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MINERAL EXPLORATION AND DEVELOPMENT ATLAS OF THE UPPER MISSISSIPPI VALLEY DISTRICT

BY

George A. Tweedy and Allen V. Heyl, Jr.

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ABSTRACT

A comprehensive mineral exploration and development atlas, covering Grant, Iowa, and Lafayette Counties in southwestern Wisconsin, was initiated as a joint Geological Survey-Bureau of Mines project in September 1947. Few detailed records of exploitation and drilling in the district remained prior to 1900, despite a long and colorful history of mining and a considerable lead-zinc production during the more active early periods (1830-1850, 1860-1870, 1890-1900), but there are records since 1900. The plan of the atlas is to assemble all available past and current data on mining, development, and prospecting; to provide for continued assemblage in the future; and to record pertinent information, such as geologic logs of drilling and uniformly scaled plan maps of mines and drilling. By December 1949 maps and information on over 300 mines and 13,900 drill-hole logs in the district had been assembled; however, a considerable quantity of information remained to be collected. The purpose of the atlas is to assist in detailed geologic mapping, to aid in the discovery of new deposits in the district, to serve as a guide for exploration, development, and mining in the district, and to facilitate the estimation of the district's ore reserves under varying economic conditions.

INTRODUCTION

The importance of providing a means for accurately recording facts pertinent to geology, exploration, development, and exploitation of any mining district has been recognized for many years. The need in the Upper Mississippi Valley zinc-lead district was expressed forcibly as early as 1862:

> "The more thoroughly a mining district is studied, and the more facts in regard to the occurrence of its metalliferous deposits are accumulated, the less ought to be the risk of commencing new enterprises, since the experience of the past is, after all, the surest guide in all matter connected with mineral deposits. Hence the immense importance, in every mining country, of keeping as perfect a record as possible of all the discoveries which are made, and of the peculiar conditions met with."1/

The statement was occasioned by the absence of geological, statistical, and operational data on the mines of the Wisconsin part of the Upper Mississippi Valley zinc-lead district in 1862 when a comprehensive geological survey of that part of the area was underway. Prior to the first State-conducted surveys and at intervals in succeeding years, numerous journals and reports sought to record activities and to complete the historical description of the industry, or to add to the knowledge of the mode of mineral occurrences and the general geology of the district.

The observation made by Hall and Whitney in 1862 2/ is as valid today as it was then. However, not until recently have serious efforts been made to accumulate under one cover the widely distributed

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1/ Hall, James, and Whitney, J. C., Report on the Geological Survey of the State of Wisconsin, Vol. I, Wisconsin Geological Survey, 1862, p. 90.

2/ Hall and Whitney, ibid, p. 2.

basic data available in southwestern Wisconsin. Mining activity had been generally recorded in the district for 130 years, but the only detailed original mine maps and drill records available today are those of work done since 1905. The records have been retained in the files of the numerous individual operators and companies that have been active in the area over a period of years, or have been accumulated from varied sources by State or Federal agencies by less ambitious attempts than the present one to compile all available reliable data.

The numerous published reports that resulted from the mining, geological, and historical surveys of the district are still of considerable value to the present day mining industry. The basic geological and mining data they contain are of greatest value today, rather than their theoretical discussions. Only the reports that were written before 1900 include the needed descriptions of the long abandoned shallow lead mines which for many years supplied most of the nation's lead. Records were seldom kept by the miners themselves, or if they were, nearly all of them have been lost. Almost no descriptive data would remain on mining in the district during the very important nineteenth century period if valuable descriptions had not been made in these published reports. Repeatedly, data thought insignificant in one period may be the criteria upon which important advancements are later made.

During the decade prior to World War II the district was considered to have no future as an important source of lead and only a minor position as a continued source of zinc. Events in the area during and subsequent to World War II have shown that, at least in the case of zinc, carefully planned geologic mapping, exploration, and development resulted in a number of successful enterprises. During the war period the Upper Mississippi Valley district rose from 15th to 5th place in national importance as a source of zinc, and the current outlook is promising for continued productivity and expansion of the district.

Formerly, it was possible for the prospector to discover, and delimit with some degree of accuracy by shallow test pitting, the substantial near-surface mineralized zones that contributed much to the district's mineral wealth. Today, the discovery and development of substantial ore reserves generally require the application of highly specialized techniques by trained geologists and mining engineers together with considerable capital outlay. The discoveries of tomorrow will require still greater skill, technology, and capital. The establishment of any substantial mining enterprise comes only after successful programs of geological study, exploration, and development.

As part of a program of geological study, mineral investigation, and development essential to the support of the Nation's war industries, the U. S. Bureau of Mines and the U. S. Geological Survey began investigations in the Upper Mississippi Valley district in 1942. Since July 1945 the U. S. Geological Survey's program has been in cooperation with the Wisconsin Geological and Natural History Survey. The investigations were first concerned with activities that might result in the immediate production of metals essential to the war program. Time was an important factor in considering sites for exploration and development. The absence of accurate district-wide compilations of authentic records of past work and geological interpretations that might be made from such records was a serious handicap, and the effects were immediately apparent. At sites where exploration and development programs were based on incomplete or fragmentary data, the ultimate results were less productive than at other sites where exploration and development were based upon the verified records of earlier work. However, the concerted effort of these agencies located several large ore bodies and extensions of ore bodies; and in the years following, as experience in the district was accumulated and all available records studied, exploration and development could be restricted with some accuracy to those sites most likely to become productive.

Shortly after the inception of the Bureau of Mines and Geological Survey projects, both agencies made concerted efforts to gather and preserve available records of old mines and drill holes in the district. Both agencies cooperated in accumulating current mining records as far as available time and personnel would permit. Also the Bureau of Mines kept records and maps of all their exploration and development programs, and the U. S. Geological Survey in cooperation with the Wisconsin Geological and Natural History Survey established a permanent file at the Wisconsin Institute of Technology of all the original and

Bean, Hanson, and Milcher
the president of WIT insist
this was part of the
original agreement

copied mine maps and drill records that they were able to obtain from the owners. These two sources became the original nucleus of records from which the Atlas was later compiled.

The need for adequate compilations and basic data on the district was the factor that finally began the current attempt to compile a comprehensive record of factual data on the exploration, development, and mining in the district. The mineral atlas compilation program described in this paper is an attempt to bring together all reliable information on past exploration, development, and mining, and to provide a simple means for recording results of current and future work in the area.

Compilation of the Atlas involves two principal phases:

1. Obtaining all of the mine and drill records of past work that might be available, discarding or qualifying those parts that appear to be of questionable accuracy, determining which of conflicting records might be more valid, and then assembling into uniform documents all of the basic information that can be found at the present time.

2. Providing a means whereby records of current and future work can be entered in the Atlas with a minimum of effort and cost, thus permitting and assuring the preservation of an up-to-date record so long as mining is practiced in the district.

At the present writing, most of the results of work done during the past 10 years and more than half of the available records of earlier work have been compiled. Strictly speaking, the atlas will never be completed until all exploration and mining work is terminated in the district. However, the compilation is already performing important functions, and its value increases with each addition to the Atlas. The Atlas is supplying needed information on past drilling and mining to mining companies and other interested parties. Likewise this most complete and comprehensive record of mining in the district is providing the State and Federal agencies with carefully catalogued and located drill records and mine maps of a uniform convenient scale for transfer, greatly expediting their district programs. In its present fairly complete state, the Atlas may serve as the basis for a district-wide ore reserve estimate based upon any economic cut-off which may prevail. The greatest value of the Atlas will be to serve as a guide to exploration, and to indicate the grade, nature, and minability of developed ore. However, the Atlas will also serve as a basic document to assist in the more rapid completion of detailed geologic mapping. Such mapping by the Geological Survey has already been shown to be most effective in the discovery of new and important deposits in the district.

ACKNOWLEDGMENT

The compilation of the Upper Mississippi Valley District Atlas was made possible by the general approval of the undertaking by large and small mining interests throughout the district and the cooperation of the mine owners and operators.

Large quantities of records of old work were made available by the Vinegar Hill Zinc Co. through the courtesy of W. N. Smith, General Manager, E. D. Deutman, General Superintendent, and O. E. DeWitt,

Exploration Engineer. C. T. Millice granted permission to utilize records of the American Zinc, Lead, and Smelting Co. S. S. Goodwin of the New Jersey Zinc Co. permitted use of records of that company's work in the district. Records of the St. Joseph Lead Co. were made available through the courtesy of John S. Brown, Chief Geologist. H. B. Ewaldt, General Manager of the Calumet Corporation, permitted use of exploration records of that company. M. W. Melcher, President of the Wisconsin Institute of Technology, provided a large file of records preserved by them. E. R. Shorey, Professor of Mining and Metallurgy, University of Wisconsin, and C. W. Stoops, ore buyer and former mine operator, Platteville, have been most helpful in the matter of locating and furnishing records of scattered tracts. E. F. Bean, State Geologist of Wisconsin, has facilitated the preparation of the Atlas.

In addition to the foregoing, information was supplied by numerous individuals whose combined efforts have contributed to the successful compilation of the Atlas. Their contributions are acknowledged and their cooperation appreciated.

In August 1945 a conference was held between C. H. Behre, Jr., of the U. S. Geological Survey, and E. F. Bean, Wisconsin State Geologist, in Madison, Wis., at which time a general plan of recording and plotting all drill holes and mine data of past and current activity was proposed as the principal objective of a cooperative U. S. Geological Survey-Wisconsin Geological and Natural History Survey program. This plan was transmitted by Behre to A. F. Agnew, A. V. Heyl, Jr., and E. J. Lyons, at Platteville, Wis.

In October 1945 a basic plan of plotting the drill holes and mine workings on a series of index section maps was organized and drawn by Lyons. Insufficient personnel prevented further work on this program at that time, beyond the accumulation of mine and drill-hole data.

A conference to determine the form and scope of the Atlas was held in Platteville, Wis., in September 1947. Present were C. E. Dutton, A. V. Heyl, Jr., and E. J. Lyons of the U. S. Geological Survey; Paul Zinner, Leon W. Dupuy, Charles H. Johnson, and J. V. Kelly of the U. S. Bureau of Mines; and Paul Herbert, James Bradbury, and R. H. Grogan of the Illinois State Geological Survey. Subsequently, the objectives of the compilation were reviewed at Washington, D. C., by Paul Zinner, then Chief, Minneapolis Branch, Bureau of Mines, and Olaf N. Rove, Chief of Mineral Deposits Branch of the Geologic Division, Geological Survey, and their respective associates.

The work of assembling, verifying, and checking accumulated material for inclusion in the Atlas is essentially a cooperative effort of the personnel of the Bureau of Mines and the Geological Survey in southwestern Wisconsin. A. V. Heyl, Jr., E. J. Lyons, and A. F. Agnew, geologists, Geological Survey, Platteville, Wis., have performed much of the task of locating, checking, and verifying many of the records which have been entered in the Atlas. The form, method of compilation, and scope of the Atlas were determined largely from experience gained at an earlier date by the Geological Survey personnel in the course of studies and detailed compilation of records within restricted areas of the district.

Preparation of standardized Atlas maps and drill records from the records obtained from all sources has been a function of the Bureau of Mines and has been conducted by and under the direction of mining engineers of the Bureau of Mines, J. V. Kelly and G. A. Apell, assisted by G. A. Tweedy. Final checking of completed compilations and preparation of final maps has been done by R. G. Gospeter, draftsman, under the direction of Paul Zinner, then Chief, Minneapolis Branch, Mining Division, and now Regional Director of Region V, Bureau of Mines.

George A. Tweedy of the U. S. Bureau of Mines wrote all the chapters of this report except those on the history of mining and the geology of the district, which were written by Allen V. Heyl, Jr., of the U. S. Geological Survey.

HISTORY OF MINING IN THE UPPER MISSISSIPPI VALLEY ZINC-LEAD DISTRICT

Only incomplete records remain of the 85 years of intense mining activity in the district prior to 1905. Our principal sources are reports presenting the results of several Wisconsin and Federal geological surveys made between 1839 and 1900. If these government surveys had not been made, very little information would remain from a period of active mining when the district was the principal source of lead in the United States.

The Upper Mississippi Valley district, figure 1, is one of the oldest mining areas in the United States. Jean Nicolet went up the

Mississippi River in 1643, but no record exists whether he noted the presence of lead in the area.3/ The first recorded indication that lead was known in the area was in 1658-1659 when Radison and Groseillers "heard of lead mines among the Boeuf Sioux, apparently in the vicinity of Dubuque, Iowa".3/ The next recorded notation was Hennepin's map of 1687, which shows lead mines located in the vicinity of the present town of Galena, Ill.3/ About 1690, Nicholas Perrot established a temporary trading post for lead opposite the present site of Dubuque, Iowa.4/ Perrot's trading post probably marked the beginning of actual mining by the French and the Indians, who soon learned the value of the lead ores.

LeSueur in 1699 made the first mining exploration of importance in the area. A description of his exploration follows:5/

> LeSueur set out from France in 1699, in D'Iberville's second expedition to Louisiana, which arrived at its destination in December (1699). He had been commissioned by the king to explore and work "the mines at the source of the Mississippi", and had 30 miners assigned to him. His reporter and companion, Penicaut, after speaking of the rapids in the Mississippi at Rock Island, says: "He found both on the right and left bank the lead mines, called to this day the mines of Nicholas Perrot, the name of the discoverer. Twenty leagues (39 miles) from there on the right, was found the mouth of a river the Ouisconsin". It was the 13th of August 1700, when they arrived opposite Fever River, which Penicant calls "Riviere a la Mine". He reports that up this little river, a league and a half, there was "a lead mine in the prairie". They passed up the Mississippi, Penicant mentioning two streams which correspond to the Platte and Grant Rivers, in Wisconsin, and says that LeSueur "took notice of a lead mine at which he supplied himself",—supposed to be what afterwards came to be known as "Snake Diggings", near (at) Potosi, Wisconsin.

3/ Thwaites, R. G., Notes on early lead mining in the Fever (or Galena) River region: Wisconsin Hist. Coll., vol. XIII, 1895, p. 272.
4/ Bain, H. F., Zinc and lead deposits of the Upper Mississippi Valley: U. S. Geol. Survey Bull. 294, 1906, p. 2.
5/ Thwaites, R. G., ibid, pp. 275-276.

In 1743 M. le Guis noted that 18 or 20 miners were operating in the Fever River region, mining during the better seasons of the year and moving south during the winter.6/ Later, in 1766, it was recorded that lead was shipped by the French twice a year from the west side of the Mississippi River in 20-ton boats. The same year Jonathan Carver, who traveled down the Wisconsin River from Portage to Prairie du Chien, Wis., visited the lead mines at Blue Mounds and reported that lead was abundant in the vicinity of the mounds.7/

These incomplete records suggest that probably the French and Indians were mining lead on a small scale during all of the 18th century, and that a number of deposits known to them later became important mines.

The first serious attempt by white men to settle in the region for the purpose of mining was that of Julien Dubuque. According to Schoolcraft,8/ the discovery of lead at this locality was made by the Indians themselves, as he states in the following paragraph:

> In 1780 a discovery of lead ore was made upon their lands by the wife of Peosta, a warrior of the Kettle Chief's village, and extensive mines have since been discovered. These were granted by the Indians to Julien Dubuque at a council held at Prairie du Chien in 1788, by virtue of which he settled on the lands, erected buildings and furnaces, and continued to work the mines until the year 1810. In the meantime (1796) he received a confirmation of the Indian grant from the Baron de Carondelet, governor of Louisiana, in which they were designated the "Mines of Spain".

6/ Thwaites, R. G., Notes on early lead mining in the Fever (or Galena) River region: Wisconsin Hist. Coll., vol. XIII, 1895, pp. 276-277.
7/ Durrie, D. S., Jonathan Carver and "Carver's Grants": Wisconsin Hist. Coll., vol. VI, 1872, p. 225.
8/ Schoolcraft, H. R., Narrative Journal of Travels, etc., Albany, 1821, p. 348.

Dubuque's principal mines were in the vicinity of the present location of Dubuque, Iowa, also along Tete de Mort River, about 12 miles south of Dubuque, and at Durango, about 6 miles northwest of Dubuque.9/

One of the results of Lieutenant Zebulon Pike's expedition up the Mississippi River in 1805 was a visit with Dubuque. He found M. Dubuque "polite but evasive" and was prevented from seeing the mines, but they signed a joint statement declaring that 20,000 to 40,000 pounds of lead were recovered per year, the yield being 75 percent of the ore smelted.10/

After Dubuque's death in 1810, the Indians continued to mine ore and trade it with the French and Americans until after 1820. In 1810 about 400,000 pounds of lead were sold by the Indians to traders in Prairie du Chien,11/ and probably other lead was shipped directly down the Mississippi from the mines.

In 1819 the permanent settlement of the area by Americans began with the arrival of Jesse W. Shull, under military protection, at Gratiot's Grove just south of Shullsburg, Wis.12/ On July 5, 1822, Col. James Johnson and others, supported by troops, arrived on the Fever River and joined the 500 Indians who were already mining there. Johnson and his associates settled at Galena, Ill., and began mining

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9/ Thwaites, R. G., Notes on early lead mining in the Fever (or Galena) River region: Wisconsin Hist. Coll., vol. XIII, 1895, pp. 282-283.
10/ Pike, Zebulon, Expedition; Phila., appendix to part 1, 1810, p. 5.
11/ Boilvin, Nicholas, Indian agent, letter to William Eustis, from Thwaites, R. G., ibid, p. 285.
12/ Bain, H. F., Zinc and lead deposits of the Upper Mississippi Valley: U. S. Geol. Survey Bull. 294, 1906, p. 3.

on a considerable scale. The towns of Hazel Green and New Diggings, Wis., were settled in 1824, after rich discoveries of lead were made there. Except for the period of the Black Hawk War in 1832, the settlement and development of the area proceeded very rapidly, and most of the important lead areas were found by 1830 13/

By an act of Congress in 1807, 14/ the government acquired ownership of the mineral lands that are now in the Upper Mississippi Valley zinc-lead district and the mineral lands of the Territory of Missouri. The Land Office was given control of these mineral lands which were reserved from sale with provision that they should be leased by the government on an annual rental. A superintendent of mines was employed, and a royalty was exacted of one-sixth to one-tenth, payable in cash or lead. This system was tried until 1846, but it proved so unsuccessful that the decision was made to sell the land. Most of the leases had been given in northwestern Illinois and in Wisconsin, but only a few leases were granted in Iowa where the system was strongly opposed by the local courts.

As a result of the rapid settlement of the Upper Mississippi Valley district (the population rose from 200 in 1825 to 10,000 in 1828) 15/ and the discovery of numerous lead deposits, the production of lead from the district increased rapidly from 1,676 short tons in the period from 1821-1823 to 6,672 short tons in 1829. 16/ After a

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13/ Meeker, Moses, Early history of the Lead Region: Wisconsin Hist. Coll., vol. VI, 1872, p. 272.

14/ Laws, U. S., vol. 4, 1807, p. 127.

15/ Chandler, R. W., Map of the United States lead mines, Cincinnati, 1829.

16/ Bomford, C., Congressional documents: 21st Cong., 1st Sess., Senate Doc. 1, vol. 1, 1829, p. 128.

drop during the unrest of the Black Hawk War the production increased to a peak of 27,134 short tons in 1847.[17] From about 1830 to 1871 the district was by far the most important lead producing area in the United States, exceeding even Missouri during that period.

Lead was smelted locally, and small lead furnaces were erected in many parts of the district. Lists of many of the more important furnaces, as well as other information on them can be obtained from some of the earlier reports.[18]

A general land survey of the area in 1834 established the townships, ranges, and sections. Dr. David Dale Owen was selected by the Commissioner of the General Land Office to take charge of a geological survey of the "Lead Region." The party consisted of Dr. Owen, Dr. Locke, and 139 assistants. The field work, which consisted mainly of locating and mapping the lead mines of the entire district, was begun in September 1839 and completed in November of the same year. A report, complete with plates and maps, was printed in 1844.[19] This survey was perhaps the first important geological study made by the United States Government in the entire area of the United States, and the first comprehensive effort to record the location of the lead deposits of the district.

17/ Winslow, Arthur, Lead and zinc deposits of Missouri: Missouri Geol. Survey, vol. VI, sec. 1, 1894, p. 147.

18/ Calvin, Samuel, and Bain, H. F., Geology of Dubuque County: Iowa Geol. Survey, vol. 10, 1899, pp. 486, 593-597.
Strong, Moses, Geology of Wisconsin: Wisconsin Geol. Survey, vol. 2, 1877, pp. 742-750.
Cox, G. H., Lead and zinc deposits of northwestern Illinois: Illinois Geol. Survey Bull. 21, 1914, pp. 14-15.

19/ Owen, D. D., Report of the geological explorations of parts of Iowa, Wisconsin, and Illinois: Congressional documents: 26th Cong., 1st Sess., H. Doc. 239, 1840, 161 pp.
Owen, D. D., ibid: 28th Cong., 1st Sess., S. Ex. Doc. 407, 1844, 191 pp.

The decline of the lead mining began in 1848, and the principal causes were the depletion of the easily found, superficial lead deposits in this area and the discovery of gold in the West.

Zinc ores in the district were first noted by Owen in 1839,[19] but owing to a lack of market for the ore and the difficulty in smelting, they were not recovered until 20 years later. The first zinc ore was gathered from the dumps of lead mines. Two smelters were erected between 1852 and 1860; one at Mineral Point, Wis., by Mr. Robert George, and the other at LaSalle, Ill., by Messrs. Matthiessen and Hegeler.[20]

As lead mining decreased in the latter half of the nineteenth century, the zinc mining increased. From 1860 to 1873 the production of smithsonite (zinc carbonate) exceeded that of sphalerite (zinc sulfide), but after 1873 the annual production of sphalerite was always greater than that of smithsonite. The first sphalerite shipped from the district was taken from the Rooney, Swift and Company's mine in 1867.[21] Zinc production increased rapidly for the first 20 years, and 10,236 tons of about 60 percent zinc sulfide concentrates and 6,084 tons of zinc carbonate concentrates were shipped from the district in 1873.

In the 1890's a roaster and magnetic separator were invented by W. P. Blake to separate the iron sulfides from the high-sulfide zinc ores, and in 1899 one of the first contact sulfuric acid plants, using the Schroeder-Grillo process, was erected at Mineral Point to manufacture sulfuric acid from the iron sulfides as a by-product of the zinc oxide plant previously established there.

20/ Hall, James, and Whitney, J. D., Geology of Wisconsin: Wisconsin Geol. Survey, vol. 1, 1862, pp. 372-373.

21/ Dugdale, R. I., Lead and zinc in southwestern Wisconsin, Southwestern Wisconsin Miners' Association, Platteville, 1900, p. 34.

About 1900, the zinc deposits of the district were actively promoted and developed by local interests. For a period of about ten years the district mushroomed with numerous development companies, and some of the mining companies made sporadic efforts to keep mining records.

Steam mills of the type used in the Joplin district, Missouri, were introduced for the concentration of ore about 1900. These power-driven gravity mills for the most part replaced the expensive, wasteful, hand-jigging and hand-dressing methods formerly prevalent in the Upper Mississippi Valley district. The mills usually consisted of a primary crushing unit plus Harz-type 7-cell wooden jigs ranging in number from one to three banks. A 50-ton mill had generally a single bank of jigs and a 100-ton mill had three banks of jigs, all steam driven. In several of the mills concentrating tables were used to re-treat the tailings.22/ This method produced a concentrate of from 25 percent to a maximum of about 60 percent zinc. However, the iron sulfide content was commonly so great in the jig product that roasting and magnetic separation were necessary to obtain concentrates that could be shipped to the smelters without a penalty.

During the period from 1908 until about 1917, mines continued to grow in size and efficiency, and concerted efforts to keep mine and drill hole records were made by the mining companies. Most of the mining at the close of World War I was by four large companies: The Vinegar Hill Mining Co.; the Mineral Point Zinc Co., a subsidiary of the New Jersey Zinc Co. (fig. 2); the Wisconsin Zinc Co., a subsidiary of the American Zinc Co.; and the Frontier Mining Co. These

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22/ Bain, H. F., Zinc and lead deposits of the Upper Mississippi Valley: U. S. Geol. Survey Bull. 294, 1906, p. 146.

companies, particularly the Vinegar Hill Mining Co., introduced modern methods of mining such as power shovels, battery locomotives and cars, and cage hoisting that reduced mining costs. The production of the district rose steadily to an all-time high in 1917, when 64,000 tons of zinc metal was produced. Rising costs, depletion of known reserves, and the depression of 1920-21 with its sudden drop in zinc prices, resulted in almost a cessation of production--a blow from which the district never fully recovered. After 1920, production increased again at a rapid rate only to drop swiftly after 1928 with the inception of the major depression of the 1930's. Except for activities by the Vinegar Hill Mining Co., large-scale prospecting had nearly ceased and the reserves, which in 1920 were still large, were reduced when the rate of production, by additional mining in the 1920's, greatly exceeded the discovery of new ore deposits by prospecting.

During the 1930's only the Vinegar Hill Zinc Co. continued active mining, though intermittent production came from several smaller companies. The most important of these companies was the Rule Mining Co. or Badger Zinc Co. that introduced and operated the first flotation mill in the district at Linden, Wis.

In 1938 the Vinegar Hill Zinc Co. established a custom jig-flotation mill at Cuba City, Wis., in connection with their acid plant and roaster, and until 1947 they milled most of the ore produced in the district. The custom mill eliminated the need for separate mills by some of the smaller mine operators, who were beginning to resume production. Numerous small mines were opened, mainly by local interests, and production rose steadily until 1947. The impetus of World War II and the resulting establishment of zinc-lead premium prices above the frozen market price by the U. S. Government in 1942 greatly stimulated mining; so during the war years between 30 and 40 mines were in operation. Considerable remilling by flotation of old jig tailings piles was carried on by several companies during this period.

When the zinc subsidies were abandoned in 1946, followed by a marked drop in the base metal prices, many of the smaller mines were abandoned. However, the discovery of several large new ore bodies during a joint exploration program started in 1942 by the Bureau of Mines and the Geological Survey had greatly stimulated the interest in new exploration in the district. The largest of these discoveries, the Gray and Bautsch ore bodies that contain more than 3,000,000 tons of ore, were opened in 1946 by the Tri-State Zinc Co. New methods and techniques in geology, prospecting, and mining stimulated the interest of large mining companies located in other districts. Several of these companies started major prospecting programs within the district in 1946-47 and used some of the new geological and prospecting techniques developed and used by the Geological Survey and the Bureau of Mines. These prospecting programs discovered a number of important ore bodies in new areas and thus increased the known minable ore reserves in the district from about 1,000,000 tons in 1942 to over 9,000,000 tons in 1949. In December 1949 four large companies--the Tri-State Zinc Co., the Calumet and Hecla Consolidated Copper Co., the Vinegar Hill Zinc Co., and the Eagle Picher Mining & Smelting Co. (fig. 3)--were engaged in large-scale mining or mine development work on these ore bodies.

A large number of mine maps and drill hole records were made since 1910, and many of the records were preserved by the mining companies, former mine operators, and owners. However, these widely distributed records were so completely heterogeneous in size, scale, and accuracy that their use was difficult at best. Also, from time to time the owners of these valuable records would lose or destroy them, and gradually they were being permanently lost. Similarly, in recent years considerable prospecting and mining has occurred in which inadequate records were being kept, and the need existed to make records to preserve the data for the future mining industry in the district.

In 1946 the need for the preservation in a permanent form of all available mining and drilling records was realized independently by the Bureau of Mines and Geological Survey field supervisors, and Mr. E. F. Bean, Wisconsin State Geologist. A general plan for a mining atlas for the Upper Mississippi Valley zinc-lead district was formulated. Shortly afterwards the Bureau of Mines undertook active completion of the Atlas, the work progressing in cooperation with the Federal Geological Survey-Wisconsin Geological and Natural History Survey field party.

THE GEOLOGY OF THE UPPER MISSISSIPPI VALLEY ZINC-LEAD DISTRICT

General Statement

The Geological Survey began a detailed restudy of the Upper Mississippi Valley zinc-lead district in October 1942. A field office of the Bureau of Mines was opened in this area in December 1942, and a joint program was established to explore and develop the ore deposits of the area. A joint drilling program for the exploration and development of additional ore was begun in January 1943. At the inception of the program five drills were operated by the Bureau of Mines. Drilling and sampling were continued by the Bureau of Mines until 1949, and numerous valuable reserves of lead and zinc ore were located by this program. In addition to the joint prospecting program, the Geological Survey has engaged in a detailed geologic study of the district in order to find useful geologic criteria for the discovery of additional ore bodies and to enlarge and expand the knowledge and limits of the potential mining district. In July 1945 the U. S. Geological Survey and the Wisconsin Geological and Natural History Survey established a cooperative program to continue the geological studies already in progress. Detailed geologic mine mapping of about 30 mines, and similar areal mapping in six important areas that comprise a total of 112 square miles, has been completed. Most of the latest data resulting from these studies are being prepared for publication. Some of the important new geological data are briefly summarized in this section.

The need for a permanent file of information on the numerous mines and prospects was realized shortly after the inception of the joint program. Maps and drill records, both originals and direct copies, were collected by the Geological Survey for the use of both field parties. Successful detailed geologic mapping and exploratory prospecting were found to be constantly dependent on the existence and availability of the widely distributed mining records. The original maps and records were in many forms, scales, and duplications; and these variations in the records necessitated much extra work. A need was realized by both parties for a general altas in which all the available data were compiled in standard form at the same scale and without duplications, so that field geologic work and prospecting could be greatly expedited. This need led to the compilation of the Atlas.

Location and Topography

The Upper Mississippi Valley zinc-lead district includes the southwest part of Wisconsin, the northwest corner of Illinois, and a narrow fringe of the northeast edge of Iowa along the west bank of the Mississippi River (fig. 1). Lead and zinc deposits are present throughout this area of more than 2,500 square miles, but recent production of ore had been restricted to about 650 square miles situated in a north-trending belt that extends through Platteville, Wis., and Galena, Ill. Discoveries of zinc ore bodies since 1942 have considerably enlarged this productive area.

Except along its east and west borders, the district lies entirely within the southern part of the well-known Driftless Area of the midwestern United States.

The topography of the district is relatively rugged as compared with most of the surrounding region. Several low escarpments and isolated detached hills rise above the general level of the gently rolling topography. A dendritic network of streams, all tributary to the Mississippi River, drains the area and occupies shallow valleys which become more deeply incised as the main river is approached.

Stratigraphy

Figure 4 shows the details of the stratigraphy of the area. The ores are chiefly in the rocks of Ordovician age, but small quantities of lead ore have been found locally in the underlying Cambrian and the overlying Silurian strata. The Decorah and upper Platteville beds are incompetent—especially the soft, plastic Spechts Ferry shale member. In contrast, the remainder of the Platteville formation and the Galena formation consist of competent dolomites.

The general characteristics of the other strata are also tabulated in figure 4. The St. Peter sandstone is a widespread aquifer. The Prairie du Chien group is, for the most part, similar lithologically to the Galena and Decorah formations.

Zinc deposits occur most commonly in the lower part of the Galena dolomite, the Decorah formation, and the upper half of the Platteville formation. The gash-vein lead deposits are limited to the Galena dolomite. Small lead, zinc, and copper deposits are found locally along the northern edge of the district in the Prairie du Chien group, and in places the St. Peter sandstone is pyritized directly beneath overlying zinc deposits.

General Structure

The area is on the gently inclined western limb of the Wisconsin arch. The regional strike of the beds within the district is approximately N. 85° W., and the dip to the south is about 35 feet to the mile. Westward and northwestward the strike in the district swings to about N. 45° W., but the amount of the dip remains the same. To the south a west-striking anticline extends west from the Wisconsin arch. Two folds of about the same magnitude are north of that anticline and cross the district in a general westerly direction. The southern anticline has an amplitude of 100-200 feet and a fairly regular westward trend, whereas the northern anticline has an amplitude of 100-170 feet and a trend that changes greatly, from southwest at its eastern end to northwest farther west. The three folds described are all asymmetric with steeper north limbs.

Most of the smaller subsidiary folds have axial trends that fall into two general groups trending respectively northwest, and west to southwest. Such lesser folds are generally elliptical in plan. A progressive decrease in intensity and magnitude of folding from south to north results in a close spacing of folds with amplitudes of 40 to 70 feet in the southern part of the district, whereas those in the north are far more widely spaced and only 10 to 20 feet in amplitude. The axial lengths of the subsidiary folds range from half a mile to two miles, their widths from a quarter to half a mile, and their amplitudes from 15 to 70 feet.

Major faults are rare and traced with difficulty, but locally both reverse and shear faults with vertical displacements as much as 50 feet have been traced several miles along their strike. Horizontal components of displacement are inconspicuous.

Structure of the Ore Deposits

The smaller, subsidiary folds are especially important in their relation to the ore deposits of this district. The common relations of ore bodies to the local folds are illustrated by the Coker mines near Mifflin, Wis. (fig. 5). The general trend of the ore bodies is N. 70° E., parallel to the axis of the larger syncline in which they lie. The Coker No. 1 mine lies along the north limb and the Coker No. 3 along the south limb of this larger syncline. In the center of the large basin is a low anticline that trends parallel to the synclinal axis. The Coker No. 2 ore body completely surrounds this anticline. All these ore bodies are localized in shear zones and fractured ground on the flanks of the folds where the beds dip at a maximum. Most of the shears (called "pitches" by the miners) commence as branches from bedding-plane faults along the plastic lower Decorah shale, curve upward to an average angle of 45 degrees into the overlying competent dolomite beds, and extend 25 to 50 feet above the bedding-plane fault. These fractures are chiefly reverse faults of 1 to 10 feet displacement and are traceable over great lengths along their strike. They usually dip toward the structurally high areas. The accompanying bedding-plane fracture and faults, where mineralized, are known as "flats". The entire shear zone exhibits relationships typical of reverse and associated bedding-plane faults elsewhere in the world. The most remarkable characteristic is the tendency for the fault zones to swing around the ends of the folds to form arcuate patterns.

The structural geology of the Coker mines (fig. 5) could not have been completed without the mine and drill records which were preserved by the mining companies that formerly operated the mines. Very few outcrops exist in the area, and the mines were inaccessible at the time the geologic map was made; thus, the structural geology is based almost entirely on the mining records. A later reopening of the mines confirmed these structures. Figure 11 shows the details of the mine maps and drill holes that were available for a part of the area shown in figure 5. The structural mapping would have been greatly expedited if the Atlas had been available at the time the geology was mapped, instead of only the uncoordinated records of several mining companies.

The Hoskins mine near New Diggings, Wis., illustrates a typical arcuate ore body at the east end of a local syncline (fig. 6). The ore body outlines the structure around the end of the fold. The "pitches", "flats", minor flexures, the slight central anticline within the larger controlling syncline, and the minor vertical tension fractures along the general central axis of the structure are typical (section A'-A, fig. 6).

Recent large-scale prospecting based on the structural patterns described above has been very successful in locating new deposits of ore along extension of known ore trends or on newly located structures.

The gash-vein lead deposits are restricted to the Galena dolomite. Their chief ore mineral, galena, occurs in veins filling vertical joints of the shear type and in pod-like masses at favorable horizons along these joints. In many deposits the ore replaces the rock adjacent to the joint and also fills the previously formed solution cavities along the joint. Several such pod-like deposits may occur one above the other at favorable horizons along the same joint. Single mineralized joints are often traceable for well over a mile; they have nearly uniform strikes, N. 70° W. being most common.

Origin of the Regional and Local Structure

The regional structure, the local structural features, and the major ore body fracture patterns appear to have been caused by regional tectonic compression. Except for the accentuation of pre-existing tectonic structural features by local solution, virtually no evidence can be interpreted as supporting the long-held theory of local slumping that sought to account at least for the small basins and the associated fractures.

The time of deformation, though not known with certainty, was definitely post-Silurian and may well have been late Paleozoic or post-Paleozoic in age.

Mineralogy of the Ore Deposits

The mineralogy of the ores is relatively simple. The known primary minerals include ankerite, barite, calcite, chalcopyrite, dolomite, galena, gold, marcasite, millerite, pyrite, quartz, silver, sphalerite, and wurtzite. An arsenic-cobalt mineral, not yet identified but possibly having the composition of CoAsS or $CoAs_2$ is known to occur in fine intergrowths with marcasite. Elements appearing in small amounts in the ores are cadmium, germanium, molybdenum, and zirconium. The silver in the galena of the ore deposits ranges between 0.12 and 2.0 ounces per ton.

In the early stages of mineralization the solutions not only leached the carbonate rocks but also silicified and dolomitized the pre-existing rocks. The silicification was earlier. Rocks that were normally calcareous but are within and bordering the ore deposits are locally completely or partly altered to massive chert or dolomite, with little change from their original appearance.

The minerals in the ore deposits fall into a regular, paragenetic sequence (fig. 8). In simple banded veins the early minerals are near the walls; but if during deposition a vein was reopened along the center or along the walls, the sequence may appear to be complex but is fundamentally still regular. Galena is commonly in large cubes; sphalerite and marcasite are usually in layered masses or in concentric mammillary nodules of radiating crystals suggesting colloidal precipitation. The sphalerite resembles wurtzite, and some evidence exists that part of it was originally that mineral.

Vertical and horizontal zoning are recognizable. Galena predominates at the higher horizons, sphalerite at greater depth. Dolomite and silica increase in quantity with depth. Nickel and arsenical cobalt minerals have been found only in the deeper deposits. Regionally there is likewise a general zoning of the ores. Lead is more abundant near the periphery of the district and zinc in a large central area (fig.). Copper, barium, and nickel are all present in largest quantity in a central zone 12 miles wide extending northwest through the entire district, apparently irrespective of structural features.

Origin of the Ores

Until recently these ore deposits were generally considered to be deposited from cold, descending or artesian waters. No criteria have yet been discovered that finally substantiate the meteoric or artesian hypothesis versus the hydrothermal hypothesis.

The best evidence to date, though not conclusive, indicates that the ores were deposited by hydrothermal solutions with temperatures probably not exceeding 100° C.23/

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PROCEDURE

The Bureau of Mines and Geological Survey had worked in close cooperation in the field for several years, and in 1947 they held a joint field conference to determine the form and scope of the present Atlas. Both agencies were familiar with the types of information needed to facilitate mineral development and the problems that would be encountered in the field in obtaining data from the numerous companies and small mine operators. A compendium of the mining and drilling data in the district, with explanatory symbols, appeared to serve the purpose.

In southwestern Wisconsin the recording of basic factual data is relatively simple owing to the form and horizontal attitude of the deposits, together with the uniform method of exploration, development, and mining throughout the district.

The Atlas comprises uniformly scaled and sized maps of the district, showing features of exploration, development, and mining in plan, supplemented by detailed logs, analyses, and other data in sufficient detail to form a convenient uniform record of all available mining data for future use in the study, evaluation, and development of the mineral wealth. The size of the district—the limits of which are still not firmly established—and the amount of exploration, development, and mining known to have been done, dictated that the undertaking be scheduled over a period of several years. Figure 9 shows the counties of Wisconsin covered by the Atlas.

Initially, it was necessary to locate sources of information in order to obtain and record all available pertinent data. The bulk of the available information came from the records of companies operating in the district, the files of Government agencies that have done similar work in the area, the records and personal observations of informed individuals, the local newspapers, and exploratory and developmental field work by the compilers of the Atlas.

Some information was, of course, obtained with the stipulation that it remain confidential. Such stipulations are respected, and drill records and maps bearing that information are marked "Confidential" and are not available for inspection by unauthorized persons. However, this requested limitation complicates the work and does not permit the fullest utilization of the Atlas.

Many times records of one company were obtained as confidential data from other companies. It was then necessary to obtain release from the original company that had specified the information as confidential. Commonly when several companies had worked in an area, letters of release were obtained from each in anticipation of encountering confidential information. Worthwhile maps and data that the owners would not permit to be removed from the premises were duplicated by contact printing, microfilming, or other photographic methods.

Microfilming is a quick and rather inexpensive method of duplicating information. Microfilm forms a readily available compact record that can be easily stored in a minimum of space. The other duplication methods such as blue prints, blue- and brown-line prints, ozalid, van dyke, and photostat are also satisfactory. They have some advantages in map duplication because of their increased readability and decreased distortions.

The use of a microfilm projector to enlarge the individual frames of the developed microfilm permits typed copies of the drill records to be made by reading directly from the projector screen. However, maps must be traced and therefore some distortion will generally exist owing to lens aberration and enlargement from the microfilm. Prints or tracings of the key maps in a district were obtained when possible, as they are easier to read and can be reproduced to give a better over-all picture. The microfilmed maps are excellent when used to supplement tracings or prints and for permanent records.

A scale of 200 feet to the inch was selected to form the basis grid of the Atlas maps. This scale represents the most satisfactory compromise in this district between detailed drawing and convenient size. Thus, each regular section of land is represented as a square slightly in excess of 26 inches on a side. Irregular sections, regardless of size or shape, are shown also in individual atlas sheets.

The sections are subdivided into quarters and sixteenths by dotted lines of different weights. All information necessary to orientation and location of any property, such as section, township, range, county, bar scale--in event of photographic reproduction--and a section reference number appears on each atlas sheet (fig. 10).

In compiling each volume of atlas maps the county is taken as the whole, and each section of land so designated by Federal land office survey, regardless of size or shape, is taken as a unit (fig. 11). Each section is numbered in sequence, without regard to township and range lines, until every section in the county bears a distinguishing number (fig. 11). These are entitled "section references" and correspond exactly with the section of land they serve to identify. Most of them will represent a block of land one mile square. In Wisconsin there are 777 section references in Iowa County, 630 in Lafayette County, and 1,203 in Grant County. Where no information of value to the Atlas is to be found in a particular section, that section reference sheet is not drawn pending information, though it continues to retain its original section reference number.

The system of assigning section reference numbers was decided upon as the most expedient method of indexing the unit sections. Not only can the individual Atlas sheets be readily referred to by section reference number, but also the drill records or logs can be more readily indexed and correlated. Confusion or error arising from use of section, township, and range is reduced to a minimum by the use of only one identifying number for each section in any one county. The indexing and filing of drill records is greatly facilitated and simplified by this system, because the binders containing the drill records need only include as many records as are convenient for handling and reference. Further, one adjustable loose-leaf binder will serve as the original container, and other binders can be added as needed.

Commonly, several property owners own land in any one section, and drilling may have been done at various times on each parcel of land. Several like-numbered sequences of drill holes may occur for each parcel of land, resulting in confusing duplication, and therefore serial numbers are assigned to the individual drill holes to eliminate this confusion.

Drill holes, about which only location or location and hole number are known, remain unserialized. Serial numbers are given to drill holes consecutively in the order identified and are never duplicated on any one section reference map. The first serial number on any map is number one, and the last serial number will be that of the last hole identified, regardless of the time lapse or location on that section reference.

Each identified drill hole, therefore, has two numbers. The first number is the serial number assigned by the compilers of the atlas, and the second number is the hole number assigned at the time of drilling. The hole number identifies the original drill hole and is a check in serializing. The serial number permits ready cross reference between drill holes on the Atlas maps and the geologic drill logs filed under the corresponding section reference numbers in the log books (fig. 12).

Inasmuch as the general geology of the district permits the use of plan maps to greatest advantage, all mine workings are shown in plan with solid lines indicating surveyed workings and dotted lines indicating unsurveyed workings or workings that are subject to question. However, the symbols and type of maps adopted when compiling an atlas should be those which will best illustrate the type of ore deposits occurring in any mining district. Longitudinal and cross-sectional views of mineralized zones to depict surface or underground mining or drilling can be adapted to depict the geology and mode of ore occurrence in almost all mining districts.

As simple a legend as was reconcilable with clarity and understanding was adopted for all atlas maps. Only four symbols were selected to show the relative mineralization encountered in the drill holes. This permits a more rapid interpretation of the maps, facilitates the transfer of data from old records, and simplifies the final drawing of the section reference maps. No information is lost, for if a question arises as to the degree of mineralization in any hole or group of holes, it can readily be determined from a study of the logs of the holes in question.

Blackened holes indicate a mineralization of at least 3 percent lead or zinc content, singly or combined, through a minimum distance of 2 feet.

One-half blackened holes indicate a mineralization of from a trace to 3 percent lead or zinc, singly or combined, through a minimum distance of 2 feet.

An unblackened hole, represented only by a circle of the same size as the other drill holes, indicates a hole in which no trace of mineralization is found. A serial number indicates that factual data is available in the log book.

The "dry-hole" symbol is used to indicate drill holes about which no information is known except location and possibly drill hole number.

Whenever possible the description of the formations present and the nature and degree of mineralization appear in the log. When compiling the drill logs for the Atlas, all possible data referring to the lithology, mineralization, geologic structures, and water penetrated should be retained, as well as all drilling information such as date drilled, driller, notations as to poor recovery, etc. Rearrangements of all of this information to fit the Atlas format are advisable, but the omission of any of the pertinent information decreases the value of the drill records for future use. The importance of a particular item of data for future mining or geological use cannot be predicted in advance, so all of the information should be retained.

The serial number and hole number on each drill log sheet are the same serial and hole numbers that appear on the map. The section reference number must appear on each log sheet, as other section references have similar serial and log numbers. Additional necessary and useful information is the collar elevation of the drill hole, property location of drill hole, the date the hole was completed, the company or operator who did the drilling, the person who logged the hole, and the type of drilling.

Most drill logs in any one mining area will be found to contain colloquial expressions accepted as a matter of custom by the local miners in preference to the more generally recognized terms. Unless the reader is familiar with the area some confusion might result in the interpretation of such terminology. In transcribing the records of drillings in Wisconsin into the log books of the Atlas, the most satisfactory arrangement was to divide the drill logs so that lithology and estimated analyses were considered and tabulated separately according to (1) strata penetrated, and (2) assayed values and depths. This method permits sufficient editing of the drill records to make them understandable to interested parties who are not familiar with the local terminology.

Plat books of the counties, showing property ownership, are an aid when starting to compile an atlas in a new and unfamiliar district. Commonly, maps of mining properties or drilling locations have reference to some property owner and thus can be identified and located by study of the plat books.

Highway maps give a good over-all picture of the towns of a mining district and the road system. Numerous small mines and drilled areas are related only to roads and road intersections. Thus, not only are maps of the roads necessary to locate the drilled areas or mine properties, but also the roads must be shown on the Atlas maps if the Atlas maps are ever to be used in the field to locate mining properties or drilling sites. Recent air photos and topographic maps are particularly useful in obtaining accurate locations of mines, drill holes, section corners, and landmarks such as roads, railroads, and section-line fences.

The land survey that included the southwest Wisconsin mining district was completed by 1840, and consequently only a few section corner and very few quarter corner markers can still be identified. Nevertheless, this mining district, unlike those of the western United States, is also a well-cultivated area in which many fence lines and intersections of fence lines constitute section lines and section corners. Furthermore, many of the roads run along the section lines, and the road intersections approximate the true section corners. Therefore in drafting the maps of Wisconsin for the Atlas, all roads are shown because many mining properties and drilled areas are tied into the roads. All passable roads are represented as being 60 feet wide. This figure is but an approximation, based on the average width of road from fence to fence; however, it is time-saving to standardize. Standardization avoids the problem of revising the Atlas every time a road is improved and widened, makes it easier to draft the maps, and side-steps the problem of determining the width of the actual right-of-way of every road to be drawn in the district.

Drilling and mine records that are pertinent to the Atlas should be recorded by microfilming, printing, or typing, even if unidentified. This recording may not seem necessary in cases where the information is already preserved and available, but in many cases drilling and mine records of the work done by individuals or small companies are disposed of, or lost, in time. Work in Wisconsin revealed that old records obtained from individuals or small companies were often disposed of when returned, either on the assumption that they had been made a matter of record or that they were no longer of any value.

Information on new section reference work sheets is generally compiled in pencil so that corrections or revisions can be quickly and easily made. When the information on a work sheet seems fairly complete, an inked tracing is drawn and prints made. These prints are issued in lieu of the old work sheet, and then any new information can be added when necessary from the latest work sheet to the inked tracing, and again make a new print.

Project headquarters for the Atlas in Wisconsin is at Platteville, Wis., a field office of the Bureau of Mines. All final drafting and printing is done at Bureau of Mines regional headquarters, Minneapolis, Minn. Consequently, the typewritten logs and penciled section reference sheets are sent from the field office to Minneapolis and the printed drill logs and latest prints of the section references are returned to the field office. Care and checking are necessary to insure that no records are lost.

When the prints accompanied by the original work sheets are received at the field office, they are carefully checked, one against the other, for errors in drafting. In the event of error or misunderstanding, it is found to be more satisfactory to make all corrections at the field office where the personnel are most familiar with the work. Only one office is then responsible for correcting errors, and possible confusion and time-taking correspondence is avoided.

Maps and records that are not properly identified or located with respect to recognized land marks or section corners will be obtained in undertaking the assemblage of an atlas. Many maps and records will have only one name on them, that of a property owner of record some years prior. Such difficulties should be anticipated, but they can be minimized by use of a card file that gives the names of a mine or property and is cross-indexed with information necessary to locate the property. This file is best accomplished by making and cross-indexing the cards as mine and property names and locations are encountered. A few cards added daily will soon result in a satisfactory working file. When completed, the file will constitute a valuable permanent record of the mines of the district and a valuable adjunct to the atlas. Names or information once of record and permitted to be lost or forgotten cannot always again be obtained.

Accumulating, sorting, recording, and indexing maps and records proceed slowly. In the final analysis there is no quick and easy method of compiling an atlas. Revision, clarification, and correction of records is a continuing process which demands attention to detail. Constant checking of information is necessary. Errors will be found in the most careful work, and alteration of maps becomes necessary as new information is obtained.

At this writing, the Atlas is authorized to cover the southwest Wisconsin zinc-lead district. However, similar deposits are known to exist in northeastern Iowa and northwestern Illinois under the same general geologic conditions. It is anticipated that this work will be expanded to include these areas.

CONCLUSION

Varied and widely scattered information on prospecting, development, and mining in southwestern Wisconsin is being collected, assembled, and tabulated to form a mineral exploration and development Atlas. Over 300 mines, many mining properties, and the locations of 13,900 drill holes are represented on the Atlas maps. Logs of drill holes are assembled, serialized, and tabulated in the log books. Estimates are that in another year approximately 20,000 logs of drill holes, the location of many additional mining properties, and maps and information on 350 mines, representing the bulk of the information currently available in the district, will have been recorded.

The Atlas sheets of Wisconsin will serve and are already serving many useful purposes. A permanent record of all the available mining information in the district is established in a centrally located and conveniently usable form. Sufficient copies are made and distributed so that little likelihood exists that in the future the records in the Atlas will be permanently lost. Exploration and operational mining engineers have an easily transferable source of information upon which to plan exploration, development, and mining programs. Geologists studying the district are provided complete maps of mines compiled from all the available scattered information. These maps are on a convenient scale for geologic map compilation and are accompanied by easily identifiable and correlated drill hole logs that contain all the recorded geology in each drill hole. The Atlas promises to greatly accelerate future geologic studies in the district. Local and district-wide ore reserve calculations are made much easier by the convenient Atlas. Unmined ore deposits and protores for future generations are placed on accessible public records for future development. Individuals or companies interested in developing commercial mines in the district have a convenient source to examine its potentialities. The many uses of the Atlas will assist in assuring the continued production of ore from the part of the district in southwestern Wisconsin.

Projects similar to the Atlas compilation for Wisconsin would be feasible and worthwhile if adapted to other mining districts in the United States. The work as described in this report, while most applicable to bedded vein deposits, can be modified to include other vein deposits by showing dip and strike, with illustrative sections on section reference maps.

If in any mining district an atlas type project is deemed advisable, and a conference is held to decide on the form and content, one salient thought should be kept in mind, namely simplicity. Atlas compilation demands patient, painstaking work, proceeds slowly, and needs constant checking and revision. For these reasons complication should be avoided. Unnecessary symbols and complicated routine will prolong the work and made it more difficult and expensive. Since all the problems in compiling the atlas cannot be anticipated, as much latitude as possible should be allowed those men who will do the work.

The completion of a comprehensive mineral atlas of a mining district will result in increased chances of success for exploratory drilling and mining development. The over-all picture of the mining district, as illustrated by the Atlas, permits a better understanding of the geology and the nature and occurrence of the ore bodies within the district. Further, a complete picture of the area could indicate favorable locations for prospecting outside the known limits of the district.

Mining districts throughout the United States contain unworked and marginal ore deposits, but the records in many of these districts have already been lost or will be lost with the passage of time. One of the functions and advantages of an atlas is that it preserves records of prospecting, development, and mining. An atlas would serve to eliminate in many places the need for venture capital to reopen mining properties to determine grade and quantity of ore available with each change of economic conditions. The unwatering and sampling of mines by successive operators would seldom be necessary. Assay values, underground workings, ore reserves, and additional data are a matter of record in an atlas.

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