GEOLOGICAL ASPECTS OF PROSPECTING
AND AREAS FOR PROSPECTING
IN THE ZINC-LEAD DISTRICT OF NORTHWESTERN ILLINOIS

BY

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BY

H. B. WILLMAN, R. R. REYNOLDS, AND PAUL HERBERT, JR.

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Topographic Mapping in Cooperation with the United States Geological Survey.
This report is a contribution of the Industrial Minerals Division

March 1, 1946
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GEOLOGICAL ASPECTS OF PROSPECTING AND AREAS FOR PROSPECTING IN THE ZINC-LEAD DISTRICT OF NORTHWESTERN ILLINOIS

by


SUMMARY

Zinc ore totaling 3 to 4 million tons and averaging 4 to 5 percent zinc is probably present in the northwestern Illinois part of the Upper Mississippi Valley zinc-lead district, according to the available drill data. The ore deposits are commonly 100 to 200 feet wide, 500 feet to about a mile long, and at depths usually between 50 and 250 feet. The major deposits range from 5 to 50 feet thick and occur largely in a vertical zone of about 100 feet in the lower part of the Galena formation and the underlying Decorah and Platteville formations.

Commercial deposits of zinc ore in northwestern Illinois have been found in an area of about 50 square miles, and only a small part of this area has been adequately prospected. Large parts of the potential area contain only scattered outcrops, and there are few, if any, records of drilling. These areas present a difficult problem in prospecting because (1) conditions are unfavorable for the use of surface geological methods, (2) favorable geological structures are so small and widely separated that pattern drilling to find them is probably too costly at present, and (3) geophysical methods of prospecting have not been successfully adapted to deposits of this type.

However, much drill, mine, and outcrop data are available in parts of the area, and these reveal many possibilities which have not been investigated by drilling. Prospecting may be based on (1) drilling to extend known ore reported in abandoned mines, in prospect drill-holes, and in water wells, (2) drilling cross-sections on the trends of known ore bodies, (3) drilling on favorable geological structures, and (4) drilling in areas of shallow lead diggings.

This report discusses the significance of theories of origin of the deposits as related to problems in prospecting, the selection of areas for prospecting, and the geological aspects of conducting a prospect drilling program. The possibilities of about 50 properties and mines are briefly discussed and the available data are summarized. In some of the localities described a considerable amount of ore is already indicated by drilling but in others the evidence favoring prospecting is slight.
INTRODUCTION

The search for new deposits of zinc and lead ore in the northwestern Illinois part of the Upper Mississippi Valley zinc-lead district has been greatly stimulated by the recent discovery and development of new ore bodies and the successful reopening of several old mines during the recent war period. Because of the revived interest in the district, the authors have conducted an extensive re-study and have prepared the following discussion of the geological aspects of the problem of prospecting with the hope that it will be of assistance to mining companies, land owners, investors, and others interested in evaluating the potentialities of the district.

The long-term prospects for zinc mining in northwestern Illinois are viewed favorably by operators in the district, but the immediate future involves many imponderable factors such as ceiling prices, tariffs, government bonuses, government stock piles, material costs, and available labor. Belief that an adequate price will permit continued operation is based on an anticipated decline in domestic production, a favorable outlook for high zinc consumption, and the proximity of the northwestern Illinois ore deposits to zinc smelters.

In northwestern Illinois a total of 3 to 4 million tons of ore averaging 4 to 5 percent zinc can be inferred from the available drilling data. Considering the zinc ore-bearing area to be that included by known deposits—approximately 50 square miles—and comparing this with the small part which has been adequately tested, the chances are good that not all the ore bodies have been discovered. The problem is, how to find ore bodies which are only 100 to 200 feet wide and from 500 feet to a mile long in such a large area.

Prospecting for zinc-lead ores in northwestern Illinois has consisted largely of drilling in extensive areas of shallow lead diggings, in areas on the trends of known ore bodies, or in the vicinity of the occasional water well that happens to penetrate ore. Wildcat holes also were formerly drilled in large numbers. When these methods of prospecting became unprofitable, combined with a declining market, some operators left the district and others waited for water wells to hit ore or took over the properties occasionally found by wildcat drilling.

The problem of discovering some scientific method of localizing the area to drill for ore, and thereby increasing the percentage of successful drill-holes, has been studied for many years by state, federal, and company geologists. These studies have shown that many ore deposits occur in certain structural positions which, if they can be recognized in the outcrops, might serve as a basis for prospecting.

In the large areas where outcrops of bedrock strata are widely scattered or lacking, the principal hope for localization of drilling is in the use of geophysical methods of prospecting. A few geophysical tests have been made in the past with slight success. Present geophysical work by the Illinois Geological Survey is not sufficiently advanced to permit definite conclusions, but it appears that the outlook for many of the established methods is not encouraging and that a large amount of basic research will be needed if the problem is to be solved.

The problem of prospecting for the shallow lead deposits which were so extensively mined in the middle part of the last century, and which have been worked only intermittently and on a small scale for many years, is not discussed in this report. Although there are ample theoretical reasons for believing that the lead deposits are far from worked out, these deposits individually are relatively small compared to the underlying zinc-lead deposits. The present studies have been directed almost exclusively to the finding of the major zinc-lead deposits. This report is presented before the current investigation is complete in order to make available the information thus far assembled. Additional information about many of the properties described is available in the files of the State Geological Survey.
ACKNOWLEDGMENTS

The investigations of zinc and lead resources and prospecting have been greatly aided by the generosity of officials of the mining companies in supplying maps and drill records, especially W. N. Smith and O. E. DeWitt of the Vinegar Hill Zinc Company; M. H. Loveman, V. C. Allen, J. E. Kaltenback, of Tri-State Zinc, Inc.; William Blair Baggaley, Joseph M. Van Matre, John E. Lickes, of the Ginte Mining Company; John Gill and William Gill, of Gill Brothers; Russel B. Paul, of the New Jersey Zinc Company; G. Kenneth Lowther and Harold W. Davis, of the Eagle-Picher Mining and Smelting Company. This project was benefited by the cooperation of the United States Bureau of Mines who at the time some of this work was done were conducting an extensive churn and diamond drilling program, in particular Owen W. Terry, Francis C. Lincoln, Ottey M. Bishop, and Alvin M. Cummings. Many drill records and maps of Illinois properties in the files of the United States Geological Survey at Platteville were kindly made available by Allen F. Agnew and Allen V. Heyl, Jr. Many property owners and lease holders have supplied data on their holdings.

This report has greatly benefited from the free exchange of ideas on the problem of prospecting with many of the men listed above, and especially with geologists of the United States Geological Survey, Charles H. Behre, Jr., Allen V. Heyl, Jr., and Allen F. Agnew.

The cooperation of drillers engaged in prospect drilling, including H. A. Butler, Lloyd George, Paul L. Gille, R. D. Gille, Samuel Hailey, Thomas Kail, James Mertens, Laurence Mertens, Guy Peterson, and Frank Ware, has been especially helpful.

The references to geophysical prospecting are based on studies by R. T. Anderson and on consultation with C. A. Bays and R. J. Piersol, all of the Illinois Geological Survey.

The active interest and support of the project by M. M. Leighton, Chief of the Survey, and J. E. Lamar, Geologist and Head of the Industrial Minerals Division of the Survey, is gratefully acknowledged.

LOCATION

The deposits of zinc ore in northwestern Illinois have all been found in Jo Daviess County in an area about five miles wide and 15 miles long that extends nearly north-south through Galena from the Illinois-Wisconsin State Line to Mississippi River (pls. 1 and 2, fig. 1). This area also contains many large tracts in which lead ore has been mined. It is referred to in this report as the “principal mineralized area,” but lead ore deposits have also been mined at many other places in Jo Daviess County, and the known mineralized district, more than 400 square miles, includes most of the county. Some lead ore has been mined from a small area along Carroll Creek, two to three miles west of Mt. Carroll in Carroll County, about 15 miles south of the nearest deposits in Jo Daviess County. A small deposit of lead ore is reported to have been worked near Freeport in Stephenson County, about 15 miles east of the Jo Daviess County deposits.

MINING INDUSTRY

During the 1930’s almost no zinc ore was produced in northwestern Illinois and it was widely believed that the commercial ore bodies were worked out. However, when a shortage of zinc for the war effort resulted in a favorable market, the Hughlett and Gray and the North Unity mines, six miles north of Galena, were reopened by the Gill Brothers in 1941 and 1942. They were closed after removing a considerable tonnage of ore which was trucked to the custom mill of the Vinegar Hill Zinc Company at Cuba City, Wisconsin.

The Graham mine, three miles north of Galena, was reopened by the Ginte Mining Company, who sank a new shaft in 1943 to mine the continuation of the Graham ore body on the Ginte property and to take additional ore from the Graham mine. The mill has a capacity of about 400 tons per day and jig concentrates are trucked to the Vin-
Fig. 1.—Zinc-lead district of northwestern Illinois.
egar Hill Zinc Company. It is one of the largest producers in the Upper Mississippi Valley region.

In 1944 Tri-State Zinc, Inc., started development of a large ore body on the Gray (Heer) property which is four miles south of Galena on the southeast trend of the famous Black Jack mine, the largest mine in the Illinois part of the district. The Gray ore body was largely outlined by drilling by the United States Bureau of Mines from 1943 to 1945. The mill has a capacity of 600 tons per day and produces flotation concentrates. It has recently become one of the largest producers in the district.

Drilling by the United States Bureau of Mines on the Black Jack trend southeast of the Gray (Heer) ore body resulted in the discovery of another major ore deposit principally on the Bautsch farm. In January 1946 Tri-State Zinc, Inc., was sinking a shaft on this deposit. When the drilling was still in progress (January 1945) the Bureau of Mines estimated the Bautsch ore body at nearly 1,000,000 tons of ore and a large tonnage has been added by later drilling by both the Bureau of Mines and Tri-State Zinc, Inc.

The Big Six, a group of local miners, sank a shaft in 1944 and 1945 near the east end of the North Unity ore body, six miles north of Galena, and have started production of high-lead zinc ore from the part of the ore body above water level. The ore is hauled to the Vinegar Hill custom mill.

The Eversoll Brothers in 1945 did a small amount of development work on the Bullfrog mine, near the old Merry Widow mine, two miles west of Galena.

The Bennets were engaged in 1945 in pumping out the old South Unity mine, 5½ miles north of Galena.

### PRODUCTION

Lead produced from Upper Mississippi Valley ores from 1821 to 1905 has been estimated to total 612,000 tons, and the peak annual production of about 27,000 tons was reached in 1845 to 1847. The production of zinc ores did not start until about 1862, and through 1905 the total production in terms of zinc metal was probably about 140,000 tons. A considerable part of the lead but only a small part of the zinc came from Illinois.

From 1906 to 1944 zinc produced from northwestern Illinois totaled 72,476 tons valued at $11,289,172, and lead totaled 12,440 tons valued at $1,482,072 (table 1). The peak of production was reached in 1919 when 6,788 tons of zinc and 1,605 tons of lead were produced.

**Table 1.—Production of Lead and Zinc in Northwestern Illinois from 1906 to 1944**

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<th>Year</th>
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<td>1942</td>
<td>133</td>
<td>17,822</td>
</tr>
<tr>
<td>1943</td>
<td>84</td>
<td>12,600</td>
</tr>
<tr>
<td>1944</td>
<td>93</td>
<td>14,880</td>
</tr>
<tr>
<td>Total</td>
<td>12,440</td>
<td>$1,482,072</td>
</tr>
</tbody>
</table>

*Compiled from U. S. Bureau of Mines reports.

In terms of recoverable metal.

The value is calculated from the yearly average weighted price of all grades of primary metal sold by producers. It includes bonus payments by Metal Reserve Company, 1942-1944.

TABLE 2.—Strata Encountered in Drilling for Zinc and Lead Ores in Northwestern Illinois

<table>
<thead>
<tr>
<th>Geological Name</th>
<th>Material</th>
<th>Driller’s Name</th>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silurian System</td>
<td>Dolomite, mostly cherty</td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>Ordovician System</td>
<td>Maquoketa formation</td>
<td>Shale</td>
<td>100-200</td>
</tr>
<tr>
<td>Galena formation</td>
<td>Dubuque member</td>
<td>Dolomite, mostly thin-bedded, grades from dense and shaly at top to vesicular with shale partings at base</td>
<td>Buff</td>
</tr>
<tr>
<td></td>
<td>Stewartville member</td>
<td>Dolomite, massive, vesicular, noncherty, upper Receptaculitides zone at base</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>Prosser member</td>
<td>Dolomite, massive, vesicular, noncherty</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, massive, cherty</td>
<td>Drab</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, contains red shale partings and red-brown chert</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, cherty</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shale, dark brownish-gray</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, noncherty, brown mottling</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, cherty</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shale, dark gray, locally contains bentonite</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, cherty</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, noncherty, dense, shale partings</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, cherty</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, noncherty</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, cherty</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, noncherty, lower Receptaculitides zone</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, cherty</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, noncherty</td>
<td>a</td>
</tr>
<tr>
<td>Decorah formation</td>
<td>Ion member</td>
<td>Dolomite, noncherty, gray to buff, mostly vesicular, contains thin green shale beds</td>
<td>Gray</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, noncherty, dark gray, contains some green shale and is partly sandy</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>Guttenberg member</td>
<td>Limestone, light tan to brown, dense, fossiliferous, thin-bedded, interbedded reddish-brown shale</td>
<td>Oilrock</td>
</tr>
<tr>
<td></td>
<td>Platteville formation</td>
<td>Spechts Ferry member</td>
<td>Shale, green, commonly contains a thin bed of light gray to white bentonitic clay near base, locally contains lenses of limestone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limestone, brown, dense, commonly contains beds and mottled areas of dolomite, contains brown shale bed near top and bottom</td>
<td>Glassrock</td>
</tr>
<tr>
<td></td>
<td>Magnolia and Mifflin members</td>
<td>Limestone, gray mottled, dense, thin-bedded, partly argillaceous</td>
<td>&quot;Trenton&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite, brown, massive</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>Glenwood formation</td>
<td>Shale, sandy, green and brown</td>
<td></td>
</tr>
<tr>
<td>St. Peter formation</td>
<td>Sandstone</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The subdivisions of the Prosser member are those differentiated by Paul Herbert, Jr., of the Illinois Geological Survey in diamond-drill cores of the U. S. Bureau of Mines on the Gray and Bautsch properties, five miles south-east of Galena. Only a few of these units can be recognized in churn-drill samples but studies of outcrops, mines, and well samples indicate they are probably continuous throughout the mineralized district. These beds have been considered the basal beds of the Galena formation in earlier reports, but recent studies in Illinois and Iowa by Paul Herbert, Jr., of the Illinois Geological Survey, and in Wisconsin and Iowa by Allen F. Agnew of the U. S. Geological Survey, indicate their correlation with the Decorah strata.
STRATIGRAPHIC POSITION OF ORE DEPOSITS

The zinc and lead ore deposits in northwestern Illinois occur in the Galena, Decorah, and Platteville formations. The character of these formations and the associated strata which are encountered in drill-holes is shown in table 2.

In northwestern Illinois the major deposits of zinc sulfide ore occur in the lower part of the Galena formation (“Drab”), in the Decorah formation (“Gray”, “Blue”, and “Oilrock”)\(^2\), and the upper part of the Platteville formation (“Clay-bed” and “Glassrock”)\(^2\), but in places they also extend upward as high as the top of the chert in the middle of the Galena formation and downward into the upper part of the “Trenton” beds in the Platteville formation, a zone totaling about 140 feet thick.

The major deposits of lead sulfide ore commonly contain little zinc sulfide and almost no iron sulfide and occur in the upper 150 feet of the Galena formation. However, the lead ore locally grades laterally to zinc ore, usually rich in lead. These gradational or mixed zinc and lead ores appear to be especially common in a zone within 25 feet of the top of the chert in the middle of the Galena formation and downward into the upper part of the “Trenton” beds in the Platteville formation, a zone totaling about 140 feet thick.

The names in quotations are widely used by drillers and miners and in previous reports. For clarity they are used in this report, and the quotation marks are omitted, except in the case of the term “Trenton” which is the only geological name that has had common use. It is no longer acceptable in the geological classification.

TYPES OF ORE DEPOSITS\(^3\)

LOWER-RUN Deposits

The major zinc-lead deposits occur principally in the lowest part of the ore-bearing zone and are referred to as “lower-run” deposits (fig. 2). They have also been called “flat and pitch” deposits from the occurrence of the ore in “flats”, which are nearly horizontal sheet-like bodies of ore between or parallel to the bedding-planes of the strata, and in “pitches”, which are similar deposits cutting across the bedding-planes. Viewed in cross-section (fig. 3) the pitches mostly dip outward from the central part of the deposits. The pitches on either side are approximately parallel to each other, and usually the outermost pitch is relatively heavily mineralized and sharply delimits the deposit. The slope of the pitches is usually over 45 degrees (from the horizontal) but is steeper in some deposits than in others. The slope of many pitches increases upward so that the pitches become parallel to or grade into vertical crevices. Also many pitches tend to flatten off to nearly horizontal in their lower part. Usually the pitch is offset at several places by horizontal or low-angle steps.

Between the pitches bounding an ore body the Oilrock is usually thin and shaly, and the limestone beds which normally comprise the greater part of the Oilrock away from the ore bodies are usually greatly reduced in thickness or are absent. Commonly the top of the Oilrock slopes downward and inward from the pitches, forming a shallow sag or syncline beneath the pitches.

In the ground between the pitches, called “coreground”, the ore occurs principally in flats but also in breccia zones, in inside pitches, in vertical crevices, and disseminated. In minable deposits the mineralized ground is usually 50 to 200 feet wide but in places it narrows to 25 feet or less, although widths as great as 300 feet have been mined. In most deposits the minable thickness varies up to about 40 feet but greater thicknesses are not rare and a maximum thickness of about 125 feet has been mined.

Longitudinally the deposits may extend for thousands of feet, may be relatively straight (fig. 4), or may curve sharply forming arcuate deposits and even com-

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\(^2\) The names in quotations are widely used by drillers and miners and in previous reports. For clarity they are used in this report, and the quotation marks are omitted, except in the case of the term “Trenton” which is the only geological name that has had common use. It is no longer acceptable in the geological classification.

\(^3\) The term “ore” is used in this report to describe mineralized ground rich enough to be mined. At present the “minimum ore” or leanest ground considered minable must average 3 percent zinc for a thickness of 6 feet. A drill-hole is classified as an ore hole if the assays show minimum ore or better. Under favorable conditions somewhat leaner ground may be mined, but unless drill data indicate that a deposit as a whole averages about 4 percent zinc or better with a thickness over 10 feet it probably would not be developed at present. Other factors may be as important as grade in determining the minability of a deposit.
Fig. 2.—Stratigraphic range of ore deposits in northwestern Illinois.
Fig. 3.—Diagrammatic cross-section showing types of occurrence of ore in lower-run deposits.

In some lower-run deposits the pitches are poorly developed or lacking, and the ore occurs largely in flats, breccia zones, or disseminated. Many variations in the shape and character of the mineralized zone have been described and need not be repeated here.¹

Most of the lower-run ore is an open-fissure deposit but some replacement is always apparent, and the disseminated-type deposits, particularly those in the Oilrock and Glassrock, may be largely replacement.

The zinc mineral is largely the sulfide sphalerite, also locally called "jack", "black jack", "strawberry jack", and "blende". Where the deposits occur above water level, the zinc sulfide has been partially oxidized, or in places almost entirely oxidized to zinc carbonate, the mineral smithsonite, locally called "carbonate" or "drybone". The grade of the ores is highly variable. Rarely, ore 20 feet or more thick will assay as high as 20 percent zinc, but 10 percent zinc is considered rich ore, and deposits averaging 4 to 5 percent zinc are considered minable. In some deposits minable ground is confined almost entirely to the pitches but usually parts of the core-ground are also minable.

Fig. 4.—Zinc-lead mines southeast of Galena.
All of the lower-run deposits contain some iron sulfide in the minerals pyrite and marcasite, locally called "sulfur" or "iron". The amount of iron in the zinc ore, in terms of metallic iron, usually varies from 5 to 20 percent. In some deposits one pitch may run very high in iron, almost to the exclusion of zinc and lead, whereas the other pitch is low in iron. Lead occurs largely in the mineral galena, which is lead sulfide. In oxidized ground the galena frequently has a thin coating of cerussite, which is lead carbonate. The amount of lead usually averages less than 1 percent but rich pockets are encountered locally. The only other mineral present in quantity is calcite, or calcium carbonate, locally called "tiff".

In most of the major lower-run deposits lateral and longitudinal variations in thickness, in width, in continuity of the pitches, in geological structure, in relative proportions and amounts of zinc, lead, and iron, are conspicuous characteristics. Although understanding of the generalized relations described above is an important aid in prospecting in the district, the frequency and sharpness of variations has been underrated, and major errors have resulted from depending on the continuity of the ore.

**Top-run Deposits**

The ore deposits which occur along crevices, especially in the upper 150 feet of the Galena formation are known as top-run deposits. Most of these deposits occur in solution channels called openings, some of which are open caves but others of which are clay-filled. Openings show a preference for certain beds, and the usual classification of openings is shown in figure 3. Between the openings the crevices are tight and usu-
ally not sufficiently mineralized to be minable. In some parts of the district all the ore occurs along one opening but in others as many as three openings are ore-bearing.

The ore is usually entirely galena which occurs in large crystals lining caves, called "cog ore", in crystals scattered through clay or dolomite sand in crevices, or in vertical sheets or veins. Locally the lead ore in the openings grades laterally to zinc ore, usually high in lead. Where zinc sulfide is present, some iron sulfide is usually present as well, and the minerals frequently occur in groups of crystals lining the surfaces of the major openings or partially filling the many small cavities in the rocks adjacent to the openings. The latter type of ore, called "brangle", is characteristic of many top-run deposits and differs from similar lower-run disseminated ore which usually shows a strong iron sulfide replacement of the wall rock.

Most of the top-run deposits which contain zinc ore are near the top of the chert in the Galena formation, about 120 feet above the Oilrock. They are usually less than 25 feet wide and only 5 to 20 feet high. Some are hundreds of feet long but, because of the small cross-section, individual deposits have never produced tonnages comparable to the lower-run deposits. Some top-run zinc deposits have such a low iron content that a jig concentrate can be produced that is nearly as high in zinc as that produced from the lower-run deposits by flotation.

Top-run zinc deposits have generally been considered suitable only for small-scale operations. Almost none of the prospecting in the region has been directed specifically toward finding this type of deposits, and because the deposits are very narrow they are seldom encountered in water wells or in widely spaced prospect drilling. In areas where top-run zinc deposits have been found, careful prospecting along parallel crevices may discover additional deposits. The potentialities of these deposits are almost entirely unexplored and possibly enough of them can be found to justify large-scale operations.

**Middle-run Deposits**

Certain deposits which combine features of both the top-run and lower-run deposits may be differentiated as "middle-run" deposits (fig. 2). These deposits mostly occur in the zone from 25 to 125 feet above the Oilrock and thus overlap the zones of the typical top-run and lower-run deposits. They appear to be closely related to vertical crevices but may be much wider than most top-run deposits. The ore is usually a disseminated or brangle deposit similar to top-run zinc ore but it is frequently high in iron and shows replacement effects not unlike the lower-run deposits. As the Oilrock and Glassrock below usually are not thinned, the deposits lack the structure of the lower-run deposits. Only three or four mines in the Illinois part of the district appear to be in ore bodies of this type, and none of them are now open for study. The middle-run deposits are probably more comparable in size to top-run deposits than to lower-run deposits and, therefore, may be generally suitable only for small-scale operations.

**Relation of Theories of Origin to Prospecting**

Much of the prospecting in the district, including both selecting areas to drill and determining the depths of drilling, has been influenced by theories regarding the origin of the ore deposits. A brief consideration of these theories, particularly as they relate to prospecting, is given below.

**Source of Ore Minerals**

For many years the meteoric or cold-water theory of origin, advanced in 1854, was favored by most of the leading geologists and was considered established almost beyond question. By this theory the lead

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Chamberlin, T. C., op. cit. pp. 529-533.
Cox, G. H., op. cit. pp. 63-100.
and zinc minerals, which were assumed to be present in minute quantities in the Galena formation, or higher formations, and were dissolved by cold groundwater, carried downward in solution, and precipitated in the places where now found. Because of this manner of origin many people believed: (1) That ore deposits were essentially confined to the zone above the imperious Oilrock, and Clay-bed, so that drilling need not go below the Oilrock; (2) that ore bodies did not extend underneath the Maquoketa shale and the Silurian dolomite, so that these areas need not be prospected; and (3) that the ores, especially the lead ores, were related to the slopes of the valleys, so that areas beneath the valley-bottoms and flat uplands need not be prospected.

The few who favored an origin by rising hot solutions derived from magmatic or igneous sources faced the objections that the ore bodies occur in a narrow relatively shallow zone approximately parallel to the present surface, no downward extensions of ore have been found, the mineralized area has no major faults to give access to rising solutions, the Oilrock and Clay-bed appear to be relatively impervious and the ores are principally in and above the Oilrock, water in the sandstones below the ore-bearing strata would prevent the rise of magmatic solutions, and no igneous rocks younger than the strata containing the ore bodies have been found.

However, since about 1930 data have been accumulating which favor the origin from magmatic solutions. These data include evidence that the minerals were formed at temperatures from 90-110° C., that the solutions which deposited the minerals were concentrated brines, as shown by the composition of liquid inclusions in the minerals, that minor amounts of elements usually associated with igneous origin are present, and that the mineral arrangement is typical of magmatic deposits. At present, the weight of evidence appears to favor strongly the theory of magmatic origin.

If the magmatic theory is correct, areas which were considered to be unfavorable in the light of the meteoric or cold-water theory, and were but little prospected, are as favorable as the areas that have been prospected. For example, ore bodies are as likely to be found beneath areas covered by the Maquoketa shale and the Silurian dolomite as where these formations have been eroded. This results not only from the fact that the ore minerals came from below but because the ground surface at the time of ore deposition was probably at least as high as Silurian dolomite throughout northwestern Illinois and at least 200 to 400 feet higher than most of the present surface. Therefore, the Maquoketa shale and the Silurian dolomite probably covered the entire area when the ore was deposited. The same data also suggest that ore deposits have no relation to the present topographic surface or to the surface distribution of the formations, other than the limited control which ore-bearing joint systems and structures have had on the development of the present topography. The possibility of discovering ore bodies by drilling on favorable topography, or the "lay of the land", is not supported by the magmatic theory.

By the magmatic theory, the Oilrock and Clay-bed could not have been an impervious barrier because the rising solutions deposited the principal ore deposits above it. So much ore has already been found beneath the Oilrock and Clay-bed, that regardless of theoretical considerations, there is ample justification for prospecting beneath them.

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Bastin, Edson S., and Behre, Chas. H., Jr., in Contribution to a knowledge of the lead and zinc deposits of the Mississippi Valley Region: Geol. Soc. Am. Special Papers No. 24, pp. 121-143, 1939.

into the top of the "Trenton". Because these beds were considered to be impervious to downward moving solutions, a great part of the drilling in the district has been only as deep as the top of the Oilrock or the top of the Clay-bed. The magmatic theory does not require that ore bodies be present in the lower strata and, in fact, the position and shape of the known ore bodies suggest that the most favorable zone for ore deposition was in the strata above the "Trenton". Nevertheless, the possibilities of the "Trenton" and lower strata are virtually untested, and ore bodies may be present in these strata.

**Origin of Ore-Bearing Structures**

Various theories have been advanced to explain the relations of the ore deposits to the major structural features of the region and also the structures within the deposits, especially the pitches, flats, and the Oilrock sags. Favorable areas for prospecting may be selected by structural studies of outcrops and drill records, but both the selection of favorable areas and the interpretation of the value of structural methods differ according to the theory of origin favored. Three major theories have been advanced—the tectonic theory, the compaction theory, and the solution theory.

By the tectonic theory the major ore-bearing structures were formed when the region was subjected to lateral pressures which produced broad anticlines and synclines, shallow basins, and long narrow troughs. Zones of deformation around the margins of the basins and in the bottoms of the troughs are thought to have given access to the mineralizing solutions and to have made the openings in which the ore minerals were deposited.

By the compaction theory the ore-bearing structures have been interpreted as the result of the "slump" of the Oilrock shale, which because of its original high content of water and volatile hydrocarbons was compacted more than the surrounding less shaly rock. The slump of the Oilrock formed the Oilrock sag, and the collapse of the overlying rocks formed the inclined fractures or pitches and the bedding-plane openings or flats.

By the solution theory the structures are explained as resulting from the partial and irregular solution of the relatively soluble Oilrock, Glassrock, and "Trenton" limestones, starting along the pre-existing joints or shear zones which gave access to rising hot solutions. The thinning of these beds by solution resulted in the Oilrock sag and the collapse of the overlying strata, thus producing the pitch and flat openings. Solution, deformation, and mineralization were essentially contemporaneous. This theory combines features of the two preceding theories, recognizing the relation of the ore deposits to the tectonic pattern of the region, but ascribing the development of the local structures of the ore bodies to solution and the resulting settling and collapse. It differs from previous collapse theories in explaining the collapse as a result of solution rather than of irregular sedimentation and compaction.

All of these theories recognize the importance of deformation in providing adequate openings for the deposition of ore minerals, and therefore, the potential value of structural studies in the selection of areas to drill. The tectonic and the solution theories, in relating the ore bodies to the regional deformation of the rocks, indicate the value of mapping the regional geologic structures. The compaction theory relates the ore bodies to the major structures only as these structures might have indirectly influenced the character of sedimentation. In attributing essentially all the structure to tectonic forces, the tectonic theory emphasizes the importance of drilling on structure, although it does not follow that all struc-

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8 Chamberlin, T. C., op. cit.
Grant, U. S., op. cit.

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9 Bain, H. F., op. cit.
Grant, U. S., op. cit.

Areas for Prospecting

The possibility of finding new zinc-lead ore bodies appears to be much better within the principal mineralized area (pl. 1) than elsewhere in the district, in spite of the considerable amount of prospecting in the former area and the very scattered drilling elsewhere. Actually, only a small proportion of the principal mineralized area has been drilled with sufficient care to be considered well prospected. The principal tracts which have been drilled, so far as the available records indicate, are shown in plate 2. Tracts where only two or three scattered holes have been drilled are not shown.

Within the principal mineralized area, properties that are close to the known deposits, especially those between deposits, should be favored, other factors being equal. Immediately adjacent to a known ore body, extensions or projections from that ore body may be found, but in general major deposits are likely to be more than 1,000 feet apart.

In the part of the mineralized district outside the principal mineralized area, the tracts where shallow lead diggings are closely spaced are preferable sites for drilling unless some record of adequate prospecting can be found. At present there is no other basis for selecting areas to prospect in this part of the district as the details of structures

Fig. 6.—Distribution of the limestone and dolomite phases of the Oilrock and Glassrock.
have not been worked out. Adequate testing of the many lead-bearing areas is a large undertaking, and if they are not found to be productive the possibilities of other parts of the district are not encouraging. A possible exception is the part of the district close to the present boundaries of the principal mineralized area. These boundaries are arbitrarily drawn and with time will probably be changed in many places.

The possibility that the principal mineralized area extends southward should also be considered. There is no apparent reason why mineralization should end at the southernmost outcrops of the Galena formation beyond which the formation is concealed by the overlying Maquoketa shale and Silurian dolomite. Nearly all exploration for shallow lead ore ended where the outcrops of the Galena formation ended, but it is reported that a few shafts through the basal Maquoketa shale found some lead ore south of the Galena formation outcrops. Zinc mineralization, although in a top-run deposit, occurs only a mile north of the southernmost Galena formation outcrops. Lead deposits, large in northwestern Illinois, occur only three to four miles north. These ore deposits occur in part beneath the Maquoketa shale, and the Bautsch ore body extends under the Silurian dolomite. Thus the presence of these formations does not in itself limit the extent of ore deposits. However, at present there is no basis for making specific drill locations south of the principal mineralized area. Drilling would be relatively deep and costly, and the chances that wildcat drilling would be successful are slight.

The possibility of mineralization in the entire region between the south edge of the district and central Carroll County is favored by the presence of lead ore deposits near Mt. Carroll where a sharp east-west trending anticline brings the Galena formation to the surface. No zinc deposits have been found in the Mt. Carroll area but there has been little prospect drilling. Samples from wells at Mt. Carroll show that both the Oilrock and Glassrock are dolomite. Thus, according to the solution theory, conditions favorable for the formation of lower-run deposits may not be present in that locality. Conditions are more favorable in the west part of Carroll County as the Oilrock is limestone at Savanna and at Bellevue, Iowa, and at the latter place the Glassrock is also partly limestone (fig. 6).

**SELECTION OF SPECIFIC LOCATIONS FOR DRILLING**

Specific locations for drilling may be selected on the basis of (1) ore known or reported in drilling, (2) trends of ore deposits, (3) favorable geological structures, and (4) lead diggings and top-run zinc ore deposits.

**Ore Known or Reported in Drilling**

The evidence strongly favors starting drilling at places where ore is known or reported in drilling and attempting to follow and extend that ore. This would include the idle or abandoned mines which are in various stages of being worked out. These vary from mines where it is estimated from drilling that 100,000 or more tons of ore is available to those where all the ore holes have been cut. Some ore deposits are well outlined by blank holes but others have not been blanked off at either end of the trend. In nearly all these cases additional drilling along the trends or in the core-ground is justified. Many ore deposits have been considered worked out on the basis of one or two blank holes at each end, in spite of the fact that blank or at least lean areas locally interrupt the continuity of ore in most deposits.

Some ore deposits have been followed largely by mining without extensive drilling. Additional flats of ore may occur both above and below the mined-out area. Examinations of old mines show that many promising leads have not been followed. Much of the mine development work has followed a more or less standard pattern and has not
adequately probed the mineralized crossings or diverging pitches which might lead to valuable runs of ore outside the major ore body. Enough of these have been found more or less accidentally to justify speculation as to how many have been missed.

Somewhat less favorable properties for drilling are those where some holes have already been drilled in ore but a mine has not been opened and the presence of a commercial ore body has not been definitely established. On some properties a considerable number of ore holes have been drilled but for some reason prospecting was not continued. On others, drilling may be adequate to prove that the mineralized ground is not extensive enough to be mineable.

Water wells which encountered ore have been the discovery holes in several ore bodies. However, the water wells which are reported to contain ore, mostly lead ore, are almost legion. In many cases the wells are very old and the present property owners have been misinformed. Unless the report can be checked with the driller or samples are available, the accuracy of the report is open to question. Usually one hole drilled close to the well will show whether or not additional drilling is desirable. Drilling a new hole has generally been considered as less costly and more accurate than dismantling the old well, cleaning it out, and sampling by shooting.

**TRENDS OF KNOWN ORE DEPOSITS**

Many ore bodies have been found by drilling on the projected trend of a known ore body. On the Black Jack trend the Gray ore body was found by a jump of nearly 2,000 feet beyond known ore, and the Bautsch ore body was found by a jump of 2,400 feet beyond the Gray ore body (fig. 4). These are relatively long jumps, and even the straightest structures curve enough so that locations at such distances cannot be made with any assurance that they will be on the trend. Long projections extending outside the principal mineralized area are especially uncertain.

The trends of nearly straight ore bodies may be prospected by drilling cross-sections at intervals of about 500 feet, and studies of the samples may show whether a favorable structure continues. As ore has already been found along the Black Jack trend for more than two miles, it appears that prospecting might profitably continue along the trend of a linear ore body for a half mile to a mile beyond known ore.

Although the major relatively straight ore trends extend roughly northwest-southeast, the principal mineralized area trends a little east of north (fig. 7). The ore trends, therefore, are nearly parallel but are offset in an echelon arrangement. Consequently, the most favorable direction for prospecting for new ore trends may be along the center line of the principal mineralized area, rather than directly at right angles to the known ore bodies.

Curved or arcuate ore bodies may have several trends. (1) Where two or more arcuate-type deposits occur nearly in a line, other deposits may occur along a projection of the line approximately through the center of the deposits. (2) Most arcuate deposits are elongated loops, portions of loops, or relatively straight ore runs which intersect to form angular loops. Prospect- ing along the trend line in the direction of maximum elongation may find other ore bodies. (3) The deposits which have long straight sides appear to be controlled by a joint system, and prospecting along the trend of these ore runs may also be desirable. (4) Where mining or drilling has revealed the presence of ore following an arc or in a nearly complete loop, the trend of the arc or loop should be thoroughly prospected to complete the loop.

The top-run ore bodies occur along crevices which are nearly straight and continuous for long distances. Nearly all of the top-run mines are confined to a single narrow crevice, or two close parallel crevices, and prospecting for extensions of such ore bodies should be along the trend of the crevices. In a few top-run mines the crossing crevices also carry ore, especially those crossing at low angles.
Fig. 7.—Trends of lower-run and top-run zinc ore deposits in northwestern Illinois.
GEOLOGICAL STRUCTURES

The study of surface outcrops and drill records to find favorable geological structures is the only method of localizing drilling not based on the location of known ore deposits. This method is therefore especially useful in prospecting for major ore trends in areas some distance from known ore bodies. Although there has been little drilling based solely on geological structure, present evidence suggests that the method has a reasonable chance of success. Many of the structural leads, such as outcrops with strong dips or shear zones, can probably be tested with as few as two holes, so that a number of structures can be investigated at relatively low cost.

In using geological structure as a guide in prospecting, the following generalizations may be made.

TROUGHS

Where narrow synclines or troughs, elongated depressions, have been outlined, they should be prospected by drilling a series of cross-sections along the axis of the structure at right angles to the trend. Cross-sections are desirable because ore might occur in a pitch on one side of the structure and not on the other.

BASINS

Where a basin-like structure, a roughly oval or circular closed depression, is found, the available data indicate that the most favorable situation for ore is near the bottom of the slopes rather than in the central or lowest part of the basin. The slope should be prospected by drilling a cross-section at right angles.

SHEAR ZONES AND PITCHES

Where shear zones or pitching crevices are found, drill-holes should be located so that they will prospect the strata beneath the pitch. The best possibilities are close to the intersection of the pitch with the Oilrock. Because pitches frequently "flat-and-pitch" and the angle of pitch may change with depth, the place of intersection of the pitch and the Oilrock cannot be accurately predicted from surface outcrops. Therefore adequate testing may require several drill-holes.

STEEP DIPS

In many areas of scattered outcrops the only evidence of structure may be an isolated exposure showing an unusually high dip. Because nearly all the regional folds in the area have dips of less than 2°, it is believed that wherever a dip of 4° or more is found, the possibility that it indicates an ore-bearing structure is worth consideration. Such dips may indicate sufficient fracturing of the rock to permit entrance of mineralizing solutions, or they may have been produced by collapse following thinning of the beds by mineralizing solutions. In prospecting such a locality, a cross-section should be drilled parallel to the direction of the dip with particular emphasis on the down-slope side, which is the side nearest the synclinal axis. Care should be taken not to drill on the basis of dips of tilted blocks which have slumped from cliffs.

DIFFICULTIES IN USE OF STRUCTURAL METHOD

As with most methods of prospecting, the structural method has limitations which localize its application and make interpretations difficult. The proper application of the method requires a consideration of the following difficulties:

(1) The synclinal sags associated with the ore generally have a relief of less than 15 feet in the top of the Oilrock, and the relief commonly diminishes upward. The syncline may not extend as high as the top of the chert in the Galena formation, although under favorable conditions it may extend beyond the top of the Galena formation. In much of northwestern Illinois the outcropping rocks are in the upper part of the Galena formation so that underlying structures may not be revealed by the outcrops.

(2) Some ore bodies have so little structure that they probably can not be found by surface structural studies. This includes deposits which are confined to narrow zones.
of small vertical extent, such as some of the deposits which are largely Oilrock or Glassrock flats or disseminated zones. Some of these are principally replacement deposits which require neither great deformation nor solution to form openings. This would also include the narrow top-run deposits which occupy openings formed by solution.

(3) In parts of the district outcrops are too widely scattered to reveal the narrow structures.

(4) The upper 125 feet of the Galena formation is so uniform in character that identifiable beds suitable for working out the structures are rare. This is the only part of the Galena formation cropping out in parts of the mineralized region.

(5) Structure maps show the composite effects of tectonic movements, settling by solution, and inequalities in original deposition and compaction of the sediments. The origin of structures by depositional and compactional variations has been given more prominence than appears to be justified. It is of doubtful importance in the formation of structures revealed by maps drawn on horizons in the ore-bearing formations. Evaluation of the relative importance of tectonic movements and solution is difficult. Structures with large amplitude and with considerable width are probably tectonic, and in general they are not mineralized, except in smaller structures imposed upon them. Small depressions, either troughs or basins, may be formed by tectonic forces, by solution, or by both. Structures where solution has been important are more likely to be mineralized than those formed by tectonics alone, but some solution structures may not have been mineralized sufficiently to form ore. In some areas where the Oilrock and Glassrock are thinned by solution, the presence at the surface of a depression equivalent to the amount of thinning may possibly be an unfavorable indication because it results from complete slumping without producing adequate openings.

PATTERN DRILLING

Pattern drilling to locate structures, as practiced in the Tri-State district, could be used in this district, but it may not be practical at present because (1) the structures are so slight that closely spaced drilling is necessary to find them, (2) the ore bodies are much more widely spaced in northwestern Illinois than in most of the Tri-State district, (3) there are no adequate structural horizons in the upper half of the Galena formation. Drilling for structure may be locally desirable as a means of confirming a structure suggested by the outcrops or other drilling, especially if a good structural horizon is known to occur at a shallow depth.

LEAD DIGGINGS AND TOP-RUN ZINC ORE DEPOSITS

The fact that many major zinc-lead deposits occur below areas of shallow lead diggings suggests a close relation in origin and has naturally led to the drilling of many lead ore deposits, or ranges, in the search for zinc ore. Such drilling has had erratic results. Many areas with rich lead ore have been drilled without finding zinc ore at depth. Also deep zinc ore bodies have been found where no shallow lead ore deposits have been mined directly above, although lead diggings are usually found nearby. As a whole, it appears that areas with lead diggings are more favorable than those without. However, the areas of lead diggings are so large that systematic drilling would be a task of considerable magnitude. Because many of the major lower-run deposits trend north-south, the north-south trending ranges appear to be preferable to those trending east-west. Otherwise selection of the larger ranges, or preferably the intersection of ranges, is the only basis for localizing drilling.

In prospecting an area of lead ranges, a drill-hole directly on the trend of a range may prospect the possibilities for lead ore but may also encounter old workings or caving ground and it may be difficult to maintain a straight hole. As there is little correlation between the trend of the lead ranges and the trends of the lower-run ore bodies, it is preferable to drill cross-sections in directions at right angles to the trend of
the nearest major ore bodies regardless of the trend of the lead ranges. Near the arcuate or loop ore bodies in Vinegar Hill Township, cross-sections should be drilled north-south because the long direction of these ore bodies is east-west. Farther south the ore bodies trend from north-south to northwest-southeast, and drilling east-west cross-sections appears to be preferable. Where the ore trends are uncertain, northeast-southwest cross-sections may be preferable.

Top-run zinc deposits are nearly all in areas of extensive lead diggings and show a closer relation to the lead deposits than to the deeper zinc ores. Drilling on the top-run deposits in search of lower ores, is in the same category as drilling on the lead ranges. In fact, the presence of top-run zinc may possibly indicate that conditions were not favorable for deposition of zinc ore at lower depths. At least one or two holes have probably been drilled to the Oil- rock at nearly all of the ten top-run deposits which have been mined fairly extensively in northwestern Illinois, and so far as known none found lower-run ore. Although this does not adequately test the possibilities for lower-run deposits, it suggests that lower-run deposits are not developed along the same crevices where the top-run deposits occur. However, nearly all the top-run deposits trend east-west and the lower-run deposits mostly trend north-south so that the latter might not be found without thorough prospecting along the top-run deposit.

The top-run zinc deposits should not be confused with the tops of the major zinc deposits which in places extend as high as the zone where the top-run deposits usually occur. A high-level zinc-lead deposit containing pitches and flats with sheet ore rather than typical top-run brangle or crevice deposits should be prospected to depth.

From a theoretical viewpoint, it appears likely that the hot and rising ore-bearing solutions would move up the dip of the strata from the zone of zinc deposition to that of lead deposition. Therefore, prospecting for zinc deposits below lead dig- gings or top-run zinc deposits might well consider both the regional and local dips of the strata. However, many other factors might control the direction of circulation, and the evidence suggests a considerable lateral migration of the solutions, especially in the zone of the shallow lead deposits.

GEOPHYSICAL EXPLORATION

In large parts of the mineralized district where outcrops are lacking or widely scattered, the principal hope of localizing the area to be drilled lies in the use of geophysical or geochemical methods to establish the presence of either ore or favorable conditions for ore. Various geophysical methods have been tried from time to time, mostly sponsored by operating companies, but no extensive program of research has been undertaken in this region.

Recently the Illinois Geological Survey has undertaken an investigation of certain methods but as this work is incomplete a detailed discussion cannot be given now. The most promising results have been achieved with the self-potential method and it appears that in at least part of the area some of the ore bodies occur under suitable physical conditions to give self-potential anomalies. Conditions required appear to be a mineralized zone of considerable thickness, the top of which occurs above groundwater level and preferably less than about 100 feet deep. However, variations in soil composition and moisture content, topography, depth to bedrock, character of the bedrock formations, composition of the ore body, and other factors influence the patterns obtained by self-potential mapping so that interpretation of the results is difficult. Many self-potential anomalies are probably not related to mineralization and it remains to be seen whether drilling of self-potential anomalies will have enough success to justify its use extensively.

The work so far suggests that a large amount of basic research will be required to develop geophysical methods suitable for prospecting.
PROSPECT DRILLING

With the first drill-hole in ore, the problem becomes one of efficient drilling to prove or disprove the presence of an ore body as inexpensively as possible. For that reason a prime consideration is to follow the ore with as widely spaced holes as possible until sufficient length and width of ore permits inferring the presence of a commercial tonnage of adequate grade. The ore may then be blocked out with intervening holes.

Whether blocking out the ore is always needed is perhaps open to question. Adequate blocking out of the ore is obviously important in some types of ore bodies, especially in the low-grade or marginal deposits which, unfortunately, are those where the lowest possible prospecting cost is essential. For relatively high-grade deposits the point is frequently made that thorough drilling of the deposits is not worth the cost. However, a study of the variations of the deposits and the history of many mining operations suggests that in most deposits the cost of additional drilling will be more than offset by the discovery of ore which would not be found in normal mining operations. Likewise important savings may result by preventing the mining of ground below the profitable grade, by showing the position of bad mining ground, and in solving many other mining problems. The need for more thorough drilling than has been the usual practice is shown by the number of unprofitable operations which have resulted from inadequate knowledge of the ore bodies.

Many mines have been opened where there was not enough drilling to prove the presence of adequate tonnage in spite of the well known fact that mineralized ground of good grade occurs in all sizes from a few tons to the largest ore body. Mines have been started on the strength of a few good drill-holes with the intention of following the ore and saving the cost of drilling. This procedure has been successful in many cases, but failures are common, and it involves an unnecessary risk.

Estimates of the tonnage minable based on results of drilling depend on interpretations regarding the continuity of the ore. Nearly all drilling shows ore at different levels, and if the drill-holes are too widely spaced it may not be possible to determine whether the ore rises from one level to another or whether it occurs in lenses at different levels.

Mines have been opened where there was not enough drilling to give an accurate grade for the deposit. It may take 50 or even more holes to give a satisfactory estimate of the grade of ore that can be mined. Even then the estimate may be inaccurate if too many holes are located on a rich pitch and this factor is not correctly evaluated in making the ore estimates. Some ore bodies are relatively symmetrical and uniform in grade but these are the exception and a brief examination of almost any mine will show the fallacy of basing any important or costly decisions on the results of one or two drill-holes. Drill-holes, especially in core-ground, may cut a vertical seam of ore several inches thick extending for 5 to 10 feet and the resulting samples may assay 15 to 20 percent zinc. Had the hole been located a foot away it would have been blank in the same interval.

It is a common occurrence where drilling is not far ahead of the stopes that the shaft turns out to be in the wrong place to give proper mine drainage.

The repeated opening of old mines emphasizes the point that not all the ore is found by following it in mining. Where the drilling is not thorough, ore is usually left until found by later prospecting.

Many mines have been opened without enough information on the character and distribution of the ore to permit proper mill design or to plan an efficient mining program.

Balancing the advantages of adequate drill data against its cost, it appears that thorough drilling may more than pay for itself and at least is a good form of insurance.
TYPES OF DRILLING

By far the greater part of the drilling in the district has been by churn drills, but in the last two years considerable diamond drilling and churn drilling on the Gray and Bautsch ore bodies by the U. S. Bureau of Mines and Tri-State Zinc, Inc., permits a preliminary comparison of the two methods. It appears that churn drilling has a slightly more consistent record of sample recovery than the diamond drilling. In certain types of mineralized ground, diamond-drill core recovery is poor and, because the fractured and permeable nature of the ground makes recovery of sludge almost prohibitive, it follows that no sample is obtained for some critical intervals. This also occurs with churn drilling but less commonly. When core recovery is good, diamond drilling provides better samples than the best that can be obtained from churn drilling.

Because of the excellent cleavage of the ore minerals, a disproportionate amount of ore minerals is usually lost in the diamond drilling, especially in zones where the interior of the flats is not completely filled so that disks of ore grind against each other. On the other hand, the churn-drill samples taken below rich zones of mineralization may be enriched by caving of the higher easily fractured ore. Thus, while churn-drills may give a self-salted sample, diamond-drill samples cannot be self-salted and tend to give a minimum assay. These may be critical factors in evaluating marginal or lean holes.

An important advantage of diamond drilling is that where core recovery is good, it is possible to tell whether or not a rich sample represents only a narrow veinlet.

It is questionable whether the advantages of diamond drilling are sufficient to justify the additional expense, currently about twice the cost of churn drilling. Diamond drilling is required where angle drilling is necessary, or where locations are inaccessible with a churn-drill rig. Some diamond drilling is desirable in blocking out ore to show the structure of the deposit and to check the results of churn drilling. If the deposit is of such character that good recovery is obtained, the greater accuracy of the samples may make a considerable proportion of diamond drilling worth while. However, some churn-drill holes are needed to provide ventilation for the mine. In prospecting, where many blank holes may be drilled, it is believed that for the same cost two churn-drill holes will give more information than a single diamond-drill hole.

DEPTH OF DRILLING

Much of the drilling in the district has been too shallow to test adequately the possibilities of the entire zone in which ore deposits occur. Many mines which were supposedly worked out have been reopened and several feet of bottom taken out or a winze or an incline has been sunk to an ore deposit in a lower formation. The theory that the Oilrock and Clay-bed served as an impermeable layer for downward moving mineralizing solutions has been so widely accepted that much of the drill prospecting has stopped at the Clay-bed or even at the top of the Oilrock.

In drilling out an ore body it is current practice to drill a few holes into the Glassrock, and where the Glassrock is thin a few holes more or less accidentally penetrate the top of the “Trenton”. Because the ore runs which have been found in the Glassrock and “Trenton” are usually narrower and less continuous than those above, more rather than less drilling is required to find and outline the ore in these beds. It is not necessary to find any great tonnage of ore to justify the additional expense of drilling all of the holes deep enough to prospect the lower beds. If Glassrock or “Trenton” ore is present, it may have an important bearing on the correct location of the shaft.

Deep drilling is especially desirable when prospecting near the toe of a pitch. In many cases holes have been stopped before they were deep enough to prospect the most likely ore-bearing zone.

Because “Trenton” ore has been found at several places throughout the district, it is believed that all prospect holes, except under special circumstances, should be drilled into the top of the “Trenton”.
LOCATION OF DRILL HOLES

When a hole is drilled into ore, customary procedure is to drill a cross-section of 4 to 6 holes across the probable trend of the ore. The trend is estimated from the structure of the outcropping rocks where possible, or it is assumed that the trend is parallel to the predominate trend of the nearest ore bodies. Drilling then proceeds along the trend. If the ore is lost another cross-section is drilled to get back on the ore.

In the location of these holes many factors have to be considered to keep on the ore. If the cross-section drilled suggests the presence of strong pitches, the approximate position of a hole on the pitches can be estimated by the depth at which ore is found, and the following hole can be located to hit the pitch or stay inside if desired. As most of the ore bodies have a slight sag or syncline in the top of the Oilrock between the pitches, a structure map on the top of the Oilrock is a help in determining the local trend of the ore-bearing structure. In order to use this information in making the location of succeeding holes, it is desirable that maps showing locations and elevations be kept up-to-date and that preliminary estimates of the amount of mineralization and a log of a hole be made as soon as a hole is completed.

An important consideration in the location of drill-holes is the thickness and character of the Oilrock, Glassrock, and "Trenton" limestones. It has long been recognized that in and close to the lower-run ore bodies the Oilrock is commonly a relatively thin and soft shaly bed. This has been variously interpreted. Frequently it has been cited as the reason for the localization of the ores. However, recent studies strongly suggest that the thinned and shaly Oilrock is a residue resulting from the solution of the limestone phase of the Oilrock formation by the solutions which deposited the ores. The same situation has also been found in the Glassrock and to a lesser extent in the upper part of the "Trenton" limestone. Within the principal mineralized area the Oilrock is considered to have a normal thickness of 12 feet although as much as 14 feet has been recorded. The normal Glassrock thickness varies from 15 to 18 feet. Therefore, wherever abnormally thin and partly shaly phases of the Oilrock and Glassrock are encountered, the hole may be close to a mineralized zone. The theory does not require that thin and shaly strata nor the associated rocks be mineralized, but at present the evidence strongly suggests that additional drilling to investigate the possibility is worth while. Likewise, the presence of a full thickness of Oilrock and Glassrock limestone, which means the absence of the shaly phases, usually indicates the hole is off the ore body, and in wildcatting or in prospecting below top-run or middle-run mineralized zones it is regarded as an unfavorable indication.

The analysis of 340 holes drilled in an area about one-fourth mile square in the north part of Vinegar Hill Township shows the relation of ore to the thinned Oilrock as follows:

<table>
<thead>
<tr>
<th>Thickness of Oilrock</th>
<th>Number of holes</th>
<th>Number of holes that are in ore</th>
<th>Percent of ore holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-5'</td>
<td>189</td>
<td>115</td>
<td>60</td>
</tr>
<tr>
<td>6-10'</td>
<td>137</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>11-15'</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

SPACING OF HOLES

Spacing of holes is quite variable but in drilling cross-sections to block out ore, holes are usually placed at 40- to 50-foot intervals. In drilling along the center line or trend of the ore body, holes may be spaced at 100 feet or more. Along relatively wide and straight ore bodies, where it is desirable to prospect ahead as rapidly as possible, moves of 250 to 300 feet are sometimes feasible. In some cases it may be practical to locate the holes so that they angle across the ore body from side to side and thus give information about pitches as well as the core-ground. This has been tried with indifferent success. It is difficult enough to

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1 Previous reports which describe the Oilrock as thickest in the ore zone were referring only to the shaly phase of the Oilrock. The Oilrock is now considered the geological unit in which Oilrock shale occurs.
stay on ore if the locations are made only 100 feet apart on the projected center-line of the ore body.

**Sampling**

In churn-drill test holes it is customary to drill 5-foot runs in unmineralized rock but when mineralization, in the judgment of the driller, is possibly strong enough to be minable the runs are reduced to 2 feet. The driller dumps the bailer into a tub, and after the relatively coarse cuttings have settled, part or all of them are placed in a pile. The entire sequence of samples from the hole accumulates in a row and samples of 5 to 10 pounds are collected for assaying, from those samples which visual inspection indicates may possibly be ore. Refinements of this technique usually consist of attempts to collect a larger proportion of cuttings to reduce the error arising from omission of the fines and to scientifically split the samples to a suitable size for assaying. There is little question that the more refined techniques give more accurate samples and are therefore desirable. However, where there is only a driller and no helper on the rig, the driller does not ordinarily take time to do more than lay out the samples. It is questionable whether the additional accuracy obtained by more careful sampling is worth the cost of a sampler, considering the additional drilling that might be done for the same expense and the fact that the ore bodies show so much variation that any far-reaching decision should not be based on any one sample or on samples from one drill-hole.

As part of its studies the Illinois Geological Survey has undertaken the study of small samples of the cuttings from all the holes drilled in the area. These samples are studied with a microscope to determine the character and boundaries of the various rock formations, and a rough estimate is made of the amount of ore minerals in the sample. These small samples are not accurately representative of the entire samples but on the whole a good correlation has been found between the mineral estimates and the assays. The value of the estimates lies principally in controlling the selection of samples to be assayed. It has been found repeatedly that samples which should be assayed are overlooked in the visual inspection of the cuttings at the drill-hole. Samples running as high as 5 percent zinc have been overlooked, usually in zones where the zinc mineral is light colored and not readily recognized. This technique also gives information about the extent of the zones of low-grade mineralization which are not minable at present, and therefore are not assayed, but which in the future may become an important source of zinc ore.
AREAS FOR PROSPECTING

The areas or properties described below include all those where there is some indication that an ore deposit may be present. It is beyond the scope of the present investigation to recommend drilling of any of the deposits described. The available data are presented and interpretations are made where possible so that companies or individuals considering prospecting can make their own evaluations. The financial risk inherent in exploration of this type is well known and is sufficient to discourage small-scale drilling programs.

The evidence favoring drilling is very slight at many of the properties described, but there has been more or less wildcat drilling in places which appear to be less favorable. Many of the possibilities can be investigated at the cost of only one or two holes, and a program of drilling a large number of properties would be successful if only one major ore body were discovered.

An important consideration in evaluating any property is the previous drilling. It is now more than 20 years since the most active period of drilling in the district, and records are entirely lacking for a large amount of that drilling. Although an attempt has been made to collect as much of these old data as possible, additional records occasionally come to light, and it is urged that all possible sources of information be investigated before undertaking drilling.

In the descriptions of the properties only sufficient data are given to show the general situation and indicate the extent of the information available. Additional information about many of the properties is available in the files of the Illinois Geological Survey.

The properties are described according to the following classification.

Properties where ore is known or reported in drilling
  Properties where considerable ore is thought to be present
    Properties with mines
    Properties without mines
  Properties where the quantity of ore is uncertain
    Properties with mines
      Lower-run mines
      Top-run and middle-run mines
    Properties without mines
      Prospect drill holes
      Water wells

Properties on trends of known ore bodies
Properties with favorable geological structures
Properties with lead diggings
  In the principal mineralized area
  Outside the principal mineralized area
PROPERTIES WHERE ORE IS PRESENT

Properties where Considerable Ore is Thought to be Present

Properties with Mines

**Birkbeck Mine**

NW. 1/4 NE. 1/4 sec. 27, T. 29 N., R. 1 E. (Council Hill Twp.) (pl. 1)

The Birkbeck mine is located about six miles northeast of Galena and two miles west of Council Hill, on a farm owned by Mrs. Thomas Birkbeck and sons. The mine was operated by the Wisconsin Zinc Company from August 1916 to March 1917 and produced 1,857 tons of zinc concentrates averaging 26.8 percent zinc and 19.5 percent iron, not including production during the last month of operation. The amount of ore mined is estimated at about 30,000 tons.

Although 65 holes were drilled on the property only 43 are in or close to the ore body. Only 6 of 23 ore holes were cut by the mine, and an estimate based on the available drill records suggests that as much as 150,000 tons of ore, averaging 4.7 percent zinc and 6.8 percent iron, may still be present. The ore body has a maximum width of about 250 feet and the length drilled is 700 feet. Several holes in the central part of the ore body show 30 to 50 feet of ore but the average is probably about 10 feet. The ore occurs principally in the 20 feet of strata overlying the Oilrock, and pitches, if present, are not well developed.

The mine map shows that the ore body trends northwest-southeast and that drilling did not establish the limits of the ore body at either end. At the northwest end of the drilled area the drill data suggest that ore may extend directly northwest on the trend of the drilled ore, or it may make a sharp turn to the northeast. If the ore turns, it may loop back to the east to form an arcuate deposit such as those which occur about a mile northwest.

Southeast of the drilled area one lean hole appears to be on the trend of the ore body about 275 feet from the mine, but it is hardly sufficient evidence to establish the end of the ore body.

**Black Jack Mine**

SW. 1/4 sec. 33, T. 28 N., R. 1 E. (East Galena Twp.) N. 1/4 sec. 4, T. 27 N., R. 1 E. (Rice Twp.) (pl. 1, fig. 4)

The Black Jack mine of the Mineral Point Zinc Company, now leased by Tri-State Zinc, Inc., is about three miles south of Galena. Nearly two million tons of ore are reported to have been taken from this mine since it was discovered in 1854. It was last operated in 1926. The deposit is a double pitch with heavy mineralization in the core-ground and rich lead ore deposits extending upward to the surface. Some stopes are reported to be over 100 feet high. A considerable tonnage of ore remains in the mine, principally in a block on the Martens property at the north end of the mine and at several places along the southwest pitch which is relatively high in iron. Much of this ore is a long distance from the hoisting shaft. There is a good possibility that the potentialities of the Glassrock and "Trenton" have not been adequately explored. Judging from the few drill-holes, the possibility of finding additional lateral extensions of ore, such as those already mined on the Wienen and Kipp properties, has not been investigated. These ore runs occur at places where the major ore body makes a sharp but small change in direction and at least one such locality appears to be unprospected.

**Buck Hill (Blewett) Mine**

SW. 1/4 NW. 1/4 SW. 1/4 sec. 9, T. 28 N., R. 1 E. (Rawlins Twp.) (pl. 1)

The Buck Hill (Blewett) mine, 1 1/2 miles north of Galena, on the farm owned by Mr. Quentin H. Blewett, was operated by the Frontier Mining Company in 1919 and 1920. About 75,000 tons of ore was mined from which 6,790 tons of jig concentrates, averaging 30 percent zinc and 21 percent iron, were produced. Drilling north of the mine after it had closed revealed the presence of additional ore. An esti-
mate based on the drilling suggests that about 100,000 tons of ore averaging 6.5 percent zinc and 10.5 percent iron may be present.

The drilling does not close off the ore body at either the north or south end. The possible westward extension of pitches, reported to have been the source of rich ore in the mine, has not been investigated. Good ore is reported to occur in the Glassrock immediately below the mine floor but was not mined out. Four of the nine holes which were drilled through the Glassrock found good ore.

Graham-Ginte Mines
Sec. 32, and NW. ¼ SW., ¼ sec. 33, T. 29 N., R. 1 E. (Vinegar Hill Twp.) (pl. 1)

The Graham and Ginte mines, three miles north of Galena, are being operated by the Ginte Mining Company. The mines are on the same ore body and are connected. The Bartell and Sherrill mine is in the upper part of this ore body and is reached by a shallow shaft between the Graham and Ginte shafts. The Graham mine was operated by the Vinegar Hill Zinc Company from 1916 to 1920. The Ginte mine was opened in 1943 to mine the continuation of the Graham ore body on the Ginte property and to take additional ore from the Graham mine. The ore body is a double pitch lower-run deposit. It is nearly straight, about 2,500 feet long, as much as 300 feet wide, and contains workable deposits in a zone about 100 feet thick. Production from this ore body to September 1945 was about 350,000 tons of ore.

Gray Mine
NW. ¼ sec. 10, T. 27 N., R. 1 E. (Rice Twp.) (pl. 1, fig. 4)

The Gray mine, four miles southeast of Galena, is operated by Tri-State Zinc, Inc. The ore body is largely on the Gray property, now owned by H. L. Heer, but at the north extends onto the Mrs. F. Fox property. The ore body was largely drilled by the U. S. Bureau of Mines who estimated 479,500 tons of ore averaging 4.3 percent zinc. The mine was opened in 1944 and only a small part of the ore body has been mined. So far as can be told from the present workings the ore body appears to be a double pitch deposit, similar to the Black Jack deposit, but the pitches are weakly developed and the ore is largely disseminated in core-ground. The limits of the ore body have not been completely determined by drilling.

South Unity Mine
NW. ¼ NE., ¼ and NE. ¼ NW. ¼, sec. 21, T. 29 N., R. 1 E. (Vinegar Hill Twp.) (pl. 1, fig. 5)

The South Unity mine, originally called the Unity mine, is on the Ensch property, six miles north of Galena. It was operated by the Vinegar Hill Zinc Company from 1910 to 1912, and produced about 130,000 tons of ore. In late 1945, the mine was being pumped out.

The ore body is part of an arcuate-type deposit and is west of the Hughlett and Gray mine which is in the same ore body. At one place the two mines are only a few feet apart. The principal workings of the South Unity mine are on the north limb of the ore body and about 800 feet long and 150 feet wide. A cross-cut 300 feet long was made to the south limb of the ore body, in which an entry about 50 feet wide and 170 feet long was made before the mine was closed.

The possibility that the ore body makes a complete circle westward joining the north and south limbs has not been adequately prospected. Drilling west of the north entry is sufficient to indicate at least a pronounced narrowing of the ore in that direction, but it appears that there has been little drilling ahead of the west heading on the south limb. If the ore body makes a symmetrical loop to the west another 800 to 1,500 feet of ore may be present. As such ore bodies are usually especially rich at the turns, this tract appears to deserve further prospecting.

None of the prospect holes on the ore body tested the possibilities of the Glassrock.

Lincoln, F. C., op. cit.
Properties where Considerable Ore is Thought to be Present

Properties without Mines

Bautsch Property
SW, ¼ sec. 10, T. 27 N., R. 2 E. (Rice Twp.)(pl. 1, fig. 4)

A large ore body was revealed by the U. S. Bureau of Mines drilling in 1944 and 1945 on the Frank and Mary Bautsch property, about five miles southeast of Galena. A shaft is being sunk on the property by Tri-State Zinc, Inc. The Bureau of Mines estimated in January 1945 that nearly a million tons of ore is present and a large tonnage was added by later drilling. The ore body is being further prospected by Tri-State Zinc, Inc.

Bell (Southcott) Property
Near center NW, ¼ sec. 35, T. 29 N., R. 1 E. (Council Hill Twp.) (pl. 1)

In 1916 and 1917 the Wisconsin Zinc Company drilled 25 holes on the Southcott farm, now owned by Everett L. and Joseph M. Bell, two miles west of Council Hill Station and about four miles northeast of Galena. Thirteen of the holes showed ore which averages 9 feet thick. The assays average 5.1 percent zinc and 3.4 percent iron. Lead is variable but one sample representing 10 feet assayed 2.8 percent lead.

No map has been found showing the exact locations of the drill-holes and only approximate locations are known. However, three cased drill-holes are probably ore holes. These holes, the most widely separated of which are about 1,000 feet apart, are located nearly in a north-south line and may show the trend of the mineralized zone. This trend coincides with an area heavily pitted with lead diggings. The outcrops show that the northernmost of the cased holes is located in a shallow syncline trending north-south.

In 1945 the U. S. Bureau of Mines drilled a cross-section of six holes at the northernmost cased hole which, according to those present at the time of the previous drilling, is at the extreme north end of the area drilled. Drilling has been temporarily discontinued.

The possibilities of this tract can probably be evaluated by drilling additional cross-sections near the cased holes at the south end and near the middle of the tract.

Ensch (Hughlett and Gray) Property
NE, ¼ NW, ¼ NE, ¼ sec. 21, T. 29 N., R. 1 E. (Vinegar Hill Twp.) (pl. 1)

Drilling about half way between the Hughlett and Gray and North Unity mines, formerly operated by the Vinegar Hill Zinc Company, six miles north of Galena on the Ensch property, outlined a small ore body about 500 feet long and, at the single place where a cross-section was drilled, about 60 feet wide. Ore was hit in 10 holes and the assays show from 6 to 12 feet of ore, averaging about 5 percent zinc. The ore is in the Oilrock and the Blue at a depth of about 180 feet. It could be reached from the North Unity mine by a drift 350 feet long, or from the Hughlett and Gray mine by a drift 700 feet long. The drilling appears to close off the ore body at the east end, but at the west end the drilling may not have been carried far enough south. A large undrilled area lies on the trend to the west and southwest.

Lincoln, F. C., op. cit.
Properties where the Quantity of Ore is Uncertain

Properties with Mines
Lower-run Mines

Hughlett and Gray Mine
N. 1/2 NE. 1/4 sec. 21, T. 29 N., R. 1 E. (Vinegar Hill Twp.) (pl. 1, fig. 5)

The Hughlett and Gray mine, six miles north of Galena on the Ensch farm, was operated by the Vinegar Hill Zinc Company from 1916 to 1924 and the ore trammed for processing to the North Unity mill. The mine was reopened by Gill Brothers and operated from 1941 to 1943. A total of about 635,000 tons of ore has been mined from this and the North Unity mine, and probably a little less than half came from the Hughlett and Gray mine.

The Hughlett and Gray mine is in the east part of an arcuate ore body. The west end of the ore body was partially mined from the South Unity shaft but the two mines were never joined, although ore is probably continuous. The main entries are about 3,600 feet long, 50 to 100 feet wide, and the highest stopes are 30 to 35 feet high.

The possibility of finding additional ore immediately outside the loop formed by the ore body is not encouraging, although the drilling is not adequate to prove the absence of ore. Drilling east of the mine appears to be adequate to close off the possibilities for extensions in that direction. Twenty-four of the drill-holes in the ore body were deep enough to test at least the upper 2 feet of the Glassrock. Ten of these holes found Glassrock ore and 14 were blank in the Glassrock. The possibility that ore may be found inside the loop may be worth further exploration. A few holes inside the loop found some ore but others show only lean mineralization.

North Unity Mine
S. 1/2 SE. 1/4 sec. 16, T. 29 N., R. 1 E. (Vinegar Hill Twp.) (pl. 1, fig. 5)

The North Unity mine, six miles north of Galena on the Ensch farm, was opened by the Vinegar Hill Zinc Company in 1914 and operated until 1921. Production from the North Unity and the Hughlett and Gray mines totaled about 635,000 tons and probably slightly more than half came from the North Unity mine. The mine was reopened and operated by the Gill Brothers in 1942 and 1943. In 1945 a shallow shaft was sunk by the Big Six, a group of local miners, to take out ore above water-level near the east end of the ore body. The ore body is an arcuate-type deposit forming a nearly complete loop with a somewhat angular outline. The loop is about 1,800 feet long and 750 feet wide. The outer margin of the ore body is marked by outward sloping pitches, and the ore was mined from the pitches and from flats beneath the pitches in an entry about 3,000 feet long, averaging about 90 feet wide on the north side of the loop and about 60 feet on the south side. Some of the stopes are 70 feet high. Ore occurs in the Oilrock and overlying strata.

There has been little drilling either east or west of the mine to explore the possibilities of more ore along the trend. Only 14 of the drill-holes in the ore body tested the Glassrock but only one of these found ore and therefore the possibilities for commercial ore in the Glassrock are not encouraging.

Northwestern Mine
Near center N. 1/2 NW. 1/4 sec. 22, T. 29 N., R. 1 E. (Council Hill Twp.) (pl. 1, fig. 5)

The Northwestern mine, six miles north of Galena and about a quarter of a mile south of the Illinois-Wisconsin state line, is on a property owned by Mrs. N. M. Kean. Two shafts 92 and 121 feet deep were sunk on the property and the mine was operated intermittently from 1904 to 1913. Incomplete production statistics suggest that from 100,000 to 150,000 tons of ore was mined.

The principal ore run is reported to make a broad curve northwest from near the shaft and was opened for 500 or 600 feet. The ore may be part of an arcuate deposit similar to the Hughlett and Gray and North Unity ore bodies farther west. Ore was found principally in a zone about 15 feet thick in the Oilrock and overlying beds. It
QUANTITY OF ORE UNCERTAIN

is reported that the mine has no well developed pitches. No mine map or drill records have been found but so far as known all the drilling was in or close to the area mined.

Unless many more holes were drilled than are now recorded, the possibilities of the deposit have not been adequately explored. Prospecting on the projected curves of the known workings would be a desirable starting place in searching for additional ore.

Pittsburg Mine
NE. ¼ SE. ¼ sec. 4, T. 27 N., R. 1 E. (Rice Twp.) (pl. 1, fig. 4)

The Pittsburg mine, about four miles south of Galena, is one-fourth mile southeast of the Black Jack mine and on the same trend. The mine is reported to have been a rich producer during 1914 and 1915, but when closed in 1916 the ore was running about 3 percent zinc and was produced entirely from the core-ground. Previously, when the production included ore from the pitch, the grade was about 6 percent. Mining of the pitch was stopped after a cave-in. Incomplete production statistics show that more than 30,000 tons of ore was mined.

The richest ore was found along a southwest-sloping pitch which was followed for about 400 feet. Although core-ground was developed as far as 270 feet northeast of the pitch, a northeast-sloping pitch was not found. The ore body appears to be in a trough which is more or less continuous with that containing the Black Jack ore body to the northwest and the Gray ore body to the southeast. However, between the Pittsburg and Black Jack mines the ore body may be cut out by the deep fill of sand and gravel along Smallpox Creek.

The Pittsburg mine maps show only a few uncut ore holes on the east side of the mine, and except for the northwest side where some bad ground was encountered, the mine appears to be well surrounded by blank holes. However, the trend of the pitch in the mine is slightly more westerly than the trend of the trough, and consequently most of the drilling to find an extension of the ore body has been east of the mine and not in the trough. It may also be desirable to check the few blank holes south of the mine and continue drilling farther south and southeast.

Vinegar Hill Mine
NE. ¼ SW. ¼ sec. 21, T. 29 N., R. 1 E. (Vinegar Hill Twp.) (pl. 1, fig. 5)

The Vinegar Hill mine, on the Virtue (Stacy) and O'Rourke properties six miles north of Galena, was operated by the Vinegar Hill Zinc Company from 1908 to 1914. About 360,000 tons of ore were mined. The mine is shaped like a figure “7” with a north-south entry about 1,000 feet long and 100 to 250 feet wide, at the north end of which a northwest entry about 80 feet wide extends for 500 feet. Some of the stopes are reported to be 100 feet high. The ore body is a lower-run deposit and is reported to be bounded on the east by an east-sloping pitch and on the north by a north-sloping pitch. An old map shows pitches on each side of the north-south entry and crossing pitches at the north end and at the south end of the wide part of the mine. The extreme west and south ends of the entries are mapped as extending outside the pitches. The ore occurs in the Oilrock and overlying strata.

The available data suggest that this ore body was well worked out. Although there has been little drilling along the east and north sides of the mine, where the ore body is sharply limited by the pitches, the areas ahead of the south and northwest entries were well drilled for several hundred feet and the area inside of the “7” was also drilled. The possibilities of ore occurring in the Glassrock and “Trenton” underlying the mine were not adequately tested during the original drilling but may have been tested by drilling in the floor. Of 37 ore holes only about ¼ penetrated the Glassrock and about 40 percent of these found some ore or strong mineralization.
ZINC-LEAD DISTRICT

PROPERTIES WHERE THE QUANTITY OF ORE IS UNCERTAIN

PROPERTIES WITH MINES

TOP-RUN AND MIDDLE-RUN MINES

Appleton Mine

NE. ¼ SE. ¼ SE. ¼ sec. 10, T. 28 N., R. 1 E. (East Galena Twp.) (pl. 1)

The Appleton mine, also called the Dinsdale mine, is on the Wilmer Winter farm, two miles northeast of Galena and was operated from 1907 to 1909. No production records are available but as much as 20,000 tons may have been mined. Zinc ore was produced from a disseminated ore body which may be a middle-run deposit. The ore was found from 25 to 50 feet above the Oilrock. The shaft is probably at least 110 feet deep. Although a few holes are known to have been drilled close to the Appleton mine, no records are available and the deposit probably has not been adequately prospected.

Betsy Mine

SW. ¼ NE. ¼ NE. ¼ sec. 27, T. 28 N., R. 1 W. (West Galena Twp.) (pl. 1)

The Betsy mine, also called the Weinschenk mine, is on the Henry Fleege farm about 2½ miles southwest of Galena. It produced lead and drybone ore between 1908 and 1913. An old map shows a shaft near the Mississippi River bluffs marked as the 'drybone' mine, a second shaft about 500 feet northeast, and a third shaft about 500 feet farther east. The two latter, reported to be 72 and 102 feet deep, are connected by a main entry 10 to 30 feet wide, the south face of which is marked on the map as a pitch. Other entries extend northward and connect with an east-west entry about 50 feet north of the main entry. Judging from the depth of the shafts, the ore occurs about 25 feet above the Oilrock. The narrow entries suggest that this is a top-run or middle-run deposit, but the low position of the ore and the possible presence of a pitch suggest that it is a lower-run deposit. The only record of drilling in this vicinity is on the mine map which shows three drill-holes north of the mine.

Big Indian Mines

SW. ¼ NE. ¼ sec. 1, T. 28 N., R. 1 W. (Rawlins Twp.) (pl. 1)

Top-run zinc and lead ore was encountered in several mines two of which were operated by the Big Indian Mining Company, on the Dooling property, two miles north of Galena. The ore occurs along a crevice trending N. 75° W. at levels ranging from 30 to 60 feet below the bottom of the north-south valley which crosses the property. The lowest ore mined was about at the top of the chert in the Galena formation. The mine was worked only for lead and was last operated in 1920. A number of shallow lead diggings occur in the vicinity. The Dooling range, which produced a large amount of lead ore, is about 500 feet south of the Big Indian development. In 1945 the Ginte Mining Company drilled on the Dooling property near the Big Indian mines but did not find ore.

Bullfrog Mine

NE. ¼ SE. ¼ sec. 22, T. 28 N., R. 1 W. (West Galena Twp.) (pl. 1)

The Bullfrog mine, on the Anthony Dempsey farm two miles west of Galena, is about 200 yards south of the Merry Widow mine. A shallow shaft was sunk by the operators of the Merry Widow mine about 1916 and was later deepened to about 37 feet by Gill Brothers. It has been reopened and in about 1945 was operated on a small scale by the Eversoll Brothers. Ore is mined at a depth of 22 feet from a crevice trending N. 85° E. The ore is a top-run deposit, low in iron, and is above the top of the cherty beds in the Galena formation.

Drill-Hole Mine

NW. ¼ NE. ¼ sec. 9, T. 28 N., R. 1 E. (Rawlins Twp.) (pl. 1)

The Drill-Hole mine is two miles northeast of Galena on the Amon farm and was operated about 1906. The shaft is 237 feet deep. Ore was found in a north-south crevice and in flat openings about 20 feet above the Oilrock, but the deposit apparently is not large. It is mostly lead ore but con-
QUANTITY OF ORE UNCERTAIN

contains some zinc ore. Scattered drilling in this vicinity did not find more ore.

**Fox River Valley Mine**
NW. ¼ NE. ¼ sec. 25, T. 29 N., R. 1 W. (Vinegar Hill Twp.) (pl. 1)

The Fox River Valley mine, five miles north of Galena on the Feehan farm, was operated before 1905. Two shafts 65 and 95 feet deep were sunk on an east-west crevice. It appears that only a little lead and zinc ore was taken from this top-run deposit. The ore was found about 175 feet above the Oilrock. There are no records of drilling in the immediate vicinity of the mine.

**Hoosier Mine**
SE. ¼ SW. ¼ sec. 36, T. 29 N., R. 1 W. (Vinegar Hill Twp.) (pl. 1)

The Hoosier mine, on the H. Smith farm, about three miles north of Galena, was operated in 1909 and 1910. A shaft about 115 feet deep was sunk on an east-west crevice and a top-run ore body about at the top of the chert in the Galena formation was mined for several hundred feet. The ore was said to be solid zinc ore lining the opening and not the brangle ore typical of many top-run deposits. On the west the ore was mined only to the limits of the lease. The operation is reported to have been handicapped by a large amount of water. There appears to have been little if any deep drilling near the Hoosier mine.

**Little Corporal Mine**
E. ½ SE. ½ sec. 15, T. 28 N., R. 1 W. (Rawlins Twp.) (pl. 1)

The Little Corporal mine is about a mile and a half west of Galena on the F. Weiters property. The mine was in operation in 1903 and operated last in 1917. A shaft about 110 feet deep reaches a top-run deposit along an east-west crevice about 20 feet below water level. The ore body is 6 to 16 feet wide and 8 to 12 feet high. It was opened about 400 feet. The mine is entirely above the top of the chert in the Galena formation and about 147 feet above the Oilrock. The ore contains little lead and is low in iron so that jig concentrates ran from 50 to 60 percent zinc. Although not worked out, it is reported that the ore in the headings is lean. A few holes tested the Oilrock, apparently without finding ore, but there is no record of any extensive drilling in the vicinity of the mine.

**Merry Widow Mine**
NE. ¼ SE. ¼ sec. 22, T. 28 N., R. 1 W. (West Galena Twp.) (pl. 1)

The Merry Widow mine, on the Anthony Dempsey farm, two miles west of Galena, is on the same crevice with the Tenstrike mine which is a short distance east. It was operated between 1910 and 1917. In 1911 and 1912 it was the largest lead producer in the Upper Mississippi Valley area. A considerable quantity of zinc ore was also produced. The ore body is a top-run deposit along a crevice running N. 75° E., but ore is also found along a quartering crevice extending southeast near the east end of the mine. The shaft is about 70 feet deep and the mine is more than 1,000 feet long. Ore was taken from several levels but principally from the upper part of the cherty beds, 100 to 125 feet above the top of the Oilrock. Several prospect holes have been drilled near the mine in search of deeper ore without success. Numerous shallow diggings show that other crevices in the vicinity are also mineralized, and top-run deposits similar to the Merry Widow may be found along them.

**Oldenburg Mine**
NE. ¼ SW. ¼ sec. 1, T. 28 N., R. 1 W. (Rawlins Twp.) (pl. 1)

The Oldenburg mine is located on the John Oldenburg farm about 2½ miles north of Galena. It was operated from 1899 to 1903 and was one of the largest top-run mines in the district. The ore occurs in a vertical east-west crevice that ranges from 6 to 30 feet wide. The ore body was 6 to 14 feet thick and followed downward for about 75 feet. Two shafts are 100 and 140 feet deep. The mine extends along the crevice for about 800 feet. The floor of the mine is near the top of the chert in the Galena formation or about 125 feet above the Oilrock. At the
east end of the mine the ore dips down and was not followed because of the water. The flow of water is reported to have been fairly strong. The area close to the mine is said to have been drilled after the mine was closed but no records are available.

**Paragon Mine**

NE. 1/4 NW. 1/4 sec. 1, T. 29 N., R. 1 E. (Council Hill Twp.) (pl. 1)

The Paragon mine, on the Joseph Temperley farm, two miles northwest of Council Hill, is on the Captain Gear range which is reported to have produced over 30,000,000 pounds of lead. Three shafts are variously reported to be 100 to 130 feet deep. The bottoms of the shafts were probably 25 to 50 feet above the Oilrock. Lead and zinc ore was found in flats in the deepest shaft. The mine was very little developed and there is no record of zinc ore production.

**Pilot Knob Mine**

NW. 1/4 SW. 1/4 NW. 1/4 sec. 33, T. 28 N., R. 1 E. (East Galena Twp.) (pl. 1, fig. 4)

The Pilot Knob mine, also called the Glen Ridge mine, is about two miles south of Galena. It has been held by the World's Products Association since 1920 but not operated. The mine consists of two shafts which are reported to be 112 and 96 feet deep and 80 feet apart. Disseminated ore 12 to 16 feet thick was mined from an elliptical area between the shafts. No pitches were found and it appears to be a middle-run deposit. The floor of the mine is reported to be about 30 feet above the Oilrock, but it may have been deepened to the Oilrock as a few slabs of Oilrock occur on the waste piles. Factors favoring prospecting on the property are the location of the mine on or close to the trend of the Black Jack mine, the occurrence of similar disseminated ore in commercial quantities in the Black Jack and Gray mines, the occurrence of the ore low in the Galena formation, and the fact that apparently no attempt has been made to trace the ore by drilling.

**Royal Princess Mine**

SE. 1/4 NE. 1/4 sec. 28 and SW. 1/4 NW. 1/4 sec. 27, T. 27 N., R. 1 E. (Rice Twp.) (pl. 1)

The Royal Princess mine is near the Mississippi River bluffs on the Devry farm eight miles south of Galena and is in the only zinc deposit that has been found in the large area of lead diggings known as the California Diggings. The mine was opened in 1903 to prospect one of the old lead diggings which had not been worked below water level. The mine was operated intermittently until about 1910. It follows an east-west crevice beneath the south wall of a valley tributary to Mississippi Valley. Three shafts were sunk. The highest, about 200 feet above the valley floor, is 265 feet deep. The workings are about 2,350 feet long but zinc ore was found only at the eastern end and was worked in an entry about 600 feet long, 40 to 50 feet wide, and about 20 feet high. The top of the zinc ore is at a level about 60 feet below the valley bottom at the mill and approximately 60 feet above the top of the chert in the Galena formation. The ore body is a typical top-run deposit but somewhat wider than usual. Good ore was reported to be present in the heading when the mine was closed. The heading is beneath a steep ridge capped by Silurian dolomite and is about 350 feet below the ground surface. There was no drilling ahead of the mine. The only recorded prospect drilling in the vicinity of the mine consists of three diamond-drill holes which were put down in the bottom of the highest shaft to prospect the 170 feet of strata between the ore body and the Oilrock. Reports on the results of this drilling are contradictory.

**Tenstrike Mine**

NW. 1/4 SW. 1/4 sec. 23, T. 27 N., R. 1 W. (West Galena Twp.) (pl. 1)

The Tenstrike mine, on the Joseph Burke farm two miles west of Galena, operated between 1907 and 1913. It is a short distance east of the Merry Widow mine and is a top-run deposit located on the same crevice and at the same level as the Merry
QUANTITY OF ORE UNCERTAIN

Widow. The mine extends west approximately 200 feet nearly to the Merry Widow property and east probably 600 or 700 feet. The ore in the main crevice is nearly all lead but quarterings extending southeast are reported to contain principally zinc ore. It is reported that a few holes drilled near the mine did not find ore below the present workings.

Waters Mine
SW. ¼ SW. ¼ sec. 13, T. 28 N., R. 1 W. (West Galena Twp.)
(Pl. 1)

The Waters mine is located in the northwest part of the City of Galena. It was operated as a lead mine for many years but about 1905 was also worked for zinc ore, principally carbonate. The shaft is about 100 feet deep. The ore is in an opening along an east-west crevice. The opening is partially filled with loose material and the ore forms the lower 4 to 5 feet. The opening averages 10 to 12 feet wide but has a maximum width of about 20 feet. East of the shaft the crevice was followed for about 1000 feet and the ore is mostly zinc carbonate. West of the shaft the ore is principally lead and zinc sulfide. The ore occurs about 125 feet above the Oilrock at a level near or slightly above the top of the chert in the Galena formation. It is reported that several holes were drilled to the Oilrock but did not find ore.

White Rose Mines
W. ½ SW. ¼, NW. ¼ sec. 23, T. 28 N., R. 1 W. (West Galena Twp.)
(Pl. 1)

The White Rose mines are located on the Kasten farm, two miles west of Galena. They were operated between 1911 and 1919 and produced principally lead ore. The dump piles contain zinc ore of the brangle type. The deposit worked appears to be along a crevice trending slightly north of east approximately parallel to the Merry-Widow-Tenstrike range which is about a quarter of a mile south. The deepest shaft is reported to be 72 feet deep and the ore is a top-run deposit in the upper cherty beds at about the same level as the ore mined along the Merry Widow-Tenstrike range. There is no record of drilling to the Oilrock in the immediate vicinity of the White Rose mines.

Properties without Mines
Prospect Drill Holes

Birkbeck Property
SE. ¼ SW. ¼ SE. ¼ sec. 22, T. 29 N., R. 1 E. (Council Hill Twp.)
(Pl. 1)

The Wisconsin Zinc Company in 1916 drilled four holes, two of which hit ore, on the property of Mrs. Thomas Birkbeck and Sons about a quarter of a mile north of the Birkbeck mine and two miles west of Council Hill. One of the holes encountered 43 feet of mineralized ground averaging 2.3 percent zinc and including a 10-foot interval that assayed 3.4 percent zinc and 90 percent iron and a 6-foot interval that assayed 6.1 percent zinc and 2.4 percent iron. In the other ore hole, 6 feet averaged 4.3 percent zinc and 6.4 percent iron. The ore is in the Oilrock and the overlying strata. The Oilrock is 120 to 130 feet deep.

Gaus Property
CEN. W. ½ SE. ¼ sec. 33, T. 29 N., R. 1 E. (Vinegar Hill Twp.)
(Pl. 1)

Nine holes were drilled in 1919-20 by A. Hollander on the John Gaus property, three miles north of Galena. Four of these holes are reported to have hit ore. Six holes drilled in 1920 by the Vinegar Hill Zinc Company found some ore but failed to check the earlier drilling. The Mineral Point Zinc Company also drilled 6 holes and encountered lean ore in 2 holes. The Oilrock was reached at depths of 140 to 160 feet.

Hudson Property
NE. ¼ sec. 20, NW. ¼ sec. 21, T. 28 N., N., R. 1 E. (East Galena Twp.)
(Pl. 1)

The Hudson property on the east side of Galena, south of the Galena River, was drilled about 1906 and it is reported that several of the 12 to 14 holes showed good zinc cuttings. The property was purchased...
by the Wisconsin Zinc Company in 1916 and an inclined shaft was started but not completed. No records or maps of the drilling have been found and only the general location of the holes is known. Considerable shallow lead ore was mined on this property by the Russell Mining Company.

**Magoon Property**
Part of Sections 15, 22, 27, T. 29 N., R. 2 E. (Scales Mound Twp.)

The Wisconsin Zinc Company drilled 20 holes on the Magoon property, two miles northwest of Scales Mound. Three widely scattered holes encountered 8 to 10 feet of top-run or middle-run ore 40 to 60 feet above the Oilrock. Several records show the thin Oilrock which is usually found with the lower-run deposits. No attempt was made to follow the top-run ore.

**Muchow Property**
SE. ¼ sec. 28, T. 28 N., R. 1 E. (East Galena Twp.) (pl. 1)

In 1918 and 1919 the Frontier Mining Company drilled 11 holes on the southeast part of the H. H. Muchow farm, two miles southeast of Galena. No drill records are available but several holes are said to have yielded fair zinc cuttings. Three more holes drilled on the property in 1942 by the Gill Brothers found only a little mineralization. Most of this drilling was on the southeast part of the farm. Good zinc cuttings were reported from the water well at the Muchow house, about 2,000 feet northwest of the area first prospected, and in 1945 a cross-section of 5 holes was drilled near the well by the Ginte Mining Company. Three of the holes showed lean ore in a zone 25 to 50 feet above the top of the Oilrock. This appears to be a middle-run deposit.

**Schaber (Spillane) Property**
SW. ¼ SE. ¼ sec. 33, T. 29 N., R. 1 E. (Vinegar Hill Twp.) (pl. 1)

In 1915 and 1916 the Cleveland Mining Company drilled 9 holes on the C. F. Schaber farm, then the George Spillane property, three miles northeast of Galena. Several of these holes are reported to have hit lean ore and they showed widespread mineralization. In 1916 and 1920 the Vinegar Hill Zinc Company drilled 10 holes and encountered ore in 2 holes. Later the Mineral Point Zinc Company drilled 12 holes and found ore in 5 holes. There appears also to have been some earlier drilling on the property. The drilling was on the side of a hill and the Oilrock varies from 135 to 200 feet deep. Only a small part of the property was prospected.

**Spillane Property**
SE. ¼ sec. 20, NW. ¼ sec. 28, NE. ¼, sec. 29, T. 29 N., R. 1 E. (Vinegar Hill Twp.) (pl. 1)

The Vinegar Hill Zinc Company drilled 48 holes on the Lake Superior Mining Company lease on the Albert Spillane farm, about five miles north of Galena. Several of these holes hit ore near the Oilrock but the drilling failed to find a commercial ore body. Study of the records shows that the ore holes occur on the flanks of a narrow syncline trending northeast-southwest. The drilling did not adequately test the structure either northeast or southwest of the ore holes and additional prospecting is worthy of consideration.

**Taylor (Burton) Property**
SW. ¼ SE. ¼ sec. 15, T. 28 N., R. 1 E. (East Galena Twp.) (pl. 1)

It is reported that seven holes were drilled about 1900 on the Taylor property, then the Burton farm, two miles east of Galena, and that several found some zinc mineralization. Two cased holes occur along the small north-south ravine, and one of these, about 200 feet from the mouth of the ravine, is reported to have had 27 feet of lead and zinc cuttings. The area is densely pitted with lead diggings, mostly along north-south crevices.
In 1923 the Vinegar Hill Zinc Company drilled a north-south cross-section along the east side of the D. Virtue property, then the William Stacy property, five miles north of Galena. A hole at the south end of the cross-section is reported to have hit 10 feet of ore assaying 3.5 percent zinc at a depth of 192 feet. The base of the ore is 10 feet above the Oilrock but some mineralization is reported down into the Oilrock. Drilling was not continued on the adjoining Glassen and O'Rourke properties, and so far as known the possibilities suggested by this ore hole have not been tested.

Properties without mines

Water wells

Water wells which are reported to have hit some zinc mineralization include the following:

Mrs. J. B. Foeching farm, three miles south of Galena, NE. ¼ NE. ¼ sec. 1, T. 27 N., R. 1 W. (Rice Twp.). This well is reported to have encountered zinc mineralization at a depth of 120 feet, approximately 40 feet above the Oilrock.

Illinois Central Railroad, at Scales Mound, SW. ¼ SW. ¼ sec. 26, T. 29 N., R. 2 E. (Scales Mound Twp.). A well drilled in 1944 had shines of zinc at 220, 230, 240, and 272 feet, probably as much as 1 percent zinc in the base of the Gray at 174 feet, and also shines in the Blue at 277 feet. As the Oilrock is thinned to only 2 feet, in a region where it is normally 10 feet thick, favorable structural conditions may be present.

Theodore Volquaidts farm, about seven miles southeast of Galena, SW. ¼ NE. ¼ sec. 26, T. 27 N., R. 1 E. (Rice Twp.). A well at the farm house is reported to have had some zinc cuttings in the last cut at a depth of 285 feet in the top of the Galena formation.

O. Sincox farm, four miles southeast of Galena, SE. ¼ SW. ¼ sec. 25, T. 28 N., R. 1 E. (East Galena Twp.). A well drilled in 1926 is reported to have had good zinc cuttings at 90 to 105 or 110 feet, about 100 feet above the Oilrock.

Spring Creek School, five miles south of Galena, NW. ¼ SE. ¼ NE. ¼ sec. 9, T. 27 N., R. 1 E. (Rice Twp.). A well at the school is said to have encountered some zinc mineralization.

A. Wilkins farm, three miles north of Galena, NW. ¼ NW. ¼ NW. ¼ sec. 4, T. 28 N., R. 1 E. The bottom sample in a well 165 feet deep at the farm house is reported to have contained good zinc cuttings.

Properties on trends of known ore deposits

Bell (Southcott) Trend

The trend of the ore drilled on the Bell (Southcott) property (p. 35) appears to be nearly north-south. No large amount of drilling has been done either north or south of the Bell property for a mile or more.

Birkbeck Trend

The Birkbeck ore body (p. 33) trends northwest but has not been closed off by blank drill-holes at either end. So far as known, no attempt has been made to drill on the projected trend of the ore body. The ore body has been drilled for only about 700 feet, and further drilling might show it to be part of an arcuate-type ore body. The Birkbeck ore body may be on the same ore trend with the Bell (Southcott) ore body which is only about one mile southeast of the Birkbeck mine. There has been very little if any prospecting between these two properties.

Black Jack Trend

The Black Jack trend contains the Black Jack, Pittsburg, and Gray mines and the
ore body on the Bautsch property south of the Gray mine (pp. 33). The Pilot Knob mine (p. 40) about 4,000 feet north of the Black Jack is at least close to the trend if not on it (fig. 4). If the Pilot Knob mine is included, mineralization continues along the trend for 3½ miles, although there are several intervals where the mineralization is too lean to be minable at present. The overall trend is about 30° west of north, but at the extreme north end of the Black Jack mine the ore appears to turn sharply to the west and end in a short distance. A few holes have been drilled west of the mine to prospect this local trend.

On the main trend northwest of the mine there has been scattered prospecting for nearly a mile and a half. Many of the drill-holes encountered mineralization, mostly iron sulphide. As the projected trend extends through the high ground around Pilot Knob, the drilling is deep and no adequate cross-sections have been drilled except close to the Black Jack mine. Most of the drilling also appears to have prospected only the east side of the most favorable area. This in part results from different opinions as to the direction of the trend line. In 1945 Tri-State Zinc, Inc., drilled a cross-section about 1,000 feet north of the Pilot Knob mine but did not find ore.

The south extension of the Black Jack trend has been prospected by cross-sections drilled by Tri-State Zinc, Inc., and the U. S. Bureau of Mines, about 1,200 feet south of the Bautsch ore body and by the Bureau of Mines about 1,800 feet south. Neither of these found ore or structural conditions favorable for ore. There has been no drilling farther south on the trend.

**Buck Hill (Blewett) Trend**

The Buck Hill (Blewett) ore body (p. 33) was thought to have an east-west trend when the mine was being operated, but later drilling shows that the ore extends north and south. The drilling does not close off the ore body on either the north or south projection of the trend. There has been no drilling in the area since this north-south trend was established, and consequently the few scattered drill-holes in the area do not adequately prospect its possibilities.

**Graham–Ginte Trend**

The Graham–Ginte ore body (p. 34) is about 2,500 feet long and has a relatively straight trend about 10° west of north. At the extreme north end the ore body makes a sharp curve to the northwest but apparently ends without extending far from the main trend. A few blank drill-holes have prospected the area immediately ahead of the mine on the northwest trend, but there has been no attempt to systematically prospect the major trend north of the mine. The trend south of the mine has not been prospected except close to the mine. About half a mile south the Wilkins farm well (p. 43) is on the trend and is reported to have hit zinc mineralization. About 1½ miles farther south the Buckhill (Blewett) mine is on the trend but at present there is no evidence to indicate a structural connection between the two deposits.

**Hughlett and Gray–South Unity Trend**

The Hughlett and Gray (p. 36) and South Unity (p. 34) mines are in the same ore body which forms a nearly complete loop elongated east-west (fig. 5). This ore body is similar in shape to the North Unity ore body located about 800 feet north. The possibility that a third ore body occurs south of the Hughlett and Gray ore body has been partially explored but additional drilling may be desirable. The east-west trend of the ore body has been explored only about 500 feet east and about 600 feet west of the mine, even though the spacing of the known ore bodies in this vicinity suggests that a separation of 500 to 1,000 feet is probable. This ore body is also on a major north-east-southwest trend described as the Vinegar Hill–North Unity trend.

**Kennedy Trend**

The Kennedy mine in Wisconsin, about a mile north of the Illinois-Wisconsin state line, is one of the largest mines in the Upper Mississippi Valley region. It is on a well-established northwest-southeast trend which
includes the Burkett, Byrne, Monmouth, Badger, and Tunnel Hill mines, the latter and southernmost being only an eighth of a mile north of the state line. In Illinois the trend line appears to extend southeast from the state line, in the center of the SE. 1/4 sec. 15, through the center of the S. line of sec. 23, T. 29 N., R. 1 E. (Council Hill Twp.). For nearly a mile southeast of the state line it follows the east bluff of Galena River. The tract within a quarter of a mile of this line is probably the most favorable. Part of this tract is in the Galena River bottomland where the depth of the valley fill is uncertain and the principal ore-bearing strata may be eroded. So far as known there has been little prospecting on the Kennedy trend in Illinois.

**North Unity Trend**

The North Unity ore body (p. 36) forms a loop elongated east-west (fig. 5). The north side of the loop is slightly curved but has a nearly east-west trend whereas the south side has nearly straight intersecting northwest and northeast trends. Additional ore might occur along either the east-west trend or the northwest and southeast trends. Although the ore body is closed off by blank holes close to the mine, undrilled areas large enough to contain commercial bodies of ore occur both east and west of the mine. The area south of the mine has been extensively drilled for some distance. The Illinois-Wisconsin state line is only about 500 feet north of the mine. There has been some drilling along the northeast trend but very little along the northwest trend.

**Northwestern Trend**

The Northwestern ore body (p. 36) is about 2,000 feet southeast of the North Unity ore body and the same distance northeast of the Hughlett and Gray ore body (fig. 5). The available records give so little data about the Northwestern ore body that its trends cannot be determined. Apparently the ore mined followed an arc which has been explored by drilling only on the north side. The possibility that additional ore bodies may occur east of the mine has not been explored and there has been little drilling either north or south of the mine.

**Vinegar Hill Trend**

The Vinegar Hill ore body (p. 37) consists of relatively straight but intersecting ore runs (fig. 5). The northwest trending ore run has been prospected for about 400 feet northwest of the mine and about 1,000 feet southeast. The major part of the mine trends slightly east of north. North of the mine this trend has been little explored in the 1,000 feet which separates the mine from the South Unity drilling. South of the mine scattered drilling follows the trend for about 1,000 feet. However, no cross-sections were drilled and, if the trend curved only slightly, ore might have been missed. Undrilled areas large enough to contain minable ore bodies occur both west and south of the mine.

**Vinegar Hill—North Unity Trend**

The Vinegar Hill, South Unity-Hughlett and Gray, and North Unity ore bodies are on a major northeast-southwest trend which also includes the Federal ore body in Wisconsin. As the arcuate-type deposits are commonly slightly staggered along the trend line, a zone one-half mile or more wide should be prospected. Southwest of the Vinegar Hill mine additional prospecting appears to be desirable throughout a large area. The trend has been partially prospected on the Spillane property (p. 42) where some ore was found.

**Trends of Top-run Deposits**

Additional ore deposits may also be found along the trends of the top-run mines as previously described (pp. 38-41). Most of these deposits are so narrow that drilling to find possible extensions of ore some distance ahead of known ore is a difficult proposition, and prospecting for other mineralized crevices running parallel to the known deposit may be preferable. This requires close spacing of holes. Also many of the top-run deposits were worked without proper provision for handling water, and consequently the possibilities of finding additional deposits in lower openings were not adequately investigated.
ZINC-LEAD DISTRICT

PROPERTIES WITH FAVORABLE GEOLOGICAL STRUCTURES

Study of the outcrops in the principal mineralized area is still in progress and when completed other structures similar to those briefly described below may be found. As noted elsewhere (p. 26) the presence of the structures described is no assurance of the presence of ore, and the term "favorable" is used in comparing geological structures and not in evaluating the chances of finding ore.

**Bartell and O’Rourke Properties**

Cen. W. ½ NW. ¼ sec. 27, T. 29 N., R. 1 E. (Counsell Hill Twp.) (pl. 1)

Outcrops along a stream on the P. Bartell and T. O’Rourke properties, about half a mile north of Millbrig, show a shear zone at least 20 feet wide, trending N. 45° W., and dipping about 75° SW. The bedding-planes in the strata on either side of the shear zone dip about 15° N. The strata exposed are in the lower part of the cherty Galena dolomite, 50 to 60 feet above the top of the Oilrock.

**Brendel and Snedeger Properties**

W. ½ sec. 25, T. 28 N., R. 1 W. (West Galena Twp.) (pl. 1)

Outcrops along the west bluff of Galena River where it flows southeast, about a mile south of Galena on the M. Brendell and Charles Snedeger properties, show closely spaced shear planes and considerable brecciation. The strata dip 3° SE. in some places and 6° NW. in others. The long straight bluff appears to be controlled by a prominent joint trending N. 40° W. The fracture planes and spaces between the breccia blocks are filled with calcite and a small amount of iron sulfide. The top of the chert in the Galena formation is exposed along the bluff at an elevation of about 660 feet above sea-level. The Oilrock is probably at an elevation of about 540 feet or only about 50 feet below Galena River. In the valley bottom the potential ore-bearing strata, including the Oilrock are probably eroded so that the most favorable area for prospecting is west of the bluff or along its trend farther northwest. This structure is of particular interest as it is on, or at least near, the Black Jack trend.

**Felderman, Lindemann, and Oldenburg Properties**

W. central part sec. 1, E. central part sec. 2, T. 28 N., R. 1 W. (Rawlins Twp.) (pl. 1)

A stream that crosses the John Felderman, H. Lindemann and Henry Oldenburg properties about two miles northwest of Galena exposes strata which dip southwest at angles varying from 3° to 10°. The strata exposed are 60 to 70 feet below the top of the Galena formation, and the Oilrock is about 185 feet deep.

**Foecking Property**

N. ½ sec. 1, T. 27 N., R. 1 W. (East Galena Twp.), and SE. ¼ sec. 36, T. 28 N., R. 1 E. (Rice Twp.) (pl. 1)

A syncline trending northeast-southwest occurs on the Mrs. J. B. Foecking farm, two miles south of Galena. The structure is based on outcrops along a stream which flows southwest to Mississippi valley. The axis of the syncline appears to be along the south side of the stream. The rocks are heavily jointed, and strata with dips up to 4° are exposed at several places. The depth to the Oilrock ranges from 100 to 125 feet in the valley bottom to 200 to 250 feet in the adjoining upland areas. A well at the Foecking farm house (p. 43), which is probably on the south flank of the structure, is reported to have encountered some zinc mineralization.

**Galena City Quarry**

NW. ¼ NE. ¼ SE. ¼ sec. 24, T. 28 N., R. 1 W. (West Galena Twp.) (pl. 1)

The Galena City quarry on Bench Street in the southwest part of Galena and the cut of the Illinois Central Railroad below the quarry expose a strong shear zone which trends N. 85° E. and dips about 45° S. In the quarry the bedding-planes dip about 10° N. but the dip decreases a short distance...
Properties with Lead Diggings

North of the quarry. The shear zone is about 20 feet wide and the strata in it are badly shattered by closely spaced shear planes. The top of the chert in the Galena formation, about 125 feet above the Oilrock, is exposed in the quarry.

Heim and Huschar Properties
Central part of sec. 33, T. 28 N., R. 1 E. (East Galena Twp.) (pl. 1)
Streams which dissect the high land on the east slope of Pilot Knob, on the Mary Heim and J. Huschar Estate properties about two miles south of Galena, expose strata with unusually high dips. Dips varying from 4° to 10°, mostly south and southwest, are exposed for several hundred feet. This area is only about 1,500 feet north of the Black Jack mine but is 100 yards or more east of the Black Jack trend. The Black Jack structure has not been definitely traced this far north of the mine and only a slight east turn would permit a correlation of the outcrops with the Black Jack structure. So far as known there has been no prospecting for the Black Jack trend this far east. The strata exposed are mostly in the upper 50 feet of the Galena formation with Maquoketa shale on the ridges between the valleys. Consequently, drilling near the outcrops would probably average about 250 feet to the top of the Oilrock.

Zeal Properties
NW. 1/4 sec. 23, T. 29 N., R. 1 W. (Vinegar Hill Twp.) (pl. 1)
The rocks exposed along a valley on the properties of John and G. Zeal, about four miles north of Galena, show a syncline trending north-south with dips of 2° to 3° on the west limb and as much as 4° on the east limb. This structure appears to be nearly parallel to the Graham-Ginte ore body which is about one-half mile to the west. The strata exposed in the creek bed are about 30 feet above the top of the Oilrock. Although there has been scattered drilling throughout this part of the area, so far as known no holes have been located on this structure.

In the Principal Mineralized Area
In general the lead ranges in the principal mineralized area are probably more favorable places to prospect for lower-run deposits than those located elsewhere in the mineralized district. In addition to the areas of diggings mapped (pl. 1), isolated diggings and small groups of diggings are widely scattered through the principal mineralized area. Some of these may have been merely prospect holes and not productive. Although the mapping of lead diggings is not complete, at least 25 areas of diggings in the principal mineralized area appear to be entirely unprospected below water level for either top-run lead and zinc or the lower-run deposits.
The "California diggings" in the Mississippi Valley bluffs about six miles south of Galena is probably the largest of the unprospected areas. In this area almost every prominent crevice for nearly 2½ miles is said to have been mineralized, and entries along the crevices are reported to extend back from the bluffs for as much as 3,000 feet. Most of the lead ore appears to have been found in openings 125 to 175 feet above the Oilrock. Many of the entries were just above water level but dams in Mississippi Valley have raised the water level so that the lowermost entries are now flooded. Because of the rugged topography, the great depth of drilling, and the doubt that water could be pumped out because of the closeness of the Mississippi River, the area has not been prospected. Along the large valley at the south end of the area where the Royal Princess Mine is located (p. 40), an area about one mile east-west and ¼ mile north-south could be prospected by churn drilling 175 to 300 feet deep. Elsewhere the area might be more effectively prospected by diamond-drill angle holes started from the base of...
the bluffs, or possibly in some of the old mine entries.

Outside the Principal Mineralized Area

Outside the principal mineralized area there has been little prospecting for lower-run deposits. In the Elizabeth area a few holes have prospected the area close to the Wishon and Skene lead mine without success. The Magoon property (p. 42) in the area of lead diggings northwest of Scales Mound has also been prospected without finding commercial ore. It is also reported that a few holes have been drilled in the Apple River area. So far as known there has been no prospect drilling in the areas of lead diggings near Warren, Stockton, Morseville, or Guilford nor in the areas of lead diggings in the part of Vinegar Hill Township west of the principal mineralized area (pl. 1).
Principal Mineralized Area showing Locations of Mines which have Produced Zinc Ore, Properties Described, and Areas Containing Large Numbers of Lead Diggings.
Areas Partly Prospected by Drilling for Zinc-Lead Ore in Northwestern Illinois.