage compartment and a counterweight pipe and ladderway compartment. The ore is hoisted in 12-ton skips by an automatically controlled hoist. The skips dump into cylindrical concrete bins at the surface, of 3,500 tons capacity, loading direct into railroad cars for transfer to the crushing plant.

Underground hauling is done in trains of 5-ton cars. The company uses both compressed air and electric locomotives for haulage underground. At the 600 level, Main Inspiration shafts, the trains are dumped by electrically operated rotary tipples, dumping five cars at a time. On the 850 level, Main Inspiration shafts, electric haulage with 5-ton side-dump type cars is in use. These cars are unloaded directly into the shaft pocket obviating the necessity for an air dumper. This type of car is now in use on the 1,200 level at the Main Live Oak shaft where the motive power, however, is supplied by compressed air locomotives. Loading of skips at both the Main Inspiration shafts and the Main Live Oak shaft is automatic.

Men and materials are handled at the Inspiration shafts in a double deck cage in one of the shafts and counterweight in the other. The hoist is an Otis Elevator hoist, controlled by the cage tender. At the Main Live Oak shaft, a large single deck cage is used. This, however, is not of the type used at the Inspiration shaft, it being operated in the usual manner by an operator stationed at the hoist house. The installation at the Inspiration shaft has been described in the following articles:


CONCENTRATORS

The Old Dominion Company operates a concentrator, treating its own and Arizona Commercial Mining Company ore. The Miami Copper
Company and the Inspiration Consolidated Copper Company each operate concentrators to treat their own ore.

*Old Dominion Concentrator.* The ore from the mine is received in a hopper at the shaft, from which it is fed by means of a pan conveyor to an inclined belt conveyor which carries it over a magnetic head pulley, feeding a 7½ Kennedy crusher. Ahead of the crusher is a grizzly, spaced to remove most of the 1-inch material. The crusher reduces the ore to about 3-inch size, which is elevated by an inclined conveyor to a 48-inch Symons Disc crusher. The disc crusher is set to about 3⁄4-inch (minimum opening). The product from the disc crusher, with the undersize from the grizzly ahead of the gyratory is elevated by an inclined belt conveyor and fed to 60 by 24-inch rolls. The roll product is the finished product from the Crusher Plant, and is about 25 percent 3⁄4-inch size.

From the Crusher Plant the ore is elevated by an inclined conveyor, passing over recording scales, to the top of the Sample Mill. Here it is sampled and diverted to either the concentrator bins or the smelting ore bins. The concentrating ore bins consist of two cylindrical, hopper bottom, concrete bins, of 1,200 tons capacity each.

The ore is discharged from the bottom of these bins by disc feeders onto an inclined conveyor, which elevates it to the head of the mill. Here the feed is divided, a portion being diverted to the New Unit bins, and balance going through the Old Unit.

The ore is drawn from the New Unit bin by pan conveyors, feeding onto a horizontal belt, weighed by a recording weightometer, and fed to a 6 by 12-foot Marcy rod mill. This mill operates in closed circuit with an Akins Spiral classifier (60-inch diameter), 23⁄4-inch rods are used as the grinding medium. The classifier overflows at about 20 percent solids, giving a product of about 12 percent 65 mesh.

The classifier overflow is sent to two Forrester flotation cells, each 10 feet long. These cells make a finished concentrate and a rough tailing. The tailing is treated in two 17-foot Forrester rougher cells which make a final tailing and a rough concentrate. The rough concentrate is returned to the original flotation feed and retreated in the primary cells. The New Unit has a capacity of approximately 300 tons per 24 hours.

The ore to the Old Unit is fed to a battery of Hummer screens. There are four screens in the battery, of which either two or three are operated as necessity arises. The screen oversize is reduced by two sets of 42 by 14-inch rolls. The roll product is elevated by elevators.
to the screens, with which the rolls are operated in closed circuit. The screen product is all $\frac{3}{4}$ inch.

The screen undersize is dewatered by means of two Dorr classifiers, the sand being sent to four Hardinge Mills for primary grinding. The overflow from these classifiers is thickened, the thickened portion being used for dilution in the primary mills, and the clear water being used for dilution in the intermediate classifiers following.

The primary mill product discharges into two Dorr classifiers. The overflow from these classifiers goes to the flotation feed pump. The sand is reground in two Hardinge mills, each operating in closed circuit with a Dorr classifier.

The overflow from the regrind classifiers goes to the flotation feed pump and is pumped to the primary flotation machines, three 15-foot and one 19-foot Forrester cells. These cells make a finished concentrate and rough tailing. The tailing is treated in four 17-foot Forrester roughing cells. The roughing cells make a final tailing and a rough concentrate, the latter being treated in a 10-foot Forrester cleaner cell, the cleaner tailing being returned to the rough cells.

The concentrate is pumped to an Akins classifier which discharges the heavier portion into concrete bins, the overflow from this classifier goes to three 40-foot Dorr thickeners. The thickened product is dewatered by means of a 14 by 14-foot Oliver filter, which discharges the filter cake directly into cars for shipment to the smelter. The heavier portion in the bins is dewatered by means of a rotary vacuum pump, the water being drawn through the filter bottoms of the bins. These bins are unloaded by a Blaisdell Excavator.

The reagents used for flotation are reconstructed coal tar, pine oil, sodium xanthate, and lime.

The lime is added dry to the ore before it enters the mill. The oils are added to the regrind mills in the Old Unit and to the Marcy mill in the New Unit. The xanthate is added to the classifier overflow (flotation feed) in both units.

The capacity of the Old Unit is about 1,200 tons per 24 hours.

The description of this mill was furnished the Bureau by the Old Dominion Company.

*Miami Mill.* This concentrator with a rated capacity of 12,000 tons is composed of three parts: the coarse crushing plant, the primary mill producing a bulk sulphide concentrate, and retreatment plant for the partial separation of pyrite from chalcocite from the bulk concentrate. The coarse crushing plant consists of Maclellan cantilever grizzlies, the oversize going to two No. 7½ Telsmith gyratory
crushers and one 14-inch Newhouse gyratory. The Newhouse gyratory is direct connected with a 500 r.p.m. motor, and is suspended on cables. The gyratory product is further crushed in 72-inch Allis-Chalmers and 78-inch Traylor rolls. The finished products passing .263-inch standard screens, is conveyed by belt conveyors to the sampling works and thence to steel mill storage bins. The primary mill is built in six units. The ore is first crushed in 8'x36" Hardinge mills run in closed circuit with Dorr duplex classifiers, then to a second set of Hardinge mills and classifiers, the final product ground to 9 percent on 48 mesh, going to modified Callow rougher cells, the rougher concentrates to cleaning cells, and the rougher tails pumped by Wilfley sand pumps to the tailings pond.

The concentrate from the cleaning cells is transferred by Wilfley pumps to the retreatment plant. In the retreatment plant, the concentrate first passes through a 6'4" Dorr duplex classifier, the sands to 6 by 12-foot ball mills for regrinding, run in closed circuit with a 15-foot bowl classifier, the overflow from the Dorr and bowl classifiers going to three pneumatic flotation machines followed by two 14-cell 24-inch Minerals Separation subaeration machines. Lime emulsion produced by grinding lime in a Hardinge mill is added to the sands from the Dorr classifier. The final concentrates from the pneumatic cells go to the filter plant, the tails to two Mineral Separation machines. The concentrate from these is returned to the pneumatic cells and the tails are pumped back to two sections of the primary mill rougher cells. The filter plant consists of three 12 by 12-foot filters, of which one only is in constant service. The final concentrate is subjected to a preliminary thickening in two Dorr thickening tanks. The ratio of concentration is about 60 to 1. The extraction is about 77 percent. About 1.50 pounds of CaO to the ton of water is added in the retreatment plant. Xanthate is used both in the primary mill and in the retreatment mill. Retreatment increases the concentrate from 20 percent to 40 percent copper, and reduces the iron from 25 percent to 20 percent and the insoluble from 20 percent to 6.7 percent.

The concentrates from the primary mill are ground in the retreatment plant to 96 percent minus 200 mesh. A description of the retreatment plant is given in the following article:


Inspiration Mill. The Inspiration concentrator is composed of 20 units of 900 tons each, a total rated capacity of 18,000 tons, and a filter plant for the combined concentrate from all units. The crushed mine product is transported from the storage bins in trains of 14 cars
each and the ore dumped into suspension type concentrator bins of 17,000 tons total capacity extending the length of the mill. The ore is drawn from the bins through gates onto apron feeders, one for each mill section, delivering to inclined belt conveyors, feeding two 8'x72" Marcy ball mills per section, in closed circuit with a 6'x27" Dorr duplex classifier, crushed to 3½ percent on 48 mesh, and 74 percent minus 100 mesh. In each unit the overflow from the classifier goes to two 8-cell Inspiration type rougher flotation machines, the concentrates going to two 3-cell cleaner machines of the same type, the tailings being returned to the roughers. The rougher tails pass to a Burch drag classifier, the slimes going to a Dorr thickener for dewatering and the thickened discharge to the tailings dump. The sands from the classifier pass to a Diester cone-baffle classifier which distributes the material to eleven Simplex double-deck concentrating tables, making a low grade concentrate, the tails after dewatering going to the tailings pile.

The combined concentrates from all units of the mill are mixed and pass through Spigot classifiers, the heavy coarse material passing directly to an Oliver filter 11'6"x12', and the slimes going to two 60-foot Dorr thickeners, the discharge going to the Oliver filter. The Oliver filter produces a product running between 36 percent and 40 percent copper and 7½ percent water. The concentrates are loaded in specially designed McGregor 60-ton railroad cars with hopper bottoms, for shipment to the International Smelter. The ratio of concentration is about 40 to 1. The overall extraction is about 80 percent.

A description of the original plant which has since been slightly remodeled is given in the following articles:


LEACHING PLANT

To treat a large tonnage of oxidized and semi-oxidized ore at the Keystone, Live Oak, and Warrior mines of the Inspiration Consolidated Copper Company, that company completed the installation of a 7,500-ton leaching plant during the fall of 1926. The ore treated consists of a product in which the copper is one-third in the form of sulphide (chalcocite) and two-thirds in the form of oxides, carbonates, and silicates. To put it in solution requires not only sulphuric acid but ferric sulphate. Higher current densities are therefore necessary than for the Ajo plant and stronger acid is used, 5-percent as against 3-percent at Ajo. The ferrous iron is not reduced in \( \text{SO}_2 \)
towers as at Ajo. Another feature differing from Ajo practice is a
different bedding procedure in the ore tanks, a more uniform bedding
being found necessary. The installation is composed of 13 concrete
lead-lined leaching tanks, ten solution tanks, a cement copper plant,
tank house of eight sections of 15 tanks each, each tank containing 84
anodes and 85 cathodes. Fourteen tanks are used for making start-
ing sheets, made by using copper anodes cast at the International
smelter, the solution for these tanks being on a separate independent
circuit. Current density is about 15 amperes per square foot. Am-
pere efficiency is about 68 percent. About 1.65 kw.h. is required per
pound of copper produced.

After 8 days leach the charge is washed with five progressively
weak wash waters, and is finally put into closed circuit with the iron
precipitation launders and finally washed with fresh water to wash
out iron and is unloaded with a William Seaver Morgan 15-ton clam
shell bucket unloader.

The ore from the mine after coarse crushing is transferred to
separate bins, and from these fed to a fine crushing plant consisting
of four sets of 78 by 24-inch Traylor rolls, one being a spare, in closed
circuit with Hummer Electric Screens, making a final product passing
3/8-inch ring. The crushed ore passes over a weightometer, through
a sampling plant, and is conveyed by belt conveyor to a distributing
belt over the tanks.

Extraction is about 85 percent and operating cost per ton about 30
cents.

This plant has been described in the following article:

Aldrich, H. W., The Inspiration Leaching Plant. Arizona Chap. American Min-
ing Congress, Oct. 1927.

SMELTER

The concentrates and ores of the district are smelted at the plant of
the International Smelting Company situated about 1 mile east of
Miami, connected to the Southern Pacific Railroad at Miami by the
Inspiration Consolidated Mining Company branch railroad, also con-
necting the smelter with the Inspiration mill, leaching plant, and mines.

This smelter is designed to treat rich, fine concentrates and unusual
precautions against dust losses and losses in transporting the material
are employed.

The concentrates from the three producing properties are trans-
ported in specially designed McGregor cars each holding 60 tons, with
hopper bottoms and openings in the bottom, sealed with wedged planks.
Sampling is done by auger, and unloading by pulling a wooden plug
out of the bottom at one end of the car, and barring the concentrates through this hole into a conveyor with specially designed trippers which distributes it evenly into a Berquist steel bunker type bin of 9,000 tons capacity, with bottom similar to the railroad cars. Unloading is done in a steel unloading shed. The necessary fluxes and crude ore are bedded in the same bin. The bins are unloaded onto belts at the bottom, conveying the mix to 6-hearth wedge roasters of which there are ten. A Cottrell plant is mounted above the roasters. The calcines are transported to two 21 by 120-foot reverberatory furnaces, in enclosed cars with receiving chute of special design at the top. On emptying the cars, receiving chutes are raised against the doors. There are three reverberatories, one not in use. They are oil fired and waste heat is utilized for making steam used in the central power plant.

There are five converter stands, four Great Falls type and one Pierce-Smith horizontal. Copper is cast in regular forms for shipment and part in the form of anodes which are for use in the Inspiration leaching plant. A Cottrell plant treats the reverberatory gases. Custom ores and flux are stored in separate bins, and crushed to 3/4 inch in an 18 by 30-inch Blake crusher followed by 54 by 16-inch rolls, and elevated to the sampling plant. The smelter has been described in the following articles:


POWER PLANTS

Power for the Old Dominion plant is generated by two Nordberg 2-cycle full Diesel engines of 1,250 h.p., direct connected with generators, and a steam plant of 2,500 h.p. oil-fired boilers. The Arizona Commercial is equipped with an oil-fired steam plant running two 600 kw. turbo generators.

Electric power for the plants of the Inspiration Consolidated Copper Company and the International Smelter is generated at a central power plant by four turbo generators aggregating 39,500 h.p., and four cross compound 15,000-cubic feet blowing engines. All equipment at the mines, mill, and leaching plant is electrically run. Power is also bought from the Salt River Valley Water Users' Association from their Roosevelt Dam and Horse Mesa Power plants.

At the Miami Copper Company power is generated by oil-fed boilers, running two 4,000-kw. turbo generators. Auxiliary plant held as reserve consists of numerous Corliss engines, not in use. Some power is also bought from the Salt River Valley Water Users' Association.

All electric power lines are inter-connected in the district.
PUMPING AND WATER SUPPLY

In the district, the Old Dominion is the only mine with a serious underground water problem. The mine workings extend under Pinal Creek, and are covered by porous dacite tuffs and flows. This dacite acts like a sponge for surface waters and makes a continuous large flow of water underground. To handle this water and occasional abnormal flood waters, the following equipment is installed:

On the 1,200-foot level, the main gathering sump for the mine, are one Prescott 1,000-gallon per minute steam pump, four Nordberg 1,500-gallon steam pumps, one Aldrich electric 1,000 g.p.m. pump, and one Kingsford 1,500-gallon electric pump, the last used for emergencies.

On the 2,250-foot level are two Aldrich 1,000-g.p.m. electric pumps, pumping to the 1,200-foot level sump, and one B.J., 1,000-g.p.m. emergency pump also pumping to the 1,200-foot level. Besides these there is a B.J. 1,000-g.p.m. single-stage electric sinking pump, of special design. The mine makes between 4,000,000 and 5,000,000 gallons per day, and the combined pump capacity is 21,000,000 gallons.

To reduce the flow of water, churn drill holes have been drilled above the old stopes on the west side and the cracked and caved ground is being grouted with mill tailings.

The water supply for the International Smelter and the Inspiration Consolidated Copper Company is obtained from six wells sunk in the valley 2½ miles from the mill and 430 feet lower in elevation. Each well is equipped with multiple stage electrically run turbine well pumps delivering to a steel sump tank of 230,000 gallons capacity. From the tank the water is pumped by electrically driven horizontal duplex pumps through a 20-inch pipe line 14,600 feet long, to a 3,000,000 gallon storage reservoir 80 feet above the concentrator, from which it is conveyed by smaller pipe lines to the smelter, mill, leaching plant, and mine.

The water supply for the Miami mill and mine is obtained from wells in the valley, water being pumped into the mill storage reservoir by two Nordberg steam pumps of 1,250-g.p.m. capacity.

LABOR

In the Globe end of the district, the underground force is preponderantly American, whereas in Miami, it is largely Mexican.

In the Old Dominion Mine and Arizona Commercial Mine, underground labor is mostly American, and labor in the shops and power plants almost entirely so. In the Old Dominion Mine, all work of a
standard nature such as development work, stoping, and most shop work is done on contract basis, with day's wages guaranteed. Rates vary with conditions, and in the mines about 45 percent earn bonus. Rates wherever possible are set in advance of work.

In the mines of the Miami Copper Company and the Inspiration Consolidated Copper Company, more than half the labor is Mexican.

In the Miami Mine practically all development work is done on contract with day's wages guaranteed. Ground is uniform and rates have been well standardized for each type of work.

At the Inspiration Mine practically all development work is done on contract. Ground is rather variable and rates are used to compensate for this.

The number of men employed by the operating companies is as follows:

<table>
<thead>
<tr>
<th>Company</th>
<th>Kind of work</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Dominion Mine</td>
<td>Mine</td>
<td>625</td>
</tr>
<tr>
<td></td>
<td>Mill</td>
<td>61</td>
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<tr>
<td></td>
<td>Surface</td>
<td>119</td>
</tr>
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<td></td>
<td>Total</td>
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</tr>
<tr>
<td>Arizona Commercial Mine</td>
<td>Mine</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Surface</td>
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<tr>
<td>Iron Cap</td>
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<td>44</td>
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<td></td>
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<tr>
<td>Miami Copper Company Mine</td>
<td>Mine</td>
<td>633</td>
</tr>
<tr>
<td></td>
<td>Mill</td>
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<td></td>
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<td>Office</td>
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</tr>
<tr>
<td></td>
<td>Total</td>
<td>1161</td>
</tr>
</tbody>
</table>
Company | Kind of Work | Men
--- | --- | ---
Inspiration Consolidated | Mine | 1310
| Mill | 90
| Leaching plant | 205
| Surface | 345
| Office |
Total | 1950

International Smelting Co. | Smelter |
| Office | 238
| Shops |

PERSONNEL OF OPERATING COMPANIES

OLD DOMINION COMPANY

General Manager...........I. H. Barkdoll........Globe
Consulting Mining Engineer........Gerald Sherman........Douglas
Consulting Metallurgist........W. B. Cramer........Warren
Consulting Geologist........Guy N. Bjorge........San Francisco, Cal.
General Purchasing Agent........J. L. Hastings........Douglas
Safety Engineer........A. Tallon........Globe
Chief Clerk........G. R. Legters........Globe
Employment Agent........W. G. Brown........Globe
Chief Electrician........M. F. Murphy........Globe
Mine Superintendent........Harry Leidich........Globe
General Mine Foreman........R. W. Mayne........Globe
Chief Engineer........H. S. Duncan........Globe
Chief Geologist........A. H. Shoemaker........Globe
Mine Master Mechanic........Joe Crothers........Globe
Chief Chemist........O. J. Tuschka........Globe
Mill Superintendent........D. L. Forrester........Globe
Mill Metallurgist........R. S. Allen........Globe
Mechanical Superintendent........Chas. Mendelsohn........Globe
Shop Foreman........F. R. Kennedy........Globe

ARIZONA COMMERCIAL MINING COMPANY

General Superintendent........H. C. Plummer........Globe
Chief Clerk........Guy A. Ligon........Globe
Master Mechanic........W. J. Tanner........Globe
Chief Engineer........F. V. Ashton........Globe
IRON CAP COPPER COMPANY

Manager................................................. F. A. Woodward........Copper Hill
Superintendent...................................... H. W. Woodward........Copper Hill
Chief Clerk.......................................... Leslie Ballard........Copper Hill
Master Mechanic................................. J. L. Farragah........Copper Hill
Chief Electrician................................. G. W. Wood........Copper Hill
Chief Chemist........................................ R. D. Dunlap........Copper Hill
Mill Superintendent.............................. M. S. Pressler........Copper Hill

INSPIRATION CONSOLIDATED COPPER COMPANY

General Manager.................................. T. H. O'Brien........Inspiration
Assistant Manager.................................. C. E. Weed........Inspiration
Consulting Metallurgist......................... G. D. Van Arsdale.....Los Angeles
Mechanical Engineer.............................. Geo. H. Booth........Inspiration
Assistant-Purchasing Agt........................ H. H. Hoyt........Inspiration
Auditor............................................. W. J. Eustace........Inspiration
Employment Agent................................ H. W. Montague.........Inspiration
Master Mechanic................................... F. C. Howe........Inspiration
Chief Electrician................................. A. N. Voss........Inspiration

Mine Department

Superintendent................................. Felix McDonald.........Inspiration
Asst. Superintendent........................... Jos. L. Johnson........Inspiration
Chief Engineer..................................... A. C. Stoddard.......Inspiration

Mill Department

Superintendent................................. G. H. Ruggles.........Inspiration
General Foreman................................. S. E. McNeil.........Inspiration

Leaching Department

Superintendent................................. H. W. Aldrich.........Inspiration
General Foreman................................. W. G. Scott..........Inspiration

Power Plant

Chief Engineer.................................... W. T. W. Plaisted.....Inspiration

Railroad Department

Superintendent................................. C. L. Woodcock........Inspiration

MIAMI COPPER COMPANY

General Manager.................................. F. W. Macleman........Miami
Chief Clerk......................................... Harry Bible............Miami
Purchasing Agent............................... W. F. Williams........Miami
Mechanical Superintendent.................... F. L. Bishop.........Miami
RAY-HAYDEN DISTRICT
LOCATION AND GENERAL GEOLOGY

This district is situated in the central part of the State in the valleys of the Gila River and Mineral Creek, a short tributary to the north. It lies to the southwest of the Dripping Spring Mountains. The district is served by the Arizona Eastern Branch of the Southern Pacific Railroad and the Ray and Gila Valley Railroad, a branch line connecting the Ray Consolidated mines with the main line at Kelvin. The principal mines are located in the Mineral Creek Valley, about 5 miles north of the Gila River at Kelvin. The ores are concentrated and smelted at Hayden, 20 miles southeast of Ray, situated on the Gila River. The town of Winkelman also on the Gila River is about a mile east of Hayden. The mining camp of Christmas, although not strictly in the Ray-Hayden District, will be so considered here. It is on the southeast end of the Dripping Spring Range, about 6 miles from Winkelman.
The geological features in the district are similar to those at Globe and Miami. The geological history is identical and the formations the same as there. There are two types of deposits in the district, disseminated chalcocite ore bodies replacing schist, similar to the ores at Miami, and contact metamorphic ore bodies replacing Carboniferous limestone, the ores being oxides and sulphides of copper. The geology of the district has been described in the following paper:

MINING PROPERTIES

There are two active mining properties in the district, the Ray Consolidated Copper Company, a subsidiary of the Nevada Consolidated Copper Company, and the Christmas Copper Company, a subsidiary of the Iron Cap Copper Company. The copper ores of the district are smelted at the Hayden Works of the American Smelting and Refining Company.

MINING METHODS

At the Ray Consolidated mines, the ores are mined by three methods of block-caving. The ore tends to break in large slabs, and the following methods are adapted to this feature:
1. Ray shrinkage stope and pillar method (used for hard ore).
2. Ray block caving method (used for soft ore).

The first two methods have been described in the literature. The third method now being tried is as follows:

The ore body to be mined is laid out in blocks 150 feet wide by 200 feet long. Haulage drifts are run the length of the block on 37½-foot centers, four drifts for each block. The stope or drawing off level is established at a level 25 to 40 feet above the haulage level, depending on the lower contour of the ore body. Two manways are driven at each corner of the retreating end of the block and a fringe drift connecting these on the slope level. Crosscuts spaced at 25-foot centers are then driven the full length of the block from the fringe drift. Raises are driven at 25-foot centers from either side of these crosscuts, and staggered at each adjacent crosscut, giving a distance of 12½ feet between raises. Small chutes are then driven from the haulage level to each of the stope raises. The raises are driven 16 feet in height, opposite raises connected, and pillars blasted. The block is then ready for drawing. This method does away with the griz-
zly level and with square-sets in finger raises, of the Inspiration and Mi-
ami methods. Development and maintenance costs are a little heavier,
but this is offset by the frequent delays which would be necessitated at
Ray from blasting boulders and slabs.

In all the methods used at the Ray mines, it is necessary to have the
main haulage level as close to the stoping level as possible. For this
reason, the haulage level drifts are subjected to heavy weight, and the
maintenance charges are large. To reduce this high charge, the levels
are now being supported by reinforced concrete. The placing of the
concrete is done pneumatically.

At the Christmas Mine of the Christmas Copper Company, the ore
bodies are of direct shipping grade, and the methods used are:
1. Overhead square-set and fill (for soft ore).
2. Inclined cut and fill (for hard ore). At this mine, the ore
bodies are irregular replacements of Carboniferous limestone.

The mining methods have been described in the following articles:
Blackner, Lester A., Underground Mining Systems of Ray Consolidated Copper
Thomas, Robert W., Mining Methods at the Ray Consolidated Copper Company's
Min. Jour., April, 1926.
Robotham, Cyril A., Pneumatic Placing of Concrete at the Ray Consolidated Cop-
per Company's Mines. Arizona Chap. American Mining Congress, Mar. 1926,
or Ariz. Min. Jour., April, 1926.

ORE AND MATERIAL TRANSPORTATION

At the Ray mines, the ore body is composed of two parts connected by
a narrow neck of ore. In laying out developments, this fact was taken
advantage of, and the ore body divided into the No. 1 mine at the east
end and the No. 2 mine at the west end, each mine being operated as
a separate unit from a separate shaft. At present, the greater bulk of
the ore is being hoisted from the No. 2 shaft.

Ore hauling underground is done by Porter Air Locomotives. The
ore is loaded into 5-ton closed body type cars, and trains are made up
of 5 cars. The cars are hauled to the stations and are dumped 3 cars
at a time from a tipple into ore pockets.

Hoisting is done at each shaft in 10-ton skips. The hoists are
electrically driven. Material and men are lowered at a separate cen-
tral shaft in a large Otis elevator. Men also enter and leave the mines
by way of incline stairways at each of the main shafts.

The ore after hoisting is screened, and the coarse material crushed
by McCullough gyratories and 72-inch Garfield Rolls to 7/8-inch ring.
There are separate crushing plants at each shaft. The ore is then
loaded into trains and sent to the concentrator bins at Hayden.
The ore at the Christmas Copper Company Mine at Christmas is hoisted and sent to the bins at the railroad, over a half mile aerial rope tramway. The mine is operated through an 850-foot shaft. All equipment is electrically driven. The ore is shipped to the smelter at Hayden for treatment.

CONCENTRATOR

The concentrator treating the ores from the Ray mines is situated at Hayden, about 20 miles from the mines. It consists of eight units of 1,500 tons capacity each, and treats 10,500 tons daily. The operations are as follows:

First—Crushed mine product stored in bins of 10,000 tons capacity.
Second—Fine crushing in a roll circuit from \( \frac{3}{8} \)-inch to minus 10 mesh.
Third—Wet Gravity concentration on Plat 0 Tables producing a finished concentrate.
Fourth—Fine grinding of table tailings in tube mill circuit to 10 percent on 100 mesh.
Fifth—Flotation concentration of tube mill circuit product, producing a finished concentrate and a reject tailing.
Sixth—Drying of table concentrates in settling bins, and of flotation concentrates by filters.

The ratio of concentration is about 12 to 1. Extraction is about 88 percent, with 96 percent sulphide and 37 percent oxide extraction.

For further details see the following article:

REDUCTION PLANT

The ores of the district, together with customs ores from other places, are smelted at the Hayden Plant of the American Smelting and Refining Company. This plant is equipped with complete mechanical sampling works. Its capacity is about 3,000 tons a day. It is equipped with McDougal and Call-Wagstaff roasters, reverberatory furnaces, Cottrell apparatus for recovery of dust in the gases, and Pierce Smith and Great Falls type converters. The converter slag is poured hot into the reverberatory furnaces. About 250 men are employed.

PUMPING

The mines at Ray are kept free of water by drainage tunnels. Pumping for domestic uses and for the plants at Hayden is done from ten shallow wells about a mile north of the intersection of the Gila and San Pedro rivers. The water is lifted by air lift installations,
and conveyed by underground pipe lines to a reservoir. From there it is pumped by three motor-driven 16 by 18-inch vertical quintuplex plunger pumps each with a rated capacity of 3,300 g.p.m. to the mill reservoir for industrial use, and two motor-driven 10 by 12-inch vertical triplex plunger pumps with a combined capacity of 1,400 g.p.m. delivered to a separate reservoir for domestic use. The description of the plant and of the old open wells, now discarded, is given in the following article:


POWER PLANT

The power for the mines and concentrator of the Ray Mines is furnished by four 1,750 kw. generators direct connected with four 2,500 h.p. triple expansion engines driven by steam, using coal as fuel. There is also a 7,500 kw. Parsons turbine direct connected with a 6,600-volt generator. A high tension line connects the power plant at Hayden with the mines at Ray. At the mines all equipment is electrically driven.

LABOR

At the mines at Ray underground labor is all Mexican. Bosses, engineers, and office force are American. At the mill and smelter common labor is Mexican. At the mine as much work as possible is done on contract. No organized welfare work is undertaken.

PERSONNEL OF OPERATING COMPANIES

NEVADA CONSOLIDATED COPPER COMPANY

RAY MINES

General Officers
General Manager.......................... C. A. Smith...................... Hayden
Consulting Geologist........................ R. C. Nowland.............. San Francisco
Consulting Mechanical Engineer.............. E. J. Franklin........... Salt Lake City
General Purchasing Agent.................. A. J. McLean............... San Francisco
Asst. Purchasing Agent.................... G. E. Stephenson.......... Hayden
Safety Engineer........................... C. H. Studley............... Ray
Asst. Safety Engineer..................... R. S. Wilson............... Ray
Cashier.................................. R. I. Ezell...................... Hayden
Accountant.............................. C. A. Hurst..................... Hayden
Electrical Engineer...................... J. D. Sullivan............ Hayden
Mechanical Engineer...................... Nels Johnson ............. Hayden
MINERAL INDUSTRIES OF ARIZONA

Mine Department
Mine Supt. .............................................. Robert W. Thomas .... Ray
Asst. Mine Supt. ...................................... C. A. Kumke .... Ray
Chief Engineer .... .................................... Moses Brown, Jr. .... Ray
Geologist .............................................. P. T. Whitehead .... Ray
Chemist .................................................. W. S. Osborne .... Ray
Chief Clerk ............................................ R. A. Cook .... Ray
Master Mechanic ..................................... T. A. Maslin .... Ray
Chief Electrician ..................................... C. E. Mitchell .... Ray
Employment Agent .................................. N. S. Good .... Ray

Milling Department
Mill Supt. ............................................. W. I. Garms .... Hayden
Asst. Mill Supt. ....................................... F. J. Tuck .... Hayden
Metallurgical Engineer ................................ T. H. Oxnam .... Hayden
Chief Chemist ........................................ C. H. Corbus, Jr. .... Hayden
Research Chemist .................................... G. L. Stevens .... Hayden
Master Mechanic ...................................... Verne Root .... Hayden
Chief Clerk ............................................ B. F. Blackman .... Hayden
Chief Electrician ..................................... C. W. Dutton .... Hayden

Power Plant
Chief Engineer ......................................... Verne Couchman .... Hayden
Asst. Chief Engineer .................................. M. A. Williams .... Hayden

Christmas Copper Company
Manager .................................................. F. A. Woodward .... Globe

American Smelting & Refining Company

Hayden Works

Superintendent ....................................... E. R. Marble .... Hayden
Business Manager .................................... C. C. Kiser .... Hayden

Jerome District

Location and General Geology

The Jerome district is situated in the north-central part of the State, in the Black Hills. The valley of the Verde River forms its northern boundary. The principal mining settlement is Jerome. The ores of the district are smelted at two settlements on the Verde River, Clarkdale and Clemenceau. The district is served by a branch line of the Atchison, Topeka and Santa Fe Railroad, between Cedar Glade and Jerome, and one between Clemenceau and Clarkdale.
The Black Hills are made up of a basement of pre-Cambrian metamorphic rocks, originally volcanic tuffs and flows for the most part, intruded during pre-Cambrian time by granitoid rocks; an overlying sedimentary series consisting of sandstones at the base, and limestones above, the latter of Devonian and Carboniferous ages; and the whole capped by Tertiary basalt flows. The ore bodies of the district occur as replacements in large nearly vertical pipes of the pre-Cambrian metamorphics. The replacement took place before the deposition of the sediments. Extensive erosion, accompanied by oxidation and enrichment of the ore, followed the ore injection. Very little disturbance occurred until after the flow of the basalts. Extensive normal faulting then took place, followed by erosion to the present time.

The ore chimneys consist of generally massive sulphides, pyrite predominating, partly replaced in the primary ore by chalcopyrite, zinc blende, and a little bornite. In the enriched parts of the ore bodies, most of the chalcopyrite, bornite, and zinc blende, and some of the pyrite have been replaced by chalcocite.

The geology of the district has been described in the following publications and articles:


MINING PROPERTIES

There are two producing mining companies in the district, the United Verde Copper Company, and the United Verde Extension Mining Company. One company is developing, the Verde Central Mines, Inc.

MINING METHODS

There are four mining methods used in the district, two for enriched ore and two for primary ore. The high sulphur content of the ore together with its high tenor prevents the use of any cheap method of mining. The methods in use are as follows:

Steam Shovel Open Pit Mining (To mine a part of the enriched zone of the United Verde Mine, which has been on fire for a number of years).

Several adaptations of square setting and fill (for soft enriched ore).

Horizontal and Incline Cut and Fill (for primary ore).
Shrinkage Stopping (for primary well defined ore bodies).

The mining methods have been described in the following articles:


ORE AND MATERIAL TRANSPORTATION

The United Verde Copper Company operates two shafts, one for ore and one for material and men. The No. 5 shaft for ore handling is an internal shaft operated from an electric hoist on the 1,000 or Hopewell Tunnel level and ore above is dropped to the Hopewell Tunnel level through staggered ore passes. Ore from deeper levels is hoisted in 7-ton skips from pockets on the 1,200, 1,800, 2,100, and 2,400-foot levels.

The United Verde Extension Mining Company maintains two shafts, the Audrey, used for ore hoisting and the Edith, used for handling men and supplies. On the 1,300-foot level, a standard gage tunnel 12,485 feet long, the Josephine Tunnel, has its portal 3 miles from the smelter at Clemenceau. Ore above the 1,300-foot level is dropped in chutes to this level. Ore below this level is dropped to the 1,400-foot and 1,600-foot levels, and is then hauled by electric motors to pockets at the Audrey Shaft and hoisted to the 1,300-foot level. The Josephine Tunnel is equipped with 25-ton electric locomotives and 30-ton cars.

The Hopewell Tunnel, 7,000 feet long, has its portal about 6.7 miles from Clarkdale. All ore is taken out through this tunnel and is delivered to the crushing plant at Clarkdale. The crushing plant has been described as follows:

Young, George J., United Verde Completes Model Crushing Plant. E. & M. J., Mar. 8, 1924, p. 396.

Hauling at the motor levels, spaced 150 feet apart is done by electric motors. The level interval below the 1,000-foot level is 150 feet.

Material and men are handled through another shaft, the No. 6, also an internal shaft with its collar at the 500-foot level. Supplies and men enter the mine through the 500-foot level tunnel, 1,600 feet long.
At the portal of this tunnel is the surface plant described in the following article:

**CONCENTRATOR**

To handle low grade "schist" ores, a 1,000-ton concentrator has been completed. This concentrator is situated at Clarkdale. It makes bulk flotation concentrate, a ratio of about 4 into 1 being made and about 94 percent extraction. Tailings are taken through a wood-stave pipe line 9,000 feet long to a launder 1,500 feet long. The pipe line has a gradient of 2 percent and an inverted syphon 60 feet deep where the line crosses the Verde River.

Fine grinding is done in two 8 by 12-foot ball mills crushing from 3 mesh to 100 mesh.

Power is furnished from the reverberatory waste heat plant, and all equipment is electrically run.

Water is pumped from the Verde River a distance of about 3,900 feet, 375 foot head, by 100-h.p. 2-stage electrically driven turbines into a 500,000-gallon storage reservoir.

Details of the plant are described in the following article:

**SMELTERS**

The ores of the district are smelted at two plants, that of the United Verde Copper Company at its smelter at Clarkdale, and that of the United Verde Extension Mining Company at its plant at Clemenceau.

**United Verde Smelter.** It consists of crushing plant, concentrator, calcining plant of twelve 21½-foot Wedge Roasters, each with six hearths, and twelve 22½-foot 7-hearth Wedge Roasters, the combined capacity being 2,700 tons; a Cottrell plant of 800,000 cubic feet per minute capacity; a reverberatory plant consisting of three 19 by 100-foot and three 25 by 100-foot furnaces equipped to burn either powdered coal or oil; a powdered coal plant of 600 tons of coal per day capacity crushing to 200 mesh; a blast furnace plant of four 48 by 320-inch furnaces, not now in use; a converter plant of 8 stands with eight 12-foot shells of Great Falls type, basic lined; and a waste heat power plant of 12 sterling M boilers 713 h.p. each, two to each reverberatory. This plant has been described in the following article:

**United Verde Extension Smelter.** This plant situated at Clemenceau consists of one 48"×26'8" blast furnace; six 21'6", 6-hearth
MINERAL INDUSTRIES OF ARIZONA

Wedge Roasters; two 25 by 120-foot reverberatories, equipped for either coal dust or oil firing; a coal pulverizing plant; a reverberatory waste heat power plant of 3,713-h.p. Stirling boilers and two 439-h.p. Stirling direct-fired boilers; and three 12-foot Great Falls Type converters; and a crushing and sampling plant. This smelter has been described in the following article:


PUMPING

The mines of the district make but little water. Surface water is drained through the Hopewell and Verde Extension Extraction tunnels. Below these levels very little water is made, and is handled by small pump installations.

Water for the plants is pumped from wells in the Verde Rivel Valley.

POWER PLANTS

Power for the United Verde operations is partly generated at the smelter and partly bought from the Arizona Power Company. Power for the United Verde Extension operation is generated at the smelter and transmitted to the mines at Jerome.

DEVELOPMENT

The Verde Central Mines, Inc. are developing ground to the south of the United Verde Copper Company. The work is being done from a vertical shaft and levels at 125, 260, 505, 670, 800, 1,000, 1,150, 1,300, 1,450 and 1,900 feet. A pyritic ore body has been found with high grade oreshoots.

LABOR

In the mines, labor is over half Mexican with the percentage of American labor constantly decreasing. Common labor at the concentrator and reduction plants, and all surface labor is Mexican.

The United Verde Copper Company has placed work in all its departments on an individual and gang-bonus basis. The general scheme of setting standards is simple, and rates for jobs are set in advance. The system is described in the following article:


Work at the United Verde Extension Mining Company is on day's wage, a slightly higher base wage being in effect than at the United
Verde Copper Company. At the Verde Central Mine, a large percentage of work is done on contract basis.

At the United Verde Copper Company works, an industrial course is given, designed to train men for executive positions. Lectures are given by their own employees on a variety of subjects.

The average number of men employed in the district is as follows:

**Mines**
- Underground: 1,230
- Surface: 350
- Office: 85

Total: 1,665

**Smelters and Mill**: 890

Grand Total: 2,555

**PERSONNEL OF OPERATING COMPANY**

**United Verde Copper Company**

*General Officials*
- General Manager: Robt. E. Tally, Jerome
- Chief Clerk: R. K. Duffey, Clarkdale
- Purchasing Agent: Dave Hopkins, Clarkdale
- Chief Surgeon: A. C. Carlson, Jerome

*Mine Department*
- General Mine Supt.: W. V. DeCamp, Jerome
- Mine Superintendent: W. W. Lynch, Jerome
- Gen. Mine Foreman: T. W. Quayle, Jerome
- Chief Engineer: C. E. Mills, Jerome
- Chief Geologist: M. F. Hansen, Jerome
- Chief Chemist: P. T. Allsman, Jerome
- Master Mechanic: Wm. Riddle, Jerome
- Employment Agent: C. L. Guynn, Jerome
- Chief Electrician: F. W. Fredell, Jerome

*Steam Shovel Department*
- Steam Shovel Superintendent: J. C. Perkins, Jerome

*Smelter Department*
- General Superintendent: Thos. Taylor, Clarkdale
- Smelter Superintendent: C. R. Kuzell, Clarkdale
- Chief Engineer: J. E. Lanning, Clarkdale
Chief Electrician...........................................A. I. Greenwood........Clarkdale
Master Mechanic.........................................Geo. Mieyr............Clarkdale
Chief Chemist...........................................A. L. Reese..............Clarkdale
Concentrator Superintendent.........................I. M. Barker.............Clarkdale

United Verde Extension Mining Company

General Officers
General Manager...........................................George Kingdon......Jerome
Assistant Manager.........................................Geo. W. Prince.........Clemenceau
Cons. Mechanical Engineer..............................Geo. M. Douglas.........Clemenceau
Purchasing Agent...........................................H. L. Goldman........Clemenceau
Safety Engineer...........................................Roy H. Marks.........Clemenceau

Mine Department
Mine Superintendent......................................R. L. D'Arcy...........Jerome
Asst. Superintendent.....................................R. D. Leisk.............Jerome
Chief Engineer...........................................Olaf Hondrum.........Jerome
Chief Clerk................................................S. E. Smith.............Jerome
Employment Agent.........................................C. J. Beale..............Jerome
Master Mechanic..........................................W. E. Kehoe............Jerome

Smelter Department
Superintendent............................................Geo. W. Prince.........Clemenceau
Asst. Superintendent......................................R. B. Green..........Clemenceau
Timekeeper................................................M. Z. Ivy...............Clemenceau
Master Mechanic..........................................John Langdon.........Clemenceau
Chief Electrician.........................................W. D. Deacon.........Clemenceau
Chief Chemist...........................................J. H. English.........Clemenceau

Verde Central Mines, Inc.
Manager.....................................................Robt. H. Dickson......Jerome
Supply Man................................................C. D. Hoatson..........Jerome
Clerk........................................................O. G. Engelder........Jerome
Master Mechanic..........................................Jack Weir.............Jerome
Asst. Master Mechanic....................................James McCloskey.....Jerome
Mine Foreman.............................................Jack Radcliffe.........Jerome
Engineer....................................................H. G. Hymer...........Jerome

Ajo District
Location and General Geology

The Ajo district is the only large copper district situated in the desert province of the State. All others lie in the mountain province Clarkdale, and two industrial railways, one between Clarkdale and fringing the high Colorado plateau. Ajo, the principal settlement, is in-
the southwestern part of the State, in the Little Ajo Mountains, a low desert range, about 40 miles south of Gila Bend and 30 miles north of the Mexican boundary. It is connected to the Southern Pacific Railroad main line at Gila Bend by the Tucson, Cornelia, and Gila Bend Railroad.

The Little Ajo Mountains are made up of a basement of pre-Cambrian granites and schists, intruded and partly covered by igneous rocks and later partly consolidated conglomerate, derived from the igneous rocks. The oldest exposed later series of igneous rocks is a series of rhyolite and rhyolite tuffs. Intruding these and doming them, is a large mass of monzonite varying in composition from granite to diorite, and from porphyry to granitoid in structure. Later dikes of andesite and basalt cut both the monzonite and rhyolite. The ores of the district replace a part of the monzonite and the rhyolite near the contacts, as veinlets of chalcopyrite and bornite where primary, and malachite, cuprite, black oxide, copper glance, and a little chrysocolla where oxidized. The shape of the largest ore body is elliptical with its major axis northwest. This ore body in cross-section is mushroom shaped, the ore spreading out under the probable capping of rhyolite now eroded. The ores in the rhyolite occur as narrow, rich veins of bornite and chalcopyrite, oxidized to malachite, cuprite, and copper glance near the surface.

In both types of ore bodies, there has been no enrichment, the primary ore having been oxidized in place to a carbonate and oxide ore of the same tenor as the primary sulphide ore. The ore minerals were deposited in veinlets in a thoroughly shattered portion of the monzonite. The mineral area covers about 168 acres.

The geology has been described in the following article:


MINING PROPERTIES

There is one producing company in the district, the New Cornelia Copper Company.

MINING METHODS

The ores of the New Cornelia Copper Company are mined from an open pit by steam shovel methods—7 Osgood 105-ton steam shovels with 4-cubic yard dippers; nine Oliver 65-ton engines; and 72 Kilbourne & Jacobs 20-cubic yard side-dump cars; jackhammers, Ingersoll Rand N-72, Waugh 60, and C. P. 5 rock drills form the major
equipment. Thirty foot benches are maintained, and blasting is done with dynamite. The details are described in the following articles:


CRUSHING PLANT FOR LEACHING PLANT

The ore from the steam shovel pit is hauled in side dump 40-ton cars to the primary crushing plant, consisting of one 24 Gates Style K gyratory crusher followed by four No. 8 Style K gyratories. The 24 Gates takes run of mine including boulders as large as 4½ by 4½ by 10 feet and crushes to 6-inch ring. Its capacity is 450 tons per hour. The crushed material from this crusher passes over 3-inch grizzlies and the oversize falls into the bowls of the No. 8 gyratories and is reduced to 3-inch ring. The crushed ore is then conveyed to a 10,000-ton storage bin, and drawn from it at a uniform rate to the secondary crushing plant.

The secondary crushing plant consists of five units of 48-inch Symons vertical shaft disc crushers, each unit consisting of one coarse and two fine crushers. This plant delivers a product passing a ¼-inch ring. Tramp iron is removed from the ore by means of powerful magnets over the conveyor belt between the storage bins and the secondary crushing plant. Crushing is done in two shifts, during which time over 5,000 tons of ore are crushed. The plant has been described in the following article:


CONCENTRATOR CRUSHING PLANT

The crushing plant for the 5,000-ton concentrator is entirely separate from that for the leaching plant. It consists of a coarse crushing plant, an intermediate crushing plant and a fine crushing plant. The ore from the side dump cars from the pit is dumped into a 500-ton receiving hopper with a discharge gate 9 by 8½-feet feeding to an 8-foot pan conveyor delivering directly into the bowl of a 54-inch McCally gyratory crushing to 6-inch ring. The crushed material is conveyed by a 48-inch belt conveyor to a 42-inch distributing belt conveyor delivering to a 5,000-ton storage bin with eight 48-inch pan feeders. The pan feeders deliver onto four 36-inch belts, each belt delivering to special Burch 2-inch ring grizzlies. The oversize from the four grizzlies falls into the bowls of four No. 8 Gates Style K gyratories crushing to 2-inch ring. The crushed material and undersize from
the ring grizzlies pass to four 24-inch belt conveyors delivering to 1½-inch ring grizzlies. The oversize from the grizzly sets is delivered to eight 48-inch Symons horizontal shaft disc crushers. The crushed material and undersize from the ring grizzlies is conveyed on 24-inch belts to four 78 by 25-inch Traylor rolls, run in closed circuit with the 24-inch conveyor. The product from the rolls is delivered to a series of conveyors forming the mill bin conveyor system, delivering ore to the 10,000-ton mill bin.

LEACHING PLANT

The oxidized ore is treated in a 5,000-ton leaching plant. It consists of 12 reinforced concrete lead lined tanks 88 feet square by 17 feet deep; a Hulett unloader for tailings removal, with a capacity of 500 tons per hour; four 1,000-ton steel tanks for acid storage; a 13 by 20-inch Blake crusher for crushing high sulphur ore from Bisbee; four 22'6", 7-hearth Wedge roasters for roasting the high sulphur ore to produce SO₂; a Cottrell precipitator, of 13-inch collector tubes for dust settling of roaster gases; a lead cooling chamber 14 by 94-feet; six SO₂ towers, four of which are 40 feet high and 20 feet in diameter, and two of which are 40 feet high and 28 feet in diameter, for the reduction of ferric iron in the solution to ferrous iron; 152 electrolytic lead-lined tanks arranged in 12 banks of ten tanks each and four banks of eight tanks each, each tank containing 84 lead anodes, 77 cathodes, a total of 12,768 anodes and 9,779 cathodes, also 25 tanks operating on starting sheets, each tank containing 77 starting blanks, a total of 1,925 blanks; a cementation plant consisting of 12 circular tanks, classifiers, and filters; and subsidiary lead-lined pumps, blowers, solution storage tanks, etc.

The crushed ore is charged into the leaching tanks, eight of which are full of ore undergoing leaching at one time, one being charged and one empty, the balance being washed. Pregnant solution goes to settling tanks before reaching the tank-house. The ore is leached for 8 days by a counter current system and upward percolation, using dilute sulphuric acid as the principal solvent, circulated by two vertical-centrifugal lead-lined pumps per leaching tank throttled to give a circulation of 3,500 to 4,000 gallons per minute through the ore. The high acid solution of 3 percent \( \text{H}_2\text{SO}_4 \) goes to the oldest ore. The nearly neutral solution coming off the newest ore goes to the reduction towers.

After a tank of ore has been subjected to leaching for about 8 days, under normal operations of 5,000 tons per day, it is taken out of the circulating circuit, thoroughly drained and subjected to five washings,
with progressively dilute solution, the fifth washing being with clear water, the first wash water being added to the main solution circuit, and the other three being stored in special tanks for washing the succeeding charge. The washed charge is then unloaded by the Hulett unloader into side-dump cars and transported to the tailings pile about a mile from the plant, about 21 train loads of eight cars each being necessary for unloading a tank.

The nearly neutral solution coming off the newest ore contains a large amount of iron in the ferric state. To reduce this to the ferrous state, necessary for economic electrolytic deposition of the copper, the solution is pumped to the top of the first pair of \( \text{SO}_2 \) towers, which are filled with \( \frac{3}{8} \)-inch boards placed on edge in layers, each layer laid at right angles to the adjacent one. \( \text{SO}_2 \) gas is forced from the bottom to the top of the towers, the solution percolating down in the opposite direction. After percolating through the first pair, it is pumped to the top of the second pair, and then to the third pair, and finally to the settling tank to settle out suspended material and to allow time for the more complete reduction of the ferric iron. The \( \text{SO}_2 \) gas is generated by the roasting in Wedge roasters of about 75 tons of crushed Bisbee high sulphur low copper ore a day. The gases are cleared of dust, and cooled by spraying with a part of the neutral solution, and then forced through the towers by a 60-inch lead fan placed between the second and third pair of towers, which draws the gas through the Cottrell precipitator, spray (cooling) chamber and the third pair of towers, and forces it through the second and first pairs. Five- to ten-percent \( \text{SO}_2 \) gas is formed. After settling, the solution is pumped to the electrolytic tank house, and the copper precipitated electrolytically. The solution containing high acid leaving the tank house joins the high acid advance leaching circuit. The electric current is supplied by two 15,000-ampere circuits 170-volts DC, each circuit having 76 tanks in series. Average current efficiency is 80 percent. The drop in voltage between anodes and cathodes is about 2 volts. About 0.8 pounds of copper is deposited per kw.h. Circulation is maintained at from 800 to 1,500 gallons per minute. The neutral solution entering the tank house contains 1.70 percent free acid and leaves with 2.10 percent, the difference being the acid regenerated.

In leaching, only about half the acid is used for dissolving copper. The remainder is used up in dissolving iron and other impurities. In order to prevent fouling of solutions, it is necessary to bypass about 73 gallons per minute from the solution circuit. This is now done from the first wash water storage tank, which contains the maximum
dissolved material. This discard passes to the cementation plant, and the copper precipitated on scrap iron. The precipitated copper is re-dissolved in a part of the neutral advance, thus reducing the ferric iron to ferrous iron, and the resulting solution goes to the tank house.

The leaching plant has been described in the following article:

CONCENTRATOR

The sulphide ore from the concentrator coarse crushing plant is delivered to a 10,000-ton suspension bunker type mill bin 300 feet long and 34 feet deep, with discharge hoppers 10 feet apart, six hoppers to each unit of the mill, of which there are five. The capacity of each unit is 1,000 tons, making the total capacity 5,000 tons. Actually 6,500 to 6,800 tons per day are put through. The discharge hoppers deliver the ore to ten 42-inch belt feeders delivering to five loading hoppers. From the loading hoppers, the ore is conveyed on five 24-inch belt conveyors to ten, 6 by 12-foot primary Marcy rod mills run in partially closed circuit with ten, 6 by 25-foot duplex Dorr classifiers, and part of the sand to ten, 6 by 12-foot Secondary Marcy rod mills in closed circuit with duplex classifiers. The overflow from both the primary and the secondary classifiers goes to flotation cells of the Inspiration type made up of 24 rougher cells, eight cleaner cells, two machines to each unit, ten machines in all. The concentrates are transferred in launders to one Dorr thickener, 58 feet in diameter, 8 feet deep, the overflow from which goes to the return water pump sump. Thickened concentrate goes to the filter plant consisting of four Oliver 14 by 14-foot continuous filters, delivering to a 24-inch belt conveyor 375 feet long discharging direct into railroad cars for shipment to Douglas.

The tailings from the flotation machines go to a tailing sand thicken- ener consisting of a rectangular concrete tank 20 by 60 feet in plan having a sloping bottom equipped with classifying cones. The overflow goes to a 200-foot tank thickener, the overflow to the return water and the sand from both through a launder to the tailings pumping plant from where it is pumped by centrifugal sand pumps through wood-stave pipe line to the tailings distributor launder and distributed to the tailings pond of 250 acres. Centrifugal pumps return as much water as possible to the mill.

Recovery at the mill is about 89 percent total copper. Sodium sulphide is added above the Marcy mills to help in the recovery of oxides, of which the recovery is 57 percent. Silver and gold recovery is
about 88½ percent and 84 percent respectively. The ratio of concentration is about 22 to 1. About 300 gallons of fresh water per ton of ore are used and 800 gallons per ton reclaimed. Marcy mills grind to 14 percent on 65 mesh. As the ore carries almost no pyrite, no lime is added to the circuit. The concentrator and coarse crushing plant have been described in the following articles:


PUMPING

Water for all purposes is obtained from a well about 6½ miles north-east of Ajo, consisting of two shafts sunk 650 feet deep in a broad desert valley. Electrically-driven pumps with a combined maximum capacity of 5,000 gallons per minute are installed pumping water through a 20-inch pipe line to the power plant cooling pond sump, from which it is pumped by 2,000 gallons per minute centrifugal pumps to the 1,000,000-gallon mill reservoir, or directly to the mill reservoir as occasion demands. The town supply is pumped separately through a 10-inch line to the domestic water tank or may be pumped from the cooling pond. The pumping plant has been described in the following article:


POWER PLANT

Power for leaching plant, pumping plant, concentrator and domestic use is generated by ten oil-fed 825-h.p. boilers, running two turbo generator sets of 7,500 kw. each. Four 1,750-kw. direct current motor generator sets convert the alternating current to direct current for the tank house. Power for the pumping plant is transmitted at 44,000 volts and stepped down to 440 volts. Power to the leaching plant and concentrator is transmitted at 2,300 and 440 volts. All equipment is electrically run at the plants.

LABOR

Common labor and machine runners at the pit are Mexican. Steam shovel runners and locomotive engineers are American. Skilled operators at the concentrator and leaching plant are American, and all foremen and mechanics and office men. The average number of employees is about as follows:

General ................................................................. 110
Leaching department............................................... 137
Mining department.................................................. 266
Concentrator department .................................................. 203
Power plant ........................................................................... 21
Mechanical department ....................................................... 106
Ice plant ............................................................................... 3

Total ................................................................................... 846

The townsite of Ajo is owned and controlled by the company, who run a cooperative store, earnings being distributed once a year to employees participating. This venture has been described in the following article:


A benefit association is maintained by the employees with aid from the company, about 95.1 percent of the employees eligible participating. A swimming pool, playgrounds, etc., are maintained by this company, and financial aid is given to the maintenance of churches.

ORE PRODUCTION

The ore production for the year 1927 was as follows:
Dry tons carbonate ore mined .............................................. 1,080,073
Dry tons sulphide ore mined ................................................ 2,291,188

Dry tons total ore mined ...................................................... 3,371,261

PERSONNEL OF NEW CORNELIA COPPER CO.

Manager ........................................ M. Curley ........................................ Ajo
General Superintendent ............... W. L. DuMoulin ......................... Ajo
Plant Superintendent .................. J. A. Potter ................................ Ajo
Mine Superintendent ................. G. R. Ingham ................................ Ajo
Assistant Plant Superintendent .... H. A. Nelson .......................... Ajo
Chief Clerk ................................ G. H. Purcell ................................. Ajo
Purchasing Agent ....................... Geo. Jay ................................... Warren
Asst. Leaching Plant Supt ............. H. Snyder ................................ Ajo
Chief Chemist ............................. C. E. Title ................................ Ajo
Master Mechanic ........................ E. M. Reid ................................. Ajo
Chief Engineer ............................. A. T. Barr ................................. Ajo
Mine Foreman ............................. T. B. Hinton .......................... Ajo
Power Plant Foreman .................. C. V. Walker .......................... Ajo
Chief Electrician ....................... L. V. Wilson .......................... Ajo
CLIFTON-MORENCI DISTRICT
LOCATION AND GENERAL GEOLOGY

This district lies in east-central part of the State near the New Mexico line. It lies in the southern extension of the Blue Range. The town of Clifton, the smelter town of the district, is in the valley of San Francisco River, one of the main headwater tributaries of the Gila River. Morenci and Metcalf lie in the rugged hills to the northwest and north, where the mineral deposits of the district occur. The district is served by a branch line of the Southern Pacific Railroad between Lordsburg and Clifton. The hills are formed of a basement of pre-Cambrian granite, overlain by a Paleozoic series, the lowest member of which is a thick bed of quartzite followed by limestones of Ordovician, Devonian, and Carboniferous ages. Unconformably overlying the Paleozoic series is a series of Cretaceous shales and sandstones, capped unconformably by Tertiary basalt flows, and finally by a thick poorly consolidated conglomerate of late Tertiary or early Quaternary age. Previous to the eruption of the basalts, the district had been subjected to extensive intrusion by a monzonite-diorite-granite mass accompanied by extensive metamorphism faulting and ore deposition. The ore bodies were introduced along major fault zones, and replaced both the Paleozoic sediments, and the intruding monzonite. They are generally vein-like in form. The primary material is of too low a tenor to constitute ore and consists of "cupriferous" pyrite in a quartz and sericite gangue. The ore bodies owe their value to secondary enrichment, the ore consisting of chalcocite and pyrite in a sericite-quartz-kaolin gangue. Silver and gold values are very small.

Subsequent to ore deposition and enrichment the district was covered by thick flows of basalt, and later by valley fill conglomerates. Subsequent uplift initiated the present erosion cycle. The lava and conglomerate have been partly stripped and the old surface and ore bodies again exposed.

The geology of the district has been described in the following publication:


MINING PROPERTIES

The Morenci Branch of Phelps Dodge Corporation is the only producing company in the district.
MINING METHODS

Most of the ore is now being mined from the Humboldt Mine from an ore body 2,000 feet long, a maximum of 600 feet wide and 1,000 feet thick. The upper 350 feet of this ore body was largely mined out by “incline slice” and other methods, previous to the consolidation of the Arizona Copper Company and the Detroit Copper Company. The Morenci Branch is now completing the mining of the upper ore by an adaptation of block caving known as the “Morenci Timbered Slide” method. Panels are laid out 150 feet wide with hand tramming drifts on 40 or 50-foot centers, and inclined slides at 33° on 20-foot centers along the drifts. Boundary shrinkage stopes 6 feet wide are run on the end and sides of the block, stope upward in successive cuts, maintaining an entrance over the sloping muck pile. Undercutting is done by driving drifts at 10-foot intervals over the timbered slides, drilling the backs and pillars between drifts and blasting. This method is adapted to soft ore and lifts of from 30 to 100 feet.

For the harder ore below the older stope ground, the “Morenci Block Caving” method has been developed. The ore is hard and tends to break in too large slabs to make either the Miami or Inspiration system applicable. As developed at Morenci, panels 168 feet wide are used, each served by three longitudinal haulage drifts, 56 feet apart. From these, steep inclines are driven at right angles, one on each side of the drift to the grizzly line 45 feet above, the tops of the raises being 28 feet apart. The interval along the haulage drift between each pair of raises is 28 feet. The tops of the raises are thus on 28-foot centers. The grizzly level drifts, run at right angles to the haulage drifts connect to the tops of the raises across the block. The bottoms of the grizzly drifts at the raise are then slot and timbered. Two grizzlies composed of 50-pound rails spaced 10 inches apart are then laid at right angles to the grizzly drifts, the grizzly centers being at 14 feet. Four finger raises are then driven off each grizzly to the undercutting level, 20 feet above, the tops of these finger raises being on 14-foot centers at the undercutting level. Grizzly level drifts and raises are driven small, eliminating timbering in most ground, and leaving a brow to control the ore flow and rendering control doors unnecessary. Boundary shrinkage stopes are then carried up to within 10 feet of the caving back. In hard ground, the Ray pillar and room system is used for caving, and for softer ground, horizontal undercutting is used for the timbered slide method. The “Morenci Block Cave” method is used for lifts of from 100 to over 200 feet, the tendency being to increase the lift.
In both methods, there is careful supervision of drawing, and the angle between caved ground and uncaved, the “angle of retreat,” kept at from 60° to 70° found to give the best results, both for keeping down undue weight and subsequent repairs, and for a minimum of dilution.

Results in 1924 and part of 1925 were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Tons</th>
<th>Percent total stpering</th>
<th>Board ft. timber per ton</th>
<th>Pounds powder per ton</th>
<th>Tons per man</th>
</tr>
</thead>
<tbody>
<tr>
<td>1924—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timbered slide</td>
<td>360,172</td>
<td>38.16</td>
<td>2.10</td>
<td>0.40</td>
<td>16.29</td>
</tr>
<tr>
<td>Block cave</td>
<td>125,743</td>
<td>13.32</td>
<td>1.60</td>
<td>0.54</td>
<td>12.39</td>
</tr>
<tr>
<td>Jan.-Aug. 1925—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timbered slide</td>
<td>413,147</td>
<td>46.38</td>
<td>2.07</td>
<td>0.46</td>
<td>17.72</td>
</tr>
<tr>
<td>Block cave</td>
<td>357,626</td>
<td>40.14</td>
<td>0.81</td>
<td>0.33</td>
<td>21.80</td>
</tr>
</tbody>
</table>

In 1925 the dilution figures for all stopes using caving methods was as follows:

<table>
<thead>
<tr>
<th></th>
<th>Expectancy</th>
<th>Extraction</th>
<th>Extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tons</td>
<td>Grade</td>
<td>Tons</td>
</tr>
<tr>
<td>Eight Months 1925 ...</td>
<td>603,345</td>
<td>2.10</td>
<td>728,031</td>
</tr>
</tbody>
</table>

For details of these two methods see the following article:

In the older high grade stopes, horizontal and incline slicing methods are used, described in the following article:

ORE AND MATERIAL TRANSPORTATION

Four openings are maintained in the mines operating on company account. The main ore hoisting shaft is the No. 6 shaft, the ore being hoisted in counter-balanced skips. Men and supplies are served by a separate shaft, the Joy shaft, equipped with large cages capable of handling timbers up to 12 feet long, and 60 men to the trip. The Longfellow shaft is maintained for waste handling and development work on the lowest level, the 1,400-foot level. Some of the upper level stopes are served by the Humboldt adit.
Underground haulage is done in trains hauled by electric locomotives on the main haulage levels.

CONCENTRATOR

The concentrator is located below the No. 6 main shaft. Primary crushing is effected in three stages, put through No. 8 McCully gyratory, followed by Symons disc crushers, followed by rolls in closed circuit with Tyler whip tap screens. The finished product of 0.28-inch ring is conveyed to the 5,000-ton fine ore bins.

From the fine ore bins, the ore is conveyed to primary Hummer screens, the undersize going to 42 Wilfley tables, and a coarse concentrate made containing some of the oxide copper. The oversize goes to four pairs of 54 by 24-inch rolls. The roll product is conveyed, elevated and further conveyed to a second set of Hummer Screens run in closed circuit with four pairs of 43 by 16-inch rolls. The undersize joins the table tails and passes to six 6 by 20-foot Dorr desliming classifiers run in open circuit with three 7 by 12-foot Allis-Chalmers ball mills, two No. 86 Marcy Mills and one 8 by 4-foot Hardinge mill. The overflow from the classifier and the crushed product goes to four 8 by 26'8" and two 6 by 25-foot Dorr circulating classifiers, run in closed circuit with the secondary mills, the overflow passing to eleven Duplex rougher cells, making a finished concentrate a middling product and a tail product. The undersize joins the table tails and passes to six 8'6"x18' Dorr rake classifiers run in closed circuit with six 8'x36" Hardinge mills, the overflow from the classifiers passes to six 14-foot diameter modified bowl type classifiers, run in closed circuit with the rake classifiers and Hardinge, through six 3-inch Wilfley pumps. The overflow from the bowl classifier and the middlings from the rougher cells pass to the secondary flotation machines composed of sixty 2'9"x3'6" duplex cells, and twenty-eight 2'9"x4' Forrester machines. The tails from these machines pass to four Dorr thickeners, the water reclaimed and the sludge to the tailings pond. The concentrates pass to cleaner cells composed of Forrester type machines, the tails from which are retreated in the rougher cells and the concentrates join the concentrates from the rougher cells and pass to 18 Dorr thickeners, also taking the overflow from eight settling tanks treating table concentrates. The sludge from these is filtered through three Oliver filters and joins the dewatered table concentrates on the concentrate loading conveyer belt loading into railroad cars for shipment to the smelter.

The capacity of the plant is 4,500 tons daily. The flotation reagents used are about 0.113 pounds of xanthate and .061 pounds of pine oil. The ratio of concentration is about 12 to 1. Fresh water requirements
are about 530 gallons per ton of table concentrate and about 1,240 gallons per ton are reclaimed. A total of about 87 percent extraction is made, 91 percent of the sulphide copper. About 14 kw.h. is consumed per ton of ore. Water is purchased from the Morenci Water Company who have a pumping plant on Eagle Creek west of Morenci.

This plant has been described in the following article:

CLIFTON SMELTER

This smelter treats concentrates from Morenci and a small amount of lease ore from Morenci and Metcalf. The ore is shipped to the smelter in 50-ton railroad cars. Concentrates are dumped into large receiving bins and from them conveyed to three 4,500-ton beds from which they are reclaimed by Messiter reclaimer, and, together with crushed flux ores from separate ore beds, conveyed to eight 6-hearth 21'7" Herreschoff air cooled roasters, fired when needed by coal fired Dutch ovens, two being installed for each roaster at the fifth hearth. Gases are freed from dust in a large dust chamber. Calcine and dust are transferred in 20-ton charge cars to two of three 22 by 100-foot reverberatory furnaces, one being kept as a spare. Matte from the reverberatories is transferred by crane in 20-ton ladles to three stands, five 12-foot Great Falls type converters, lined with magnesite brick. Slag is poured into the reverberatories, and copper further treated and polled and cast into bars for the market. Gold and silver contents are so low that refining is not necessary.

The reverberatories are connected to seven Stirling boilers of 712 h.p. each, and three 384-h.p. direct-fired boilers are kept in reserve.

The smelter has been described in the following article:

POWER PLANTS

There are two power plants, one at Morenci and one at Clifton. The Morenci plant consists of the following: five Nordberg Carels Diesel engines, 5-cylinder 2-cycle vertical type, of 1,000 h.p., direct connected with 4 AC generators (3 Westinghouse and 1 General Electric) 2-phase, 60-cycle, 2,400-volt, 850-kv.a and one Nordberg air compressor, 23½ inches and 40 by 27-inch 2-stage 6,400 cubic feet per minute capacity. The generators furnish electric power to run two G.E. exciter sets, one Westinghouse exciter set, one G.E. Motor Generator set and one Westinghouse motor generator set, both making di-
rect current, and one Ingersoll-Rand 700-foot 2-stage compressor 11 and 18 inches by 16 inches.

Connected with the boilers at Clifton are: two Curtis type horizontal steam turbines, two G.E. Turbo-generators of 2,500 kv.a., six Auto transformers, two Crocker-Wheeler generator sets and two exciter sets. There are also one Ingersoll-Rand 2-stage cross compound Corliss engine compressor and 3 cross compound duplex Nordberg Corliss blowing engines, both steam-run.

LABOR

All labor in the mines except bosses and some timbersmen is Mexican. Skilled operators at the concentrator, smelter, and shops are American. The ratio of Mexicans to Americans is about fifty-fifty. The total payroll is about as follows:

<table>
<thead>
<tr>
<th>Department</th>
<th>Payroll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morenci mining</td>
<td>478</td>
</tr>
<tr>
<td>Coronado-Metcalf</td>
<td>8</td>
</tr>
<tr>
<td>Concentrating</td>
<td>182</td>
</tr>
<tr>
<td>Smelting</td>
<td>189</td>
</tr>
<tr>
<td>Morenci surface</td>
<td>79</td>
</tr>
<tr>
<td>Clifton surface</td>
<td>25</td>
</tr>
<tr>
<td>Industrial railroad</td>
<td>29</td>
</tr>
<tr>
<td>Power &amp; Mechanical</td>
<td>122</td>
</tr>
<tr>
<td>Total operating</td>
<td>1,112</td>
</tr>
<tr>
<td>Non-operating</td>
<td>614</td>
</tr>
<tr>
<td>Leasing department</td>
<td>27</td>
</tr>
<tr>
<td>Total payroll</td>
<td>1,200</td>
</tr>
</tbody>
</table>

PERSONNEL OF OPERATING COMPANY

Manager .................................................. Frank Ayer
Assistant Manager ...................................... W. M. Saben
Superintendent of Mines ............................. McHenry Mosier
Superintendent of Concentrator ..................... Arthur Crowfoot
Superintendent of Smelter .......................... J. G. Lindley
Superintendent of Power ............................ R. M. McDougall
Chief Clerk .......................................... H. W. Hill
Manager Supply Department ......................... J. R. Bowie

SUPERIOR DISTRICT

LOCATION AND GENERAL GEOLOGY

The Superior district is situated in the mountains about 15 miles west of Miami. The principal settlement is the town of Superior.
The district is connected with the Southern Pacific Railroad, Hayden Branch by the 31-mile Magma Arizona Railroad, owned and operated by the Magma Copper Company.

The geological features at Superior are the same as for the Globe-Miami-Ray districts. The ore deposits were introduced along faults, and the ore replaces the rocks cut, the larger part replacing a large sill of diabase. The geological features of the Magma Mine have been described in the following article:


MINING PROPERTIES

There are two operating companies in the district, the Magma Copper Company and the Belmont Copper Mining Company, the latter in the development stage.

MINING METHODS

The method used at the Magma Mine is locally termed pillar and stall method, an adaptation of rill stoping and fill, the fill being obtained from a glory hole on the surface. In hard ground, the ore is mined by cut and fill in narrow sections, and the pillar later mined by modified Mitchell slice method followed by fill. Extraction work is all done in the footwall of the vein with crosscuts at about 150-foot intervals to the vein. The dip of the vein is about 78° and the width varies from 10 feet to over 30 feet. Stopes are carried 100 feet high as a rule, sometimes increased to 200 feet. The mining methods have been described in the following article:


ORE AND MATERIAL TRANSPORTATION

The Magma Mine has been developed by five shafts of which two are used for hoisting, two for exhaust airways, and one is in process of equipment for hoisting. The two main shafts are connected with two adit levels, the main adit connecting at the 500-foot level. One of the main shafts, the No. 2 was sunk from the upper adit level corresponding to the 200-foot level of No. 3 shaft. No. 2 and No. 3 shafts are 800 feet apart, and are equipped with skips and underhung cages. Each shaft has three compartments, the skips running in counterbalance. Hoisting is done by electric hoists. Ore is hoisted to the 200-foot level storage bins and dropped to the 500-foot adit level, where it is transferred to ore cars and hauled by electric locomotives to the smelter or concentrator, depending on the grade. Waste is
hoisted from the No. 2 shaft and dumped into a raise connecting the surface glory hole with the 2,250-foot level. All ore is dropped or hoisted to ore pockets at the 2,000 and 2,250-foot levels. The deepest operating level is the 2,550-foot level.

CONCENTRATOR

Most of the ore is hauled in trains of 12 cars each from the adit level to a wooden mill storage bin, under which are eight pan feeders delivering to a conveyor belt discharging through 10-inch grizzlies to a 12 by 24-inch Blake jaw crusher, followed by vertical Symons crushers crushing to 1-inch ring. The mill is built in three sections of 250 tons each. Each section takes the Symons product, and further crushes it in three 64½ Marcy ball mills run in closed circuit with a Callow screen. The undersize goes to six Wilfley tables, and the concentrates to an Akens classifier, from which the coarse material is combined with the flotation concentrates, and the fine is further dewatered in a 46-foot Dorr thickener. The Wilfley tails are elevated to a drag classifier run in closed circuit with a Chalmers and Williams 5 by 10-foot tube mills, the overflow going to modified Callow cells, six rougher and six cleaner cells. All finished concentrates are pumped by Wilfley pump through a 4-inch pipe line about one-half a mile long to four Oliver filters at the smelter, discharging onto a belt conveyor, distributing the concentrates to the bedded mix bin at the smelter. No attempt is made to drop pyrite, as it carries appreciable silver values. The ore treated is a mixture of bornite, chalcopyrite, and pyrite in a gangue of silica and chlorite. The grade of the heads is about 6 percent copper and $1.50 to $2.00 gold and silver.

SMELTER

The Magma smelter consists of five Hereschoff 8-hearth roasters, delivering calcines to a 100 by 22-foot reverberatory furnace, oil-fired, equipped with waste heat boilers: two 12-inch Great Falls type converters; a Cottrell plant, blower, etc. The smelter treats customs ores. The reverberatory has been described in the following article:

POWER PLANTS

The mine and mill equipment is electrically run, the power being partly bought from the Salt River Valley Water Users' Association from Roosevelt and partly generated by waste heat and oil-burning boilers of 1,750 h.p. connected with 1,500-kw. generators.
LABOR

In the mine, the majority of the force is Mexican. Most work is done on contract basis.

The average number of men employed in the district is as follows:

**Magma Copper Co.**

<table>
<thead>
<tr>
<th>Department</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine</td>
<td>450</td>
</tr>
<tr>
<td>Mill &amp; smelter</td>
<td>165</td>
</tr>
<tr>
<td>Surface</td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>60</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>675</td>
</tr>
</tbody>
</table>

**Belmont Copper Mining Co.**

| Total             | 50     |
| Grand Total       | 725    |

DEVELOPMENT

The Belmont Copper Mining Company is developing a fault fissure similar to the Magma vein from a vertical shaft 1,200 feet deep. Promising showings have been cut and some ore is being shipped.

ORE PRODUCTION

During the year 1927, the approximate production of the district was as follows:

From Magma, 222,000 tons, assaying: 6.6 percent Cu., 3.44 oz. Ag., 0.031 oz. Au.

PERSONNEL OF OPERATING COMPANIES

**Magma Copper Company**

<table>
<thead>
<tr>
<th>Position</th>
<th>Name</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Manager</td>
<td>Wm. Koerner</td>
<td>Superior</td>
</tr>
<tr>
<td>Asst. Manager</td>
<td>E. G. Dontzer</td>
<td>Superior</td>
</tr>
<tr>
<td>Purchasing Agent</td>
<td>Frank Sarrer</td>
<td>Superior</td>
</tr>
<tr>
<td>Safety Engineer</td>
<td>B. Foraker</td>
<td>Superior</td>
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<tr>
<td>Mine Department</td>
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<tr>
<td>Chief Clerk</td>
<td>Gus Mrkvicka</td>
<td>Superior</td>
</tr>
<tr>
<td>Master Mechanic</td>
<td>Jack Weitzel</td>
<td>Superior</td>
</tr>
<tr>
<td>Chief Electrician</td>
<td>C. D. Knight</td>
<td>Superior</td>
</tr>
<tr>
<td>Mine Superintendent</td>
<td>Fred W. Snow</td>
<td>Superior</td>
</tr>
</tbody>
</table>
COURTLAND-GLEESON DISTRICT
LOCATION AND GENERAL GEOLOGY

This district lies in the southeastern end of the Dragoon Mountains in the southern part of the State, between the valley of the San Pedro River and the Sulphur Springs Valley. It is served by a branch line of the Southern Pacific Railroad.

This part of the Dragoon Mountains is made up of a highly faulted complex of pre-Cambrian granite and schist, overlain by Paleozoic beds similar to those at Bisbee, the lower member being a thick bed of quartzite, the intermediate beds a series of shaly and sandy limestones of Cambrian age, and the top member a thick series of Carboniferous pure marbleized limestone. Irregularly distributed and largely eroded remnants of Lower Cretaceous conglomerates and shales occur sparingly. Intruding this complex are several varieties of igneous rocks, the most important being a fine granite, a large mass of monzonite porphyry, and a later quartz monzonite porphyry. The ore bodies of the district occur as irregular replacements of the Cambrian and Carboniferous limestones by pyritic copper ores and pyritic lead-zinc-silver ores, the latter being highly oxidized. The relations of the ore bodies to the quartz monzonite porphyry intrusive suggest a genetic relation between the two. The geology has been described in the following publications:

MINING PROPERTIES

The following properties are operating in the district: Great Western Copper Co., Germania Group of the Calumet and Arizona Mining Co., the Andes Copper Co. (operating intermittently), the Tejon Mining Company, the Mystery Mining Co., the Jacobson lease on the Costello group, and the Shannon Copper Company, (also operating intermittently).

MINING

The principal ore production is from the Germania group of the Calumet and Arizona Mining Company where lessees are making small shipments of oxide ore to the Calumet and Arizona smelter in Douglas. Copper ore, mostly oxidized, is being shipped by lessees on the Great Western Copper Company ground. The Andes Copper Company mines are closed down but contemplate resumption of work in the future. The Tejon Mining Company is developing, and small shipments of lead ore are being made from the Mystery Mining Company and the Jacobson lease. The Shannon Copper Company mines are closed down. The district has had a notable production in the past, but the better and more accessible ores have been largely exhausted.

PERSONNEL OF OPERATING COMPANIES

GREAT WESTERN COPPER CO.
Manager.................................................W. J. Young, Jr...............Tucson

GERMANIA GROUP
Manager..............................................Harry Clark...............Bisbee

ANDES COPPER COMPANY
Manager.............................................William Holmes..........Courtland

TEJON MINING COMPANY
Superintendent.................................Frank W. Giroux.........Gleeson

MYSTERY MINING COMPANY
Manager............................................John Gleeson........Gleeson

JACOBSON LEASE
Manager.............................................C. K. Jacobson........Gleeson

SHANNON COPPER COMPANY
Superintendent.................................William Saundercock.....Gleeson
ARIZONA BUREAU OF MINES

BRADSHAW MOUNTAINS
LOCATION AND GENERAL GEOLOGY

The Bradshaw Mountain districts in the north-central part of the State have a number of operating copper properties scattered over a wide area. The principal settlement is the city of Prescott. The copper mining centers are Walker, Mayer, Canon, and Constellation. The district is served by the Phoenix-Prescott-Ash Fork branch of the Santa Fe Railroad and by the Prescott-Cleator branch of the Santa Fe Railroad. The Bradshaw Mountains are made up of a complex series of pre-Cambrian schists and slates, intruded by large granite and monzonite masses. The copper ore bodies occur as veins and lenticular replacements of the schist by massive pyrite and chalcopyrite. In some of the copper veins, accessory amounts of zinc blende and galena occur also.

MINING PROPERTIES

The principal operating companies are: The Sheldon Copper Company, the Arizona Redlands Copper Company, the Blue Bell Mine, the DeSoto Mine, the Barbara Mining Company, the Kay Copper Corporation, and the Groom Prospect.

MINING AND DEVELOPMENT

Sheldon Copper Company.—This company is operating a vein deposit of chalcopyrite galena ore near the settlement of Walker. The company is sinking their main shaft to develop the property for future mining. The shaft is being sunk an additional 400 feet making a total depth of 1,300 feet. The ore is hoisted and treated in a 200-ton flotation mill. The coarse crushing plant consists of Vulcan crus her, and Symons disc crusher, delivering a material passing ¾-inch ring to a 300-ton fine ore bin. The ore is further crushed by primary and secondary rod mill, the last in closed circuit with a Dorr classifier, and goes to five tables, the tailings being treated by a 16-cell flotation machine. The concentrates are transported by launder to a 40-foot Dorr thickener a mile away and the thickened concentrate filtered through two filters 8 by 6 feet in diameter. The dried concentrates are then hauled by gasoline locomotive in narrow gage cars through the Sheldon Tunnel 8,400 feet long (Old Poland Tunnel) to the Poland bin. From there they are loaded onto railroad cars for shipment to the smelter. The equipment is electrically driven, power being purchased from the Arizona Power Company.
Arizona Redlands Copper Co.—This company is developing a series of lenticular deposits in schist, about 3 miles north-east of Mayer. The development is from a 600-foot shaft.

The Blue Bell Mine.—This mine, owned by the Southwest Metals Company, is being operated by lessees. The deposit consists of a large lense of pyrite and chalcopyrite in schist. Leasing operations are being conducted on the upper levels where the ore has been enriched. The mine is opened up by two shafts, the deepest to a depth of 1,500 feet.

The mine is situated about 3 miles south of Mayer.

The DeSoto Mine.—This mine is also owned by the Southwest Metals Company, and is being operated by lessees. The mine is at Middleton, about 4 miles south of Mayer. It is opened up by four tunnels to a depth of 1,000 feet on the vein. The ore is similar to that of the Blue Bell. It is transported to bins at the railroad by aerial tram.

Barbara Mining Co.—This property is situated west of the Arizona Redlands. Work is being done from a tunnel, to intercept the downward extension of a rich oxidized copper outcrop in schist, at a depth of 300 feet.

Kay Copper Corporation.—This property is situated near the town of Canon, on the Black Canon road between Phoenix and Prescott. The ore occurs as lenses of massive pyrite and chalcopyrite replacing schist. The property is developing from a 1,200-foot shaft. Power is brought from the Arizona Power Company. The mine makes considerable water and pumps aggregating 650 gallons are installed.

Groom Prospect.—This prospect is about 15 miles northeast of Wickenburg, on the western flanks of the Bradshaw Mountains. The country rock is coarse pre-Cambrian granite. Work is under way prospecting the downward extension of a large vein outcrop of copper stained gossan.

PERSONNEL OF OPERATING COMPANIES

Sheldon Copper Company
Superintendent..........................S. W. French......................Walker

Arizona Redlands Copper Company
Manager.................................L. J. Soper......................Mayer
DOS CABEZAS DISTRICT

LOCATION AND GENERAL GEOLOGY

This district is situated in the Dos Cabezas Mountains, a northwestern extension of the Chiricahua Mountains. The principal settlements are the towns of Dos Cabezas and Mascot. The Mascot and Western Railroad, owned and operated by the Central Copper Company connects the district with the main line of the Southern Pacific Railroad, at Willcox.

The Dos Cabezas Mountains are formed from a basement of pre-Cambrian schist, overlain by a Paleozoic series consisting of a basal quartzite, overlying Cambrian and Ordovician limestone, and Devonian and Carboniferous limestones. Unconformably overlying the Paleozoic sediments is a series of sandstones and shales of lower Cretaceous age. The whole series of metamorphics and sediments has been subjected to intense faulting, and intrusion by andesites, rhyolites, and diabase, and partly covered by extrusive flows, tuffs, and breccias. The copper deposits occur as irregular replacements of both limestone and diabase near the contacts, and are associated with contact metamorphic minerals, especially magnetite.

MINING PROPERTIES

The only operating copper mining company is the Central Copper Company.

DEVELOPMENT

The property of the Central Copper Company comprises three mines: the Mascot, Elma, and Copper. The Mascot and Copper mines are developed by tunnels and vertical shafts on the southwest side of the
range. The Elma Mine is on the northeast side of the range and is developed by a 450-foot vertical shaft.

The Elma Mine is connected with the Mascot by an 8,600-foot aerial tramway, delivering the ore into the bins at the Mascot tunnel portal. The ores from the Mascot and Elma are transported by a 10,600-foot aerial tramway to the mill bins near the town of Mascot.

CONCENTRATOR

The company has completed a 500-ton flotation concentrator for the treatment of all ore, not running at present. No unusual features attach to this plant. The ore is hard and grinding expensive. As much iron sulphide and magnetite as possible is to be dropped.

POWER

The power installation consists of five 300-h.p. Diesel engines direct-connected with generators. All mine and mill equipment is electrically run.

WATER SUPPLY

An ample water supply is obtained from a series of wells, sunk in the valley below the town, and pumped to reservoirs.

PRESENT ACTIVITY

A small force is being maintained on development work, and a small amount of ore is being treated at the mill.

PERSONNEL OF CENTRAL COPPER COMPANY

Manager.................................................................J. W. Prout, Jr.
Engineer..............................................................F. W. Sherman
Purchasing Agent....................................................W. A. Woodward

SWANSEA DISTRICT

LOCATION AND GENERAL GEOLOGY

This district lies in the Buckskin Mountains, in the west-central part of the State, south of the valley of the Bill Williams River. It is connected with the Parker cut-off branch of the Santa Fe Railroad by the 25-mile Arizona and Swansea Railroad. The principal settlement is the town of Swansea.

The Buckskin Mountains are made up of a pre-Cambrian complex of amphibole and mica schists and granite gneiss capped by much metamorphosed marbles interbedded with sericite schist and amphibo-
ites. The ore bodies are irregular replacements of the marble along fault planes, and consist of pyrite, chalcopyrite, and specular iron. The geology has been described in the following publication:


MINING PROPERTIES

The only operating company is the reorganized Swansea Consolidated Gold and Copper Mining Company, known as the Clara Swansea Mining Company.

MINING OPERATIONS

The mine has been opened up by a number of shafts, but is now being operated from a three-compartment vertical shaft 600 feet deep. The ore bodies are mined by square-set and fill, as the ground is very heavy, and considerable sorting is necessary. The ore is shipped direct to customs smelters.

Power is generated by Diesel engines direct connected with generators, and water is pumped from the Bill Williams River by an electrically driven pump through a 3-inch pipe line to a reservoir at the mine. The labor used is largely American. Development work is done on contract basis, and other work on day’s pay.

SILVERBELL DISTRICT

LOCATION AND GENERAL GEOLOGY

This district is in the Silverbell Mountains, northwest of Tucson. The district is served by the Arizona Southern Railroad, between Red Rock and Silverbell, owned and operated by the American Smelting and Refining Company.

The Silverbell Mountains are made up of a complex of marbleized garnetized Paleozoic limestones intruded by a large mass of monzonite. The ore deposits are of two types, metamorphic replacement deposits of oxidized and sulphide ore in limestone, largely exhausted, and oxidized and enriched ore, replacing monzonite in a large shear zone.

MINING ACTIVITY

There are two properties operating in the district, the Silverbell Mine, operated by the American Smelting and Refining Company and the El Tiro Mine, operated by Percy Williams. The El Tiro Mine is opened up by tunnels and raises, and siliceous ore is being mined for shipment to the Hayden smelter. The ore is partly oxidized and partly enriched sulphide. The Silverbell Mine is
prospecting the southern extension of the El Tiro shear zone with shafts and drifts, and is also making small shipments of siliceous flux to the Hayden Smelter.

LABOR

The underground force at both properties is Mexican, and work is done largely on contract basis. About 80 men are employed at each mine.

PERSONNEL OF OPERATING COMPANIES

SILVERBELL MINE

Superintendent ......................... Albert Kohler ............... Silverbell
Manager .............................. J. Kruttschnitt, Jr. .......... Tucson

EL TIRO MINE

Superintendent ................................ Jack Kevan ............... Silverbell
Manager ..................................... Percy Williams ............ Tucson

MISCELLANEOUS COPPER DEPOSITS

The deposits described and listed below are the more important of those which have not been fully developed on account of a variety of reasons, chief of which is lack of transportation facilities. They constitute the principal reserves for future operations in the State.

BAGDAD DEPOSIT

This deposit is situated northwest of the McCloud Mountains, about 30 miles west of the town of Hillside, near the Mohave-Yavapai line, in the central part of the State. The deposit has been partly developed by churn drilling, tunnel, and shafts, and a reserve of several million tons of low grade ore blocked out, with indications of a considerably greater ultimate tonnage. The ore occurs as a blanket of enriched disseminated ore in a large mass of monzonite porphyry intruding schist. This deposit is at present inaccessible.

PATAGONIA DISTRICT

Several deposits of enriched ore of the porphyry type occur in the Patagonia Mountains, which have been partly developed. The principal ones are the Three R Mine and the Andes Copper Company. The Three R Mine has had a notable production in the past, and considerable low grade ore remains in the mine. The Andes Copper Company deposit has been partly developed, and a small tonnage of low grade disseminated ore blocked out. The possibilities of a large tonnage of the same grade of ore is good.
Only one mine is producing copper ore in this district, the Santo Niño. This is a deposit of chalcopyrite ore replacing quartz monzonite.

**GUNSIGHT DISTRICT**

This district lies in the Gunsight Hills in the desert province of the state, 24 miles southeast of Ajo. The deposits consist of veins of enriched and primary pyrite-chalcopyrite ore in andesite and rhyolite. Spasmodic shipments are made, but lack of cheap transportation and insufficient water development have hampered development.

**CERBAT MOUNTAINS**

In this range, in the northwest corner of the State, several large low grade deposits have been partly developed, near the settlement of Mineral Park. They are of two types, disseminated deposits in porphyry and oxide ore in conglomerate.

**OLD HAT DISTRICT**

In this district in the northeast slopes of the Catalina Mountains, northeast of Tucson, are contact metamorphic deposits in Paleozoic limestones near the contact of a large mass of intrusive diorite. The deposits have been partly developed. Lack of cheap transportation has prevented full development.

**WHITE MESA SANDSTONE DEPOSITS**

These deposits are different from all others in the State. They are situated in the northern part of the State, 25 miles southeast of Lee's Ferry. The ore occurs as impregnations by copper carbonates and a little copper glance of cross-bedded white sandstones of Jurassic age. Considerable work has been done on them, but their extreme inaccessibility (125 miles from the nearest railroad at Flagstaff) has prevented their full development.

**TUCSON MOUNTAIN DEPOSITS**

Several deposits of copper ore exist in the Tucson Mountains, west of Tucson. Very little work has been done on them. They are generally small or of low grade.

**COPPER CREEK DISTRICT**

This district lies in the Galiuro Mountains, east of the town of Mammoth. The deposits have been considerably developed, and con-
sist of chimneys and veins of pyrite-chalcopyrite ore in diorite and porphyry. The mines are hampered by lack of cheap transportation, being 30 miles from the nearest railroad point at Winkelman.

**LONE STAR DISTRICT**

This district is situated in the Gila Mountains, north of the town of Safford, in the eastern part of the State. Several deposits of disseminated ore exist in the district, intimately associated with a quartz monzonite intrusion cutting andesite. Insufficient work has been done on the oxidized outcrops to indicate the tenor of the enriched and primary ore below. Fairly large outcrops of copper-stained porphyry occur.

**CUNNINGHAM PASS DISTRICT**

In this district, situated in the Harcuvar Mountains in the west-central part of the State, occur a number of vein deposits of chalcopyrite-pyrite ore with silica-hematite gangue. These veins cut granite gneiss and schist. The ore carries high gold values. Lack of cheap transportation, and adequate water supply have hampered development.

The only operating company is the Wenden Copper Mining Company, who are prospecting from a 1,000-foot vertical shaft.

**GRAND GULCH MINE**

This deposit is situated in the Grand Wash Cliffs, north of the Colorado River, in the northwestern corner of the State. The occurrence is unique, the ore, consisting of carbonates, oxides, and copper glance on the outer fringe of a cylindrical plug of brecciated limestone filling an apparent sink hole in Carboniferous limestone. The mine has had a notable production of hand sorted high grade ore in the past. It is extremely inaccessible, the shipping point being St. Thomas, Nevada, 40 miles away. The property is now idle.

Besides the above deposits, a great number of smaller deposits occur, which may develop into important deposits.
LEAD MINING

Lead deposits occur in the State in two types of deposits, that in which the lead occurs free of other metals or where they are in minor amounts, and that type in which it occurs in association with zinc minerals. In this section of the bulletin, only the first type will be considered, the other type being treated under the heading of Complex Ores.

BISBEE DISTRICT

The location and general geology of this district have already been given under Copper Mining. The lead ores of this district occur in the same way as the copper ores, although not as intimately associated with the porphyry. The greater bulk of the ore is mined from the Shattuck Mine of the Shattuck-Denn Mining Corporation, and the South-West Division of the Phelps Dodge Corporation, Copper Queen Branch.

MINING METHODS

At the Shattuck Mine, the lead ore occurs, associated with a large chimney of silica breccia. The ore occurs as cerussite and anglesite in veinlets and beds in the breccia and in irregular limestone replacements near the contacts. Earlier mining of high grade pockets has badly caved the area now being stope. Mixed with the lead ore are stringers and beds of high grade carbonates of copper, and irregular masses of lead-free siliceous gold-silver ore. To successfully mine the area, underhand square-setting is employed in narrow panels followed closely by fill. Careful sorting and selective mining is employed and four products shipped, copper ore, direct shipping lead ore, mill grade lead ore, and gold-silver ore. The lead ore carries good silver values, most of the silver being in the form of chloride.

In the Southwest Mine of the Copper Queen, similar conditions exist. Here most of the high grade ore has been shipped, but the remaining ground was left in better condition. Top slicing and underhand square-setting and fill methods are employed, and two products shipped. From Copper Queen ground a considerable tonnage of both high and low grade ore is obtained from lessee's operations.

CONCENTRATOR

All the mill ore from the camp is treated at a custom sulphidizing flotation plant operated by the Phelps Dodge Corporation, Copper
Queen Branch. The Shattuck-Denn concentrator was shut down on the completion of this plant.

The ore from the mines is transported in standard dump cars from the mine entrance and tramway terminal to an unloading pocket at the mill, having a pan conveyor running the entire length of the bottom, functioning as a feeder to an incline conveyor leading to the crushing plant. It is crushed in one 18 by 36-inch Farrel Blake Type crusher, the crushed material conveyed by belt conveyor to one 4-foot Symons Vertical cone crusher, crushing to $\frac{3}{8}$-inch maximum, and is then conveyed to the sampling mill, where it is cut four times in process of further crushing and mixing. The sampled ore is conveyed to four 150-ton fine ore bins. From these bins it is drawn by four belt feeders and delivered over belt conveyors equipped with a weightometer to a 75-ton Marcy ball mill, operating in closed circuit with a 6-foot Dorr duplex classifier. The overflow from the classifier is a product 75 percent through 200 mesh, 0.7 percent plus 48 mesh and is 35 percent solid. It goes first to an 8-cell 18-foot Mineral Separation sub-air machine, making a preliminary high gold-silver concentrate without sulphidizing. The tails from this machine pass to a 14-cell 18-inch Mineral Separation sub-air machine, where sodium sulphide is added, and a lead concentrate made. It is found that selective flotation is necessary on account of the inhibiting effect of sodium sulphide on silver and gold minerals. The combined concentrates pass to a Dorr thickener and thickened concentrates filtered through an Oliver filter delivering directly to railroad cars for delivery to the lead smelter at Douglas. The finished concentrates contain 17 percent moisture. Reagents used are the following:

<table>
<thead>
<tr>
<th>Reagent</th>
<th>Pounds per ton</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eureka No. 70</td>
<td>0.520</td>
<td>Frother &amp; Collector</td>
</tr>
<tr>
<td>Lewis coal tar</td>
<td>0.218</td>
<td>Frother</td>
</tr>
<tr>
<td>Sodium sulphide</td>
<td>4.960</td>
<td>Sulphidizer</td>
</tr>
<tr>
<td>Xanthate</td>
<td>0.087</td>
<td>Collector</td>
</tr>
<tr>
<td>Sodium silicate</td>
<td>0.638</td>
<td>Slime dispersal</td>
</tr>
<tr>
<td>Soda ash</td>
<td>0.490</td>
<td>Neutralizing salts and acidity</td>
</tr>
<tr>
<td>Barium carbonate</td>
<td>1.230</td>
<td>Mineral coagulant and neutralizing salts</td>
</tr>
<tr>
<td>Pine oil</td>
<td>0.021</td>
<td>Frother</td>
</tr>
</tbody>
</table>
Barium carbonate is added to coagulate colloidal lead minerals. Alkalinity is maintained by the use of soda ash. Sodium silicate acts as a coagulator of gangue slime. Due to constant change in character of ore great skill is necessary on the part of the operators as constant change in relative amounts of reagents is necessary.

The grade of material treated is about as follows: 6 to 8 percent Pb, 5 to 10 ounces Ag, 0.02 to 0.10 ounces Au, 55 to 65 percent SiO₂, 0.8 percent Al₂O₃, 10 to 15 percent Fe, 1 to 1.5 percent Mg, 1.5 to 3 percent CaO, 0.5 percent S (mostly in sulphate form) and about 0.08 percent Mn.

Recoveries are about 82.61 percent Pb, 74.81 percent Ag and 66 percent Au. The ratio of concentration is about 6.6 into 1. No water is reclaimed.

The above data were furnished the Bureau by the Phelps Dodge Corporation, Copper Queen Branch management, together with the description of the lead smelter at Douglas.

In the metallurgical design, the work previously done on Shattuck ores by the Shattuck-Denn concentrator was of very material aid. A description of this concentrator, now idle, is given in the following article:


COPPER QUEEN LEAD SMELTER

This plant located at Douglas, consists of an automatic ore sampling and crushing plant with ore bins; a Dwight Lloyd sintering machine; a 9-hearth Queen type roaster; a blast furnace; a small basic lined converter for the treatment of matte; and the necessary accessories including bag house, conveyors, lead kettles, casting machine and stack.

All materials received are weighed on steel scales, sampled for moisture, and dumped or shoveled into a 50-ton pocket for ores and a special small pocket for concentrates. The ore from the 50-ton pocket is transferred by pan feeder and conveyor into a 7½ gyratory crusher, delivering a 3-inch product. The crushed material is elevated by bucket elevator and is cut by a 60-inch Snyder sampler saving 1/10 as sample. This 1/10 passes over a shaking feeder through a Telsmith crusher, delivering 11/16-inch product to a 42-inch Snyder sampler where a second 1/10 is cut. This second cut, 1 percent of the original feed, passes over a shaking feeder to a set of 12 by 24-inch rolls, crushing to 1/4-inch feeding to a riffle sampler of the Jones type, making duplicate samples, with a cut of either 1/2, 1/4, 1/8, or 1/16 of the 1 percent
One of these samples is held for umpire and the other goes to the bucking room for preparation for assaying.

Where the ore is oxidized, the rejects from the first two samples join and pass over an electrically vibrated screen, the oversize conveyed to the coarse ore bins and the undersize, minus $\frac{1}{4}$ inch is conveyed together with the riffle sampler rejects to the fine ore bins. The capacity of the three coarse ore bins is 1,500 tons each, 4,500 tons total. For sulphide ore, the oversize reject from the screen is crushed in a Symons disc crushe to $\frac{1}{4}$ inch, and the screen fines and crushed material conveyed to the fine ore bins by conveyor equipped with traveling bedding tripper.

Concentrates are sampled by tenth shovel sample, and the tenth shovel sample re-cut by tenth shovel, the resulting 1 percent being taken to the bucking room for subsequent treatment. The reject from the small pocket is conveyed and bedded in the fine ore bins. The fine ore bins also are fed by the main conveyor with flue dust and bag house fume.

Flux is crushed in the crushing plant and stored in special bins, and special bins are reserved for coke.

Conveyors, run in tunnels underneath the bins, have the proper mix from each bin fed onto them, the coarse ore, flux, and coke delivered to a bucket elevator, and transferred to bins above the blast furnace, and the fine ore transferred after elevating to the bins above the Dwight Lloyd sintering machine.

The fine mix discharges from the bins above the sintering machine onto a circular revolving distributing plate, from which by plows into an oscillating feeder box, which distributes a layer of charge 4 inches deep onto the pallets of the Dwight Lloyd sintering machine. This machine consists of a series of pallets in the bottom of each of which is a grating,—the pallets forming an endless chain running on rollers at each end. The pallets are moved over a suction box by a sprocket wheel, and here the charge is ignited by an oil flame, and the gases sucked through the pallet by a suction fan. The speed is regulated so that complete sintering takes place during the time each pallet is in the suction box. The discharged sinter cake drops into a small hopper feeding a skip which elevates it to one of the six bins over the blast furnace.

The blast furnace charge is obtained by discharging by pan feeder the required amount of each constituent from the bins, coarse ore mix, sinter, flux, coke, and reverts, into a weigh car. The charge consists of 8,000 pounds. After weighing, the charge car dumps the charge into
the top of the blast furnace. Scrap iron and dross are weighed at separate scales and fed by hand.

The blast furnace produces lead bullion, matte, slag, and gas. The lead bullion is tapped from the lead well at the bottom into pots and transferred to the lead kettles. The slag and matte are periodically tapped through a breast jacket at one end of the furnace, the slag going to the dump and the matte, after cooling, broken up and stored for retreatment.

The lead kettles hold 50 tons each, and are heated by an oil flame. Air is blown through the impure lead, and a large part of the impurities oxidized, rising to the surface as dross, which is skimmed off, drained through a small kettle with perforated bottom, and resmelted in the blast furnace. The purified lead is siphoned into moulds, making 95-pound pigs for shipment to an eastern refinery.

The gases from the blast furnace, sintering machine, and hoods above the settlers, matte pans, and lead wells, pass through a flue to a dust chamber, and thence through flues to fans forcing it through the bag house, a brick-steel-concrete structure built in 8 sections in which are hung 1,008 woollen bags. Any section may be taken from the circuit and the fume shaken to the bottom of the section onto a concrete floor. After 3 feet of fume has collected, it is ignited, and the resulting clinker reclaimed and delivered to the fine ore bin conveyor.

The accumulated matte is retreated for a period of about 5 or 6 days each month. It is first crushed to 3/4-inch mesh in the crushing plant, and delivered to the nine hearth roasters. The calcines after cooling are delivered to a special part of the fine ore bins and bedded with the requisite fine ores, and this special mixture sintered. This sinter and the requisite coarse ore, fluxes, etc., are then smelted in the blast furnace. The products from this smelting undergo the same treatment as usual except that the matte, now of higher copper grade, 35 percent copper and 10-12 percent lead, is poured into a small basic lined converter, and the lead fumed off and caught in the bag house, and the resulting matte transferred to the copper converters.

The smelter is a customs plant, but obtains much of its product from the mines and concentrator in Bisbee. Impurities such as zinc, arsenic, antimony, cadmium, and bismuth, increase the difficulties in smelting, and necessitate special fluxes to prevent undue slag losses. Copper in the ores is partly saved in the matte, but as it usually is in small amounts in the ore, the percentage of saving is small as compared to that in a copper furnace due to larger slag losses.
TONOPAH BELMONT DEVELOPMENT COMPANY

The mine operated by this company is situated in the Big Horn Mountains, about 20 miles southwest of Wickenburg. The nearest railroad point is Palo Verde on the main line of the Southern Pacific Railroad, connected to the mine by a 22-mile road.

The Big Horn Mountains are made up of a basement of pre-Cambrian schist and gneiss, intruded and partly covered by Tertiary andesites. The ore deposits consist of veins cutting the andesite. The primary ore consists of galena, blende pyrite, and a little chalcopyrite, carrying important gold and silver values in a quartz gangue. The primary ore has been partly oxidized into carbonates and sulphates.

MINING

The mine is opened up by a 500-foot shaft with levels on the 100, 250, 400, and 500. The ore occurs as a shoot in the vein, and is stoped by a modified shrinkage method. It is hoisted to the 100 level and trammed to the mill through an extraction tunnel.

MILLING

The ore is treated in a 65-ton flotation concentrator, making a bulk concentrate. Sodium sulphide is used to float oxidized lead minerals. The ore from the mine is dumped in wooden mine ore bins from which it is drawn and crushed in a 10 by 16 Universal crusher and stored in a second crushed ore bin. It is transferred from this second bin by a Hamell feeder to a 5 by 5 C I W ball mill run in closed circuit with a 4'6" x 21'4" Dorr C classifier, the overflow going to a contact tank, and from there to 2 by 3 Callow flotation cells, arranged in three units of eight, three, and three cells each. The tails from the finishing cells are treated on two Wilfley tables, and the tails thickened in a 10 by 30 Dorr thickener, and the thickened tails go to the tailings pile. The flotation concentrates from the primary cells pass to a 20 by 10 Dorr thickener, the thickened concentrate pumped by a Dorroco pressure pump to a 6-foot three-leaf American filter and the dewatered concentrate shipped to the El Paso smelter. The concentrates carry 5 to 6 percent zinc. Good extraction is made of lead and copper but poor extraction of gold.

POWER

Electric power is generated by Diesel engines, fuel being hauled from Palo Verde by truck.
LABOR

Labor is partly Mexican and partly American, American predominating. Work is done on day's pay basis.

PERSONNEL OF COMPANY

Superintendent................................. John L. Dynan..............Belmont
Mill Superintendent........................... H. M. Lewers..............Belmont

EMPIRE MOUNTAINS

LOCATION AND GENERAL GEOLOGY

The Empire Mountains form the north-east end of the Santa Rita Mountains, being separated from the main range by Empire Wash. The nearest settlement is Pantano, on the main line of the Southern Pacific Railroad. The mines are situated from 10 to 15 miles south of Pantano.

The Empires are made up of a basement of Paleozoic limestone, covered by a thick series of Cretaceous conglomerates, sandstones, and sandy shales. The whole has been extensively intruded by quartz porphyry and other minor intrusives. The lead ores bodies now being exploited are irregular replacements of Carboniferous limestone. All so far found have been thoroughly oxidized into carbonates and sulphates of lead, associated with a little copper carbonate and oxidized zinc minerals and abundant limonite. The association of these ore bodies with the quartz porphyry intrusions is not close.

MINING PROPERTIES

The principal operating and producing company is the Hiltano Explorations (Subsidiary of Calumet & Arizona Mining Co.).

MINING

Development work is being undertaken from a number of openings, and considerable ore shipped of a high lead tenor, chiefly from development faces.

LABOR

Mexican labor is employed almost exclusively underground, with American skilled surface labor and bosses.

PERSONNEL OF OPERATING COMPANY

Manager........................................ H. A. Clark...............Warren
Superintendent.............................. J. B. Harper..............Pantano
MISCELLANEOUS MINING

Lead ore in small amounts is mined from a number of scattered districts. Lead concentrates are shipped from Tombstone from the treatment of old mine and mill dumps. During the year ore was shipped from the Golden Rule Mine 5 miles east of Dragoon at the northern end of the Dragoon Mountains. Lead ore is being developed in a prospect 25 miles west of Hillside in the McCloud Mountains. Ore was mined and shipped from the Blue Bird Mine in the Galiuro Mountains, southeast of Winkelman. The earliest located lead district in the State, the Castle Dome district, shipped a small amount of high grade ore. Mining in this district has been practically continuous since the early seventies. A little high grade galena ore and some oxidized lead ore is mined regularly from the Patagonia and Santa Rita mountains, the most important producers being the Jefferson Mine on the west slopes of the Santa Rita Mountains and the Hardshell and Mowry mines in the Patagonia Mountains. The mine of the Hilltop Metal Mines Company at Hilltop in the Chiricahua Mountains, a large producer in the past, was closed down at the end of 1926. The Shawmut Mine near Kelvin is being energetically developed and some lead silver ore shipped.
COMPLEX ORE DEPOSITS

GENERAL INTRODUCTION

There are three types of complex ore deposits in the State; those in which the ore minerals are mixtures of lead and zinc oxides, carbonates, sulphates, and silicates; those in which the ore minerals are mixtures of lead, zinc, and iron sulphides with minor amounts of copper sulphides; and those in which the ore consists of mixtures of copper, zinc, and iron sulphides in various gangues.

The first type of deposits has been successfully mined and the combined product, when high enough in combined lead and zinc, shipped to oxide plants, sacrificing any precious metal content. At one plant treating this type of ore, sulphidizing the lead minerals and sacrificing the zinc was tried, and a metallurgical success made. Successful sulphidizing and flotation of oxidized zinc minerals has not yet been accomplished.

In the second type of deposit, a great number of which occur in the State, the high precious metal content has prevented the shipment of a combined lead-zinc ore to oxide plants without large sacrifice. The lead and zinc can be successfully separated into two high grade products by differential flotation, and a number of plants have been constructed and a number are under construction to do this. The zinc concentrates in some of the ores treated are low enough in gold and silver to ship to eastern plants for treatment at a low treatment rate. Unfortunately for the great majority of ores, when a separation is made, an important amount of the gold and silver values go with the zinc concentrates, necessitating either a high treatment charge for their recovery, or their sacrifice. The freight rates to the nearest zinc plant are high as compared to those to the nearest lead plants at Douglas and El Paso. A zinc plant in the State would be a great boon to the zinc-lead and zinc-copper mines of the State.

The third type of deposit in which the ore consists of mixtures of copper, zinc, and iron sulphides, is represented by several large deposits in the State. The separation into zinc and copper concentrates by differential flotation is now feasible. The high freight rates and treatment charge to the nearest zinc reduction plants has prevented their successful development, except where the copper content alone is in paying quantity, and the zinc sacrificed, or penalties paid for it at the copper smelters.
CERBAT MOUNTAINS DISTRICT

This district lies in the mountains north of Kingman, in the north-western part of the State. The principal mining settlements are Chloride, Mineral Park, Golconda, and Stockton Hill. The deposits at Chloride are near the terminal of the Chloride-Kingman branch of the Santa Fe Railroad. The ores from the other centers have to be hauled from 2 to 10 miles to the nearest railroad points.

The Cerbat Mountains are made up of a pre-Cambrian complex of granite gneiss, and hornblende and biotite schists intruded by dikes and larger masses of monzonite, granite porphyry, and diorite porphyry. In the southern part of the range, the earlier formations are covered by andesite flows and andesite tuffs and breccias. The mineral deposits occur in veins traversing the schist and gneiss. The primary ore consists of mixtures of zinc blende, galena, pyrite, and subordinate amounts of chalcopyrite with important gold and silver content, in a quartz gangue. Some of the veins are closely associated with the porphyry, monzonite, and diorite intrusions. The geology of the district has been described in the following publication:


MINING ACTIVITIES

The principal mines operating are the following: The Chloride Mining Company operating the Hidden Treasure group of claims through tunnels and winze; the Monarch Lead Mining Company developing the Tennessee and Schuylkill mines; the Oro Golconda Mining Company developing the Golconda, Oro Plata, and other claims; the Comstock Silver Mining Co., operating the Banner and other veins near Stockton Hill; the Great Tennessee Mining Company developing the Schenectady vein by shaft and drifts; and J. S. Murray and associates developing a vein system near Chloride.

There are two concentrators operating in the district, a 200-ton differential flotation mill at Chloride operated by the Chloride Mining Company, and a 150-ton differential flotation mill at Stockton Hill, operated by the Comstock Silver Mining Co. At both mills, two products are made, a 45 to 50-percent zinc concentrate and a 60-percent lead concentrate carrying copper. In both mills, customs ore is treated on a toll basis. The precious metals in both mills are about evenly divided between the lead and zinc concentrates.

The zinc product from these two concentrators is sent to an experimental plant at Kingman operated by J. S. Murray and associates.
The concentrates are subjected to a chloridizing roast, the lead and silver fumed off and caught in bag houses, and the zinc calcines shipped to eastern retort plants.

The number of men employed in the district is as follows:

<table>
<thead>
<tr>
<th>Company</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride Mining Co., Mine</td>
<td>20</td>
</tr>
<tr>
<td>Chloride Mining Co., Mill</td>
<td>8</td>
</tr>
<tr>
<td>Great Tennessee Mining Co.</td>
<td>10</td>
</tr>
<tr>
<td>Murray Mines</td>
<td>10</td>
</tr>
<tr>
<td>Murray Reduction Plant</td>
<td>10</td>
</tr>
<tr>
<td>Comstock Silver Mining Co., Mines</td>
<td>10</td>
</tr>
<tr>
<td>Comstock Silver Mining Co., Mill</td>
<td>4</td>
</tr>
<tr>
<td>Oro Golconda Tunnel</td>
<td>15</td>
</tr>
<tr>
<td>Monarch Lead Co.</td>
<td>10</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
</tr>
</tbody>
</table>

The district employs preponderantly American labor.

ORO BLANCO DISTRICT

This district is situated in the Oro Blanco Mountains, about 20 miles northwest of Nogales, and is 4 miles north of the Mexican line. The principal mining settlement is Ruby. The shipping point for ore and supplies is either Nogales or Amadoville on the Tucson-Nogales branch of the Southern Pacific Railroad. The length of haul is about 25 miles.

The Oro Blanco Mountains are made up of a series of sandstones and conglomerates and sandy shales of lower Cretaceous age, intruded and capped by andesite tuffs and breccias. The ore deposits consist of veins traversing the andesite and basal conglomerate of the Cretaceous. The primary ore consists of a mixture of silver and gold-bearing zinc blende galena and subordinate amounts of chalcopyrite in a quartz gangue.

MINING ACTIVITIES

There are two properties developing, of which the more important is the Eagle Picher Lead Company Montana Mines Operations, developing the Montana Mine by shaft, drifts, and diamond drill. The Idaho Mine is also developing a similar deposit north of the Montana Mine.
MINERAL INDUSTRIES OF ARIZONA

CONCENTRATOR

The Montana Mines Operations have started a 150-ton differential flotation concentrator to be completed early in 1928. The expected flow sheet follows: The ore from the mine is to be hoisted and dumped into an 18 by 18-foot hopper from which it is to pass to an 18-inch crusher, and then through 42-inch geared rolls, the crushed product elevated to a trommel with ½-inch openings, run in closed circuit with the rolls. The trommel undersize is to go to two 4 by 5-foot Leahy screens with 2½ mm. openings, the oversize going to high speed rolls and back to the trommel and the undersize to a belt drag deslimer, the coarse going to a 100-ton hopper. The hopper is to deliver to eight launder classifiers, the coarse material going to eight Shakelford tables, making a primary lead concentrate, a middling product and a tail product. The middlings are to join the launder classifier overflow and to go to a belt drag deslimer run in closed circuit with a ball mill. The slimes, joining the slimes from the belt drag deslimer following the Leahy screen, are to pass to a 50-foot Dorr thickener, the thickened pulp to a 4-inch diaphragm pump to a 12-inch elevator delivering to two Butchart flotation machines. These are to make a lead concentrate froth, which will join the lead concentrates from the Shakelford tables and will go to a 15-foot Dorr thickener, the thickened pulp to a 4-inch diaphragm pump, to an 8-inch elevator, delivering to a 4 by 6-foot American filter, delivering a dewatered lead concentrate cake ready for shipment. The tails from the lead cleaner flotation machines are to go to two Butchart lead rougher flotation machines, the froth going back to the lead cleaner cells, and the tails going to two Butchart flotation machines for zinc cleaning, the froth passing to a 3-inch American pump, pumping to a 4 by 6-foot American filter, delivering a dewatered zinc concentrate ready for shipment. The tails from the zinc cleaner cells are to pass to two Butchart flotation machines, the froth being pumped back to the zinc cleaners by a 3-inch American pump, and the tails joining the tails from the Shakelford tables, are to be pumped by a 4-inch Wilfley pump to the tailings pile.

POWER

The mine and mill plant are electrically run, the power being generated by Diesel engines.

LABOR

Underground labor is largely Mexican. Skilled mechanics and millmen on the surface are American.
SIERRITA RANGE

This range is situated about 20 miles south of Tucson. The principal mining settlements are Twin Buttes and Olive Camp. The nearest shipping point is Sahuarita on the Tucson-Nogales branch of the Southern Pacific Railroad. A branch line also connects Sahuarita with Twin Buttes.

The range is made up of a much faulted and metamorphosed series of Paleozoic and lower Cretaceous limestones and sandstones, intruded by granite and andesite, and covered in the northern part of the range at Olive Camp by andesite tuffs and breccias. The ore deposits at Twin Buttes consist of contact metamorphic replacement deposits in Paleozoic limestone, associated with much garnet. The deposits worked in the past were copper deposits. Large zinc blende chalcopyrite-pyrite deposits have not as yet been worked, and only partially developed. The deposits in Olive Camp consist of veins and stockworks of zine blende-chalcopyrite galena ore in both Paleozoic limestone and in andesite breccia.

MINING ACTIVITY

One property, the Helmet Peak Mining Company, is developing in the district. The deposit consists of a stockwork in andesite, and work is being done by drifts from two shafts.

CONCENTRATOR

A differential flotation customs concentrator is under construction at Sahuarita to make two products, a zinc concentrate and a lead-copper concentrate.

INACTIVE PROPERTIES

Two large deposits of complex ores have been developed, but are now inactive, one at Twin Buttes and one at Olive Camp. In both of these the ores consist of mixtures of zinc blende chalcopyrite and pyrite, carrying silver and gold values.

LABOR

The labor used is Mexican.
PATAGONIA DISTRICT

In this district in the southern part of the State, only slight activity in the development of complex ore deposits is in progress. Several large deposits exist and in several of them, very considerable tonnages are indicated. The ores are mixtures of zinc blende, galena, chalcopyrite, and pyrite in siliceous gangues. Only one property is actively developing, the Morning Glory Mine. Here the ore consists of zinc blende, chalcopyrite, and pyrite, occurring in a series of veins cutting Paleozoic sediments.

The Patagonia and Santa Rita mountains contain a great number of deposits of complex ores, with zinc blende as the predominant ore mineral. The high freight rate on zinc concentrates to eastern treatment plants and the high treatment charge necessary for them to make a saving of the included gold and silver, have prevented the exploitation of these deposits. An electrolytic plant for the treatment of high gold and silver bearing zinc blende concentrates would enormously stimulate this as well as other complex ore districts in the State.

BRADSHAW MOUNTAINS

In this range south of Prescott, early mining was mostly for free milling gold ore from narrow but persistent veins traversing schist. The free milling ore gave out in most of these veins at very shallow depths, and the ore changed into zinc-blende-pyrite, galena-chalcopyrite ore in which the gold values were locked up with the sulphides. The indications from what work has been done at depth are that this low grade ore will continue to reasonably great depths. The margin of profit is small, and vanishes if no return can be realized for the zinc content. Here as in other districts with like ore deposits, an electrolytic plant would have a greatly stimulating effect.

DRAGOON AND LITTLE DRAGOON MOUNTAINS

These two ranges in the southern part of the State contain a number of large complex ore deposits, now idle. In one of them, the copper values were sufficiently high that the ore was mined and the zinc content ignored, during the high copper market of the war years. This property was extensively worked, and a large tonnage of chalcopyrite-zinc blende ore developed. With a zinc reduction plant close to the deposit, this as well as a number of others in the district could be worked at a substantial profit.
SUPERIOR DISTRICT

The Magma Copper Company, the Belmont Mining Company, and the Black Bess Mining Company have here developed considerable reserves of zinc blende-galena ore. This ore can be mined at a very small profit under present conditions, and would be undoubtedly mined and greatly developed if a zinc plant existed in the State.

ARIVAIPA DISTRICT

This district lies in the Santa Teresa Mountains in the south-central part of the State, 60 miles north of Willcox, and 25 miles east of Hayden. The district is far from the railroad. One company, the Arivaipa Mining Corporation, is actively developing, and has shipped considerable oxidized lead and lead-zinc ore. The ore here occurs in the oxidized form replacing Paleozoic limestone. Zinc occurring in the oxidized state is not yet amenable to flotation. At present, experiments are under way to treat the ore, and lead ore is being shipped. An experimental mill was run in the early months of the year, but is now closed.

MISCELLANEOUS DEPOSITS

Complex ore deposits are known to exist in a great number of other localities in the State, but in most of these scattered occurrences very little work has been done. Most of them are far from transportation, and there is little incentive to develop them under present conditions.
GOLD AND SILVER MINING

Gold and silver mining was the first mining to be done in the State, and in the southern part, considerable mining for these metals was done by the Spaniards and Mexicans before the Mexican War. Arizona ranks high as a producer of gold and silver chiefly due to the precious metal contents of the large quantity of copper ore mined. The State has, however, a number of districts in which gold and silver predominate, and these districts have produced a number of large mines. The richer ore has been largely exhausted, and the lower grade ore is now being exploited.

OATMAN-KATHERINE DISTRICT

This district is situated in the Black or River Range, in the northwestern part of the State, east of the valley of the Colorado River. The principal mining communities are Oatman, Gold Road, and Katherine. The town of Kingman, 20 miles east, on the main line of the Santa Fe Railroad, is the distributing point for the district.

The Black Hills are composed of a thick covering of Tertiary volcanic flows and breccias made up of andesites, latites, and rhyolites, over a basement of pre-Cambrian granite. The ore, consisting of free gold and minor amounts of silver, occurs in veins traversing the volcanic series and penetrating the pre-Cambrian granite at the Katherine Mine. The gold and silver are associated with banded quartz, adularia, and calcite. The geology of the districts has been described in the following publication:


MINING PROPERTIES

The chief operating companies in the Black Hills are the Tom Reed Gold Mining Company, the Katherine Gold Mining Company, and the Gold Ore Mining Company. Prospecting and development work is being undertaken by a great number of companies, chief of which are the Katherine Extension Mining Company, Katherine Treasure Vault, Inc., the Sunnyside Consolidated Mines Company, the Western Apex Mining Company, and the Eureka Mine of the United Verde Copper Company.

MINING METHODS

The prevailing mining methods are adaptations of shrinkage and in-
cline cut and fill for the thicker veins, and overhead stull mining with or without fill for smaller veins.

ORE AND MATERIAL TRANSPORTATION

The mines are all entered by shaft, and the ore hoisted by either skips or cage.

MILLS

There are two mills in operation, the Tom Reed Mill at Oatman, and the Katherine Mine at Katherine, both of them all-cyanide mills.

*Tom Reed Mill*—This mill has had an intermittent run during the year treating its own ore and some customs ore.

The run of mine ore is subjected to primary crushing in a No. 2 gyratory and 15 by 22-inch Dodge Crusher to 2½-inch ring. It is then conveyed and elevated to the mill bin. From this bin the ore is fed by a chute and feeder to an Allis-Chalmers 6 by 5-foot ball mill, run in closed circuit with a Dorr duplex classifier. The overflow flows by gravity to two pairs of Dorr classifiers each in closed circuit with an Allis-Chalmers 5 by 6-foot ball mill. The overflow flows to an 11.5 by 40-foot redwood Dorr thickener. From the primary thickener the pulp is transferred by air lift to a series of four Dorr agitators 11.5 by 40 feet each made also of redwood, connected in series. The agitated pulp is transferred by air lift to a Frenier pump lifting to a second pump which lifts to a distributing box, and from there divided into the head tanks of two series of 9 by 30-foot steel Dorr thickeners, operating on counter current decantation system. The thickened pulp passes to distributing pipes leading to the tailings pond. The overflow solution from the head tanks of the two decantations series flows direct to the ball mills. The overflow pregnant solution from the primary thickener passes to the filter, and the classified solution pumped to a redwood sump. Zinc dust is added by a Merrill zinc feeder and emulsifier, and the whole pumped to two Merrill 300-ton precipitating presses. The precipitated solution flows from the presses to two 6 by 6-foot alternating measuring tanks, discharging automatically into a 5 by 27-foot steel barren solution tank. The precipitates are refined in roasting muffles and a Steele-Harvey No. 150 tilting furnace.

For further details see the following article:

*Katherine Mill*.—Run of mine ore is hoisted in counterbalance skips
and dumped into a 100-ton bin, discharging over a bar grizzly of 1\(\frac{1}{2}\) inch spaces, to a 24 by 12-inch Allis-Chalmers Blake type crusher, delivering a 2\(\frac{1}{2}\) -inch product. The grizzly fine and crushed material is conveyed to a 150-ton silo type mill ore bin. The ore is then transferred by apron feeder and crushed in two stages by 6'x6' open trunnion type Allis-Chalmers ball mill in closed circuit with duplex Dorr classifier followed by 6'x6' open trunnion type Allis-Chalmers Ball-Peb mill also in closed circuit with a classifier. The first mill uses 5-inch steel balls and the second 2\(\frac{1}{2}\)-inch balls. The final classifier material consists of 57 percent minus 200 mesh 17 percent plus 80 mesh. Two hundred sixty tons a days are treated. The primary thickener is a 30 by 10-foot Dorr. Overflow from this flows to the mill sump tanks. Thickened pulp is pumped by a No. 4 Dorrco suction pump to the first of a series of three 28 by 14-foot Dorr agitators. The overflow from the last agitator is split. 15 percent going to the second and 85 percent to the first of five decantation thickeners, four 28 by 10-foot Dorr and one 28 by 10-foot Hardinge super-thickener, the super-thickener being the last in the series. The thickened pulp from the super-thickener goes to the tailings pond. It contains 65 percent solids. The tanks are stepped, allowing the solution to flow by gravity back through all the thickeners. The overflow from the first thickener goes to a Hardinge classifier, and the filtrate from this classifier goes to the precipitation plant consisting of Crowe vacuum equipment with a Merrill zinc dust feeder and a 36-inch twenty frame Merrill precipitation press.

The Dorr thickeners discharge 40 percent to 50 percent solids. The overflow from the primary thickener is used as mill solution, due to classification difficulties. Cyanide consumption is about 0.16 pounds per ton of ore treated. Lime consumption is about 3 pounds per ton. Water consumption is 0.62 ton per ton of ore, and is obtained from the mine. Zinc dust consumption is about 0.7 pound per ton of solution. Tailing loss is about 15 cents per ton of ore, undissolved and 4.5 cents dissolved. The cost of the mill was about $365 per ton capacity, a total of $95,000.

The description of the mine and mill of the Katherine Gold Mining Company is given in the following article:

POWER PLANTS

Equipment at the Tom Reed and Katherine plants are electrically run. Power is purchased from the Kingman Power Company for the Tom Reed. At Katherine it is generated by direct-connected
Diesel engines consisting of two 360-h.p. Fairbanks Morse, one 200-h.p. De La Vergne and one 200-h.p. Chicago Pneumatic machine burning 24° Baumé oil, hauled from Kingman by truck. Operating costs are 1.718 cents per kw.h.

LABOR

Most of the underground labor is American, and work is largely on day’s pay basis. Some contracting is done on development work. The average number of men employed is as follows:

<table>
<thead>
<tr>
<th>Mine</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom Reed and Gold Ore</td>
<td>55</td>
</tr>
<tr>
<td>Katherine</td>
<td>131</td>
</tr>
<tr>
<td>Sunnyside</td>
<td>12</td>
</tr>
<tr>
<td>Eureka</td>
<td>10</td>
</tr>
<tr>
<td>Katherine Treasure Vault</td>
<td>10</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>233</strong></td>
</tr>
</tbody>
</table>

DEVELOPMENT WORK

In the Oatman district, the greater bulk of the work being done is development work. A new shaft is being sunk by the Tom Reed and Gold Ore companies to open up Aztec territory. Drifting on the Sunnyside is under way, the United Verde Copper Company is prospecting the Eureka vein by drifts and diamond drill, and work is being done on United Western ground. In the Katherine district, considerable development work is being done by the Katherine Gold Mining Company and work is under way at the Katherine Treasure Vault.

PERSONNEL OF OPERATING COMPANIES

**Tom Reed Gold Mining Company**

Mine Superintendent.................................Jack Shank..................Oatman
Purchasing Agent..................................Victor Light.................Oatman

**Katherine Gold Mining Company**

Manager..............................................R. L. Dimmick.............Katherine
Mill Superintendent............................Eugene Ireland..............Katherine
Mine Superintendent............................C. R. Waters...............Katherine
Cons. Geologist....................................Ira B. Joralemon........San Francisco
Cons. Metallurgist.................................A. L. Blumfield..........San Francisco
WHITE HILLS DISTRICT

This district is an old one which has had little work done for many years. It is situated in the White Hills, about 20 miles north of Chloride, the nearest rail point. The hills are made up of a basement of pre-Cambrian granite gneiss covered by thick andesite breccias of Tertiary age. The ore occurs as silver chloride in quartz veins traversing the andesite. The camp had a noteworthy production in the nineties of high grade ore. The larger of these veins, notably the G.A.R., are now being opened up by the White Hills Silver Mines, Inc., at greater depth than the early work. No production has yet been made.

TOMBSTONE DISTRICT
LOCATION AND GENERAL GEOLOGY

This district, in the southeastern part of the State, was one of the early bonanza silver producers of the State. Since the exhaustion of most of its high grade ore, the mines have been worked sporadically, and lower grade ore mined. The district lies in the Tombstone Hills, a northwest extension of the Mule Pass Mountains, in which the Bisbee deposits occur. The principal settlement is the town of Tombstone. The district is served by a branch of the Southern Pacific Railroad between Fairbanks and Tombstone.

The geology of the Tombstone hills is similar to that at Bisbee, with the exception that the intrusive rock is there a diorite of post-Cretaceous age. The ore deposits consist of replacement veins and saddle veins in both the Paleozoic and Cretaceous sediments. The commercial ore is all oxidized and the ore minerals are silver chloride, free gold, and oxidized silver-bearing lead minerals, chiefly cerussite.

MINING PROPERTIES

The principal mines of the district are owned by Phelps Dodge Corporation operating as the Bunker Hill Mines. All work is done on lease account.

MINING OPERATIONS

The mines are scattered over a large area, and are generally worked from shallow shafts. Various mining methods are employed, varied to suit local conditions. Several lessees have put up small concentration and cyanide plants, which are run intermittently on old mine dumps. Most of the crude ore is shipped as siliceous flux to the Copper Queen smelter at Douglas, and lead concentrates and some crude lead ore shipped to the Copper Queen lead smelter.
LABOR

Lessees employ Mexican labor almost exclusively, with no fixed rates of pay.

WICKENBURG-CONGRESS DISTRICT

LOCATION AND GENERAL GEOLOGY

This district is situated in the central part of the State on the southwest flanks of the Bradshaw Mountains. The principal mining communities are Wickenburg and Congress Junction, both on the Ash Fork-Phoenix branch of the Santa Fe Railroad.

The hills in the district are made up of a basement of pre-Cambrian schists and granite, partly covered with Tertiary andesite flows and breccias. The ore deposits consist of free gold-bearing quartz veins carrying minor amounts of pyrite and galena, cutting the pre-Cambrian complex.

MINING ACTIVITY

There are two mines producing, both of them old rich mines.

*Vulture Mine.*—This mine, situated in the Vulture Hills, south of Wickenburg, is being operated in a small way on extensions of the Vulture vein and on pillars left by previous operators. The ore is treated in a 25-ton amalgamation mill, using water pumped from the mine. About 40 tons a day are mined. The labor employed is mostly American, and work done on day’s-pay basis. All work is done above the water level. Power is generated by two 55-h.p. 4-cycle Ingersoll-Rand vertical type Diesel engines.

*Congress Mine.*—This mine, near Congress Junction, was also an old bonanza producer. The tailings pile from the old mill is now being reworked on a small scale.

In addition to these two producers, considerable prospect and development work is being conducted by a number of operators.

WINIFRED DISTRICT

LOCATION AND GENERAL GEOLOGY

This district lies in the Phoenix Mountains about 15 miles northeast of Phoenix. The hills are formed from pre-Cambrian schist and granite, overlain partly by Quaternary basalt. The ore occurs as free milling gold in quartz veins in granite and schist.

MINING ACTIVITY

The only producing company is the Anglesite Mining and Develop-
ment Company operating the Jack White property, about a mile north of the old Union Mine. It is mining and developing a vein in granite developed to a depth of 350 feet and treating the ore in a ten-stamp amalgamating mill, using water pumped from shallow wells near the mine. One other property is developing the extension of the Union Vein system.

PEARCE DISTRICT

This district is situated in the southeast part of the State in the Pearce Hills, in the center of the Sulphur Springs Valley. The hills are made up of Tertiary andesite flows and breccias. The ore occurs as silver chloride and bromide, and free gold, in a series of quartz-calcite veins cutting the andesite and breccia. The only producing company is the Commonwealth Development Company, operating the Commonwealth Mine, and shipping the ore as siliceous flux to the Copper Queen Smelter at Douglas. Most work is done on lease account, and Mexican miners employed.

BABOQUIVARI MOUNTAINS

This range, about 45 miles southwest of Tucson, is situated in the desert province of the State. The nearest railroad point is Tucson. The range is made up of a basement of pre-Cambrian granite, overlain by Tertiary volcanics, mostly andesite breccias. The ore deposits consist of veins carrying gold and silver chloride cutting andesite.

MINING ACTIVITY

During the year the Allison Mine was actively developed by the Tom Reed Gold Mining Company, and temporarily closed at the end of the year, after proving up a satisfactory tonnage of ore.

MISCELLANEOUS DISTRICTS

A number of districts are developing mines and prospects and making occasional small shipments of ore and bullion. The principal ones are the Dos Cabezas district in the Dos Cabezas Mountains in the southeastern part of the State, where there are a number of small gold mines worked intermittently; the Kofa district north of Yuma, where several veins are now being developed; the Greaterville Placers, on the northeast side of the Santa Rita Mountains, from which a small amount of gold is won by crude placering; the Fortuna Mine east of Yuma, one of the early bonanza mines has been reopened and some development
work done; and intermittent work is done in Duncan, south of Mor-enci on gold veins. Some development work is also being done on
gold veins in the Dripping Spring Mountains north of Winkelman.
ASBESTOS MINING

INTRODUCTION

Arizona is the leading state in the Union in the amount of asbestos mined. The value of the deposits lies chiefly in the excellent grades of the material available. The variety of asbestos is "chrysotile," the fibrous form of the mineral serpentine. There are two localities in which good grade deposits occur, one of which, in the bottom of the Grand Canyon, cannot be mined due to transportation difficulties.

SALT RIVER BASIN DEPOSITS

LOCATION AND GENERAL GEOLOGY

The deposits now being mined and several others yet undeveloped lie in the very much dissected plateau through which the Salt River and its tributaries have cut their channel, northeast of Roosevelt Lake. The deposits are far from the railroad, necessitating careful sorting and milling to make them commercial.

The hills in which the deposits occur consist of a basecent of pre-Cambrian granite overlain by the Apache series of sediments of Algonkian or early Cambrian age. This series consists of shale beds overlain by a thick quartzite member with a basal conglomerate, overlain by impure, cherty limestones, capped by a second thick quartzite bed. The whole series has been extensively intruded by dikes and sills of diabase. The asbestos deposits occur at or near the contact of the diabase sills and the impure limestone. The usual contact mineral formed is serpentine. Where the serpentine has been subjected to peculiar conditions of pressure or through other causes it has crystallized into asbestos, the fibres being at right angles to the bedding and diabase contacts. This is known as cross fibre asbestos.

MINING PROPERTIES

There are three producing mines, those owned by the Arizona Asbestos Association at Chrysotile, the Regal Asbestos Company Mines, and the Accident group owned by R. M. Anderson. Several other deposits are located.

MINING

The mining is conducted in a very similar manner to that of thin coal seams. No definite system is used. Considerable sorting is done
and generally the waste is used as fill. The deposits are generally flat, and the mines are entered by tunnel run on the bed.

The value in these deposits lies in the high proportion in the beds of long fibre material, capable of being hand sorted. This material with fibres over 3/4 inch long is known to the trade as Crude No. 1, and commands a high price. Crude No. 2 containing fibres from 5/16 to 3/4 inch long commands a smaller price, but sufficiently high to mine at a profit. The proportion of Crude No. 1 and Crude No. 2 runs as high as 20 percent in the better parts of the veins, and varies from 10 percent to 20 percent. The run of mine material is carefully hand-sorted and Crude No. 1 and Crude No. 2 are saved, sacked, and shipped, and the poorer material stored in stock piles.

LABOR

The labor employed in the mines is Mexican, and a good deal of the work is done by contract. About 230 men are employed in the district in asbestos mining.

PRODUCTION

In 1925, the Arizona production amounted to about 90 tons, and the output increased materially in 1926 and 1927.

PERSONNEL OF OPERATING COMPANIES

<table>
<thead>
<tr>
<th>Mine</th>
<th>Superintendent or Manager</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona Asbestos Association</td>
<td>Frank Knuckey</td>
<td>Chrysotile</td>
</tr>
<tr>
<td>Regal Asbestos Mine</td>
<td>John L. Alexander</td>
<td>Rice</td>
</tr>
<tr>
<td>Accident group</td>
<td>R. M. Anderson</td>
<td>Globe</td>
</tr>
</tbody>
</table>

The mines have been described in the following article:

CINNABAR (MERCURY) MINING

INTRODUCTION

Cinnabar has been known in the State for many years, and has been mined sporadically from a number of deposits, scattered over a wide area. At present only one locality is being exploited. Here quite extensive low grade deposits exist. The district is handicapped by its inaccessibility, making for high operating costs.

MAZATZAL MOUNTAIN DEPOSITS

This range of mountains lies to the north and east of Roosevelt Lake, between the valleys of the Verde River and Tonto Creek. The nearest railroad point is Miami.

The range is made up of pre-Cambrian schists, granites, and quartzites. On the western flanks of the range, Tertiary andesites and basalts have partly covered the pre-Cambrian complex. The cinnabar deposits occur as veins in schist accompanied by pyrite, quartz, calcite, and impure siderite. A little serpentine and tourmaline also occur in some of the veins. The deposits are situated in Slate, Alder, and Sycamore creeks, and are reached by wagon roads off the Pine-Payson Highway.

OPERATING COMPANIES

The principal operating company is the Tonto Mining Company, whose holdings are in Slate Creek. Most of the work has been exploratory and little stoping has been done. Several stills have been erected which are run intermittently.

The personnel of the company is as follows:

General Manager.......................................................L. E. Foster
Superintendent.........................................................M. J. McGrath

The mines have been described in the following publication:

MOLYBDENUM AND TUNGSTEN MINING

INTRODUCTION

Mining for rare metals such as these is usually done on a small scale and intermittently, due to great variation in price and very limited demand. During the war years the unusual prices and demands for these two metals much stimulated their exploitation, and a number of deposits were actively worked. Since the end of the war, a little mining has been done and a few new deposits developed.

PATAGONIA MOUNTAINS

During 1927, a rich deposit of molybdenite, molybdenum sulphide, was discovered and developed at the Santo Niño Mine, southwest of Washington camp, closely associated with a deposit of chalcopyrite. This deposit occurs at the bottom of a vein-like deposit of chalcopyrite in quartz monzonite. Several carloads of hand-sorted ore were shipped during the year.

HUACHUCA MOUNTAINS

Several deposits of scheelite, calcium tungstate, were actively developed during 1927, but no shipments were made.

LITTLE DRAGOON MOUNTAINS

During the year, a little work was done on the placer deposits of hubernite, manganese tungstate, occurring at Russelville, but no shipments were made.

MISCELLANEOUS DEPOSITS

Deposits of molybdenite occur in the Santa Rita Mountains near Helvetia, and deposits of wulfenite (lead molybdate) occur in the Empire Mountains, at the Mammoth Mine, Vulture Mine, Tucson Mountains and a great number of other localities, associated with oxidized lead ores.
FELDSPAR MINING

The only deposit of feldspar actively exploited is situated in the Cerbat Mountains, near the town of Kingman. The deposit consists of nearly pure orthoclase (potassium-alumine silicate) occurring in a pegmatite dike in pre-Cambrian gneiss. The product is mined and shipped without treatment to ceramic plants in California. About 2,100 tons was produced in 1927. The deposits are operated by the Gold Cliff Central Company, George B. McDevitt, of Kingman, manager.
GYPSUM MINING

Impure gypsum is mined from a playa deposit east of the town of Douglas, in the Sulphur Springs Valley. Mining is done by scrapers, and the product trucked to Douglas where it is burnt to form plaster, marketed as Douglas Plaster. The deposits are worked intermittently.
ONYX MINING

Two deposits of onyx occur in the State and both have been actively exploited. One occurs at Mayer, 15 miles southeast of Prescott, and was formed by extinct hot springs. The deposits are quarried extensively and steady shipments made of fine ornamental stone. The deposits at Cave Creek north of Phoenix have been developed, but only small shipments made. They are also extinct hot springs deposits.

OPERATING PROPERTIES

The principal operating company in the State is the Yavapai Onyx Mining Corporation, actively exploiting the Mayer deposits. A second company, the Arizona Onyx Products Company, was organized at the end of the year to quarry the Cave Creek deposits.

MAYER OPERATIONS

The Yavapai Onyx Mining Corporation has large quarries north of Mayer on the bank of Big Bug Creek. The deposits consist of bedded calcite and aragonite beautifully colored by iron oxides. The contrast of the white to light green material with different shades of red stained material, make a beautiful ornamental stone when polished. Especially popular is a unique dark green and red variety known as "Paisley shawl" onyx. The thickness of the deposit varies from a few inches to 25 feet, and covers an area of about a square mile. It is quarried in large slabs, and shipped to the company's finishing plant at Dyersville, Iowa.

CAMP CREEK OPERATIONS

The Arizona Onyx Products Company is planning extensive quarrying of their deposits on Camp Creek west of Cave Creek, about 52 miles north of Phoenix. Here the deposit consists of boulders of calcite and aragonite in soft travertine. These boulders are cemented together with plaster of paris, sawed into blocks, and then polished. The finishing plant of this company is at Phoenix.

PERSONNEL OF OPERATING COMPANIES

Yavapai Onyx Mining Corporation

President ........................................... Joseph A. Kelly
Vice President ...................................... J. H. Devaney
Secy. and Asst. Treasurer.......................... J. W. Walsh
Director of Sales.................................. F. J. Lawlor
Manager............................................. W. O. Belford

ARIZONA ONYX PRODUCTS COMPANY
President and Manager.............................. Omar B. Carter
Vice President....................................... Fred Derck
Secretary-Treasurer................................ Thos. C. McReynolds, Jr.
LIMESTONE QUARRYING

Limestone is quarried extensively in two localities: at Cedar Glade between Prescott and Ash Fork, and at Forrest Station between Douglas and Bisbee. At Cedar Glade, the formation quarried is Carboniferous limestone. Mining is done in open pits, and the broken limestone trammed to kilns where it is burned and shipped as lime. At Forrest Station, an outcrop of Cretaceous limestone is quarried by cutting a bank into the formation. The broken limestone is loaded into railroad cars and shipped to the smelters at Douglas for flux. A little is also used as road material.
OIL PROSPECTING

Drilling for oil is being pursued in a number of localities in the State, but oil in commercial amounts has not yet been found.

HOLBROOK AREA

In this area considerable drilling has been done in the past and drilling is now under way to test favorable structures in the outcropping Permian Kaibab formation. Drilling is testing the underlying Carboniferous formations. A little gas has been encountered, and a few thin oil sands, but no commercial oil to date.

INTER-MOUNTAIN VALLEYS

Drilling is under way to test the possibilities of the thick late Tertiary and Quaternary Valley fills occurring widely distributed in the State. Oil sands have been reported from drilling in the San Simon Valley near Bowie, but no commercial oil encountered. The formations drilled are all either flood plane deposits or playa deposits. This type of deposit has not produced oil elsewhere. Drilling is also being undertaken in the Salt River Valley, Sulphur Springs Valley, San Pedro Valley, and Colorado River Valley in similar formations.
COAL MINING

Coal beds are found in three localities in the State, in upper Cretaceous formations. The most extensive exposures are in the Black Mesa in the northeast corner of the State, in the Navajo and Hopi Indian reservations. Some mining is done there to supply local needs at the Indian agencies at Tuba City and Keams Canyon. Coal is mined from the Mancos Shale and Mesaverde formations. A section at the mine 14 miles southeast of Tuba City is given by Gregory\(^1\) as follows:

<table>
<thead>
<tr>
<th>Feet</th>
<th>Inches</th>
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<tbody>
<tr>
<td>1.</td>
<td>4</td>
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<tr>
<td>2.</td>
<td>6</td>
</tr>
<tr>
<td>3.</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>8</td>
</tr>
<tr>
<td>6.</td>
<td>1</td>
</tr>
<tr>
<td>7.</td>
<td>1</td>
</tr>
<tr>
<td>8.</td>
<td>1/2</td>
</tr>
<tr>
<td>9.</td>
<td>3 6 1/2</td>
</tr>
<tr>
<td>10.</td>
<td>6</td>
</tr>
<tr>
<td>11.</td>
<td>15</td>
</tr>
<tr>
<td>12.</td>
<td>4</td>
</tr>
<tr>
<td>13.</td>
<td>10</td>
</tr>
</tbody>
</table>

This mine is in Mancos Shale.

At the Keams Canyon Mine, the following section is given by Gregory. These beds are part of the Mesaverde formation.

<table>
<thead>
<tr>
<th>Feet</th>
<th>Inches</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>30</td>
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<tr>
<td>2.</td>
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<td>3.</td>
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<td>4.</td>
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<tr>
<td>7.</td>
<td>2</td>
</tr>
<tr>
<td>8.</td>
<td>5</td>
</tr>
</tbody>
</table>

\(^1\)Gregory, H. E., Geology of the Navajo Country. Prof. Paper, U. S. Geol. Surv., 1917; pp. 142-144.
Gregory states: "At a number of points along the rim of Black Mesa, coal beds exceeding 2 feet in thickness were noted, and groups of strata 10 to 20 feet in thickness, including shale and coal from which 3 to 5 feet of coal might be obtained, are not uncommon."

Gregory further states: "The coal from Black Mesa varies greatly in quality. Near Blue Canyon, specimens were obtained which were firm and broke with a fracture similar to that of high-grade bituminous coal. On the other hand, coal beds 6 to 8 inches thick at two localities between Chilchinbito and Marsh Pass consist essentially of carbonized plant fragments embedded in sand and clay. . . . In general the coal from the upper beds of Black Mesa may be classed as sub-bituminous. . . . Dry samples from the Tuba Mine, analyzed in the Survey laboratory, contained 15.1 percent ash and showed a heat value of 6,415 calories or 11,550 British thermal units. The corresponding figures for the Oraibi coal are 11.78, 6,660 and 11,980. As compared with the coal from the Gallup area, the Black Mesa coals, so far as indicated by two analyses, have much more ash and a slightly lower calorific value, but a higher percentage of fixed carbon."

Similar coal seams are found north of Mogollon Rim, about 45 miles south of Holbrook, near Pinedale. Veatch\(^1\) reports coal beds in two horizons, separated by from 10 to 12 feet of shale, the upper beds being composed of bony coal, and the lower beds of better grade. Thicknesses of coal from this lower bed vary from 1 foot 7 inches to 3 feet. No analyses were taken.

The Deer Creek coal field lies in Reed Basin, northwest of the Santa Teresa Mountains, southeast of Christmas. Coal occurs here in Upper Cretaceous formations, interbedded with volcanic material. The series has been much faulted and folded, resulting in considerable crushing of the coal. High ash and much interstratified shale and bone characterize these beds, which are generally lenticular in form and from

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10 to 36 inches in thickness. Attempts at producing coke resulted in a very friable product of doubtful value. The field has been described in the following publication:

MANGANESE MINING

The mining of manganese was actively pursued during the abnormal war price period. In 1927 only one district produced, the Bisbee district. The ore occurs there in high grade lenses in limestone near the surface, and is being mined from open pits.
SALT AND THENARDITE (SODIUM SULPHATE) MINING

INTRODUCTION

This mining is confined to the deposits at Camp Verde, southeast of Clarkdale, in the valley of the Verde River. The deposits consist of lake deposits of late Tertiary or early Quaternary age, associated with thick deposits of marl, limestone, and silt, known as the Verde formation. The salts composed of thenardite, glauberite, halite, gypsum, and minor amounts of calcium and magnesium chlorides, were formed by natural selective evaporation and crystallization in certain parts of the formation. They are being exploited by the Sodium Products Corporation.

MINING METHODS

Mining is being done by a power shovel which works in a bank of salt on the west side of the Verde River, about 2 miles southwest of Camp Verde. Hand held drills are used for primary drilling and for block-holing large pieces. The impure broken salt is loaded into motor trucks and transferred to a receiving bin through a grizzly, the oversize being sledged down by hand.

TREATMENT

The bin delivers to a Jeffrey crusher, crushing to 1½-inch ring, discharging to a belt conveyor delivering to an intermediate storage bin. From this bin automatic feeders deliver to a conveyor delivering to a series of log washers, the first in the series consisting of two washers side by side, the remaining washers following in tandem. These washers remove included clay and dissolve as much as possible of the sodium chloride. Washing is done by spraying clear water from perforated pipes above each washer, the water being under 30 pounds pressure. No water is reclaimed, and some sulphate is lost in the process. The final washed material is delivered upon impact screens, removing surplus water, which discharges onto a belt conveyor delivering to a cylindrical oil-fired drier 8 feet in diameter and 50 feet long. The function of this drier is three-fold: to dry the wet product; to dehydrate gypsum into a powder; and to transform glauberite into a powder. These last two substances are later screened out as dust. The dried material is delivered to a bucket elevator and discharged upon an impact screen, removing minus ¼-inch, and sending oversize to a
set of rolls. Undersize is stored upon a dump. The roll product is delivered by a series of screen conveyors, the troughs of which are punched plate screens. The material is thus sized into $\frac{3}{4}$ to $\frac{1}{2}$-inch ten-mesh to $\frac{3}{4}$-inch and minus 10 mesh, and is delivered to separate bins. The sized material from the bins is hauled by motor truck to Clemen-ceau for shipment to the market. Power for operations is furnished by the Arizona Power Company. About twenty motors are used in the plant with an aggregate of about 245 h.p.

LABOR

American and Indian labor is employed and an average of about 15 to 20 men are on the payroll.

PRODUCTION

Operations in 1927 have been underway since March 1, and about 16,500 tons of sodium sulphate produced, with about a grade of 95 percent sodium sulphate, 2.3 percent insoluble, 0.3 percent magnesium sulphate, 1.3 percent calcium sulphate and 1.8 percent chlorides. A little sodium chloride is sorted out at the mine and sold to cattlemen.

PERSONNEL OF SODIUM PRODUCTS CORPORATION

President and General Manager.............................................R. W. Coad
Superintendent.................................................................James Allen
Asst. Superintendent.........................................................John Quinn

The deposit and operations have been described in the following article:

Young, George J., Mining Sodium Sulphate at Camp Verde, Arizona, E. & M. J., July 16, 1917, p. 97.
APPENDIX
ORE MARKETS
COPPER ORES

There are the following customs smelters treating customs copper ores mined in the State:

- Copper Queen Reduction Works, Douglas, Arizona
- Hayden Smelter, Hayden, Arizona
- El Paso Smelting Works, El Paso, Texas
- International Smelter, Miami, Arizona
- Magma Smelter, Magma, Arizona

The Calumet and Arizona smelter treats a limited amount of customs ore on special contract. The treatment rates can be obtained by applying to the above plants.

LEAD ORES

The following plants treat customs lead ores and concentrates:

- Copper Queen Reduction Works, Douglas, Arizona
- El Paso Smelting Works, El Paso, Texas

The treatment rates can be obtained from the above plants on application.

ZINC ORES AND CONCENTRATES

The nearest zinc reduction plants, treating customs ore are the following:

- United States Zinc Co, Amarillo, Texas
- Bartlesville Zinc Co, Bartlesville, Oklahoma

The open schedule on zinc concentrates at the Bartlesville Zinc Company plant is as follows:

- Zinc: Pay for 80 percent at St. Louis spelter quotation less $0.001 per pound of zinc paid for.
- Treatment charge: Twenty Dollars ($20.00) per ton of concentrates, dry weight, when spelter is quoted at 6 1/2c St. Louis or less; for each 1c increase over 6 1/2c, add $2.50 per ton of concentrates.
- Lime: One percent free, excess penalized at the rate of $1.00 per unit.
- Delivery: F.O.B. Bartlesville, taking a rate of about $6.60 from Arizona points.
- Payments for gold, silver, lead and copper: Pay for 65 percent at New York quotations, less a treatment charge of $5.00 per ton of
concentrates. No payments and no added treatment charge if value is less than $5.00.

MOLYBDENUM AND TUNGSTEN ORES AND CONCENTRATES

The market for the ores and concentrates of these metals is very limited, and the prices varied and somewhat nominal.

For molybdenite concentrates, as nearly clean product as possible is desired free of copper, the usual Arizona impurity. The largest ultimate consumers are the manufacturers of molybdenum steel. Concentrates are bought by brokers.

The tungsten market is also a very limited one, and the greater bulk of the ores imported. The marketing center is New York.

MANGANESE ORES

The principal consumers of these ores are the makers of manganese steel. Most of the manganese ore used is imported, and only the highest grade material can be commercially handled in Arizona. It is marketed directly to the steel mills using it, these mills being situated on the Atlantic seaboard.

FELDSPAR

This is used almost exclusively in the ceramic industry. The nearest markets are the California ceramic plants, centered around Los Angeles, to which it is sold direct.

THENARDITE

This is used in the paper pulp mills and in the manufacture of stock remedies and glass. The demand for acid-free high grade product is good. It is sold direct to the consumers.

ASBESTOS

The asbestos market is controlled by the Canadian producers. The long fibre high grade crude commands a premium and finds a ready market to manufacturers of asbestos cloth.

MERCURY

The nearest market for mercury is at San Francisco. The market is poorly organized.

ONYX

The Yavapai Onyx Corporation product is shipped to Dyersville, Iowa for finishing, and the polished onyx slabs are sent to Chicago where the company maintains a show room at 30 North Michigan Avenue. The principal consumers are the building trades.
EXPLORATION COMPANIES

MODEL REPORT

A model for a report on a property submitted for sale is given below. This was furnished by Julius Kruttschnitt, Jr. of the American Smelting and Refining Company, Tucson, Arizona.

ELEMENTS OF REPORTS ON MINE EXAMINATION

The following brief analysis of the subdivisions and arrangements of a report on the examination of a mine or prospect is designed to serve as a guide to students and engineers and not as a comprehensive presentation of all the elements and phases involved.

I. Purpose and Scope of Report

A report should represent an orderly exposition of data obtained in the course of an investigation. The data thus gathered should be sufficiently comprehensive to form the basis of a logical conclusion.

Objects of a Mining Report

1. In case of a prospect or partially developed mine the objects are:
   (a) To determine the geologic and economic merits of the property.
   (b) To estimate the financial outcome based on an assumption as to metal content of ore expected.
   (c) To outline a campaign of exploration.

2. In the case of a developed deposit with ore reserves the objects are:
   (a) To determine the volume and average metal content of the ore exposed.
   (b) To ascertain the amenability of the ore to some economical metallurgical treatment.
   (c) To determine the productive capacity of the mine.
   (d) To estimate the financial outcome.
   (e) To calculate the present value as a criterion of the price which might safely be paid for the deposit.

II. Summary and Conclusions

This heading should include a brief summary of conditions and findings, and a condensed statement of conclusions and recommendations. Contrary to the usual practice, this should be placed at the very begin-
ning of the report, following introductory statement relative to purpose and scope of report.

III. Location and Description

Under this caption the location of the property should be briefly stated with reference to geography, mining districts, and transportation facilities. Mention should be made of means of reaching property. A location sketch is also helpful. The extent of the property and its general physical aspect should be described.

IV. History

A short historical sketch is of occasional interest; and in cases where mines have produced, a study of production statistics is important and should be presented.

V. Geology and Mineralization (Important)

1. Areal and structural geology with special reference to appearance, width, and persistence of outcrops and other surface manifestations of mineralization. In important cases a surface geologic map is most helpful in clarifying the subject and minimizing the text.

2. Geology and mineralization as revealed underground should be depicted clearly and concisely; and supported by maps when warranted.

A word picture of the type of mineralization and mode of occurrence is important; also a fairly detailed description of the ore-minerals and associated gangue-minerals, supported when necessary by illustrations, photomicrographs, etc.

General—At this stage, the examination of a prospect, including a few samples, usually ends here, unless conditions of unusual interest are found.

VI. Faulting

In cases where the operations and the continuity of the ore are apt to be affected by faulting, the fault problem should be given serious consideration.

VII. Development

Under this heading should be described the manner in which the deposit has been developed, and the extent and condition of the underground workings (supported by suitable mine maps).

VIII. Sampling and Estimation of Ore Reserves

The method of sampling and the interval between samples should be presented, as well as the ways in which sampling and assaying were checked. The treatment of erratic values should be clearly stated.
The factors used in estimating tonnage should be explained, and the extensions of ore beyond working faces should be consistent with the general behavior of the mineralization.

Factor for reducing cubical contents to tons.

Moisture determinations.

Complete assay plans should be attached to the report showing the position, width, and assays of individual samples.

Important. Except in the case of gold mines, assay results should never be posted in terms of dollars, but in ounces and percentages.

Longitudinal sections should accompany the report showing the tendency of ore shoots and limits of ore blocks. It is helpful to post on each block the average grade and tonnage as calculated.

IX. Ore Tests

Tests for a suitable metallurgical process should be made where concentration of values is feasible or desirable. The sample for such tests should be carefully prepared and represent a composition of the mine sampling. The results of the test should be briefly shown in the body of the report or as an appendix.

X. Productive Capacity of Mine

The productive capacity of most mines, and particularly those of the vein type, possess certain limitations subject to determination or close approximation. The ability of a mine to produce a given tonnage of such and such grade is often an important factor in the calculation of financial outcome of current operations, and therefore deserves an important place in the report.

XI. Operating Costs

Operating costs, being a controlling factor in the financial outcome of a mining venture, deserve careful analysis, and may be determined closely.

1. Direct Costs
   Development (Factor)
   Mining (Detailed Estimate)
   Milling (Detailed Estimate)

   The minimum factor in the average mine may be stated as the amount of development work (expressed in feet or dollars) necessary to make available one ton of ore to replace each ton extracted. This factor is usually guessed at, but may be closely estimated.
2. Indirect Costs
   Outside general office expense.
   Taxes
   Insurance (Liability, fire, etc.)
   General Expense Visiting officials
   Consulting engineers
   Auditing
   Boarding-house
   Care of grounds
   Town, maintenance, lighting, sanitation

XII. Estimate of Outcome

Estimates of outcome should be given in detail and based on—
1. Shipping products shown in mill tests or crude ore
2. Smelting schedules actually quoted
3. Costs as carefully estimated
4. Average metal selling prices, and for varying prices

XIII. Appraisal and Present Value

Appraisal of the value of ore reserves and future possibilities (in partially developed or uncertain cases).

Present value can be determined in cases where ore deposits are approximately delimited or the probable life of the property reckoned.

XIV. Future Development

A more or less definite program of future development should be mapped having in view the enlargement of the then scale of operations or the maintenance of the same by making available currently at least as much new tonnage as is being extracted.

XV. Factors Affecting Operations

1. External
   a. Labor conditions & supply
   b. Water
   c. Fuel
   d. Power
   e. Transportation
   f. Topography
   g. Supplies in general
   h. Equipment, mine and mill

2. Internal
   a. Hardness of rock
   b. Condition of walls
   c. Mining methods
   d. Tramming
   c. Drainage
   f. Ventilation
   g. Equipment

XVI. Titles

Mining engineers are seldom equipped to pass on the legality of titles. Competent counsel should be employed by the examining engineer or
his client to pass on the legal phases of a transaction involving the purchase or lease of a mine. The evidence of ownership or good title may pertinently be discussed by the engineer prior to undertaking an expensive examination.

General. Should include a study of the business administration as affecting—(a) Engineering technique; (b) Operating methods; (c) Management and accounting methods; (d) General efficiency of operations.

Requisites
1. Clearness and conciseness of expression.
2. An observance of sequence in the presentation of facts.
3. Data offered in support of conclusion should be the result of close personal observation and physical measurements, and in sufficient detail so that calculations may be checked by some other engineer.
4. Thoroughness and accuracy.

EXPLORATION COMPANIES

The following companies maintain exploration departments:

AMERICAN SMELTING AND REFINING COMPANY
Julius Kruttschnitt, Jr., Manager..................................Tucson, Arizona

PHELPS DODGE CORPORATION
P. G. Beckett, Manager..............................................Douglas, Arizona

PHELPS DODGE CORPORATION, COPPER QUEEN BRANCH
J. P. Hodgson, Manager..............................................Bisbee, Arizona
(Lead Properties)

CALUMET AND ARIZONA MINING COMPANY
H. A. Clark, General Manager.....................................Warren, Arizona

UNITED VERDE COPPER COMPANY
Robert Tally, General Manager.....................................Jerome, Arizona

UNITED VERDE EXTENSION MINING COMPANY
George Kingdon, General Manager..............................Jerome, Arizona

SHATTUCK-DENN MINING CORPORATION
T. O. McGrath, General Manager.................................Bisbee, Arizona
EAGLE PICHER LEAD COMPANY
Geo. W. Potter, Vice President.........................Picher, Oklahoma

UNITED STATES SMELTING, REFINING & MINING COMPANY
D. D. Muir, General Manager..........................Salt Lake City, Utah

MAGMA COPPER COMPANY
William Koerner, General Manager....................Superior, Arizona

TOM REED GOLD MINING COMPANY
Victor Light, Purchasing Agent.......................Oatman, Arizona
APACHE POWDER COMPANY PLANT

Curtis, Arizona, P. O. Benson, Arizona

This plant has a capacity of 18,000,000 pounds of explosives per annum. It consists of a department for manufacturing nitric acid, and a dope manufacturing department where such materials as wood pulp, cotton, flour, cornmeal, etc., are prepared. Every precaution is taken to prevent accidents. In each building where explosives are handled not more than two men are allowed at one time. The buildings are widely separated from one another and are protected by embankments of fine sand.

The nitroglycerine is made by mixing fuming sulphuric acid (from Company’s plant at Douglas Smelter of Calumet and Arizona Copper Company) with purified nitric acid and glycerine.

The nitric acid is the active agent. The sulphuric acid is separated in the process, recovered and concentrated. Nitroglycerine is mixed with dope in batches of 1,000 pounds to form dynamite. Guncotton is used in place of nitroglycerine in the production of blasting gelatine. The paper cartridges are made by machinery, those to be used for blasting gelatine are dipped in hot paraffin.

The blasting gelatine cartridges are loaded by hand but the dynamite by mechanical loaders.

In European practice the dope used is infusorial earth (Kieselguhr). Forty-percent powder means 60 percent infusorial earth (which is inert) and 40 percent nitroglycerine.

In modern American practice the dope is selected for its active properties and no inert dope is used. The powder is graded 40 percent when it has the same power as the corresponding European powder of 40-percent grade.

The powder is packed in wooden boxes each holding 50 pounds. These boxes are made in the plant. They are dovetailed at the corners but nailed top and bottom in nailing machines that drive all the nails for top or bottom in one operation.

Rigid tests are applied to all materials entering into the manufacture of the explosives. Similarly all finished products are tested before shipment from the plant. Each batch is separately tested for ballistic strength, sensitivity and by lead block test to determine explosive strength.

Xanthate is also manufactured by the company and sold to concentrators using the flotation process.
A research laboratory is maintained as well as the works laboratory. In the former, numerous flotation tests are made on various ores with different reagents.

The industrial railway is operated by H. K. Porter Company's fireless locomotives. A fireless locomotive consists of a tank and cab mounted on trucks. The tank is filled two-thirds with water, then steam is added until the temperature of the water is raised to 352° F.

The steam is delivered to the cylinders through a reducing valve at an operating pressure of 25 pounds per square inch.

For ordinary switching purposes the locomotive can be used continuously for 3 hours before requiring recharging. There is no firebox, no fire, no risks from sparks, no staybolt, no boiler repairs, no scale, no danger of explosion and no noise. One man can operate it. It can be used as a fire engine by attaching a hose to the blow-off pipe.
INDEX

Accident Group, 101, 102.
Acid Plants, 18, 19.
Ajo District, 51.
Alder Creek, 103.
Aldrich, H. W., 34, 39.
Alexander, John L., 102.
Allen, A. W., 53.
Allen, Jas., 116.
Allen, H., 40.
Allen, R. S., 38.
Allis-Chalmers Ball Mill, 62.
Allison Mine, 99.
Allsman, P. T., 50.
Amadoville, 88.
Ambler, J. O., 22.
American Filter, 89.
American Smelting & Refining Company, 123.
Ander Copper Company, 69.
Andes Copper Mine, 75.
Anglesite Mining and Development Co., 98.
Apache Powder Company, 19, 125-126.
Apache Sediments, 101.
Arivaipa District, 92.
Arivaipa Mining Corporation, 92.
Arizona Asbestos Corporation, 101, 102.
Arizona Commercial Mining Company, 24.
Arizona Copper Company, 60.
Arizona Eastern Branch of S. P. R., 40.
Arizona Onyx Products Co., 107.
Arizona Power Company, 40, 71.
Arizona Redlands Copper Company, 70, 71.
Arizona and Swansea Railroad, 73.
Arnold, C. E., 29.
Asbestos Market, 118.
Asbestos Mining, 101, 102.
Ashton, F. V., 38.
Atchison Topeka and Santa Fe Railroad, 45.
Akins Classifier, 30, 31.
Ayer, Frank, 64.
Baboquivari Mountains, 99.
Bagdad Deposit, 75.
Bag House, 80, 82.
Ballard, Leslie, 39.
Bancroft, Howland, 74.
Banner Mine, 87.
Barbara Mining Company, 70, 71.
Barium Carbonate, 79.
Barker, L. M., 51.
Barkdoll, I. H., 38.
Barr, A. T., 58.
Bartlesville Zinc Co., 117.
Beale, C. J., 51.
Beale, L. R., 72.
Beckett, P. G., 21, 123.
Belford, W. O., 108.
Belmont Copper Mining Company, 65, 67.
Benedict, P. C., 46.
Benefit Association
Copper Queen, 20.
Calumet and Arizona, 20.
New Cornelia, 58.
Bible, Harry, 39.
Big Bug Creek, 107.
Big Horn Mountains, 83.
Bill Williams River, 74.
Bisbee, 9.
Bisbee Queen Development Company, 10, 12.
Bisbee-Douglas District
Copper Mining, 9-23.
Lead Mining, 78-82.
Manganese Mining, 114.
Bishop, F. L., 39.
Bishop, H. J., 22.
Bjorge, Guy N., 38.
Black Bess Mining Company, 92.
Black Mesa, 111.
Blaisdell Excavators, 31.
Blaisdell Tanks, 13.
Blake Crusher
Ajo, 54.
Magma, 66.
Black Hills, 45, 46.
Black or River Range, 93.
Blackman, R. E., 45.
Blackner, Lester A., 42.
Blast Furnace, 15, 48, 49, 80, 81.
Block Caving
Miami, 23-27.
Inspiration, 24-25.
Old Dominion, 24.
Ray, 41-42.
Morenci, 60-61.
Bisbee, 11.
Blue Bell Mine, 70, 71.
Blue Bird Mine, 85.
Blue Range, 59.
Blumfield, A. L., 96.
Booth, G. H., 29, 39.
Bonillas, Y. S., 10.
Bonus System
Copper Queen, 20.
United Verde, 49.
Bowie, 23, 110.
Bowie, J. R., 64.
Bradshaw Mountains, 70, 91.
Brown, Moses J., 45.
Browning, W. C., 65.
Buckskin Mountains, 73.
Buell, L. T., 22.
Bunker Hill Mines, 97.
Burch Ring Grizzlies, 53.
Burch, H. Kenyon, 29, 33, 57.
Burch Ring Grizzlies, 53.
Burch, H. Kenyon, 29, 33, 57.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch, H. Kenyon, 29, 33, 57.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
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Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
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Burch Ring Grizzlies, 53.
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Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
Burch Ring Grizzlies, 53.
MINERAL INDUSTRIES OF ARIZONA

Crofoot, Arthur, 63, 64.
Cunningham Pass District, 77.
Curley, M., 58.
Cut and Fill Mining Method
  Christmas, 42.
  Jerome, 46.
  Superior, 65.
  Bisbee, 10.
Dacite, 23, 36.
D'Arcy, R. L., 51.
Davenport, F. S., 22.
Davey, A. J., 40.
Davey, Thos. S., 72.
Dawe, George, 22.
Deacon, W. D., 51.
DeCamp, W. V., 49, 50.
Deer Creek Coal Field, 112.
DeKalb, Courtenay, 18, 53.
Derek, Fred, 108.
DeSoto Mine, 71.
Detroit Copper Company, 60.
Devaney, J. H., 107.
Devonian Limestone, 46.
Diabase, 23, 101.
Dickson, Robert H., 11, 51.
Diesel Plant
  Copper Queen, 19.
  Old Dominion, 35.
  Clifton, 63.
  Central Copper Company, 73.
  Katherine, 95-96.
Diester Cone-Baffle Classifier, 33.
Dimmick, R. L., 95, 96.
Disseminated Copper Deposits
  Bisbee, 9.
  Miami, 25.
  Ray, 41.
Don Luis, 9.
Dontzer, E. G., 67.
Dorr Bowl Classifier, 12.
Dorrco Pressure Pump, 83.
Dorr Circulating Classifiers
  Copper Queen Concentrator, 13.
  Old Dominion Concentrator, 30.
  Miami Concentrator, 32.
  Inspiration Concentrator, 33.
  New Cornelia Concentrator, 56.
  Morenci Concentrator, 62.
  Sheldon Concentrator, 70.
  Tonopah Belmont Concentrator, 83.
Dorr Tray Thickener, 13.
Dorr Thickeners
  Copper Queen Concentrator, 13.
  Old Dominion Concentrator, 30.
  Miami Concentrator, 32.
  Inspiration Concentrator, 33.
  New Cornelia Concentrator, 56.
  Morenci Concentrator, 62.
  Magma Concentrator, 66.
  Sheldon Concentrator, 70.
  Tonopah Belmont Concentrator 83.
Montana Operations Concentrator, 89.
Dos Cabezas, 72.
Dos Cabezas District
  Copper, 72.
  Gold, 99.
Dos Cabezas Mountains, 72.
Douglas
  Copper, 9.
  Gypsum, 106.
Dragoon Mountains, 68, 91.
Dripping Spring Mountains, 40, 100.
Drysdale, Geo. R., 21.
Duffey, R. K., 50.
Du Moulin, W. L., 57, 58.
Duncan, H. S., 38.
Duncan, 100.
Dunlap, R. D., 39.
Duro Brick, Tile, and Cement, 18.
Dutton, C. W., 45.
Dwight Lloyd Sintering Machine, 81.
Dyersville, Iowa, 107.
Dyanan, John L., 84.
Eagle Creek, 63.
Eagle Picher Lead Company
  Exploration Dept., 124.
Elma Mine, 72.
El Paso Smelting Works, 112.
Elzing, M. J., 23.
El Tiro Mine, 74.
Empire Mountains, 84.
Empire Wash, 84.
Engelder, Arthur, 22.
Engelder, O. G., 51.
English, J. H., 51.
Eureka Mine, 93.
Eustace, W. J., 39.
Ezell, R. I., 44.
Farragh, J. L., 39.
Farrell, Blake-type Crusher, 79.
Faust, P. A., 40.
Pearing, J. L. Jr., 46.
Feldspar Market, 118.
Feldspar Mining, 105.
Feuchere, Leon, 10.
Flagstaff, 70.
Flannagan, J. F., 68.
Flinn, H. P., 94.
Flynn, F. N., 63.
Foraker, B., 67.
Forrest Station, 109.
Forrester, D. L., 38.
Forrester Flotation Machines
  Copper Queen Concentrator, 13.
  Old Dominion Concentrator, 30.
  Morenci Concentrator, 62.
Fortuna Mine, 99.
Foster, L. E., 103.
Franklin, E. J., 44.
Fredell, E. W., 50.
French, S. W., 71.
Gahl, Rudolph, 33.
Galiuro Mountains, 76, 85.
Garfield Rolls, 42.
Garms, Walter I., 43, 45.
Gardner, E. D., 103.
Gates Gyratory Crushers, 53.
Gay Lussac Towers, 18.
Germania Group, 69.
Gila Mountains, 77.
Gila River, 23, 40, 59.
Giroux, Frank W., 69.
Gleeson, John, 69.
Globe Hills, 23.
Glover Towers, 18.
Golconda, 87.
Golconda Mine, 87.
Gold Cliff Central Company, 105.
Gold and Silver Mining, 93-100.
Goldman, H. L., 51.
Gold Ore Mining Company, 93.
Gold Road, 93.
Good, N. S., 45.
Goss, W. P., 47.
Grand Canyon Deposits, 101.
Grand Gulk Mine, 77.
Grand Wash Cliffs, 77.
Granite, 68.
Granite Porphyry, 9.
Grant, F. R., 29.
Graybeal, E. V., 40.
Greaterville Placers, 99.
Great Tennessee Mining Company, 87.
Great Western Copper Company, 69.
Green, R. B., 51.
Greenwood, A. I., 51.
Gregory, H. E., 111-112.
Groom Prospect, 71.
Gungho District, 76.
Guyn, C. L., 50.
Gypsum Mining, 106.
Hansen, M. F., 50.
Harcouvar Mountains, 77.
Hardinge Mill
Miami Concentrator, 32.
Morenci Concentrator, 62.
Hardshell Mine, 85.
Harper, J. B., 84.
Hastings, J. L., 21, 38.
Hawley, F. G., 40.
Hayden, 40.
Hayes, F. H., 22.
Helmet Peak Mining Company, 90.
Helvetia, 104.
Henrie, H. C., 20, 22.
Hensley, J. H. Jr., 40.
Herreschoff Roasters
Clifton Smelter, 63.
Magma Smelter, 66.
Hidden Treasure Group, 87.
Hill, H. W., 64.
Hillside, 75.
Hilltop Metal Mines Company, 85.
Hiltano Explorations, 84.
Hinton, T. B., 58.
Hoatson, C. D., 51.
Hoatson, Chester, 68.
Holbrook Area, 110.
Holmes, William, 69.
Hondrum, Olaf, 51.
Honeyman, P. D., 40.
Hopewell Tunnel, 47.
Hopi Reservation, 111.
Hopkins, Dave, 50.
Horse Mesa Power Plant, 35.
Howard, L. O., 40.
Howe, F. C., 39.
 Hoyt, H. H., 39.
Huachuca Mountains, 104.
 Hughes, R. W., 40.
Hulett Unloader, 54.
Humboldt Mine, 60.
Hummer Screens
Inspiration Concentrator, 33.
Clifton Concentrator, 62.
Old Dominion Concentrator, 30.
Hunt, H. D., 32, 40.
Hurst, C. A., 44.
Hymer, H. G., 51.
Idaho Mine, 88.
Ingham, G. R., 58.
Inspiration Cons. Copper Company, 24.
Inspiration Flotation Machines
Inspiration Concentrator, 33.
New Cornelia Concentrator, 56.
Inter-mountain Valleys, 110.
International Smelter, 34-35, 117.
Ireland, Eugene, 95, 96.
Iron Cap Copper Company, 24.
Irving, E. F., 15, 22.
Irving, Joseph, 14.
Irwin, D. D., 21.
Ivanhoe Copper Company, 12.
Ivy, M. Z., 51.
Jacks, M. E., 22.
Jacobsen, C. K., 69.
Jay, George, 22, 58.
Jefferson Mine, 85.
Jerome, 45.
Jerome District, 45-51.
Johnson, J. L., 39.
Johnson, Nels, 44.
Jones Sampler, 80.
Josephoon, Ira B., 52.
Josephine Tunnel, 47.
Junction Shaft, 14.
Jurassic Sediments, 76.
Katherine, 93.
Katherine Extension Mining Company, 93.
Katherine Gold Mining Company, 93, 95.
Katherine Treasure Vault, Inc., 96.
Kay Copper Corp., 71.
Keams Canyon, 111.
Kehoe, W. E., 51.
Kelvin, 40.
Kerns, R. W., 35.
Kennedy Crusher, 30.
Kennedy, F. R., 38.
Kevan, Jack, 75.
Keystone Mine, 29.
Kidde, John, 61.
Kingsdon, George, 51.
Kingman, 87, 93, 105.
Kingman Power Company, 95.
Kiser, C. C., 45.
Knight, G. D., 67.
Koerney, Frank, 102.
Kofa District, 99.
Kohler, Albert, 75.
Kruttschnitt, Julius Jr., 72, 75, 119, 123.
Kumke, C. A., 45.
Kuzell, C. R., 50.
Labor
Globe-Miami, 36-37.
Ray-Hayden, 44.
Jerome, 49.
Ajo, 57.
Clifton-Morenci, 64.
Superior, 67.
Swansea, 74.
Silverbell, 75.
Tonopah-Belmont, 84.
Hiltano Explorations, 84.
Montana Mine, 89.
Sierrita Mts., 90.
Oatman-Katherine, 96.
Tombstone, 98.
Asbestos Mining, 102.
Thenardite Mining, 116.
Lane, E. B., 40.
Langdon, John, 51.
Lanning, John E., 48, 50.
Lauzen, Carl, 103.
Lavender, H. M., 22.
Lawlor, F. J., 108.
Leaching
Copper Queen, 14.
Inspiration, 33.
Ajo, 54.
Lead Mining, 78-85.
Leahy Screens, 89.
Lee's Ferry, 76.
Legrand, C., 21.
Legters, G. R., 38.
Leidich, Harry, 38.
Leisk, R. D., 51.
Lerchen, F. H., 90.
Lewers, H. M., 84.
Light, Victor, 96.
Ligon, Guy A., 38.
Limestone Replacement Ore
Bisbee, 9.
Christmas, 40.
Hiltano, 84.
Limestone Quarrying, 109.
Lindgren, Waldemar, 46, 59.
Lindley, F. G., 64.
Little Ajo Mts., 52.
Little Dragoon Mts., 104.
Live Oak Mine, 28.
Lone Star District, 77.
Lordsburg, 59.
Lowell, 9.
Lower Cretaceous Sediments, 68, 72.
Luchessa, J. J., 40.
Lynch Dust Collecting System, 12.
Lynch, W. W., 50.
Maclean, A. J., 44.
Maclean, F. W., 39.
Macleman Cantilever Grizzlies, 31.
Magma Copper Company, 65-68.
Magma Smelter, 66.
Magma-Arizona Railroad, 65.
Mammoth, 76.
Mammoth Mine, 104.
Mancos Shale, 111.
Manganese Mining, 114.
Manganese Ore Market, 118.
Marble, E. R., 45.
Marcy Ball Mills
Inspiration, 33.
Magma, 66.
Copper Queen Lead Concentrator, 79.
Marcy Rod Mills
Copper Queen, 12.
New Cornelia, 56.
Morenci, 62.
Marks, Roy H., 51.
Martin, John, 61.
Mascot, 72.
Mascot and Northern R. R., 72.
Mascot Mine, 72.
Maslin, T. A., 45.
Mayne, R. W., 38.
Mazatzal Mts. Deposits, 103.
McCloskey, James, 51.
McCullough Mts., 75.
McCullough Gyratory Crusher, 42.
McDermid, A. S., 25.
McDevitt, Geo. B., 105.
McDonald, Felix, 24, 39.
McDougall, R. M., 64.
McDougal Roasters, 43.
McGrath, M. J., 103.
McGrath, T., 22.
McGregor Railroad Cars, 34.
McKenna, J. E., 23.
McLean, A. J., 44.
McNabb, T. C., 68.
McNeil, S. E., 39.
McNerney, Thomas, 23.
McReynolds, Thos. C. Jr., 108.
Mendelsohn, Chas., 38.
Mercury Market, 118.
Mesa Verde Formation, 111.
Messiter Reclaimer, 63.
Miami Copper Company, 24.
Mieyer, George, 11, 51.
Mills
  Tom Reed, 94.
  Katherine, 94-95.
Mills, C. E., 47.
Mineral Creek, 40.
Mineral Park, 87.
Minerals Separation Flotation Machines, 32.
Mining Methods
  Bisbee-Copper, 10.
  Globe-Miami, 24-27.
  Ray-Christmas, 41-42.
  Jerome, 46-47.
  Ajo, 52.
  Morenci, 60-61.
  Superior, 65.
  Bisbee—Lead, 78.
  Tonopah-Belmont, 83.
  Hiltano Exploration, 84.
  Oatman-Katherine, 93-94.
  Tombstone, 97.
  Asbestos Mining, 101-102.
  Thenardite Mining, 115.
Miscellaneous
  Copper Mining, 75-77.
  Lead Mining, 85.
  Gold Mining, 99-100.
  Molybdenum, 104.
  Complex Ore, 92.
  Mitchell, C. E., 45.
  Mitchell, Graham John, 10.
  Mitchell Slice, 65.
  Mitke, C. A., 47.
  Model Mine Report, 119-123.
  Mogollon Rim, 112.
  Molybdenum Mines, 104.
  Molybdenum Ore Market, 118.
  Monarch Lead Mining Company, 87.
  Montague, H. W., 39.
  Montana Mine, 88.
  Montana Mines Operations, Eagle
      Picher Lead Company, 88.
  Monzonite, 68.
  Morenci, 59.
  Morenci Water Company, 63.
  Morning Glory Mine, 91.
  Mosier, McHenry, 64.
  Mowry Mine, 85.
  Mrkvicka, Gus, 67.
  Mule Pass Mountains, 9.
  Murphy, M. F., 38.
  Murray Chloridizing Plant, 87-88.
  Murray, J. S., 87.
  Mystery Mining Company, 69.
  Nacozari, 15.
  Navajo Reservation, 111.
  Nelson, T., 40.
  Newhouse Gyratory Crusher, 32.
  New Cornelia Copper Company, 52-58.
  Nevada Cons. Copper Company, 40-45.
  Nichols, F. E., 49.
  Night Hawk Leasing Company, 10, 12.
  Nitrate, 18.
  Nogales, 88.
  Nowland, R. C., 44.
  Oatman, 93.
  Oatman-Katherine District, 93-96.
  O'Brien, T. H., 39, 40.
  Oil Prospecting, 110.
  Old Dominion Company, 24.
  Old Hat District, 76.
  Olive Camp, 90.
  Oliver Filter
      Copper Queen Copper Concentra-
      tor, 13.
      Old Dominion Concentrator, 31.
      Inspiration Concentrator, 32.
      New Cornelia Concentrator, 57.
      Morenci Concentrator, 63.
      Magma Concentrator, 66.
      Copper Queen Lead Concentrator, 79.
  Onyx Mining, 107-108.
  Onyx Marketing, 118.
  Ore Markets, 117-118.
  Ore Production
      New Cornelia Copper Company, 58.
      Magma Copper Company, 67.
      Asbestos, 102.
      Thenardite, 116.
      Oro Blanco District, 88-90.
      Oro Blanco Mts., 88.
      Oro Golconda Mining Company, 87.
      Oro Plata Mine, 87.
      Osborne, W. S., 45.
      Otis Elevator, 42.
      Oxman, T. H., 43.
Paleozoic Sediments

Bisbee, 9.
Morenci, 59.
Courtland, 68.
Dos Cabezas, 72.
Silverbell, 74.
Sierrita Mts., 90.
Old Hat District, 76.
Pantano, 84.
Palo Verde, 83.
Pantano, 84.
Patagonia District, 75, 85, 91, 104.
Pearce District, 99.
Pearce Hills, 99.
Pension System, 20.
Perkins, J. C., 47, 48.
Phelps Dodge Corporation
- Copper Queen Branch, 10, 78.
- Morenci Branch, 59.
- Exploration Dept., 123.
Phoenix Mts., 98.
Pidgeon, G. C., 22.
Pigott, Curtis, 22.
Pillar and Stall Method, 65.
Pinal Mts., 23.
Pinto Valley Company, 24.
Pinedale, 112.
Plaistead, W. T. W., 39.
Plat O Tables, 43.
Plummer, H. C., 38.
Plummer, S. G., 22.
Pohle Air Lift, 18.
Porter Air Locomotives, 42, 126.
Potter, J. A., 56, 68.
Power Plants
- Bisbee-Douglas, 19.
- Globe-Miami, 35.
- Ray-Hayden, 44.
- Jerome, 49.
- Ajo, 57.
- Clifton-Morenci, 63-64.
- Magma, 66.
- Central Copper, 73.
- Swansea, 74.
- Tonopah-Belmont, 83.
- Montana Mine, 89.
- Oatman-Katherine, 95.
- Vulture, 98.
Pratt, H. H., 21.
Pre-Cambrian Formations
- Bisbee, 9.
- Globe-Miami, 23.
- Jerome, 46.
- Ajo, 52.
- Morenci, 59.
- Courtland, 68.
- Bradshaw Mts., 70.
- Dos Cabezas, 72.
- Swansea, 73.
- Tonopah-Belmont, 83.
Calumet and Arizona Smelter, 17.
International Smelter, 34.
United Verde Smelter, 48.
United Verde Extension Smelter, 49.
Clifton Smelter, 63.
Magma Smelter, 66.
Hayden Smelter, 43.
New Cornelia Leaching Plant, 54.
Robotham, Cyril A., 42.
Roosevelt Dam Power Plant, 35.
Roosevelt Lake, 101.
Root Blowers, 13.
Root, Verne, 45.
Rose, J. H., 66, 68.
Ruby, 88.
Ruggles, G. H., 39.
Russelville, 104.
Saben, W. M., 64.
Sacramento Hill, 11.
Safford, 77.
Sahuarita, 90.
Salt River, 101.
Salt River Basin Deposits, 101-102.
Salt River Valley, 110.
Salt River Valley Water Users Association, 35, 66.
Salt and Thenardite Mining, 115-116.
Sample Mill, 15, 16, 30, 80.
Samuel, J. M., 22.
San Francisco River, 59.
San Pedro Valley, 68, 110.
San Simon Valley, 110.
Santa Teresa Mts., 92.
Santa Rita Mts., 85, 91.
Santa Nifio Mine, 76, 104.
Sarrer, Frank, 67.
Saundercock, William, 69.
Schrader, Frank C., 87.
Schenectady Mine, 87.
Schuykill Mine, 87.
Schrae-Revelman E., 102.
Scott, J. W., 22.
Scott, W. G., 39.
Selective Mining, 78.
Shakelford Tables, 89.
Shannon Copper Company, 69.
Shank, Jack, 96.
Shattuck-Denn Mining Corp., 10.
Shattuck Mine, 10, 78.
Shawmut Mine, 85.
Sheldon Copper Company, 70.
Sherman, F. W., 73.
Sherman, Gerald, 11, 21, 38.
Shoemaker, A. H., 38.
Short, M. N., 65.
Shrinkage Stoping, 24, 41, 47.
Sierraitas Mts., 90.
Silverbell, 74.
Silverbell District, 74-75.
Silverbell Mts., 74.
Silverbell Mine, 74.
Simplex Double Deck Concentrating Tables, 33.
Simon, W. W., 68.
Sirdevan, W. H., 47.
Slate Creek, 103.
Smith, C. A., 44.
Smith, H. De Witt, 47.
Smith, Joseph, 40.
Smith, S. E., 51.
Smelters
Copper Queen, 15-16, 80-82.
Calumet and Arizona, 16-17.
International, 34-35.
Hayden, 43.
United Verde, 48.
United Verde Extension, 48-49.
Clifton, 63.
Magma, 66.
El Paso Smelting Works, 117.
United States Zinc Co., 117.
Bartlesville Zinc Co., 117.
Snow, F. W., 66, 67.
Snyder, H., 58.
Snyder Sampler, 80.
Sodium Products Corporation, 115-116.
Soper, L. J., 71.
Southwest Division, Copper Queen Mine, 78.
Spigot Classifiers, 33.
Square-Setting, 10, 24, 41, 46.
Stanley, I. H., 80.
Steam Shovel, 10, 46, 52.
Stephenson, G. E., 44.
Stevens, G. L., 45.
Stockton Hill, 87.
Stoddard, A. C., 29, 39.
Stout, H. H., 21.
St. Thomas, Nevada, 77.
Studley, C. H., 44.
Sullivan, J. D., 44.
Summerville Cons. Mines Company, 93.
Superior, 64.
Superior District, 64-68.
Swansea, 73.
Swansea District, 73-74.
Sycamore Creek, 103.
Symons Disc Crushers, 30, 53, 62, 66, 70, 79.
Tallon, A., 38.
Tally, Robert E., 50.
Tanner, W. J., 38.
Taylor, Thos., 50.
Tejon Copper Company, 69.
Telsmith Gyratory Crusher, 31.
Tennessee Mine, 87.
Tenney, J. B., 10.
Tertiary Basalt, 46, 59.
Tertiary Conglomerates, 23, 59.
Thenardite Market,
Thenardite Mining, 115-116.
Thomas, Robert W., 118.
Three R Mine, 75.
Title, C. E., 58.
Tobelmann, Henry A., 56.
Tombstone District, 85, 97.
Tombstone Hills, 97.
Tom Reed Gold Mining Company, 93.
Tonopah-Belmont Development Company, 83-84.
Tonto Creek, 103.
Tonto Mining Company, 103.
Top Slicing, 10, 24, 60.
Transportation of Ore and Materials
Bisbee, 11-12.
Ray-Hayden, 42-43.
Jerome, 47-48.
Morenci, 61-62.
Ajo, 53.
Traylor Rolls, 32, 34, 54.
Trischka, Carl, 22.
Tuba City, 111.
Tucson, Cornelia and Gila Bend R. R., 52.
Tucson Mountain Deposits, 76.
Tuck, F. J., 45.
Tungsten Mining, 104.
Tungsten Markets, 118.
Tuschka, O. J., 38.
Twin Buttes, 90.
Tyler Whip-Tap Screens, 62.
Union Mine, 99.
United States Smelting, Refining and Mining Company, 124.
United States Zinc Company, 117.
United Verde Copper Company, 46, 123.
United Verde Extension Mining Company, 46, 123.
Universal Crusher, 83.
Upper Lowell, 9.
Van Arsdale, G. D., 14, 39.
Veatch, A. C., 112.
Verde Central Mines, Inc., 46.
Verde Formation, 115.
Verde River, 49, 115.
Voss, A. N., 39.
Vulcan Crusher, 70.
Vulture Hills, 98.
Vulture Mine, 98.
Walker, 70.
Walker, C. V., 58.
Walker, Joseph, 22.
Walsh, J. W., 108.
Warren, 9.
Warrior Mine, 33.
Waters, C. R., 96.
Water Supply
Globe-Miami, 36.
Ray-Hayden, 43-44.
Ajo, 57.
Morenci, 63.
Central Copper Company, 73.
Swansea, 74.
Weed, C. E., 39.
Weir, Jack, 51.
Weitzel, Jack, 68.
Wenden Copper Mining Company, 77.
Western Apex Mining Company, 93.
Whitehead, P. T., 45.
Whiteley, E. E., 22.
White Hills District, 97.
White Mesa Sandstone Deposits, 76.
White Tailed Deer Mine, 12.
Whiting, M. A., 29.
Wickenburg, Congress District, 98.
Willecox, 72.
Wiley Pumps, 32, 62, 66, 89.
Wiley Tables, 62, 66, 83.
Williams-Seaver-Morgan Unloader, 34.
Williams, M. A., 45.
Williams, Percy, 75.
Williams, W. F., 39.
Wilson, Eldred D., 68.
Wilson, L. V., 58.
Wilson, R. S., 44.
Winifred District, 98.
Winkelman, 40, 77.
Wittenau, Ernest, 22.
Wolverine and Arizona Mining Company, 10.
Wood, G. W., 39.
Woodcock, C. L., 39.
Woodward, H. W., 39.
Yavapai Onyx Corporation, 107.
Young, George J., 17, 47, 116.
Young, W. J. Jr., 69.
Ziesmer, H. M., 11, 22.
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