CATALOG OF RECORDED EXPLORATION DRILLING AND MINE WORKINGS, TRI-STATE ZINC-LEAD DISTRICT--MISSOURI, KANSAS, AND OKLAHOMA

By Louis C. Brichta
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INTRODUCTION AND SUMMARY

This report summarizes the progress made by the Federal Bureau of Mines in assembling and compiling a catalog of available logs of drill holes and maps of mine developments in the Tri-State Zinc-Lead District in northeastern Oklahoma, southeastern Kansas, and southwestern Missouri. It supplements an interim report (11)3/ published in 1955, and for convenience of the reader repeats much of the general descriptive matter pertinent to the district contained in that report. The work of procuring and recording the data was begun in August 1949 and was recessed in May 1959.

The catalog preserves the records of accomplished explorations and mine developments in the district and provides a readily available source of information for individuals and firms interested in planning mineral explorations, Government agencies estimating of reserves of mineral resources, and the mining industry for general use.

The records are not on open file permission to inspect much of the information must be obtained from the mining companies, engineering firms, and others who provided mine maps and logs of drill holes on a confidential basis. Advice on gaining access to the records may be obtained by writing the Department of the Interior, Bureau of Mines, 206 Federal Building, Bartlesville, Okla. The Bureau of Mines will be pleased to arrange for the inspection of these records by those interested in further developing the resources of the District.

The Tri-State Zinc-Lead District was so named in 1917--69 years after the discovery of lead ore near Joplin, Mo., in 1848, and a few years after the discovery of large, high-grade zinc-lead deposits in Oklahoma and Kansas. Mining began about 1850 in southwestern Missouri and for more than 20 years was confined to that area and restricted to extracting lead ores.

1/ Work on manuscript completed July 1959.
2/ Former Bureau of Mines mining engineer.
3/ Underlined numbers in parentheses refer to items in the bibliography at the end of this report.
In 1871 the line of the St. Louis and San Francisco Railway was extended through southwestern Missouri into Kansas, and within the next few years zinc smelters were built in Kansas. Following the establishment of these facilities, exploration, development, and mining of the zinc-lead sulfide resources progressed rapidly, expanding at a pace that caused the Tri-State district to become for several years the world's leading producer of zinc. For a few years before 1910 and from 1920 through 1926, ores mined in the district contributed more than one-half of the total domestic zinc production.

Progressive depletion of high-grade ore deposits caused a gradual and then a marked decline in the district's output of zinc and lead. In July 1958 depressed metal-market prices of both lead and zinc forced a complete but probably temporary stoppage of mining in the district.

Except for the time during the early years of mining activities, the churn drill was the medium for prospecting and exploration, and the log of the drill hole was the accepted guide to mine development and mining. The consensus of local mine operators, geologists, and mining engineers is that at least 100,000 exploration holes, costing more than $30 million, were drilled in the district.

Records of some of the early drilling and mine developments are destroyed or lost, but the Bureau has copies of descriptive logs of 95,721 drill holes, recorded on microfilm, and mine maps of 2,036 properties within the 760,000 acres of the more productive part of the district. The locations of 63,141 drill holes and the mine workings on 532 properties are plotted on 134 completed standard catalog half-section maps and 28 completed fractional-section maps; the locations of 4,361 drill holes and the mine workings on 96 properties are plotted on 46 partly completed standard catalog maps. Maps or microfilm frames of maps of 1,032 mines on 1,408 properties are on file, but not transferred to standard catalog maps. Microfilm frames of the 95,721 drill-hole logs and mine maps are assembled in 145 reels.

ACKNOWLEDGMENTS

The generous assistance and cooperation of the many mine operators and property owners in the district are gratefully acknowledged. The companies to whom the Bureau is indebted for supplying most of the drilling logs and mine maps from which the catalog records and maps were prepared include: The Eagle-Picker Co., Federal Mining & Smelting Co., National Lead Co., American Zinc, Lead & Smelting Co., Scott Mining Co., Rialto Mining Co., Grace Jarrett Mining Co., Wm. M. Stewart Engineering Co., and K. L. Koelker Engineering Co.

HISTORY AND PRODUCTION OF THE TRI-STATE ZINC-LEAD DISTRICT (1, 6, 9, 12)

The name, Tri-State Zinc-Lead District, was first bestowed on the group of mining districts in southwestern Missouri, northeastern Oklahoma, and southeastern Kansas in 1917 and was a substitute for the more cumbersome name, Missouri-Kansas-Oklahoma District, by which the group had been known previously.
In the beginning, however, and until 1876 when ores were discovered near Galena, Kans., all producing mines were in Missouri, in the district known as Southwestern District of Missouri.

Mining in southwestern Missouri closely followed the discovery of lead ores at Leadville and Joplin in Jasper County in 1848 and near Granby, Newton County, in 1850. Later discoveries in these and other counties led to the construction of smelting plants, and the district became a modest producer of lead, shipping its products to railhead or river points by wagon train; it remained so for more than 20 years. Zinc ores were associated with those of lead in nearly all the mines, but marketing conditions made their exploitation economically infeasible.

In 1871 the line of the St. Louis-San Francisco Railway was extended through southwestern Missouri into Kansas, and within the next few years zinc smelters were built in Kansas to treat sphalerite ores. The establishment of these facilities lent impetus to exploration for lead and zinc-lead ores in southwestern Missouri. Many new mining camps were established in several counties in that part of the State. In 1876 deposits were developed near Galena, Kans., and a lead smelter was built there in 1878.

During the ensuing 39 years, through 1917, southwestern Missouri maintained leadership in metal production in the district. The output of its mines increased materially during that time, accounting for more than half of the total domestic production of zinc for several years before 1916. Peak production was reached in 1916, when produced concentrates contained 30,827 tons of recoverable lead and 155,527 tons of recoverable zinc—53.3 and 65.1 percent, respectively, of the total output of the Missouri-Kansas-Oklahoma district.

The year 1918, however, marked an abrupt decrease in production from southwestern Missouri, as operators abandoned the low-grade mines in that part of the district and transferred their activities to the comparatively richer fields under development since 1914 in Ottawa County, Okla. Southwestern Missouri produced only 190 tons of zinc and lead concentrates in 1957, and none in 1958 or the first half of 1959.

Mining in northeastern Oklahoma was begun about 1891, in the Peoria Camp, Ottawa County. Discoveries of ore at Quapaw in 1897 and at Miami in 1905 preceded the period of greatest activity, which followed discovery of the large, high-grade ore deposits at Picher, Cardin, and Century in 1914 (6). By 1916 exploration had progressed northward into Kansas, where mines were developed in the Baxter Springs-Blue Mound area.

The 28-year period of maximum production by the Tri-State Zinc-Lead District had its beginning in 1917. Only in the depression years (1931-32) were operations below the prevailing high rate. For 7 years (1920-26) ores from the district were credited with 52 to 65.9 percent of the domestic output of zinc. Peak production year was 1926, when the recoverable metal content of concentrates was 102,117 tons of lead and 423,800 tons of zinc, of which Ottawa County, Okla., and Cherokee County, Kans., produced, respectively,
68.2 and 27.8 percent of the lead and 64.3 and 29.8 percent of the zinc. Credit for high production during the era was due primarily to the high-grade ores of Oklahoma.

Eventual depletion of high-grade deposits and the consequent lowering of the grade of mine-run ore caused a gradual and then a marked decline in the district's output of lead and zinc. After 1946 the production in no single year equaled that of any year, except 1932, between 1897 and 1946. In July 1958 depressed metal-market prices of both lead and zinc forced a complete, but probably temporary, stoppage of mining in the district.

Total output of the Tri-State Zinc-Lead District from 1850 to July 1958 in terms of recoverable metals in concentrates was 2,807,094 tons of lead and 11,569,825 tons of zinc, valued at $2,028,718,349, based on prevailing average yearly market prices of the metals (9, 14).

TRI-STATE DISTRICT AREA AND ITS GENERAL GEOLOGY

The area in which most of the mining in the Tri-State district has been done covers approximately 1,200 square miles and extends from the Wentworth Camp in Missouri on the east to the Melrose Camp in Kansas on the west and from Neck City on the North Fork of Spring River on the north to Newtonia, Mo., on the south (fig. 1). The area lies on the northwest flank of the Ozark uplift. The surface slopes generally westward to the valley of Spring River, then rises gently to the west over a divide and descends to the Neosho River in Kansas and Oklahoma. Altitudes range from about 1,200 feet on the east to 800 feet on the west.

Spring River, flowing south through the western part of the district, is, with its tributaries, the main drainage channel of the district. The present land surface east of Spring River approximates the unconformity between the once overlying Pennsylvanian formations and the underlying Mississippian rocks. Many outliers of Cherokee shales and sandstones filling sinkholes and erosion valleys occur throughout the district east of Spring River; this area, presenting a typical Karst topography, illustrates the solubility of the Mississippian limestones. West of Spring River the principal surface formation is Cherokee shale, and the topography becomes rolling prairie broken only by the Neosho River and a few meandering creeks that flow into it (fig. 2).

The geology of the Tri-State district has been described in publications of the Missouri Geological Survey (1), the State Geological Survey of Kansas (2), the Federal Geological Survey (3, 4, 5), and G. M. Fowler (7, 8), consulting geologist, Joplin, Mo.

Table 1 presents a generalized geologic section of the Tri-State district according to Fowler (8).

Sedimentary rock thicknesses ranging from 1,045 to 1,815 feet below the surface have been recorded in the few deep wells that have penetrated igneous rocks in the district. The strata have a regional dip to the northwest of about 30 feet to the mile.
FIGURE 1. - Principal Part of Tri-State Zinc-Lead District, Showing Mined Areas.
FIGURE 2. - Map Showing Principal Geologic Features of Tri-State Zinc-Lead District.
### Table 1. Geologic Formations in Tri-State District

<table>
<thead>
<tr>
<th>Period</th>
<th>Series and character of formations</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvanian</td>
<td>Cherokee - shale and sandstone</td>
<td>0-300</td>
</tr>
<tr>
<td>Mississippian</td>
<td>Chester - limestone, sandstone, and shale. Occurs as outliers and in scattered sinkholes in Missouri. Overlies the Boone in the Oklahoma-Kansas field. Boone - limestone, cotton rock, chert, and dolomite - originally all limestone. Northview and Chattanooga shales and Compton limestone. Probably absent in most of the district except in southeastern part.</td>
<td>0-100, 100-400</td>
</tr>
<tr>
<td>Ordovician</td>
<td>Largely dolomite.</td>
<td>70-1,000</td>
</tr>
<tr>
<td>Cambrian</td>
<td>Dolomite and sandstone.</td>
<td>0-800</td>
</tr>
<tr>
<td>Pre-Cambrian</td>
<td>Granite and probably other igneous rock that intruded the granite.</td>
<td></td>
</tr>
</tbody>
</table>

The ore deposits occur chiefly in strata comprising the Boone formation, but some ore also has been mined in the overlying Chester formation. In the Missouri part of the district, the surface is largely the lower 100 to 300 feet of the eroded Boone formation. In the Oklahoma-Kansas area, the partly eroded Boone formation is approximately 400 feet thick and is covered with the more recent Chester and Cherokee formations, the latter as thick as 300 feet.

The Boone formation was divided by Fowler (7) into 16 units designated consecutively (except "I") as "B" to "R" beds. The correlations are made by examining churn-drill logs, drill cuttings, and underground and surface exposures. Mineralization of the M bed along solution channels and fracture zones and of the O, P, and Q beds, in sheet ground mines, formed the deposits from which most of the ore in the district was produced. The principal ore minerals are sphalerite and galena; associated rock minerals are chert, dolomite, calcite, and jasperoid. In many deposits a form of gouge, locally termed selvage, occurs, especially where deformation and alteration have been intense. Cadmium, gallium, and germanium in extremely small quantity are associated with the sphalerite.

Throughout the district ore is found only where structural deformation created favorable premineral reservoirs; all the strata are barren elsewhere (8). The most prominent structural feature of the mining region is the Miami trough, an irregular series of fault basins following a northeasterly course for more than 40 miles in the western part of the district. Other prominent
structures to which ore mineralization is related include the Bendelari trough, which trends northwestward from the Miami trough at a point near the Kansas-Oklahoma State line; the Joplin anticline with related parallel fractures trending northwest through the Joplin area; and the Seneca fault extending southwestward through Spurgeon, Mo., into Oklahoma (fig. 2).

EXPLORATION AND MINING

Early prospecting was done through shallow shafts; as costs became greater, owing to increased depth and underground water, churn drilling came into general use, and the drill-hole log became the accepted guide to mine development and mining. Much of the early exploration was too shallow, as little was known of the ore depth; and much of the record of the early work has not been preserved. Frequent occurrence of ore bodies lying adjacent to shale basins or slumps has led to what is locally termed shale drilling, designed to locate the contact between the Cherokee shale and the Boone limestone by drilling lines of holes on 200- to 400-foot centers. From the data obtained, a contour map of the base of the shale is made, and the area adjacent to the deep shale is prospected by deep drilling.

The drill holes, conforming to the westward dip of the mineralized beds, range in depth from 50 feet or less in the eastern part of the district to 500 feet or more in the western part. Logs of the holes are kept by the drillers, and the drill superintendent or geologist makes his record from the cuttings placed in piles representing successive depth intervals. Depth of shale and marker formations, open ground, water flow, mineralization, and other data of interest are noted on the driller's log. Drillers classify ore grade according to the following terms, and where samples are not assayed, the equivalent values shown have been found generally satisfactory (10).

<table>
<thead>
<tr>
<th>Zinc terms</th>
<th>Zinc sulfide, percent</th>
<th>Lead terms</th>
<th>Lead sulfide, percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trace zinc.......</td>
<td>0.50</td>
<td>Trace lead.....</td>
<td>0.02</td>
</tr>
<tr>
<td>Thin zinc shines.</td>
<td>1.00</td>
<td>Thin lead shines.</td>
<td>0.05</td>
</tr>
<tr>
<td>Fair zinc shines.</td>
<td>1.50</td>
<td>Fair lead shines.</td>
<td>0.25</td>
</tr>
<tr>
<td>Zinc shines.....</td>
<td>2.00</td>
<td>Lead shines.....</td>
<td>0.40</td>
</tr>
<tr>
<td>Good zinc shines.</td>
<td>2.50</td>
<td>Good lead shines.</td>
<td>0.80</td>
</tr>
<tr>
<td>Zinc.............</td>
<td>3.00</td>
<td>Lead.............</td>
<td>1.00</td>
</tr>
<tr>
<td>Fair zinc........</td>
<td>4.00</td>
<td>Fair lead........</td>
<td>2.00</td>
</tr>
<tr>
<td>Good zinc........</td>
<td>5.00</td>
<td>Good lead........</td>
<td>3.00</td>
</tr>
<tr>
<td>Rich zinc.........</td>
<td>7.50 or better</td>
<td>Rich lead........</td>
<td>5.00 or better</td>
</tr>
</tbody>
</table>

It should be noted that many of the assays shown on drill logs are in terms of 60-percent zinc sulfide and 80-percent lead sulfide. Other assays are shown in terms of pure sulfides; for these the metal equivalents are 67 percent of the zinc sulfide and 86.6 percent of the lead sulfide content. A few companies report assays in terms of metallic content.
Tri-State zinc-lead deposits, mainly of low metal content, were exploited for over 100 years, principally because the ore bodies were large, relatively shallow, and easily mined and milled. Most of the ore was obtained by underground mining operations, although substantial quantities, from shallow deposits in the Missouri part of the district, have been mined by opencut methods. Underground, the ore bodies are mined by the room-and-pillar system, the character of the roof governing the distance between pillars, which generally varies from 20 to 50 feet (12, 13). From 8 to 15 percent of the excavated area is left in pillars, many of which are removed wholly or in part before mining is finished. In mines where ore occurs in more than one bed and intervening barren beds are strong, the ore bodies are mined on separate levels. In mines where the barren beds are not thick enough to support a level, the entire face is mined, creating headings that measure 40 to 100 feet from floor to roof. Sheet ground deposits range from 7 to 14 feet in thickness (9).

Although logs of drilling and maps of underground workings of some of the early, shallow mining operations probably were not maintained, the operators soon found that it was to their benefit to keep up-to-date mine maps and accurate drill-hole records. These recorded data have proved valuable in guiding later exploration and development and in locating surface improvements and buildings at the workings. Churn-drilling exploration usually provides enough basic information to determine within satisfactory limits the tonnage and grade of zinc-lead ore bodies, on which the value of a prospective mine or mineral property is estimated. The consensus of local mine operators, engineers, and geologists is that over 100,000 holes, costing more than $30 million, have been drilled in the district.

BUREAU OF MINES CATALOG OF RECORDED DRILLING AND MINE WORKINGS

In August, 1949, the Bureau of Mines began collecting and cataloging copies of available logs of drill holes and maps of mine developments in the Tri-State Zinc-Lead District. By May 1959, when the work was suspended indefinitely, the catalog contained photographic reproductions of the descriptive logs of 95,721 drill holes and the mine maps of 2,036 properties within the 760,000 acres of the more productive part of the district. Exhaustive search and investigation of all known sources of information failed to reveal additional logs or maps. Records of some of the early drilling and mine developments apparently were destroyed or lost, as perhaps were some later records.

As a basis for cataloging, each land section in the district was designated by a reference number beginning with 1 at the southeast corner of each county and running west to the county boundary line, thence east on the next row of sections on the north to the county boundary line. Continuing in this manner, consecutive sections were numbered until the entire county had been covered (see fig. 3).

For mapping purposes, each land section was represented by two standard half-section maps, each designated by the index number of the section followed by "N" or "S" to indicate, respectively, the north half-section and the south half-section (fig. 4). The drill-hole sites and mine workings shown on original land and mine maps furnished by landowners and/or mine operators were
FIGURE 4. - Standard Half-Section Map with Mine Workings and Drill Hole Locations.
<table>
<thead>
<tr>
<th>JOHN HARTLEY</th>
<th>OPPERMANN</th>
<th>DAVE TREAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NUMBERED SERIES</strong></td>
<td><strong>&quot;CZ&quot; SERIES</strong></td>
<td><strong>NUMBERED SERIES</strong></td>
</tr>
<tr>
<td>HOE NO.</td>
<td>LOCATION</td>
<td>HOE NO.</td>
</tr>
<tr>
<td>1</td>
<td>1-6</td>
<td>CZ-1</td>
</tr>
<tr>
<td>2</td>
<td>J-6</td>
<td>CZ-2</td>
</tr>
<tr>
<td>3</td>
<td>K-5</td>
<td>CZ-3</td>
</tr>
<tr>
<td>4</td>
<td>J-7</td>
<td>CZ-4</td>
</tr>
<tr>
<td>5</td>
<td>J-9</td>
<td>CZ-5</td>
</tr>
<tr>
<td>6</td>
<td>H-10</td>
<td>CZ-6</td>
</tr>
<tr>
<td>7</td>
<td>H-10</td>
<td>CZ-7</td>
</tr>
<tr>
<td>8</td>
<td>H-10</td>
<td>CZ-8</td>
</tr>
<tr>
<td>9</td>
<td>H-10</td>
<td>CZ-9</td>
</tr>
<tr>
<td>10</td>
<td>H-10</td>
<td>CZ-10</td>
</tr>
<tr>
<td>11</td>
<td>H-11</td>
<td>CZ-11</td>
</tr>
<tr>
<td>12</td>
<td>H-11</td>
<td>CZ-12</td>
</tr>
</tbody>
</table>

**"OLD HOLES"**

<table>
<thead>
<tr>
<th>HOE NO.</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE 1</td>
<td>1-6</td>
</tr>
</tbody>
</table>

**FIRST HOLE NORTH HALF NO.**
**LAST HOLE NORTH HALF NO.**
**FIRST HOLE SOUTH HALF NO.**
**LAST HOLE SOUTH HALF NO.**

KANSAS
Cherokee County
Compilation Date: APRIL 10, 1951

FIGURE 5. - Standard Index Sheet Corresponding to a Standard Half-Section Map.
plotted on the maps. Standard index sheets giving the coordinates of the drill holes on each mine property accompany each half-section map (fig. 5).

The Bureau of Mines files contain 134 completed standard half-section maps and 28 completed fractional-section maps on which are plotted the locations of 63,141 drill holes and the mine workings on 532 properties. On 46 partly completed standard maps are shown the locations of 4,361 drill holes and the mine workings on 96 properties (fig. 6).

On file, but not transferred to standard half-section maps, are original maps or microfilm copies of maps of 1,032 mines on 1,408 properties. Figure 7 shows the land tracts for which drill-hole logs are available, but the hole locations are not plotted on standard half-section maps. Figure 8 shows the land tracts for which maps of mine workings are available but not plotted on standard half-section maps.

Drill-hole logs and mine maps were photographed on 35-mm. film with a portable microfilm camera in the offices and homes where the records were made available, thus facilitating the work and obviating the possibility of loss of the records. The films, on which are recorded the 95,721 drill-hole logs and mine maps of 2,036 properties, are on 145 reels.

Data in the catalog are adequately indexed for ready reference with respect to subdivisions of the land survey, half-section map reference number and corresponding index, microfilm reel number, and name of mine.

The logs and maps preserved by the Bureau constitute a record of factual information readily available to individuals and firms interested in planning mineral explorations, to Government agencies for formulating estimates of mineral resources, and to the mining industry of the district for general use.

The catalog is not on open file; permission to inspect much of the included material must be obtained from the mining companies, engineering firms, and others who provided mine maps and logs of drill holes on a confidential basis. Advice on procedure for obtaining access to the records may be obtained by writing to the Bureau of Mines at Bartlesville. Applicants should give the land-survey description of the property on which information is requested and specify the type of data desired.
FIGURE 7. - Land Tracts on Which Drill-Hole Logs are Available—Holes Not Plotted on Standard Half-Section Maps.
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2. HAWORTH, ERASMUS. The University Geol. Survey of Kansas, vol. 8, 1904, pp. 54-126.


