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Prepared in cooperation with the Wisconsin Geological and Natural History Survey

Klemic and West—GEOLOGY OF THE BELMONT AND CALAMINE QUADRANGLES, WISCONSIN—Geological Survey Bulletin 1123-G

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By HARRY KLEMIC *and* WALTER S. WEST

GEOLOGY OF PARTS OF THE UPPER MISSISSIPPI VALLEY ZINC-LEAD DISTRICT

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[Plates are in pocket]

GEOLOGY OF PARTS OF THE UPPER MISSISSIPPI VALLEY LEAD-ZINC DISTRICT

GEOLOGY OF THE BELMONT AND CALAMINE QUADRANGLES, WISCONSIN

By Harry Klemic and Walter S. West

ABSTRACT

The Belmont and Calamine quadrangles in Lafayette County, Wis., include about 110 square miles of the Upper Mississippi Valley zinc-lead district. The general concordance of upland altitudes in the area is probably due to peneplanation. The rocks have a southerly and southwesterly regional dip that is modified by folding. A thick layer of soil and loess conceals bedrock in most places.

The exposed rocks are of Middle and Late Ordovician age and have an aggregate thickness of about 400 feet. The oldest exposed rocks, the uppermost 35 feet of the St. Peter Sandstone of Middle Ordovician age, are poorly cemented and consist of highly permeable white to yellow beds composed almost entirely of fine to coarse well-rounded quartz grains. These rocks are generally crossbedded.

The Platteville Formation, of Middle Ordovician age, which overlies the St. Peter Sandstone, averages about 65 feet in thickness and includes, in ascending order, the Glenwood Shale Member, the Pecatonica Dolomite Member, the McGregor Limestone Member, and the Quimbys Mill Member. The McGregor and Quimbys Mill Members are composed of limestone in much of the zinc-lead district but are composed of dolomite in many parts of the two quadrangles.

The Decorah Formation, of Middle Ordovician age, overlies the Platteville Formation. The Decorah averages about 32 feet in thickness and consists of, in ascending order, the Spechts Ferry Shale Member, the Guttenberg Limestone Member, and the Ion Dolomite Member. In some parts of the two quadrangles, all the carbonate rocks in the Decorah Formation are dolomite.

The Galena Dolomite, of Middle Ordovician age, overlies the Decorah. It is about 220 feet thick and consists of two units of almost equal thickness: a cherty unit that contains thin layers of interbedded nodular chert and an overlying noncherty unit.

The Maquoketa Shale, of Late Ordovician age, is the youngest formation present. In the study area, it occurs only in the northwestern part of the Belmont quadrangle, where an estimated 40 feet of beds remains. The formation consists of blue or gray shale and thin-bedded gray dolomite. Near its base is a thin zone rich in depauperate fossils and phosphatic nodules.

The upper part of the Platteville Formation, the Decorah Formation, and the cherty unit of the Galena Dolomite are the principal host rocks for zinc and lead ores.

Principal structural features are a south-southwesterly regional dip of about 15 to 20 feet per mile and folds ranging from one having a length of several miles and about 190 feet of relief—the Meekers Grove anticline—to minor basins and domes a few thousand feet long and having only a few tens of feet of relief.

Joints are numerous and well formed in all the carbonate rock units. A close relationship between trend of joints and the direction of stream channels is suggested by a comparison of the strikes of joints with the drainage pattern.

Only a few faults having a relatively minor displacement are exposed at the surface, but faults having inferred horizontal displacements of 25 and about 200 feet in subsurface rocks have been described by others in mines no longer accessible.

Estimates of ore production from mines in the quadrangles are about 500,000 tons of zinc ores from large underground mines and about 9,500 tons of galena from shallow surface workings and from small underground mines. No lead or zinc mines have been operated in the quadrangles since 1952.

Sphalerite and galena are the principal ore minerals. Marcasite and pyrite are abundant, and barite is commonly associated with the ores. Weathering has altered sphalerite to smithsonite and the iron sulfides to iron oxides. Chalcopyrite and associated malachite, azurite, and iron sulfides and oxides have been found at one locality in the Calamine quadrangle.

The lead and zinc ores are associated with openings along vertical joints (crevice deposits) or with systems of inclined and horizontal fractures (pitch and flat deposits). Crevice deposits occur mainly in the Galena Dolomite; residual concentrations of galena are found at the surface in the soil above some crevice deposits. The pitch and flat deposits occur in a zone that extends from the upper part of the Platteville Formation into the lower part of the Galena Dolomite and are principally zinc deposits. The ore fills fractures and occurs in breccia zones on the footwall sides of the inclined fractures. Solution thinning, dolomitization calcitization, and silicification have altered the host rocks.

The probable sequence of events in the emplacement of the ores is interpreted to be as follows: The rocks in the district were broken by joints and fractures, and solution by meteoric waters occurred, enlarging openings and thinning calcareous beds. Sets of inclined fractures then formed along zones of solution thinning. Dolomitization and silicification began early and continued through this stage of fracturing. Solutions carrying the ore metals entered the openings below the water table, and the ore minerals were deposited. Calcitization occurred during and after the deposition of the ores.

An area favorable for prospecting for lead and zinc deposits is probably present in parts of the two quadrangles. Closer spacing of prospect drill holes may be desirable in places where the Platteville and Decorah Formations are mostly dolomitic than in places where they are more calcareous.

INTRODUCTION

LOCATION, ACCESSIBILITY, AND CULTURE

The Belmont and calamine quadrangles, located in Lafayette County in southwestern Wisconsin, include about 110 square miles of the Upper Mississippi Valley zinc-lead mining district (fig. 47.) Darlington, the county seat, is on the east edge of the area, and Platteville is 6 miles west of the western boundary of the areas.

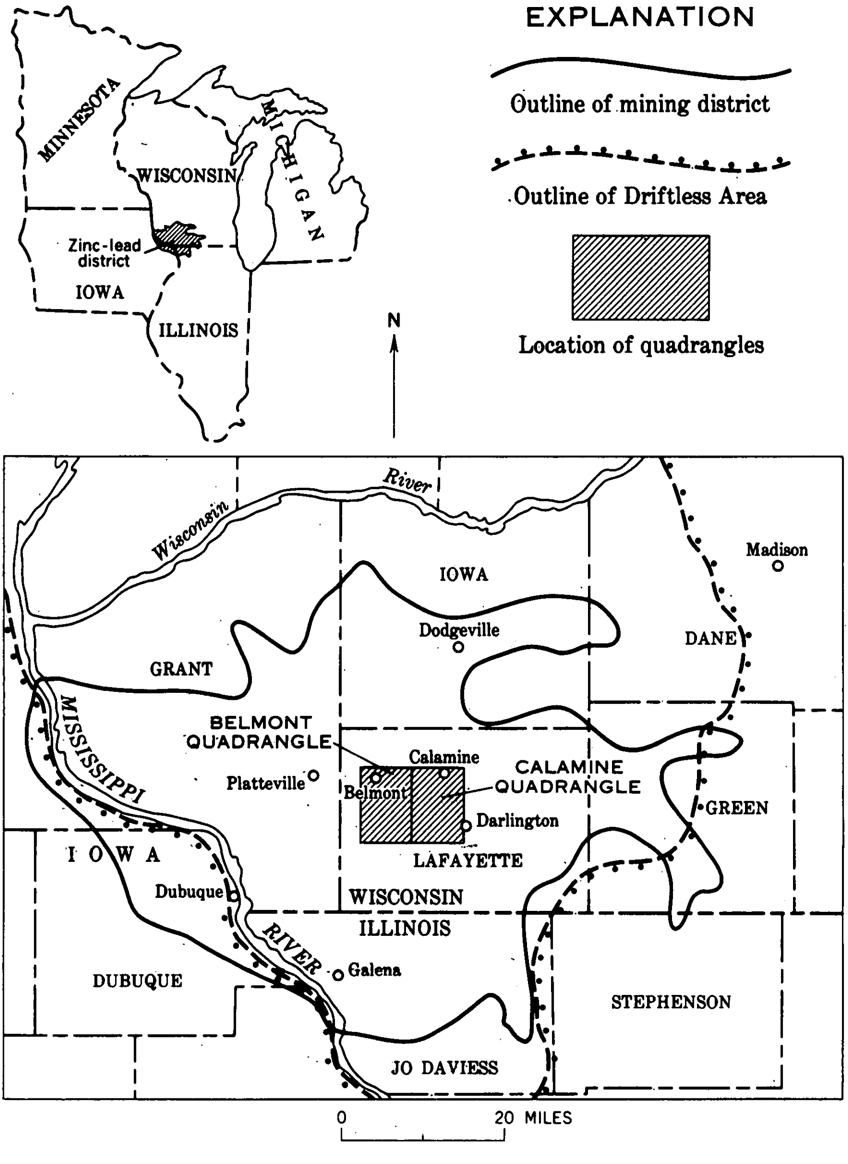

FIGURE 47.—Index map of southwest Wisconsin, northwest Illinois, and northeast Iowa, showing the outline of the Upper Mississippi Valley zinc-lead district, the outline of the Driftless Area, and the location of the Belmont and Calamine quadrangles.

The area is accessible by U.S. Route 151, State Routes 23, 81, and 126, and several county roads. The roads form a grid that generally follows section lines, and no place in the two quadrangles is more than three-quarters of a mile from a public road. Private lanes provide additional access. A branch line of the Chicago, Milwaukee, St. Paul, and Pacific Railroad crosses the northern part of both quadrangles from Platteville east through Belmont to Calamine. The main line of the railroad extends north from Darlington through Calamine to Mineral Point. The villages of Belmont and Calamine, having populations of about 1,200 and 100, respectively, are the two largest communities that lie wholly within the quadrangles. Most of the region has about 3 or 4 families per square mile. Dubuque, Iowa, about 30 miles southwest of Belmont, and Madison, Wis., about 60 miles northeast of Calamine, are the nearest larger cities.

Dairying, livestock raising, grain-seed raising, and cheese manufacturing are the principal industries. Crushed stone for local road repair and construction, for concrete aggregate, and for agricultural lime is produced in a few quarries. Lead or zinc mines have not been operated in the Belmont or Calamine quadrangles since 1952.

Farm crops, chiefly hay, corn, barley, and oats, are the most abundant vegetation in the Belmont and Calamine quadrangles. Deciduous trees, including oaks, elms, poplars, maples, basswood, boxelder, ash, ironwood, black walnut, hickory, butternut, wild fruit trees, hawthorn, and willow, grow along streams, in farm woodlots, and in the relatively small areas that are too steep and rocky for pasturing livestock. Thickets of sumac, hazelnut, blackberry, raspberry, elderberry, gooseberry, wild grape, ivy, and bittersweet and thick growths of nettles, thistles, and other weeds grow in uncultivated and unused farmland and along the streams and gullies.

The area has a temperate continental climate, whose temperature ranges generally from −20° F or colder to about 110° F. Prolonged hot spells are common in the summer, and prolonged periods of below-zero weather occur in winter. The mean annual temperature is about 47°F, and the mean annual precipitation is about 33 inches. The average snowfall is about 40 inches. Severe electrical storms, sometimes accompanied by high winds and hail, occur during the summer. Tornadoes have occasionally inflicted heavy property and crop damage in the area. In general, however, the climate is invigorating and pleasant, although the winters are rigorous.

CURRENT AND RECENT PROJECTS

Mapping of the first of a group of twelve 7½-minute quadrangles in the central part of the mining district was started in 1951 by the

U.S. Geological Survey in cooperation with the Wisconsin Geological and Natural History Survey. This work is a continuation of geological study of the Upper Mississippi Valley district started in 1942 by the U.S. Geological Survey as part of a Strategic Minerals Investigation program and continued after 1945 as a cooperative project with the Wisconsin Geological and Natural History Survey (Agnew and others, 1956; Heyl and others, 1959). The purpose of the study is to increase the potential reserves of lead and zinc in the district by determining the structural and other geologic controls of ore deposition.

The geologic data are being published on topographic maps at a scale of 1: 24,000 and a contour interval of 10 feet. Structure contours on 10-foot intervals have been drawn using the top of the Platteville Formation as a datum plane in the nine northern quadrangles. The top of the McGregor Limestone Member of the Platteville Formation and the top of the cherty unit of the Galena Dolomite are the datum planes in the three southernmost quadrangles.

In the study area W. S. West, A. F. Holzle, and J. W. Allingham mapped parts of the Calamine quadrangle between 1954 and 1957; W. S. West and Harry Klemic completed mapping of the quadrangle in 1958 and mapped the Belmont quadrangle in 1958 and 1959. The areal bedrock geology and structure of the two quadrangles are shown in plate 22. About 7 square miles of the Meekers Grove area in the southwestern part of the Belmont quadrangle was previously mapped by Heyl and others (1959), and only a part of this area was reexamined. In plate 22 the outlines of all mine workings and the faults in the southwestern part of the quadrangle shown on the map are taken from the above-mentioned report; most of the outcrop locations, the locations of old lead diggings, and dip and strike and joint measurements in the southwestern part of the quadrangle shown on the map are from that report and from maps compiled by Chamberlin (1882) and Grant (1906).

Aerial photographs and enlarged topographic maps were used in plotting geologic data. Key stratigraphic horizons and drill-hole collars were surveyed by telescopic alidade to determine altitudes of control points for the structure contour maps. The U.S. Geological Survey drilled 24 holes in the Belmont and Calamine quadrangles to obtain geologic information. Logs of these holes are included in this report (p. 411–428). Information obtained from water-well drillers and from drilling records of mining company prospects was also used in preparing the geologic maps.

A. F. Agnew and T. E. Mullens, project chiefs, technically and administratively coordinated the mapping in the Belmont and Calamine quadrangles with that in adjoining quadrangles. Ralph Chartraw, J. W. Reddy, R. M. Borcherding, and A. R. Taylor assisted in the surveying of control points and in the compilation of geologic information. Larry Dixon assisted in the study of the drill cuttings in the laboratory.

PREVIOUS GEOLOGIC WORK

Geologic investigations of the Upper Mississippi Valley zinc-lead district began in the early part of the 19th century and are continuing at present. Extensive studies were made by the State geological surveys of Wisconsin, Illinois, and Iowa, and by private individuals. The general geology of the district was described by Owen (1847), and other important studies were reported by Whitney (1862, 1866), Hall and Whitney (1858, 1862), Daniels (1854), Percival (1855, 1856), Shaw (1873), Strong (1877), Chamberlin (1882), Jenney (1894), Grant (1903, 1906), Bain (1905, 1906), Grant and Burchard (1907), Cox (1914), Kay (1929, 1934, 1935, 1939, 1940), Kay and Atwater (1935), Bays and Raasch (1935), Behre and others (1937), Agnew and Heyl (1946), Agnew and others (1956), Willman and Reynolds (1947), Reynolds (1958), Heyl and others (1959), Brown and Whitlow (1960), and Whitlow and Brown (1963). Heyl and others (1959) compiled a list of hundreds of references to geology and mining in the district.

ACKNOWLEDGMENTS

Information furnished by well and exploration drillers, particularly Messrs, Gille, Beets, Moore and Siegal, Judd, Cook, Faherty, Hauser, Kabele, Dagenhardt, Williams, DeWitt, Bauer, Webber, and others, is greatly appreciated. The New Jersey Zinc Co. contributed a considerable amount of geologic information obtained during exploratory grid drilling, and their cooperation is gratefully acknowledged. It is a pleasure to acknowledge also the cooperation extended to the authors by local residents and property owners who furnished information on wells, old lead diggings, and mines and permitted access to their properties.

A. V. Heyl, Jr., contributed much information about the zinc-lead district in addition to that in the reports which he coauthored.

PHYSIOGRAPHY AND SURFACE FEATURES

The Belmont and Calamine quadrangles are in the Wisconsin Driftless section of the Central Lowlands province (Fenneman, 1938). The Pecatonica River and its tributaries drain much of the area, although the Galena (Fever) River drains approximately the southwest half of the Belmont quadrangle. The divide between the two drainage systems is at 1,050 feet or more above sea level.

Geologic structural features have markedly influenced the development of the drainage pattern. The Pecatonica River flows southward in a synclinal valley. The influence of joints on the pattern of erosion is suggested by abrupt changes of about 45° or 90° in trend of straight segments of the river valley, by the easterly trends of the large tributary streams, and by the roughly semirhombic outline of high ground along stream valleys between their subsidiary dry valleys. In the southwestern part of the Belmont quadrangle, west-southwest and south-trending streams form the major drainage net. In general, west- and east-flowing streams have steep south banks.

Maximum relief in the Belmont quadrangle is about 330 feet. The highest point, at the extreme northwest corner of the quadrangle, is about 1,160 feet above sea level; the lowest point, where the Galena (Fever) River leaves the quadrangle near the southwest corner, is at about 830 feet. The highest point in the Calamine quadrangle, 1 mile east-northeast of Seymour Corners, is about 1,100 feet above sea level; and the lowest point, where the Pecatonica River leaves the east-central border of the quadrangle, is at about 800 feet. The general concordance in altitude of the uplands in these quadrangles and in adjoining areas is due probably to peneplanation of the region (Trowbridge, 1921).

Gradients are relatively gentle along the major streams. The Pecatonica River drops less than 20 feet in about 6 miles in the Calamine quadrangle. Bonner Branch drops only about 20 feet per mile between Belmont and the Pecatonica River. Wood Branch and Ames Branch have flood plains that slope about 20 feet per mile. The flood plains of Rowe Branch and Madden Branch slope about 25 or 30 feet per mile.

The watersheds are relatively flat topped or rounded uplands having slopes that steepen near the stream valleys. Bedrock is only sparingly exposed on the uplands and in the upper courses of streams. Bedrock is exposed in the bottoms of some gullies, although few outcrops occur in many deep gullies in small stream valleys that have relatively steep gradients. Along stream valleys that have steeply sloping banks on one side, bedrock may be well exposed along the steep slopes. In many places, particularly in the Calamine quadrangle, large blocks of rock are slumped on hillsides and at cliffs along streams. Bedrock is also exposed in roadcuts, in ditches along roads, in unpaved roads, and in old diggings.

Where the soil is thick it is generally black or dark gray, but where the mantle is thin the soil may be stained by limonite. Thick layers of soil and loess are deeply gullied in many places; in some valleys alluvial deposits of soil are cut by gullies as much as 8 or 10 feet deep that have vertical or near vertical sides. A layer of residual chert generally marks the base of the soil.

STRATIGRAPHY

GENERAL STATEMENT

The rocks exposed at the surface in the Belmont and Calamine quadrangles are of the Middle and Upper Ordovician Series. Rocks that may be of the Upper Cambrian Series and rocks of the Lower Ordovician Series have been penetrated in the area by drill holes (Heyl and others, 1951). The Ordovician rocks are underlain by sedimentary rocks of Late Cambrian age along the Wisconsin River north of the zinc-lead district. Rocks of Early Silurian age cap the mounds a short distance north and northwest of the Belmont quadrangle (Taylor, 1964). A generalized columnar section of the rocks exposed or penetrated by drilling in the Belmont and Calamine quadrangles is shown in plate 23. Nowhere in the area is a complete sequence of these rocks exposed. Information on the combined thickness of the units is based on measurements made at several outcrops and on drill-hole data.

CAMBRIAN SYSTEM

Heyl and others (1951) assigned 15 feet of sandstone and red-green shale to the Jordan Sandstone Member of the Trempealeau Formation; the rock was penetrated by churn drilling at 542 feet above sea level in the SE¼ sec. 21, T. 2 N., R. 1 E., near the Raisbeck mine in the Meekers Grove area of the Belmont quadrangle (pl. 22). The rock contains trace amounts of pyrite and marcasite. Ten feet of siliceous and glauconitic dolomite penetrated in another drill hole in the Meekers Grove area was tentatively assigned to the Cambrian. Because sandstone, green and red shale, and siliceous dolomite were noted in cuttings assigned to the Prairie du Chien Group of Early Ordovician age and because little or no detailed information is available on the nature of the Cambrian strata in areas closely adjoining the Meekers Grove area, the assignment of these cuttings to the Cambrian is only tentative (Heyl, oral communication, 1960).

Grant (1906, p. 25) stated that the Potsdam Sandstone (as he named the Cambrian strata) has a maximum thickness of about 1,000 feet and averages about 700 feet in thickness. Heyl and others (1959, p. 6) stated that the Cambrian strata thicken southward from about 1,000 feet at the north edge of the mining district to about 1,300 feet at Platteville. Near Dubuque, Iowa, about 15 miles to the southwest, the top of the Precambrian rocks penetrated in drill holes is about 1,200 feet below sea level (Brown and Whitlow, 1960), and Cambrian rocks are 1,350–1,500 feet thick. At Platteville, Wis., "granite" was penetrated at a depth of 1,714 feet in a deep well, the collar of which is about 900 feet above sea level (Thwaites, 1931, p. 725); the base of the Cambrian at Platteville, therefore, is about 800 feet below sea level.

In the Meekers Grove area, a drill hole about 1,000 feet north-northeast of the one that penetrated siliceous and glauconitic dolomite extended down to 440 feet above sea level without completely penetrating the Lower Ordovician rocks. If 1,300 feet of Cambrian beds is postulated below this, the base of the Cambrian would be 860 feet or more below sea level.

ORDOVICIAN SYSTEM

LOWER ORDOVICIAN SERIES

PRAIRIE DU CHIEN GROUP

The Prairie du Chien Group was named by Bain (1906, p. 18) for rocks exposed near Prairie du Chien, Crawford County, Wis. It was known previously as the Lower Magnesian Limestone (Owen, 1847, fig. 1). Strata of this group do not crop out in the Belmont or Calamine quadrangles but have been penetrated in drill holes. The rocks of the Prairie du Chien Group sampled by drilling in the Meekers Grove area are buff and pink dolomite, cherty dolomite, cherty oolite, siliceous sandstone, and red and green shale. They contain traces of pyrite and marcasite. The greatest thickness of the Prairie du Chien noted in these drill holes was 158 feet. Heyl and others (1959, p. 9) stated that the Prairie du Chien has a maximum thickness of about 250 feet and that the combined thickness of the Prairie du Chien and the St. Peter Sandstone, which overlies it unconformably, is about 320 feet.

MIDDLE ORDOVICIAN SERIES

ST. PETER SANDSTONE

The oldest formation that crops out in the Belmont and Calamine quadrangles is the St. Peter Sandstone. It was named by Owen (1847, p. 170) for rocks exposed along the St. Peter River (now the Minnesota River) near St. Paul, Minn. In the northern part of the Calamine quadrangle (pl. 22), the St. Peter Sandstone crops out along the Pecatonica River, along Bonner Branch from its mouth to the west edge of the quadrangle, along the stream between Bonner Branch and Wood Branch, and along part of Wood Branch. The St. Peter Sandstone is exposed in the Belmont quadrangle (pl. 22) only along the Galena River (formerly the Fever River).

Only the uppermost 35 feet of the St. Peter is exposed in the two quadrangles, but the thickness of the formation as measured in drill holes is generally much greater, although it is variable. The thickness is only 55 feet at a well in sec. 36, T. 3 N., R. 1 E. but is about 275 feet in a well at Belmont and 340 feet near Meekers Grove. In the Calamine quadrangle, 131 feet of sandstone has been penetrated in a well in sec. 8, T. 3 N., R. 3 E., 125 feet in sec. 26, T. 3 N., R. 2 E., and 104 feet in sec. 28, T. 3 N., R. 3 E. Southeast of the Calamine quadrangle the formation pinches out locally, presumably because insufficient sand was deposited to fill irregularities in the surface of rocks of the Prairie du Chien Group.

The St. Peter Sandstone is composed of poorly cemented quartz sand in beds that range in thickness from less than 1 foot to 5 feet. Cross-bedding is common. The quartz grains are fine to coarse, equant, subangular to well rounded, and well sorted. The grains are clear to frosted white, and some are stained yellow to pink or reddish brown by iron oxides. Calcite and dolomite cement the grains throughout much of the formation, but in a bed 1 foot or less thick about 4 feet from the top of the formation the grains are cemented by iron oxides, which are probably decomposition products of pyrite.

Thiel (1935, p. 559–613) and Tyler (1936, p. 55–84) made sedimentary and petrographic analyses of St. Peter Sandstone from several localities, and the reader is referred to their reports for statistical details. In general, they found that most of the sand grains are between one-eighth and one-half a millimeter in diameter. Quartz is the most abundant mineral; pyrite, marcasite, and limonite are very abundant locally. Feldspar, including both potassium feldspar and plagioclase, occurs in trace amounts and is more abundant in the lower than in the upper part of the formation. Glauconite occurs in the upper part of the formation in some localities. Heavy accessory minerals other than limonite and pyrite in the St. Peter Sandstone include, in approximate order of abundance, zircon, tourmaline, rutile, leucoxene, garnet, titanite, hornblende, and hypersthene. The heavy minerals combined total less than one-tenth of 1 percent by weight of the rock.

Pyrite is commonly found in drill cuttings from the upper part of the formation. Thiel noted that iron is abundant in the upper parts of outcrops that are devoid of a covering of overlying beds, and he considered such iron to be an infiltration from the glacial drift. Some of this iron may, however, be derived from the decomposition of iron sulfides in the upper part of the formation. Heyl and others (1959, p. 10) stated that the iron sulfide may be more abundant in local areas that have zinc-lead deposits in overlying rocks and in areas that are related to major structural features.

Chemical analyses of the St. Peter Sandstone from many different localities, as compiled by Thiel (1935, p. 601, table 17), indicate that it is of relatively uniform composition. The ranges in composition of 20 samples that he described are as follows:

	Range (percent)		Range (percent)
SiO_2	96.74–99.89	CaO	.00–0.84
Al_2O_3[1]	.05–1.31	Na_2O[2]	.01–0.15
Fe_2O_3	.05–1.45	K_2O[2]	.02–0.36
FeO[2]	.07–0.16	Loss on ignition[2]	.10–0.72
MgO	.00–0.22		

[1] Al_2O_3 and Fe_2O_3 not reported separately for 3 samples.
[2] FeO, Na_2O, K_2O only reported for 2 or 3 samples. Loss on ignition reported for only 9 samples.

The sandstone is very porous and permeable because it consists dominantly of rounded sand grains and only a little carbonate cement or interstitial matrix. Measured porosity of chunks of St. Peter Sandstone ranged from 24.6 to 31.1 percent (Thiel, 1935, p. 589).

Tyler (1936, p. 82–83) suggested that a sedimentary terrain was the immediate source of the St. Peter Sandstone and that the Mt. Simon Sandstone and the Huronian quartzites served as a partial or entire source. Because of the nature of mineral inclusions in the quartz grains, he considered that most of the quartz was ultimately derived from a granitic terrain and minor amounts were derived from a metamorphic terrain. The prevalence of frosted sand grains and the scarcity of very fine grained material suggest that the sands were reworked by wind, but the relative evenness of the top of the formation and the presence of phosphatic nodules in the overlying Glenwood Shale Member of the Platteville Formation indicate an aqueous environment. Marine fossils were reported in the St. Peter Sandstone in some localities in Minnesota by Sardeson (1896, p. 64–87), but we have found none in the Belmont or Calamine quadrangles.

PLATTEVILLE FORMATION

The Platteville Formation is the lowest of the principal zinc-lead ore bearing formations in the Upper Mississippi Valley district. It lies conformably on the St. Peter Sandstone. The formation was named by Bain (1905, p. 18–19) for rocks that crop out near Platteville, Wis., and a reference section about 8 miles southwest of Platteville was described by Agnew and others (1956, p. 274–285). The Platteville there is 54 feet thick. On the basis of this and other exposures, it has been subdivided into four members; they are, in ascending order, the Glenwood Shale Member, Pecatonica Dolomite Member, McGregor Limestone Member, and Quimbys Mill Member (pl. 23).

The Platteville is the oldest formation of carbonate rocks exposed in the Belmont and Calamine quadrangles. It crops out along all the major stream valleys in the northern part of the Calamine quadrangle (pl. 22), along parts of Bonner Branch and Wood Branch in the northeastern part of the Belmont quadrangle, and along Rowe and Madden Branches and the Galena River in the southern part of the Belmont quadrangle (pl. 22).

A complete section of the Platteville Formation is not exposed at any single outcrop in either quadrangle, and only a small number of the water wells for which we have logs and a few holes drilled for geologic information penetrate its entire thickness. In three holes drilled near Meekers Grove and eight others drilled south and southwest of the Belmont and Calamine quadrangles, the Platteville Formation ranges from 55 to 70 feet in thickness and averages about 65 feet (Heyl and others, 1951, p. 35). Logs of six water wells drilled in the Belmont quadrangle also show an average thickness of 65 feet for the Platteville. This thickness was used in interpreting structural features by projection from control points below the top of the formation. Regionally the thickness of the formation changes only gradually, but locally it varies fairly abruptly because the thickness of the upper member is variable.

GLENWOOD SHALE MEMBER

The basal member of the Platteville Formation is little more than a thin parting consisting of dolomite, quartz sand, and shale or clay. It is less than a foot thick in much of the Belmont and Calamine quadrangles. Near Meekers Grove it ranges in thickness from 1 to 9 feet, as indicated in logs of drill holes prepared by Heyl and others (1951, p. 33–34), and consists of green sandy shale that contains some pyrite and a little galena. At its type locality in Glenwood township, Iowa, the Glenwood Member consists of 15 feet of shale beds, of which the lower 8 or 10 feet are arenaceous (Calvin, 1906, p. 74–75).

The Glenwood stratigraphic horizon is marked by small patches of green clay in outcrops where the upper part of the St. Peter Sandstone and the lower part of the Pecatonica Dolomite Member crop out. This part of the section is generally poorly exposed, but the clay can be found by close examination of the overburden. Soil creep on some steep slopes moves the clay, and shallow digging may be required to locate the exact position of the Glenwood. Springs and water seeps may also indicate the Glenwood horizon, as, for example, along Bonner Branch in the northern part of the Calamine quadrangle, where the Glenwood contains little shale but consists mainly of sand and phosphate nodules.

PECATONICA DOLOMITE MEMBER

The Pecatonica Dolomite Member of the Platteville Formation about 20 feet thick, overlies the thin Glenwood Shale Member and underlies the McGregor Limestone Member. It was named by Hershey (1894, p. 175) for rocks exposed along the Pecatonica River. Agnew and others (1956, p. 277) designated an outcrop along this river at Lattice Bridges, Green County, Wis., as a type outcrop, in which the rock is similar to that in the mining district.

In the Belmont quadrangle, the Pecatonica crops out along Bonner Branch near the east edge of sec. 9, T. 3 N., R. 2 E., along the Galena River, and along Rowe Branch and some of its tributaries in secs. 21, 22, and 23, T. 2 N., R. 1 E. The unit also crops out along all the major streams in the northern half of the Calamine quadrangle. It has also been penetrated in several drill holes, but except for a few logs of drill holes in which the thickness of the member is given, the drill logs give practically no information about local features of the member.

The Pecatonica Member consists of very fine to medium-grained buff to pale-gray dolomite that weathers to light yellowish brown and contains casts of marine fossils. The lower 2 feet contains abundant medium to coarse grains of well-rounded and frosted quartz, a small percentage of which have overgrowths of clear euhedral quartz. The quartz is similar to that in the underlying Glenwood Shale Member and in the St. Peter Sandstone. It is unlikely that the overgrowths were formed in the Pecatonica Member, because rounded and euhedral grains occur together.

Phosphatic nodules consisting of coprolites and other fossil fragments and ranging generally from 1 mm to 1 cm in longest dimension are abundant in the lower 2 feet of the member. X-ray analysis of the phosphatic material shows that it is francolite, a carbonate-bearing apatite.

The lower part of the Pecatonica can be recognized by its texture and by its position near the St. Peter Sandstone. The rest of the member is similar to rock in the lower part of the overlying McGregor Limestone Member where the McGregor is dolomitic. Well drillers in the area seldom distinguish between the two members in logging their drill holes.

The Pecatonica has beds that are thick enough to quarry as building stone. The rock has a pleasing appearance, is an excellent masonry material. and is very durable. It has been used for lintels and sills in many old stone buildings.

MCGREGOR LIMESTONE MEMBER

The McGregor Limestone Member lies conformably on the Pecatonica Dolomite Member. It was named by Kay (1935, p. 286) for rock exposed near McGregor, Iowa. In early geologic reports of the mining district (Hall and Whitney, 1862, p. 23) this rock is called the Trenton, a name that is still applied to it by local miners and well drillers. The McGregor crops out along all the major streams in the

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northern two-thirds of the Calamine quadrangle (pl. 22). In the Belmont quadrangle (pl. 22), it crops out along Bonner Branch in secs. 9, 16, and 17, T. 3 N., R. 2 E., along Wood Branch in sec. 28, T. 3 N., R. 2 E., along Madden Branch in secs. 11 and 14, T. 2 N., R. 2 E., along Rowe Branch and its tributaries, and along the Galena River.

The McGregor Member is about 30 feet thick. In three drill holes near Meekers Grove, it is 30–35 feet thick (Heyl and others, 1951, p. 33–34). At a quarry about 1 mile north of Darlington and just east of the Calamine quadrangle, it is 31 feet thick.

Two lithologic units can generally be recognized in the McGregor. The lower, about 10–15 feet thick, was called the Mifflin Member by Bays (1938, p. 269). In parts of the Belmont and Calamine quadrangles and in areas to the west, the unit consists of very fine grained light-gray limestone in thin nodular beds containing abundant marine fossils; locally, some thin beds are composed of pale-brown aphanitic limestone that has a conchoidal fracture and weathers to a chalky light gray. In much of the Calamine quadrangle and in areas to the east, the lower unit consists of dolomite. The upper unit was called the Magnolia Member by Bays and Raasch (1935, p. 298). At the reference section of the Platteville Formation southwest of Platteville (Agnew and others, 1956, p. 274–275), this unit is about 15 feet thick and consists of limestone and a small amount of interbedded dolomite. In part of the Belmont quadrangle, in the Calamine quadrangle, and in adjoining areas to the east, the upper unit is composed of dolomite or dolomite interbedded with limestone. The rock is medium- to light-gray or light-brownish-gray limestone or dolomite and is fine grained. The rock in the uppermost beds, which may be very fine grained or aphanitic, breaks with a conchoidal fracture. Where the McGregor is entirely dolomite, the boundary between the two units is transitional—the basal beds resemble the underlying Pecatonica Member, and the upper beds resemble the overlying Quimbys Mill Member where that member is also dolomitic.

The McGregor Member is an ore-bearing unit south of the Belmont and Calamine quadrangles, near Shullsburg and New Diggings (Agnew and others, 1954; Mullens, 1964). In mineralized areas the beds of the McGregor may be partly altered to gray shale owing to solution of carbonates and concentration of insouble residual constituents. Mullens (1964) reported that the member was locally thinned as much as 15 feet by this process.

QUIMBYS MILL MEMBER

The Quimbys Mill Member, as defined by Agnew and Heyl (1946, p. 1585–1587), is the uppermost member of the Platteville Formation.

The type section is in a quarry at Quimbys Mill in the SE cor. sec. 11, T. 1 N., R. 1 E., in the New Diggings quadrangle, Wis., where it consists of 6 feet of limestone overlain by 6 feet of dolomite. The unit is called the glass rock by local miners and well drillers because it has a conchoidal fracture and because upon breaking it sounds somewhat like breaking glass; it is described under that name in early reports (Percival, 1855, p. 16; Whitney, 1862, p. 163–164). It crops out along all the major streams in the northern half of the Calamine quadrangle (pl. 22). In the Belmont quadrangle (pl. 22) it crops out in the southern part along the Galena River, Rowe Branch, and Madden Branch and in the northeastern part along Bonner Branch in secs. 16, 17, and 18, T. 3 N., R. 2 E., and along Wood Branch in sec. 28, T. 3 N., R. 2 E.

Agnew and others (1956, p. 283) stated that the Quimbys Mill Member is less than a foot thick in the western part of the mining district, 13–14 feet thick east of the center of the district, and more than 18 feet thick in the eastern part of the district, southeast of Shullsburg, Wis.

In the Belmont and Calamine quadrangles, the Qimbys Mill Member ranges in thickness from 3½ to 17 feet, as reported in the logs of water wells and holes drilled for geologic information and as measured in quarries or at natural outcrops. The thickness in several places is shown in plate 24. Variations in thickness are probably due in part to thinning by solution in mineralized areas. Many of the thicknesses that are taken from records of water-well drilling may be slightly in error because of inaccurate identification of rock types and uncertainty of depth at which the rocks were penetrated. We believe, however, that most of the well drillers identify the glass rock correctly.

The Quimbys Mill Member is composed entirely of limestone in some areas, partly of limestone and of dolomite in other areas, and entirely of dolomite in still other areas. Typical unweathered limestone of this unit is dense, aphanitic or very fine grained, and pale purplish gray on dry freshly broken surfaces; when wet, it is pale brown and has a color and texture somewhat like that of a slightly faded piece of milk chocolate. Dolomite in the member is dense, fine to very fine grained or almost aphanitic, and medium to light gray or light-brownish gray or buff. The composition is shown in plate 24. Chert occurs locally as round lumpy nodules or in silicified beds. The member is an ore-bearing unit in the mining district and is known to be mineralized in places in the Belmont and Calamine quadrangles, as shown by locations of old diggings and prospect pits in plate 22. The rock of the Quimbys Mill Member is used locally as a building stone. It has a pleasing appearance and is durable.

The formation is too thin, however, for large-scale commercial quarrying.

DECORAH FORMATION

The Decorah Formation, which overlies the Platteville Formation and underlies the Galena Dolomite, was named by Calvin (1906, pp. 60, 84) for rocks exposed near Decorah, Iowa. It consists of three members: the Spechts Ferry Shale Member at the base, the Guttenberg Limestone Member, and the Ion Dolomite Member at the top. Well drillers and local miners refer to the Spechts Ferry Member as the clay bed, the Guttenberg Member as the oil rock, and lower and upper parts of the Ion Dolomite Member as the blue and the gray, respectively.

The Decorah Formation thins eastward in the zinc-lead district, owing largely to thinning of the Spechts Ferry Shale Member. It consists of about 44 feet of limestone and shale in the western part of the district, about 41 feet of dolomite, limestone, and shale in the central part of the district, and 30 feet of dolomite and only small amounts of shale in the east-central part near Darlington (Agnew and others, 1956, p. 286).

In the Belmont and Calamine quadrangles, the Decorah, as measured in 52 widely scattered drill holes, ranges in thickness from 19 to 44 feet and averages about 32 feet. It consists principally of the Guttenberg and Ion Members.

Agnew and others (1956, p. 283) stated that a regional disconformity exists between the Decorah and Platteville Formations, but the Decorah appears to lie conformably on the Platteville. In fact, the lower part of the Decorah may locally be lithologically indistinguishable from the Platteville because very fine grained or aphanitic limestone, similar to that of the McGregor and Quimbys Mill Members of the Platteville, occurs in the Spechts Ferry and Guttenberg Members of the Decorah. In addition, the thickening of the Spechts Ferry to the west is somewhat complementary to the thinning of the Quimbys Mill. The three members of the Decorah are mutually conformable.

SPECHTS FERRY SHALE MEMBER

The Spechts Ferry Shale Member of the Decorah Formation was named by Kay (1928, p. 16) for rocks exposed near Spechts Ferry, Iowa. The member there consists of about 9 feet of shale and interbedded limestone and includes a few inches of brown shale that underlies limestone similar to that of the Quimbys Mill Member farther east.

In much of the Belmont and Calamine quadrangle area, the Spechts Ferry is represented only by thin partings of green shale or clay and thin beds of limestone aggregating a foot or less in thickness. The limestone is light gray to purplish brown and very fine grained to aphanitic. Phosphatic nodules the size of small pebbles or granules occur sparsely in this member. Locally, as in a quarry at Calamine, a thin parting of green shale only an inch or so thick is all that marks the Spechts Ferry horizon. The Spechts Ferry was not recognized along the east edge of the Calamine quadrangle in the vicinity of Darlington. The Spechts Ferry Member is as much as 5 feet thick in the southwestern part of the Belmont quadrangle. Heyl and others (1951, p. 33) assigned to this member 5 feet of limestone and some green shale that were penetrated by a drill hole near the SW cor. sec. 21, T. 2 N., R. 1 E. The member is 5 feet thick in outcrop along Madden Branch in NW$\frac{1}{4}$ sec. 14, T. 2 N., R. 1 E., where it consists of fossiliferous light-gray limestone in beds ranging from less than an inch to about 5 inches in thickness. The limestone weathers chalky white or light gray because it contains much clay that remains as a coating of insoluble residue on weathered surfaces. Thin layers of clay also occur as partings in the limestone. Except for the amount of clay in the limestone, the Spechts Ferry here is similar in bedding and in texture to the limestone of the underlying Quimbys Mill.

X-ray analyses were made of two samples of clay collected from the Spechts Ferry Member by A. R. Taylor. One, from a sample taken about a foot above the base of the member near Arthur, Grant County, Wis., contains illite and a mixed-layer montmorillonite; green clay taken from the top of the member is illite. Allen (1932, p. 259–269) reported crescent-shaped shards, apatite, and sanidine in clay from the Spechts Ferry Member, and he believed that the clay originated as a volcanic ash.

Small phosphatic nodules similar to those in the Pecatonica Dolomite and Glenwood Shale Members of the Platteville Formation occur locally in the Spechts Ferry Shale Member. They are francolite, a form of apatite.

The Spechts Ferry Member contains sphalerite, galena, and iron sulfides in places, but it is too thin in the Belmont and Calamine quadrangles to be an important ore-bearing unit.

GUTTENBERG LIMESTONE MEMBER

The Guttenberg Limestone Member of the Decorah Formation is the name given by Kay (1928, p. 16) to about 16 feet of brownish-gray fine-textured limestone exposed near Guttenberg, Iowa. The member, where unaltered, is 12–14 feet thick in most of the mining district (Agnew and others, 1956, p. 289). Logs of 69 holes drilled in the Belmont and Calamine quadrangles show that the Guttenberg ranges from 1 to 17 feet in thickness and averages about 12 feet. In areas of sulfide mineralization, the Guttenberg is thinner than average and may vary markedly in thickness within relatively short distances.

The Guttenberg Member generally consists of limestone, but in most of the Calamine quadrangle it is composed of dolomite. Where the Guttenberg is thin, in areas of sulfide mineralization, the rock contains less carbonate, and the relatively insoluble residual material is compacted into brown shale that is referred to locally as the oil rock because it contains hydrocarbons. The limestone of the Guttenberg has been dolomitized and silicified in some areas of intense mineralization, and it is an ore-bearing unit that has been mined in many places. Areas underlain by thinned or altered rock of this member are generally considered to be favorable places in which to prospect for ore.

The combined thickness and the composition of carbonate rocks in the Guttenberg and Spechts Ferry Shale Members in the Belmont and Calamine quadrangles are shown in plate 24. The thickness of the Guttenberg Member in a hole drilled near the center of the southeastern quarter of the Calamine quadrangle may be significant, for lead and zinc sulfides were found in the drill cuttings there.

The Guttenberg Member is poorly exposed in outcrop in the two quadrangles. It can be seen in a quarry in the SE¼ sec. 8, T. 3 N., R. 3 E., near Calamine, where it consists of 10 feet of fossiliferous dolomite that contains minor amounts of green shale flakes and phosphate nodules at its base. In a quarry on the east side of State Route 23 in the SE¼ sec. 27, T. 3 N., R. 3 E. the Guttenberg Member is about 9 feet thick and consists of dolomite and a clayey parting about 0.2 foot thick about 6 feet above the base of the member.

In a small quarry in the SW¼NW¼ sec. 19, T. 2 N., R. 2 E., in the Belmont quadrangle, the Guttenberg is almost 10 feet thick and consists of limestone. Limestone of the Guttenberg Member also crops out along Madden Branch in the southwestern quarter of the Belmont quadrangle and along Bonner Branch and Wood Branch in the northeastern quarter of the quadrangle.

ION DOLOMITE MEMBER

The name Ion Dolomite Member of the Decorah Formation was proposed by Kay (1929, p. 650) for 16 feet of argillaceous limestone and calcareous shale exposed near Ion, Allamakee County, Iowa. Agnew and others (1956, p. 293, 308), in their interpretation of the type section, included about 5 feet of beds that Kay had assigned to the Guttenberg. They reported that the Ion is dolomitic in the eastern and central part of the mining district and it is consistently 20–22 feet thick in outcrops and in many drill holes. The base of the Ion is transitional with the underlying Guttenberg in the western part of the district, and the top of the Ion is transitional with the overlying Galena Dolomite in the eastern part.

In the Belmont and Calamine quadrangles, the Ion ranges from 8 to 33 feet in thickness and averages about 21 feet, as reported in logs of many drill holes. Only 7 logs reported thicknesses greater than 25 feet. These excessive thicknesses could be due to misidentification because of transitional lithologic features at the base and top of the member. Only one log showed a thickness less than 15 feet; therefore, a range of 15 to 25 feet may be more realistic. The thickness of the member and its generalized composition are shown in plate 24. The Ion Member consists of gray to buff or grayish-orange fossiliferous dolomite or limestone and patches or thin partings of green clay or shale.

Local miners and drillers have divided the member into lower and upper units called the blue and the gray, respectively, on the basis of color differences. The lower unit is composed of dolomite in much of the Calamine quadrangle, but in places in the northwest quarter of the Calamine quadrangle and in the Belmont quadrangle, it is composed of limestone. The limestone is very fossiliferous in places, and some is almost a coquinite. Locally, in mineralized areas, it has been thinned and dolomitized. The upper unit is composed of dolomite at most places in the Calamine and Belmont quadrangles, but along Pats Creek and Madden Branch in the Belmont quadrangle it consists mainly of limestone.

The Ion Member is an important ore-bearing unit in the zinc-lead district and has been mined in many places. It has been removed by erosion in about 10 percent of the area of the Belmont and Calamine quadrangles. Only relatively shallow basal parts of ore deposits are likely to remain where such erosion has occurred.

GALENA DOLOMITE

The Galena Dolomite was called the upper magnesian limestone in very early reports on the geology of the mining district. It was later named the Galena Limestone by Hall (1851, p. 146) for rocks exposed near Galena, Ill. The formation, however, consists principally of buff dolomite and contains some white or light-gray chert in the lower half. The cherty phase has been differentiated in the mapping (pl. 22).

We have mapped two lithologic units in the Galena that were described by Agnew and others (1956, p. 259–269). These are a lower, cherty unit and an upper, noncherty unit. The fossil sponge *Receptaculites oweni* Hall is common in certain strata of the Galena. This is a large fossil, which on flat surfaces is roughly circular and may be as much as 9 inches in diameter. It contains closely spaced cells and has a crude resemblance to the seed cluster in a large sunflower. Cross sections of this fossil on vertical surfaces consist of rows, a few inches long, of parallel vertical grooves about 1/16-inch wide and about 1/2-inch long. The lowest stratigraphic occurrence of this fossil is in or above the major zinc-ore zone in the mining district (pl. 23).

The Galena Dolomite underlies more than 80 percent of the area of the Belmont and Calamine quadrangles and is an important ore-bearing unit. It is also used as a building stone and for road metal, concrete aggregate, and agricultural lime.

CHERTY UNIT

The cherty unit of the Galena Dolomite in the Belmont and Calamine quadrangles ranges in thickness from 105 to 115 feet, as reported in logs of several drill holes. The dolomite in the unit, where fresh, is buff, dense, and hard and contains sand-size or larger grains. Some of the rock contains vugs filled or coated with coarse calcite. Bedding surfaces are tight and poorly formed in the fresh rock. Upon weathering, bedding partings become more numerous, and the rock becomes porous and granular. Some weathered beds consist of poorly cemented sand-size rhombs of dolomite. Much of the interstitial material in the beds may have been calcite. Samples of fresh dense rocks, when leached in dilute hydrochloric acid, decompose into sand made up of rhombs of dolomite as the more soluble interstitial carbonate dissolves. X-ray analysis of unweathered Galena Dolomite taken from drill cuttings shows that some of the rock is composed entirely of dolomite and some consists of a mixture of dolomite and calcite.

The chert occurs in layers that range from solid sheets, or closely spaced nodules that form almost solid sheets, to sparsely disseminated nodules. The sheets are as much as 6 inches thick, and most nodules are at least an inch thick. The chert, where fresh, is whitish or light-gray and vitreous and may have pore spaces filled with clear dolomite. Upon weathering, the chert becomes devitrified and chalky. Silicified marine fossils are common in the chert, and siliceous fossils occur locally in the dolomite.

The basal part of the cherty unit is in most places a noncherty dolomite about 10 feet thick that contains streaks and patches of green shale in the lower 2 or 3 feet. Above this part is a zone 10–13 feet thick that contains several chert layers, each an inch or two thick. The chert is light gray or white and, in places, forms solid layers, but it occurs generally as separate nodules a few inches to about a foot in diameter. Next is a zone 10–13 feet thick in which chert nodules are relatively sparse or absent and in which specimens of *Receptaculites oweni* are abundant, particularly in a layer a few feet above the underlying zone of abundant chert and, locally, in a second layer about 4 feet below the top of the sparse chert zone. Above this fossil zone chert is interlayered with dolomite, and no particular horizon marker can be recognized up to the top of the cherty unit. Thin partings of green shale occur sparsely throughout the section.

NONCHERTY UNIT

The noncherty unit of the Galena Dolomite lies conformably on the cherty unit and is about 115–120 feet thick (Agnew and others, 1956, p. 267; Mullens, 1964) in areas adjoining the Calamine and Belmont quadrangles. The top part is eroded away in most of this area, but the entire unit remains in the extreme northwest corner of the Belmont quadrangle. It is poorly exposed, however, except in a few quarries—for example, those near the central part of NE¼ sec. 15, T. 3 N., R. 1 E., in the NW¼ sec. 14, T. 3 N., R. 1 E. (west of Belmont), and in the SE¼ sec. 9, T. 3 N., R. 1 E. The beds consist of buff or grayish-orange medium-grained dolomite and yellowish shale or clay patches and contain many fossils. *Receptaculites* is very abundant in some layers. The rock near the surface is weathered, and it consists largely of sand-size rhombs of dolomite.

UPPER ORDOVICIAN SERIES

MAQUOKETA SHALE

The Maquoketa Shale, which overlies the Galena Dolomite, was named by White (1870, p. 181) for rocks exposed along the Little Maquoketa River in Iowa. Only about 40 feet of Maquoketa beds remain in the extreme northwest corner of the Belmont quadrangle, and this is the only occurrence in the area mapped. There are no good exposures; the Maquoketa, as shown in plate 22, is located by projection of contacts mapped by Taylor (1964) in the Rewey quadrangle, and by Agnew (1963) in the Platteville quadrangle. Thick, sticky mud that forms after rains in fields in the NE¼ sec. 9, T. 3 N., R. 1 E., is probably derived from weathered shale in the Maquoketa. A zone of depauperate fossils at the base of the Maquoketa (Agnew and others, 1956, p. 300) is exposed just north of the Belmont quadrangle about half a mile east of the western edge of the Rewey quadrangle. "Depauperate" as used in this report refers to the small size of the individual fossils and is used as a stratigraphic term without genetic implications. Phosphatic fossils in this zone consist of francolite, a carbonate apatite like that of the phosphatic nodules in the Pecatonica Member of the Platteville Formation.

The Maquoketa consists of blue or gray shale and gray thin-bedded dolomite. In the Belmont quadrangle the rock weathers to a clayey loam containing weak fragments of dolomite.

A regional disconformity between the Maquoketa Shale and the Galena Dolomite was described by DuBois (1945, p. 15). The possible significance of this disconformity with relation to emplacement of the ores is discussed in a later section (p. 406). An erosional unconformity between the overlying Silurian rocks and the Maquoketa in the western part of the mining district was described by Brown and Whitlow (1960). Neither of these features can be recognized in the Belmont or Calamine quadrangles.

The Maquoketa is not an ore-bearing unit in this area. Local farmers report that well water from the Maquoketa is not so palatable as that from the underlying formations.

DEPOSITS OF UNKNOWN AGE

SANDSTONE DIKES

Joint fillings composed of quartz sand cemented by dolomite—sandstone dikes—occur in some of the beds above the St. Peter Sandstone in the mining district. We have not seen any in the Belmont or Calamine quadrangle, but Heyl and others (1959, p. 46) reported that sandstone dikes occur in the McGregor Member of the Platteville Formation east of Meekers Grove in the center of the south part of SW¼NW¼ sec. 24, T. 2 N., R. 1 E. We searched unsuccessfully for these dikes, but the outcrop may now be concealed. Just north of the Calamine quadrangle, in sec. 11, T. 3 N., R. 2 E., nearly vertical ribs less than 1 inch thick composed of relatively hard sandstone are exposed in an outcrop of the uppermost few feet of flat-lying beds of St. Peter Sandstone. These may be cemented fissure fillings of sand. Local well drillers report that they occasionally drill into quartz sand at unexpected horizons. J. W. Whitlow has shown us places in and near Dubuque, Iowa, where sandstone dikes a few inches thick crop out in the Pecatonica and McGregor Members of the Platteville Formation. The sand grains in these dikes resemble those in the St. Peter Sandstone; probably, the sand was forced up into the joints and fractures by hydraulic pressure during a period of structural disturbance or was carried by ground-water movement, possibly artesian, in dipping strata under earlier and somewhat different physiographic conditions than those prevailing at present.

The dikes near Dubuque occur also in the noncherty unit of the Galena Dolomite. They are therefore younger than the Galena Dolomite, but their minimum age is not known. Inasmuch as the St. Peter Sandstone underlying this general area is a very poorly cemented rock and is a good aquifer, there is no reason why such fissure fillings might not form today. If the St. Peter Sandstone and overlying rocks were to be shattered by an earthquake in a place where the hydrostatic pressure in saturated St. Peter Sandstone could be released to give a sudden artesian flow, sand grains would be forced upward into the fissures. Dolomite or calcite from the percolating groundwaters might then cement the quartz sand. Sandstone dikes formed by the activity of an 1811 earthquake in its epicentral area at New Madrid, Mo., were reported by Fuller (1912, p. 51–52, pl. 111).

The occurrence of galena and sphalerite in sandstone dikes has been reported (Whitlow and Brown, 1963; Heyl, A. V., Jr., oral communication, 1961), but whether these minerals were in the crevice before the sand was emplaced, were carried in with the sand, or were deposited after the dikes formed has not been resolved.

UNCONSOLIDATED SURFICIAL MATERIALS

Overlying the bedrock in most areas in the Belmont and Calamine quadrangles is a layer of residual or colluvial chert and a thick mantle of residual soil and loess. Some of the chert may be residual colluvium from chert layers in Silurian formations that have been eroded from the study area but still remain on the mounds to the northwest. The bulk of the chert and rock fragments, however, are residual products of weathering of the Galena Dolomite.

The soil and loess mantle is relatively thick over much of the area. Local well drillers report 5–15 feet of unconsolidated material over bedrock at many places. Five feet is the most common thickness reported, but as much as 40 feet has been logged. Excessive amounts of such material would be penetrated if a drill hole were located in a soil-filled crevice.

The residual soil is brown and clayey and contains lumps of dolomite and chert at the base. It is overlain by brownish-black and grayish-brown earth rich in organic material. Loess occurs extensively as a grayish-orange silty clay that is as much as a few feet thick, but in most places it is intermixed with organic material and differs little in appearance from the residual soil. The soil profile has been changed by erosion, and some of the flood plains in broad valleys contain intermixed residual soil and loess. A few thin layers of alluvial chert gravel occur between thick layers of soil that are exposed in some deep gullies.

The soil and loess in stream valleys are so cohesive that vertical or even slightly overhanging banks may be as much as 10 feet high. Deep gullies are very common in sod-covered flood plains along flat-bottomed stream valleys and along some small valleys that have appreciably sloping stream gradients. Figure 48 shows a typical gully. In many places, outcrops of bedrock that were accessible during periods of earlier but relatively recent geologic studies are now covered by soil and silt.

FIGURE 48.—Gully in soil and loess in Belmont quadrangle, Wisconsin, showing typically steep sides.

STRUCTURE

The Belmont and Calamine quadrangles are in an area in which gently dipping Paleozoic strata overlying the southwest flank of a southward-plunging dome of Precambrian basement rocks are locally deformed by folds. Regionally the rocks dip a little west of south at about 10–20 feet per mile. Thwaites (1931, p. 719–750) described the general configuration of the buried Precambrian surface and in his figure 1 showed a fault trending east-northeast from the Calamine quadrangle for about 40 miles. He did not, however, show any control points on which the interpretation of this subsurface fault is based. Heyl and others (1959, p. 26–67, figs. 12 to 45) described the major and minor structures of the Upper Mississippi Valley zinc-lead district and presented their theories as to the origin of the structures. They described the district as bounded by the Wisconsin dome on the north, the Wisconsin arch on the east, the Savanna-Sabula anticline on the south, and the Forest City basin on the west. They divided folds within the district into three orders of magnitude. Their first-order folds are as much as 40 miles long and 3–6 miles wide and have amplitudes of as much as 200 feet. These trend roughly east-west. Their second-order folds, between or superimposed on first-order folds, average more than 10 miles in length and have amplitudes of 40–100 feet. Their third-order folds have lengths of about 1,000 feet to 2 miles and amplitudes of 10–60 feet. They stated that the folds were formed probably by lateral compression by north- and northeastward-directed forces and that solution thinning has accentuated the folding.

Relatively few faults are exposed in the mining district, but if the rocks were better exposed, perhaps many more would be recognized. Heyl and others (1959, p. 35–43) believed faults to be numerous, although generally of small displacement. They stated that the horizontal displacement along one fault may be as much as 1,000 feet. They interpreted many minor structural features as faults of tectonic origin, but other geologists who have done detailed mapping in the mining district have shown relatively few faults.

Joints are numerous and well formed in the rocks of the mining district. Many joint sets striking approximately east, north, and in quartering directions to the northwest and northeast have been noted. However, many other joints trend in directions intermediate between these. Some of the mineralized joints or joint sets have been traced for a few miles.

FOLDS

We have mapped the structure of the Belmont and Calamine quadrangles as reflected by the top surface of the Quimbys Mill Member of the Platteville Formation. The altitude of this horizon was determined at many places by surveying outcrops and elsewhere by surveying contacts of other rock units and calculating the interval to the top of the Quimbys Mill above or below such locations, assuming known average thicknesses of the intervening rock units. The altitude of the key horizon was also determined at sites of water wells and prospect drill holes. Telescopic alidades were used to project elevations from U.S. Geological Survey bench marks and other known-elevation points. The structure contours, shown on plate 22, are based on these measurements and on our interpretation of the probable trend of contours between control points. The outcrops and drill holes used as control points are indicated on plate 22. The structure contours in the southwestern part of the Belmont quadrangle are based on data compiled by Grant (1906) and by Heyl and others (1959), as well as on new data. Subsurface data that was obtained by grid drilling in this area and made available by the New Jersey Zinc Co., some water-well logs, and measurements that we made in adjoining areas were used in this work.

We, and others who have mapped here before us, have included some information which we cannot verify. Some was written into logs, or told to us from memory by drillers who did not prepare a log of the hole while drilling. Although the measurement of the collar elevation of a drill hole may be accurate to within one-tenth of a foot, the depth to a particular rock unit may not be as indicated in the well log because other measurements were faulty, drill cuttings were misidentified, or the log was incorrectly prepared. The evaluation of such information is subjective. Unfortunately, we cannot distinguish logs that are reasonably accurate from others that are significantly in error, but list the rock units in proper order and in what appear to be reasonable thicknesses. Even if some of the well logs have errors of as much as 10 feet—1 contour interval—they are of value in areas having no nearby outcrops, for they give approximate positions of rock units.

Along stream valleys where some of the beds have been thinned by solution, large blocks of rock bounded by joints have slumped and tilted. Where overburden is thick and exposures are poor, partly concealed slumped blocks are distinguished with difficulty from undisturbed outcrops of bedrock, but only control points that were considered reliable were used.

Trends of fold axes and locations of domes and basins in the Belmont and Calamine quadrangles are shown in figure 49. The largest fold is the Meekers Grove anticline, which arches northward into the southern part of the Belmont quadrangle (pl. 22). This is one of the first-order folds described by Heyl and others (1959, p. 29–31). Maximum structural relief within the Belmont quadrangle between the crest of the anticline and the trough of the Georgetown syncline on the northwest flank of the anticline is about 200 feet, but the difference in altitude between the crest of the anticline and the nearest low of the adjoining syncline is about 110–130 feet. The anticline is asymmetric; the north limb is the steeper. The dip of the north limb averages about 2°, but locally dips are as steep as 14°; in one place a dip of 20° was measured by Heyl and others (1959, pl. 3). The south limb of the anticline has an average dip of about 0.5° (Mullens, 1964). Closure on the anticline is about 80 feet.

The cherty unit of the Galena Dolomite is exposed in the axial part of the Meekers Grove anticline, and the Decorah and Platteville Formations are exposed along north-sloping valleys on the north flank. The St. Peter Sandstone is exposed where the anticline is breached by the Galena River (pl. 22).

Immediately to the north of the Meekers Grove anticline is a syncline which Heyl and others (1959, p. 30) called the Georgetown syncline and classed as a first-order fold. It is doubly plunging, deepening to the east and west of a structural saddle in the southeastern part of the Belmont quadrangle at the approximate position of a divide between Rowe Branch and Ames Branch. The top of the Quimbys Mill Member in the syncline plunges from more than 900 feet above sea level at the saddle to less than 790 feet above sea level at the western edge of the Belmont quadrangle and to less than 830 feet above sea level at the eastern and southern edges of the Calamine quadrangle.

A broad structural prominence extends southward from the northern edge of the mapped area to the saddle in the Georgetown syncline. Its boundary is near the 900- or 910-foot structure contours, and structural lows on its flanks extend to less than 880 feet above sea level. The Seymour-Kendall township upland, a physiographic high, is within part of this area. The prominence is about 7 miles wide at its north edge and narrows to less than half a mile at its south end. A few structural apices at 940–950 feet above sea level and a few depressions less than 910 feet above sea level occur within this area. Because of

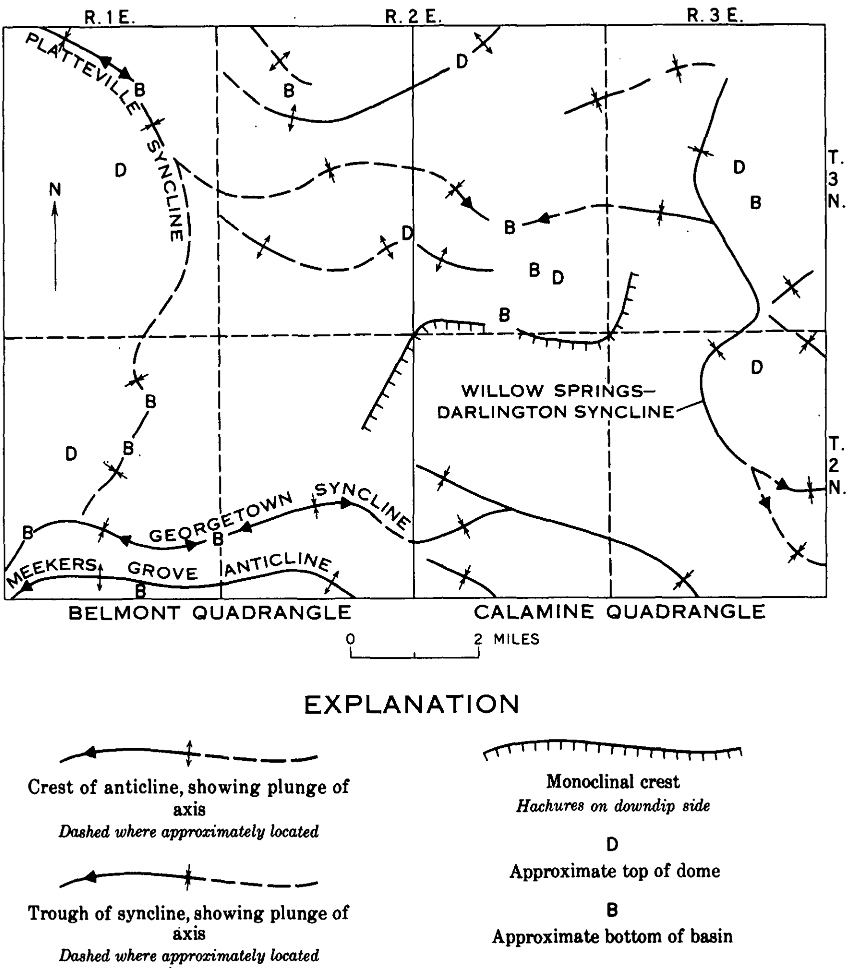

FIGURE 49.—Index map showing trends of folds more than 1 mile long and locations of domes and basins in the Belmont and Calamine quadrangles, Wisconsin.

insufficient control points, the outlines of these smaller structures on the prominence are not accurately known, but, in general, a few of the larger ones have an easterly elongation.

Another first-order fold described by Heyl and others (1959, p. 31, fig. 13) is the Platteville syncline. In our interpretation of the structure, this fold trends eastward just north of the Belmont quadrangle, and a branch of the fold trends southeastward from the northwest corner of the quadrangle through and beyond Belmont. As shown in figure 49, axes of forks of this branch of the Platteville syncline can be projected southward to the Georgetown syncline and eastward toward the Willow Springs-Darlington syncline. The major axis might also be terminated near Belmont. Other interpretations of the trend of this structural feature are possible.

A syncline in the Calamine quadrangle, here called the Willow Springs-Darlington syncline, plunges gently southward from near Calamine to Ames Branch in Darlington township. A branch of the syncline trends into the Darlington city area. The trough of this syncline is about 40 feet deep and may be deeper, but the total rise on the east limb is not known because it extends beyond the area mapped. This syncline is a second-order fold (see p. 384).

The southern and southeastern flanks of the broad structural high in the Seymour-Kendall township upland area are monoclines as well as limbs of synclines.

Several small domes and basins, which are third-order folds, are indicated by the structure contours on plate 22.

FAULTS

Faults in which the fault surface is exposed are relatively rare in the two quadrangles, but a few have been observed, some in underground workings that are no longer accessible. The faults shown on plate 22 in the southwestern part of the Belmont quadrangle were mapped by Heyl and others (1959, pl. 3). We have presented an interpretation of inferred faulting along the north limb of the Meekers Grove anticline in secs. 21 and 24, T. 2 N., R. 1 E., modified from that of Heyl and others.

We have mapped only two additional faults in the two quadrangles. One is exposed in a large quarry in NW¼SW¼ sec. 21, T. 3 N., R. 2 E. (pl. 22). The cherty unit of the Galena Dolomite on the west wall of the quarry is nearly flat. Near the southwest corner of the quarry, as mined in the summer of 1959, is a northwest-trending vertical shear zone several feet wide. Several chert layers, which can be correlated on both sides of the sheared zone by the variation in thickness of intervening beds, are about 2 feet lower southwest of the shear zone than they are northeast of it. The south face of the quarry had an exposed vertical face along which brecciated rock and pale-green and yellow crevice clay were in place against a fault or joint plane that trends N. 65° W. in alinement with the faulted rock on the west face of the quarry.

A vertical fault is exposed in a roadcut along State Route 23 north of Ames Branch near the northern boundaries of secs. 21 and 22, T. 2 N., R. 3 E., about 3 miles south of Darlington. The fault trends about N. 75° W., and the north side is displaced less than a foot upward relative to the south side.

The existence of these faults, in areas where otherwise structural deformation appears to have been only minor, suggests that minor faults may be numerous in the district. A. V. Heyl, Jr., and M. R. Brock (oral communication, 1960) reported that in a quarry just east of the Calamine quadrangle and north of Darlington joints on two sides of an almost perpendicular break in the quarry floor are offset a few inches horizontally. The several joints on both sides appeared to be similarly spaced, and the offset is therefore probably due to horizontal movement.

We believe, however, that slumping, minor folding, and solution thinning of beds are the causes of some of the seemingly faulted structures in the Belmont and Calamine quadrangles. Accordingly, in plate 22 we present an interpretation somewhat different from that given by Heyl and others (1959, p. 35, figs. 13, 14, and pl. 3) of structures in secs. 21 and 24, T. 2 N., R. 1 E., where bedrock is poorly exposed. If the key rocks exposed there are not slumped, then contrary local directions of dip and strike may be explained by faulting or local folding. The Platteville and Decorah Formations are fractured and jointed in this area and may be faulted; they are also somewhat altered and thinned by solution. Heyl and others inferred that thrust faulting having a displacement of 20 feet has occurred in the NW¼ sec. 24; they showed one fault extending eastward about half a mile and another, near the western edge of sec. 24, trending north-northwestward for about 500 feet. We have inferred an east-northeast-trending fault, but evidence is insufficient for estimating the amount of displacement or for extending the inferred fault for any great distance; there is no evidence for a north-northwest-trending fault.

The fault shown at the Trego mine in SE¼ sec. 21, T. 2 N., R. 1 E. (pl. 22) is modified from Heyl and others (1959, pl. 3) and is based on reported subsurface features. Heyl and others (1959, p. 37–38, fig. 23, and pl. 3) mapped a subsurface fault having about 25 feet of horizontal displacement in the Liberty mine in sec. 16, T. 2 N., R. 1 E.

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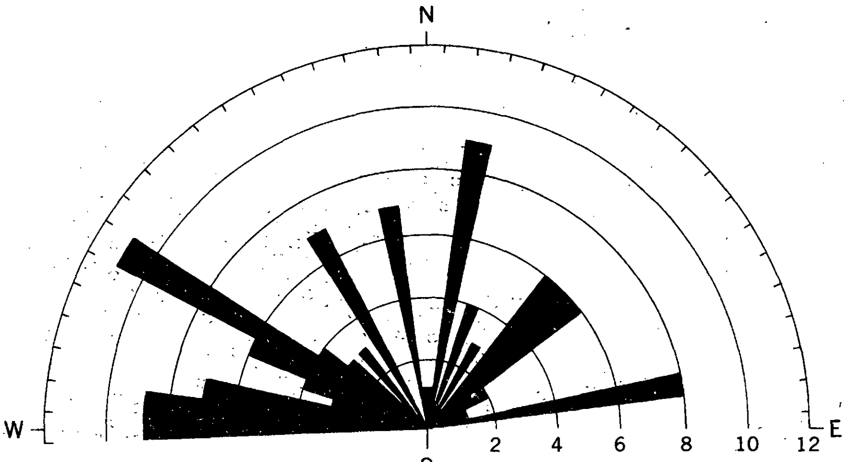
They reported that an extension of the eastern end of the Connecting Link No. 1 ore body, traced by drilling, ends along trend in the form of a large vertical fracture or fault that abruptly delimits the northwestern end of the Connecting Link No. 2 ore body. They stated that the fault has offset the fracture zones of the two ore bodies by about 200 feet and that the fault predates the mineralization but postdates the fracture systems of the ore bodies.

Inclined faults and fractures and open horizontal fractures are associated with many ore deposits, and where filled with ore they are called pitches and flats. These are described in detail in the section on the forms of ore bodies (p. 402–403). The pitches, some of which are reverse faults, generally strike parallel to and occupy one or both sides of elongate zones of fractured and solution-thinned beds in the Platteville and Decorah Formations. The beds in and immediately overlying the zone of solution generally sag down, forming or accentuating what are called third-order folds (Heyl and others, 1959, p. 34, 35, 46–49) or solution synclines.

Irregular fractures occur in rocks in folded areas, but in general the formation of numerous joints in the rocks relieved stresses, and the strata, as exposed in large quarries, are commonly jointed and not fractured irregularly. In mineralized areas, however, particularly around pitch and flat deposits, irregular fractures are more numerous.

JOINTS

The prevalence of extensive joint systems is a marked feature of the rocks in the mining district. Joints occur in all the formations exposed in the Belmont and Calamine quadrangles, but they appear to be less numerous in the St. Peter Sandstone, which is not extensively exposed, than in the overlying carbonate rock. Some of the joints are large open crevices, others are well formed but closed or relatively tight, and some are poorly formed or only poorly exposed. Figure 50 shows the trends and relative number of joints measured in the Belmont and Calamine quadrangles. The joints are plotted on the diagram by 5° groups. Sets trending about N. 50° E. and N. 50° W. are the most numerous in the Belmont quadrangle, but many also trend west-northwest and north-northeast. Groups of joints in the Calamine quadrangle trend about east, N. 60° W., N. 30° W., N. 10° W., N. 10° E., N. 40° E., and N. 80° E. The great number of places where only one set of joints is exposed tends to obscure the fact that in the two quadrangles two sets of joints in a conjugate system intersect at about 105°. We believe the joints to be of tectonic origin. Some joints in the mining district are actually faults having minor displacement.



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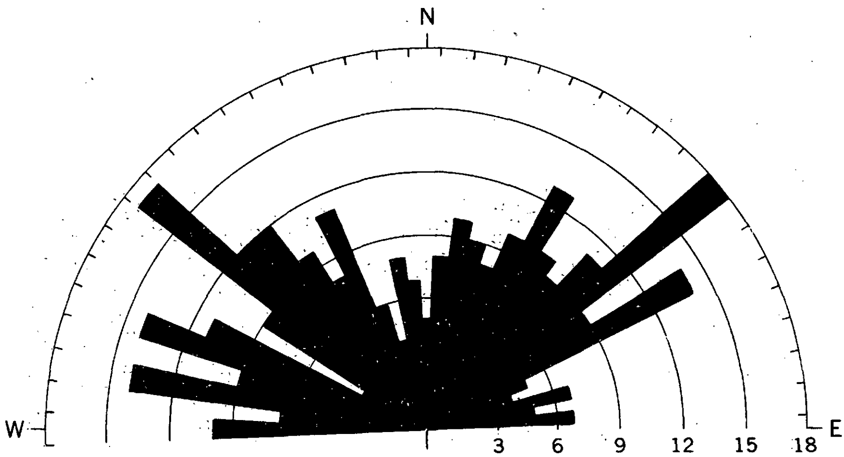

B

FIGURE 50.—Diagrams showing trends of joints in the Belmont and Calamine quadrangles, Lafayette County, Wis. *A*, joints in Calamine quadrangle; 136 joint measurements plotted in 5° groups; each concentric interval represents two joint measurements. *B*, joints in Belmont quadrangle; 333 joint measurements plotted in 5° groups; each concentric interval represents three joint measurements.

Some open joints are exposed at the surface. In areas where bedrock is concealed, the presence of joints and crevices are at places indicated by linear differences in color of plant foliage or by very shallow depressions in the sod in grassy fields. Differences in color of soil can also be noticed in creviced areas, but tilling of the soil has obscured this in many places.

The joints and crevices form extensive passages for movement of groundwaters. Some wells drilled into or near crevices tap ample supplies of water, but polluted waters also move long distances along crevices and enter these wells, making them unsuitable as sources for domestic consumption. Many joints and crevices are mineralized, and much shallow mining has been done along crevices.

ORIGIN OF THE STRUCTURAL FEATURES

The axes of major structural features in Wisconsin and adjoining areas of the north-central States trend roughly north. The Wisconsin Dome of Precambrian rocks, as contoured by Thwaites (1931, fig. 1), is elongate to the south, and the Wisconsin Arch in overlying Paleozoic rocks extends southward as the LaSalle anticline (Pirtle, 1932, fig. 1). The Illinois basin to the south of the zinc-lead district and the Forest City basin to the west also trend nearly north. Axes of the smaller structures within the zinc-lead district trend generally east (Heyl and others, 1951, fig. 13) but veer to the north or south in places. Some of these structures are discontinuous, and delineation of their axial trends is largely a matter of individual interpretation.

The major domes and basins began to form probably in Precambrian time and fluctuated in altitude, size, and shape during Paleozoic time, influencing the nature of the sediments deposited and the structural features formed in the sedimentary rocks. Within the zinc-lead district, however, the Ordovician rocks were deposited in a period of prolonged stability that was interrupted by an uplift after the Prairie du Chien sediments were deposited but resumed after the St. Peter Sandstone was laid down. The upper Middle Ordovician strata extend over large areas with relatively uniform thickness, and even the Wisconsin Arch to the east of the district was covered by these rocks. The Upper Ordovician rocks that once covered the district thicken to the northeast and northwest (Agnew and others, 1956, p. 259). The existence of widely separated remnants of Lower Silurian formations indicates that the uplift of this part of the north-central States occurred after Early Silurian time. In the basins to the south, east, and west, rocks of Carboniferous age were deposited, but these are not known to have extended over the Wisconsin Arch east of the mining district or into the mining district itself. Major uplift in and to the north of the district occurred, therefore, in post-Early Silurian and possibly pre-Carboniferous time. The regional slope of the surface of the buried Precambrian rocks in southern Wisconsin and the regional slope of the surface of Middle Ordovician strata are very similar, and both surfaces rise to the north. The greater uplift to the north was probably accompanied by faulting in the Precambrian basement rocks and the overlying Paleozoic rocks. Gravitational forces and drag forces also affected the Paleozoic strata.

We believe that both horizontal and vertical forces were acting to deform the sedimentary strata as the Precambrian basement rocks were uplifted but that differential vertical uplift and possibly tilting of fault blocks in the basement complex were the primary causes. The asymmetry of the Meekers Grove anticline and of the monocline at the southern edge of the anticline (Mullens, 1964) suggests that the sedimentary rocks overlie a tilted fault block. Also, the angular changes in direction of features such as the monocline at the southern and southeastern edges of the structural prominence in the part of the Seymour-Kendall upland in the Calamine quadrangle seem more likely to have been caused by block movement rather than by simple compressive folding. The horizontal and vertical movements in the basement could readily account for the jointing and faulting or shearing in the overlying sedimentary rocks.

More third-order folds in the district as a whole and in the area we have mapped appear to be synclines rather than anticlines. This evidence suggests that they may be solution synclines rather than compressive folds, for in compressive folding the number of anticlines and synclines would probably be nearly equal. However, the prevalence of synclines may be stressed in the literature because ore bodies are known to occur in many synclines and third-order anticlines may therefore be more abundant than one would believe from reading the geologic literature on the district.

We consider the faults, including the major pitch-type faults and the joints, to be of tectonic origin. They probably formed in one general period, but there may have been different stages of tectonism. Heyl and others (1959, p. 37–39) described subsurface faults having horizontal movement that have displaced pitch-type fracture systems.

The pitch-type fractures generally flank and overlie solution-thinned zones in limestone. Solution cavities and porous zones also occur along vertical joints and crevices, but the walls of pitches are not generally described as being cavernous or porous due to solution. Therefore, we believe that an early period of fracturing and solution created zones of weakness along which later tectonic fracturing formed pitch-type faults. Some inclined fractures were formed by subsidence of beds overlying solution-thinned beds, as described by Mullens

(1964). If some of these pitch-type fracture systems are offset by faults, a still later generation of tectonic fracturing must have occurred. As these late faults are said to be mineralized with unsheared ore, they are most probably pre-ore faults.

MINERAL DEPOSITS

The principal mineral products of the Belmont and Calamine quadrangles are zinc, lead, dolomite, and limestone. A copper deposit has been explored in the southeastern part of the Calamine quadrangle, but it apparently proved uneconomic. The locations of mines and prospects, old lead diggings, and stone quarries are shown on plate 22.

HISTORY OF DEVELOPMENT

Lead mining in this part of the district probably began about 1700, when a French mining and exploration expedition came into the area (Thwaites, 1895, p. 275–276), although lead had been mined earlier in some parts of the district. By 1820, lead ore, in what was then considered large quantities, had been discovered in Lafayette County (Western Historical Co., 1881). A lead-smelting furnace was erected near Meekers Grove in 1823; others were erected at Willow Springs in 1828, 1830, and 1839; and one was built north of the present site of Calamine in 1829.

Percival (1855, p. 22–92, map) described the location and character of some lead and zinc deposits in the area of the Belmont and Calamine quadrangles. They include the following: The Elk Grove diggings and Strawberry diggings in Elk Grove township; the Buzzard's Roost diggings in Benton township near Meekers Grove (pl. 22); the Skidmore diggings in what is now sec. 2, T. 2 N., R. 2 E., and others farther to the east along the south side of Vinegar Branch west of Darlington; the Forked Deer diggings west of the West Pecatonica between Wood Branch and Bonner Branch; Kings diggings on the south side of Wood Branch, west of the Pecatonica and north of Vinegar Branch; and the Pillings diggings on the east side of the Pecatonica River opposite Bonner Branch and south of the village of Calamine. No additional workings in this part of the district are shown on the maps of Whitney (1862) or Chamberlin (1882).

By 1907 mining had been done at: the Dall and Cook mines in sec. 22, T. 2 N., R. 1 E., the Trego, Anthony, and Raisbeck mines and associated surface diggings in sec. 21, T. 2 N., R. 1 E.; the Cockleburry Hill mine in sec. 14, T. 2 N., R. 1 E.; the Knee Deep diggings and unnamed diggings in sec. 23, T. 2 N., R. 1 E.; and the Jones-Churchill range in sec. 33, T. 3 N., R. 1 E. (Bain, 1906, p. 89–92; Grant, 1906, pls. 2, 4, 15, and 16). The ore body of the Southwestern Wisconsin mine was discovered in sec. 24, T. 3 N., R. 2 E., in an area of old surface diggings. This mine was brought into production in 1906, and the M. C. mine opened in an adjoining part of the same mineralized area was operated in 1913. Northwest of the Dall mine, the ore bodies of the Connecting Link No. 1 mine, the Connecting Link No. 2 mine, and the Big Dick mine in secs. 15 and 16, T. 2 N., R. 1 E., were discovered by 1918, and the mines were worked until 1920 (Heyl and others, 1959, p. 233–234). The Raisbeck mine was reopened briefly in 1929 and 1930. The Liberty mine was opened in 1943 on an extension of the Big Dick mine ore body in sec. 16, T. 2 N., R. 1 E., and was worked until 1946.

In 1947 personnel of the U.S. Bureau of Mines drilled and sampled the M. C. mine ore body (Apell, 1949), and in 1948 and 1949 they also drilled exploratory holes in the western extension of the Big Dick mine ore body in sec. 16, T. 2 N., R. 1 E. (Grosh, 1950). The U.S. Geological Survey drilled three exploratory holes for geologic information in the vicinity of the Trego, Anthony, and Raisbeck mines in 1949. The Liberty mine was reopened in 1949, 1950, and again in 1951. The Dall mine was reopened in 1950 and was worked at intervals until 1952. In 1951, 1952, and 1953, the New Jersey Zinc Co. drilled a grid of exploratory holes in the southwestern part of the Belmont quadrangle. The U.S. Geological Survey drilled 24 holes for geologic information in the Belmont and Calamine quadrangles in 1955.

The history of the copper prospect in sec. 22, T. 2 N., R. 3 E., south of Ames Branch, is not known. Allingham (1963) stated that copper was first discovered near Mineral Point in 1837, and the last serious attempt to mine copper in the area was in 1875. The copper prospect near Darlington may have been tested in the interval in which copper deposits were being worked in the Mineral Point area.

PRODUCTION

The amounts of lead and zinc produced in the Belmont and Calamine quadrangles up to the present time are not known, as the record of the tonnage produced from some of the old lead diggings is only approximate. The surface diggings were worked by hand, and the ores were hand cobbed and relatively low in impurities. The percentage of metal content of these ores was therefore more comparable to that in milled concentrates than to that in ores produced, mostly later, in large underground mines in the general area. Chamberlin (1882, pl.

10) compiled a map showing the following production, in tons, of lead ore from some of the diggings in the district up to 1882:

Diggings and location	*Production*
Strawberry diggings, in Elk Grove township	3,000
Elk Grove diggings, in Elk Grove township	2,500
Forked Deer and other diggings, between Wood Branch and Bonner Branch in Kendall and Willow Springs townships	2,500
Kings and other diggings near Wood Branch in Willow Springs township	500
Diggings south of Vinegar Branch in Darlington township	500
Diggings near Calamine in Willow Springs township	500

Old surface diggings south of Meekers Grove, referred to as the Buzzard's Roost diggings by Percival (1855, p. 84), lie partly within the Belmont quadrangle. Strong (1877, p. 709) recorded estimates of production from some of the diggings in this group. Among these, Anthony and Dixon's diggings in the SE¼ sec. 21, T. 2 N., R. 1 E., about a quarter of a mile south of Jenkinsville, yielded about 180 tons of blende (sphalerite) and 5 tons of lead ore (galena) per year in the period from 1872 to 1876.

The diggings of Kesting and Hines, in the SE¼ sec. 21, a short distance southeast of Anthony and Dixon's diggings, yielded about 225 tons of drybone (smithsonite) per year for about 10 years.

The diggings of Spensley Winn and Co. about a quarter of a mile southwest of Meekers Grove post office, as located in 1877, yielded about 700 tons of sphalerite and about 20 tons of galena in 1875 and 1876.

Heyl and others (1959, p. 233–238, figs. 89, 90) compiled information that indicates the order of magnitude of zinc-lead ore production from some of the larger mines. This information and our estimates of production are summarized in the following paragraphs. No estimates can be made for other mines in the Belmont and Calamine quadrangles.

The Big Dick mine, in secs. 15 and 16, T. 2 N., R. 1 E. (pl. 22), had a main shaft 128 feet deep ending in the lower part of the Ion Member of the Decorah Formation. The linear extent of the mine workings is about 2,000 feet, and the main branch of the workings was reported to have stopes 35–45 feet high. A north-northwest-trending ore branch is about 800 feet long, and a small southern branch about 200 feet long. Probably about 200,000 tons of material was excavated from workings of this size. An estimate of 100,000 tons of ore does not seem unreasonable for this mine. The ore averaged 10 percent zinc in 1920, and the jig concentrates were about 30 percent zinc. A large tonnage of low-grade ore remained when the mine was abandoned in 1946.

Several carloads of galena concentrates were obtained in 1947 and 1948 from ores mined from a small lead ore body on an extension of the north-northwest-trending branch of the Big Dick ore body.

The Connecting Link No. 1 and No. 2 mines, in secs. 15 and 16, T. 2 N., R. 1 E., have shafts 130 and 121 feet deep, respectively, extending into the lower part of the Decorah Formation. The combined production from the two mines was about 100,000–250,000 tons of zinc-lead ore. Jig concentrates from the No. 1 and No. 2 mines averaged 33 and 29 percent zinc, respectively. The ore was rich in galena and iron sulfides, and contained some barite.

The Liberty mine, in sec. 16, T. 2 N., R. 1 E., had a shaft 131 feet deep and was estimated by Heyl and others (1959, p. 234) to have produced about 20,000 tons of concentrates that contained 20–25 percent zinc and 1–3 percent lead.

The Trego and Anthony mines, in sec. 21, T. 2 N., R. 1 E., had shafts 90 and 75 feet deep, respectively. The linear extent of the workings was about 1,100 feet, but the ore in the Trego mine occurred mostly in a single flat in the Guttenberg Member of the Decorah Formation, and the workings were only about 6 feet high. Probably about 20,000–50,000 tons of ore was produced from these mines. The zinc concentrates contained 25 percent zinc and 25 percent iron. The ore contained some barite.

The Dall mine and the adjoining Cook prospect are in sec. 22, T. 2 N., R. 1 E. The shafts at the old Dall mine were 120–130 feet deep. The ore was in the Decorah Formation, and some ore may extend below the old workings into the Platteville Formation. About 200,000–500,000 tons of ore was produced. Iron sulfides were abundant in the ore.

The Southwestern Wisconsin mine, in sec. 24, T. 3 N., R. 2 E., had a shaft about 80 feet deep that extended into the Platteville Formation. It produced about 4,000–5,000 tons of ore. The jig concentrate averaged 53 percent zinc. Barite was abundant in the ore, and there were surface diggings for galena above the ore body.

The M. C. mine, in sec. 24, T. 3 N., R. 2 E., produced about 500 tons of ore that averaged 8–10 percent zinc and yielded a concentrate containing about 40 percent zinc, 6 percent iron, and 11 percent barium. About 120 tons of zinc concentrate and 8 tons of lead concentrate were shipped. The ore body was drilled by the U.S. Bureau of Mines (Apell, 1949) and was found to extend for several hundred feet to the west of the mine.

Samples of copper-rich rock have been found on the dumps of some unnamed old diggings in the NE¼SE¼ sec. 21, T. 2 N., R. 3 E., in the southeastern part of the Calamine quadrangle. The site is about half a mile south of where Wisconsin Route 23 crosses Ames Branch and about 500 feet west of the highway. The surface of the ground is pitted and hummocky, and a thick turf conceals the bedrock and most of the dump material. Loose pieces of Galena Dolomite, some with surfaces stained by malachite, can be found in the pits. Samples of copper-bearing rock can be found by digging beneath patches of yellowed and stunted grass. Some specimens that may have been part of an ore pile were found at one such place.

The structural and stratigraphic features of the copper deposits elsewhere in the district are similar to the zinc-lead deposits, and some of the deposits yielded considerable amounts of metal. The lack of information about the copper prospect in the Calamine quadrangle, the sparsity of ore specimens, and the fact that the workings do not appear to be extensive suggest that the deposit yielded very little copper.

MINERALOGY OF ZINC-LEAD DEPOSITS

The primary ore minerals of the zinc-lead deposits are sphalerite and galena. Smithsonite, an alteration product of sphalerite, and cerussite, an alteration product of galena, are secondary minerals, but only smithsonite has been found in sufficient abundance in oxidized deposits to form an ore of secondary minerals. Chalcopyrite and associated cuprite, malachite, and azurite were found in an old prospect in the southeastern part of the Calamine quadrangle but were apparently not abundant enough to form a copper ore body.

Marcasite, pyrite, calcite, dolomite, and barite are the principal gangue minerals. Iron and copper sulfides and barite have been recovered as ore minerals in some mines in other parts of the Upper Mississippi Valley zinc-lead district.

Dolomite, calcite, and quartz are the principal minerals of the country rocks. Chert and silicates, principally the clay minerals illite and montmorillonite, occur in the carbonate rocks and may constitute a few percent of the rock. The phosphate francolite is abundant in a few thin zones but is negligible in amount in the total section of rock exposed.

Sphalerite, which is the most abundant zinc mineral, ranges in color from a honey-yellowish brown to dark brown and reddish brown, but most of it is brown or dark brown. It occurs as veins or sheets a few inches thick and as disseminated crystals as much as an inch in diameter. Coarse disseminated sphalerite crystals are referred to in the district as "strawberry jack." Some of the sphalerite in veins has botryoidal surfaces on which other minerals are attached.

Smithsonite, the second most abundant zinc mineral, occurs in parts of the ore bodies above the water table. Some deposits were worked mainly for smithsonite. The village of Calamine may have been named for deposits of smithsonite, locally called calamine, that were worked in that area. The smithsonite is in the form of light-brown or rustlike cellular crusts or masses, some of which have cores of sphalerite. The smithsonite ores are called "drybone ores" because their cellular structure resembles the structure of dried bone. Minor amounts of hemimorphite and hydrozincite occur in the "drybone ores."

Galena, the most abundant lead mineral in the district, occurs as large composite cubic crystals, coarsely crystalline sheets, and small disseminated crystals in zinc ores and in the porous country rock. Coarsely crystalline galena is called cog ore in the district. Weathered galena is coated with cerussite, and this coating may protect the galena from further decomposition, for galena remains in many deposits in which sphalerite has been altered to smithsonite.

Pyrite and marcasite are abundant in many of the deposits. The pyrite is commonly in the form of radiating rectangular crystals or of crystalline masses intermixed with sphalerite. Marcasite occurs in the same manner, and reniform layers of marcasite encrust masses of pyrite. Pyrite generally remains undecomposed in weathered ore on the mine dumps, but marcasite, particularly the reniform variety, is replaced pseudomorphically by limonite—or goethite. Pyrite occurs abundantly in the uppermost few feet of the St. Peter Sandstone. In most natural exposures of these beds, the pyrite has been oxidized, and the rock is cemented by iron oxides.

Barite in the form of white platy masses is associated with sphalerite and galena in some deposits. Tabular crystals of barite may be found on the surface of massive barite in a few localities.

Chalcopyrite and other copper minerals have been mined in the district and occur in minor amounts in some zinc-lead deposits.

Coarsely crystalline calcite is the most abundant gangue mineral in the zinc-lead deposits. It occurs in many crystal forms and ranges in color from clear and colorless to opaque white. Some crystalline calcite shows phantom crystalline forms of earlier stages of crystallization, and Heyl and others (1959, p. 90) recognized four crystal habits representing these stages. The early stages are scalenohedral, and the later stages are rhombohedral.

Dolomite is an abundant gangue mineral and is the major constituent of the country rocks. Most of the dolomite closely associated with the ore bodies is secondary and occurs as sand-size rhombs containing little or no interstitial material. Some of the dolomite is pale pink, pale orange, or white and appears to have been deposited during the period of ore mineralization. The dolomite is much finer grained than the calcite associated with the ore.

Many other minerals that occur in the district and may occur in the Belmont and Calamine quadrangles were reported by Heyl and others (1959, p. 84). Among these are:

Primary minerals	*Secondary minerals*	
Ankerite	Anglesite	Goslarite
Cobaltite or safflorite	Aragonite	Greenockite
Gold	Aurichalcite	Gypsum
Millerite	Bravoite	Honessite
Muscovite	Chalcocite	Psilomelane
	Copiapite	Pyromorphite
	Copper	Sauconite
	Covellite	Sulfur
	Epsomite	Zincian-montmorillonite
	Erythrite	

Many of these minerals have been found only in barely detectable amounts. The great bulk of the ores consist of only a few minerals, but because the ores contain traces of arsenic, cadmium, cobalt, nickel, copper, gold, manganese, and silver, a great variety of secondary minerals may form when these ores are weathered under different local conditions.

PARAGENESIS

The sequence of deposition of the major minerals as interpreted from successive layering in vugs and other openings is as follows: Iron sulfides were deposited on the wallrocks, zinc sulfide coated the iron sulfides, and galena crystallized on the zinc sulfide. Barite and calcite were deposited after galena. A late stage of iron sulfide after galena was reported by Jenney (1894, p. 210). Heyl and others (1959, p. 96–101) showed that the detailed sequence includes early and late stages of iron sulfides and barite, that chalcopyrite is a late-stage mineral, and that four successive stages of calcite deposition occurred.

MINERALOGY OF THE COPPER PROSPECT

The ore fragments from the copper prospect in the Calamine quadrangle (p. 397) that are available for study consist of elongate pieces of interspersed copper and iron sulfides and secondary minerals. The fact that the various minerals are layered suggests that they were formed in open spaces. The broader faces of the samples are rough surfaces coated with a crust as much as 3 cm thick composed of limonite pseudomorphic after marcasite. Malachite forms a thin layer under the limonite crust and is intermixed with the limonite. The main body of the ore samples consists of chalcopyrite and of cuprite and goethite pseudomorphic after chalcopyrite; all occur in grains generally less than 1 mm in diameter. The samples contain interspersed malachite and minor azurite. Small, square or rectangular grains of pyrite and marcasite and remnants of partly altered grains are intermixed sparsely with the chalcopyrite.

X-ray spectrometer analysis of samples of the ore shows no trace of chalcocite, bornite, or violarite, which have been reported from other copper localities in the district. There are only questionable indications of the presence of pyrrhotite and tenorite, which have also been reported (Allingham, 1963; Heyl and others, 1959, p. 84–89).

Analyses of a selected sample of copper ore from the copper diggings are given in the following table:

Serial No		278053
Field No		HK59-S1-1
Mo	percent	0.038
Cu	do	31.92
Total Fe	do	18.16
Au	ounces per ton	.01
Ag	do	.01

NOTE.—D. L. Skinner, U.S. Geol. Survey, analyzed Cu by electrolytic method, Au and Ag by fire assay, and total Fe by volumetric method; D. L. Ferguson, U.S. Geol. Survey, analyzed Mo by colorimetric method.

Semiquantitative spectrochemical analysis (method of Myers and others, 1961) of a split of the same sample made by N. M. Conklin, U.S. Geological Survey, showed the following composition, in percent:

Cu[1]	>10	Ni	.015
Fe[1]	>10	Mn	.007
Si	3.0	Ba	.007
Ca	.7	Co	.007
Pb	.15	Yb	.003
Al	.15	Y	.003
Mg	.15	Cr	.0015
Na	.07	V	.0015
Mo	.03	Ag	.0007
Ti	.015		

[1] Major constituent.

NOTE.—Looked for but not found: K, P, As, Au, B, Be, Bi, Cd, Ce, Dy, Er, Eu, Ga, Gd, Ge, Hf, Hg, Ho, In, Ir, La, Li, Lu, Nb, Nd, Os, Pd, Pr, Pt, Re, Rh, Ru, Sb, Sc, Sn, Sr, Sm, Ta, Tb, Te, Th, Tl, Tm, U, W, Zn, Zr.

The sequence of depositions of minerals in the copper prospect appears to be as follows: a layer of marcasite or of marcasite and pyrite was deposited first, followed by chalcopyrite. The small amounts of marcasite and pyrite intermixed with the chalcopyrite were deposited probably along with the chalcopyrite. The sulfides were later oxidized and altered to malachite, cuprite, goethite, and azurite.

LEAD AND ZINC DEPOSITS

The lead and zinc deposits occur in two main forms: deposits associated with openings along vertical crevices, called crevice or gash vein deposits; and deposits associated with systems of inclined and horizontal fractures, called pitch and flat deposits. Closely spaced crevice deposits are called a range. Sphalerite, galena, pyrite, marcasite, barite, and calcite are the main primary minerals in both types. The crevice deposits are principally lead deposits but may contain much zinc, whereas the pitch and flat deposits are chiefly zinc deposits that contain lesser amounts of lead. Some ore bodies consist of pitch and flat deposits below and crevice deposits above.

TYPES OF ORE BODIES

CREVICE DEPOSITS

The crevice deposits are concentrations of lead and zinc sulfides lining open spaces along joints and fractures, mainly in the Galena Dolomite. Commonly, they extend to the surface of the bedrock and are overlain by soil containing residual concentrations of galena. The sphalerite is altered to smithsonite, and the iron sulfides are altered to limonite in the oxidized parts of the deposits. In some deposits the ore extends laterally away from the crevice in porous or cavernous beds of dolomite, which are called openings by local miners. The more dense rock above the openings is called caprock.

The sequence of deposition of the ore minerals was pyrite, marcasite, sphalerite, galena, and calcite (Bradbury, 1959, p. 22), but variations of this sequence are common. In some caves lined with ore, the main parts of the caves are filled with clay and silt, which were presumably washed in from above; slabs of the ore minerals that have fallen from the roof and walls of the caves are embedded in this material.

The crevice deposits were discovered early because of the presence of residual galena; early workings of such deposits (commonly called diggings) consisted of shallow pits sunk in weathered rock along the crevices. Alined diggings generally indicate a crevice deposit in which the ore was largely in the crevice itself, but large areas having many pits probably indicate that ore there occurred in openings that extended away from the crevices or occurred in several closely spaced crevices.

PITCH AND FLAT DEPOSITS

The pitch and flat deposits are the largest ore deposits in the district. They are mined principally for sphalerite, but they also contain galena, iron sulfides, and barite in significant amounts. Some contain copper minerals. The ore occurs along inclined and horizontal fractures and in solution-thinned and brecciated zones on the footwall side of the inclined fractures. These inclined fractures may occur singly (single pitch systems) or in pairs with opposing outward dips (double pitch systems). The pitches may extend through more than 50 feet of beds at angles of 45° or more from the horizontal. Many are in the form of steplike fractures, offset along bedding planes, but some extend for tens of feet as planar fractures (Heyl and others, 1959, figs. 23, 30, and 43). Some pitches steepen upward and extend as vertical crevices; others arch over and end along the horizontal bedding planes, commonly in the lower part of the cherty unit of the Galena Dolomite. The bases, or toes, of many pitches flare out and merge with bedding-plane fractures in the Spechts Ferry Shale Member of the Decorah Formation; others terminate in the Quimbys Mill Member of the Platteville Formation. Vertical fractures or breccia zones occur beneath the toes of some pitches.

The thinned and brecciated beds on the footwall sides of pitches and near the pitches are generally extensively mineralized and contain significant amounts of ore in some deposits; where pitches are widely separated, however, the intensity of mineralization decreases away from the pitch on the footwall side, and the central part of the interval between pitches is commonly only weakly mineralized or barren.

The flats are ore-filled openings along bedding planes. They may extend continuously between opposing pitches or may extend only a short distance from a pitch. Slumping and sagging of beds are common along flats. The beds on the footwall side of single pitches and between opposing pitches are commonly arched downward, forming shallow synclines, but the downfolding is less pronounced in strata above and below those which are broken by the pitch fractures (Chamberlin, 1882, figs. 40, 44, 48; Mullens, 1964).

The pitch and flat systems are complex in some places. A few parallel-dipping pitches and fractures may occur on one side of an ore zone, and a weaker set of opposing pitches may occur on the other; flats may extend between the pitches at more than one horizon. Minor fractures that are roughly parallel to the main pitch fractures occur commonly.

Pitches with associated flats are known to extend hundreds or even thousands of feet in long sinuous forms (Heyl and others, 1959, pls. 3, 5). The Raisbeck mine, which lies just west of the Belmont quadrangle, is shown by Heyl and others (1959, pl. 3) to have two parallel opposing pitches about 50–200 feet apart that extend for about 3,000 feet along the eastward-trending ore body. The ore bodies in the Liberty, Big Dick, Connecting Link No. 1 and No. 2, and Dall mines all had one set of inclined fractures. In the Dall mine, however, the fracture system curves and forms an almost complete loop, and the pitch dips outward along the periphery of the ore body (pl. 22).

WALLROCK ALTERATION

In addition to the solution thinning of limestone beds, the wall rocks around many of the deposits have undergone dolomitization and minor silicification that may be observed in thin section. The extent and intensity of this alteration away from the ore bodies is not known, but in other parts of the mining district where the Prairie du Chien Group is exposed, silicification of these beds has been very extensive. Heyl and others (1959, p. 105) reported that the St. Peter Sandstone is silicified along many faults and fracture zones and beneath pitch and flat ore bodies in the district, but that silicification in the Platteville and Decorah Formations and the Galena Dolomite is generally confined to areas of the larger zinc ore bodies in the area described in this report. Such silicification resulted probably from the deposition of silica that was mobilized by decomposition of silicate impurities in the carbonate rocks undergoing solution.

Thin layers of dolomite in the Quimbys Mill Member of the Platteville Formation have been silicified locally into a white or light-gray jasperoid rock that grades into dolomite and has the same texture as the dolomitic part of the bed. Such rock was cut in a drill hole in the SE¼SW¼SE¼ sec. 16, T. 2 N., R. 3 E., in the Calamine quadrangle (Carlson, 1956).

Dolomitization of wallrocks around some ore bodies is manifested in the presence of pale-pink rhombs of coarse sand-size dolomite closely associated with the ore. We have seen such dolomite grains only in rocks that are dolomite in the Belmont and Calamine quadrangles, but according to Heyl and others (1959, p. 107), dolomite occurs in veins, in crystal crusts lining vugs, and as replacement of limestone in other parts of the district.

Another type of dolomite, occurring in beds which are limestone in areas away from the ore bodies, is relatively dense and has a texture similar to that of the unaltered limestone. Some dolomitic rocks contain calcite between dolomite grains and, where unaltered, may be termed "calcareous dolomite." The leaching of such interstitial calcite results in a residual dolomite. Beds that have been residually enriched in dolomite may be thinned by compaction. Some of the leached beds are composed almost entirely of poorly cemented sand-sized dolomite grains. Such beds, where not compacted, are very porous and permeable.

Another type of alteration is the calcitization of dolomitic rock. Calcitization, as used in this report, means the introduction of, or the replacement by calcite. The introduction of calcite is the principal form of calcitization discussed here. The amount of replacement of other minerals by calcite is not known. In and around many of the mineralized bodies coarsely crystalline calcite occurs in vugs, in pore spaces, and as a replacement or recrystallization of relatively dense fine-grained rocks. Veins of calcite occur both in limestone and in dolomite beds.

The alteration of limestone to dolomite on a regional scale in the Galena, Decorah, and Platteville Formations is a subject beyond the scope of this report, but the existence of limestone and dolomite facies in these formations in the mining district calls attention to this question. A potential significance of these facies is discussed in the following section.

ORIGIN OF THE ORES

The features of the zinc-lead ores and their observed relations to the country rocks suggest the following sequence of events in the formation of the ore deposits:

1. The rocks of the district were broken by joints, fractures, faults, and breccia zones, probably during general emergence of the land mass from below sea level.
2. Waters moved through these openings, dissolving limestone and dolomite and enlarging the openings. The solution of carbonate rock thinned some impure beds, thereby increasing, relatively, the clay and residual shale content of these beds. Dolomitization, in the sense that calcareous dolomite or dolomitic limestone became more dolomitic by preferential solution of calcite, and silicification began at this stage.
3. Inclined and vertical fractures and faults formed along the solution-thinned zones, and overlying beds dropped or sagged into the voids resulting from the solution thinning. Dolomitization and silicification continued during this stage.
4. Solutions carrying the ore metals displaced earlier solutions in the system of joints, fractures, and solution cavities, and the ore minerals were precipitated. Some dolomitization, including recrystallization of dolomite and possibly deposition of dolomite as a replacement of calcite, occurred during the early part of this stage. Calcitization occurred in the latter part of this stage and continued after the ore minerals were deposited.
5. Folds, minor fractures, and local faults formed in the sedimentary strata, probably owing to differential vertical movements in the Precambrian basement rocks.
6. Weathering in shallow surface zones resulted in alteration of sulfide ores to secondary minerals. Residual enrichment of lead ores occurred at the surface along some mineralized fracture zones.

These stages in the formation of the ore bodies are commonly recognized by geologists who have studied the mining district, but not all would present them in the same order. Our views are in general agreement with those of Bradbury (1959, p. 27–28). Whether the solutions that thinned the beds were ground water or ore solutions is a matter of dispute.

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We believe that a possible clue to the origin of the zones of solution thinning may lie in the shapes of these zones. The outlines of many pitch and flat deposits in the district are elongate sinuous forms and shorter arcuate forms, somewhat resembling a system of meandering stream channels, oxbow bends, and cutoffs such as may be seen in many large stream valleys. These zones may have formed by subterranean solution of the limestone beds underlying a system of meandering and partially joint-controlled streams on an old surface. The drag effect of the flowing surface waters on subterranean waters in joints and fractures may have resulted in the movement of greater volumes of ground water beneath the streams, with a resulting increase in the solution of calcite in the limestone beds beneath the streams. Where some surficial change caused a diversion of the stream at the surface, the drag effect on subterranean waters would cease along the old channels and begin beneath the new channels. Heyl (oral communication, 1960) suggested that an old erosion surface along which such a drainage system may have existed is represented by the regionally disconformable contact between the Maquoketa Shale and the Galena Dolomite, which was described by DuBois (1945, p. 15). The limestone beds in the Platteville and Decorah Formations, and calcareous zones in the Galena Dolomite, would be the nearest calcareous beds to such a surface. The Guttenberg Member of the Decorah Formation and the Quimbys Mill Member of the Platteville, the limestones at the top of this sequence have been thinned by solution more extensively than have the limestone beds of the McGregor Member of the Platteville. This thinning suggests that the waters responsible for the solution thinning were most active at the top of the section and that their movements were controlled by some feature above rather than below this zone.

The question of whether the formation of the inclined fractures or pitches and minor synclines was due to lateral compressive forces or to subsidence along zones of solution thinning has been debated. Heyl and others (1959, p. 56–67, 108–128) favored the hypothesis of lateral compression, whereas Mullens (1964) considered subsidence to be the major force involved. Many geologists consider that the ore metals came probably from a magmatic source in the Precambrian basement rocks of the district. Others postulated that the ore metals may have been introduced into the ground-water system from a source outside the district. The temperature at which liquid inclusions were formed in minerals in the ore deposits was about 100°C or lower, as calculated by Newhouse (1933). Such temperatures are within the range to be expected in deeply buried connate or ground waters or in telethermal magmatic waters.

The ores were probably deposited in a relatively shallow position, shallow enough to be within the meteoric ground-water system that existed at the time. We believe that the ore solutions, once they became part of the near-surface ground-water system, saturated the rocks to which they had access. If they were hot ascending solutions after entering the near-surface ground-water system, major concentrations of ore should be found under anticlines and domes into which the hot solutions would have moved because of the difference in density between hot solutions and cool ground-waters. As such entrapped solutions reacted with the host rocks and cooled, the ore minerals would have been precipitated. Yet the ore deposits in this district are not concentrated in anticlines. This suggests that the presently existing fold system had not formed prior to the mineralization, or that there was little density difference between ore solutions and ground-waters.

GEOLOGIC FACTORS IN PROSPECTING

The types of metalliferous deposits most likely to be found within the Belmont and Calamine quadrangles are zinc-lead deposits, some containing associated iron sulfides and barite, and possibly deposits of copper sulfides and carbonates. The known copper deposits in the Upper Mississippi Valley occur in the same geologic environment as the zinc-lead deposits.

The stratigraphic interval that has heretofore yielded deposits of economic value lies between the middle of the Platteville Formation and the base of the Maquoketa Shale. The larger deposits, those containing tens or hundreds of thousands of tons of ore, had most of the ore in beds above the top of the Platteville Formation, and large zinc-lead deposits will probably not be found in areas where the Galena and Decorah Formations have been removed by erosion. A metalliferous deposit in the Quimbys Mill Member that is exposed in a valley may, however, extend into the valley sides where it may be overlain by other mineralized beds and thus constitute an ore deposit of economic significance.

Vertical or near-vertical crevice deposits, principally of galena and smithsonite, which occur in the Galena Dolomite, offer rather narrow targets for vertical drilling; therefore, unless these deposits are delineated by surface features, the chance is small that they will be discovered by drilling vertical test holes. Lines of old pits or of several shallow pits may indicate mineralized crevices that have been previously worked, and projections of the crevices might possibly be located by shallow drilling.

The pitch and flat deposits offer the greatest target areas for vertical drilling. As most such deposits are largely within the Decorah Formation and the lower, cherty unit of the Galena Dolomite, an area underlain by these beds is potentially favorable ground if old surface diggings in which ore minerals have been found occur or if the rock shows signs of alteration. Much of the old lead mining in crevice deposits was restricted to levels above the water table. Adjoining areas along trend with old diggings may be favorable for prospecting, even though they may have no surface indications of the ore minerals.

The noncherty unit of the Galena Dolomite is not known to contain pitch and flat deposits in the Belmont or Calamine quadrangles. The existence of limestone facies in the cherty unit, however, may indicate the presence of deposits of economic value; if solution thinning similar to that in the limestone beds of the Decorah and Platteville formations has occurred in limestone beds of the Galena Dolomite, then systems of openings parallel to bedding, inclined fractures, and breccia zones may have formed in and above this limestone. In such places, pitch and flat deposits or their equivalent may exist well above the base of the Galena Dolomite. This hypothesis is based on our interpretation that solution thinning of limestone beds preceded and was a necessary condition for the formation of the systems of fractures typical of pitch and flat deposits.

Locally, the Quimbys Mill and McGregor Members of the Platteville Formation and the Guttenberg and Ion Members of the Decorah Formation are composed almost entirely of dolomite. Because solution thinning is apparently less extensive in dolomite than in limestone, we believe that solution-thinned zones and the pitch-and-flat-type deposits that occur in such zones are not so common or extensive here as in areas where the Platteville and Decorah Formations are composed largely of limestone. The M. C. mine, in sec. 24, T. 3 N., R. 2 E., in the Calamine quadrangle near Truman, may be an example of a deposit in such an environment. There, at least part of the Quimbys Mill Member consists of dolomite, and the pitches and flats are thin (Heyl and others, 1959, p. 252), even though the presence of many old surface diggings in nearby areas suggests extensive lead-and-zinc mineralization.

The combined thickness of the Decorah Formation and the Quimbys Mill Member of the Platteville Formation in many places in the Belmont and Calamine quadrangles is between 40 and 48 feet. Where their combined thickness is less than 40 feet, solutions may have thinned the beds. In places where the beds are dolomitic and are mineralized, such as at the M. C. mine, and at the U.S. Geological Survey drill hole in the SE¼ sec. 7, T. 2 N., R. 3 E., the amount of thinning may reflect the amount of limestone in the beds at the time of districtwide solution thinning of the limestone. The average thickness of the combined section of the Decorah Formation and the Quimbys Mill Member of the Platteville Formation is about 45 feet at the M. C. mine, but the same interval of beds at the site drilled in sec. 7 is only about 28.5 feet. The thinness of these beds and the presence of sulfide minerals in the drill cuttings from the drill site suggest that the site should be further explored.

In localities where nearly all the Platteville and Decorah Formations consist of dolomite and no system of fractures like that in the pitch and flat deposits is formed, the ore solutions that entered the system of vertical crevices may have deposited a greater percentage of galena than is common in pitch and flat deposits and a greater percentage of sphalerite than is common in crevice deposits. The Rodham mine in the northern part of the Shullsberg quadrangle (Heyl and others, 1959, p. 231; Mullens, 1964 may be a deposit of this type.

A closer spacing of drill holes should be used in attempting to locate ore bodies in the eastern part of the Belmont quadrangle and in the Calamine quadrangle than is generally used in parts of the district where the Platteville and Decorah Formations are more calcareous. The basis for this suggestion is the fact that pitch and flat systems offer much larger targets for vertical drilling than do crevice deposits.

Much of the intensive prospecting for ore in the district has been in and around areas of old surface diggings and along trends of elongate zones of mineralization. Grant (1906, p. 85, 86) and more recent workers in the district stated that such places, particularly those that lie in synclinal basins, are favorable places to prospect for ore. We concur in this statement with regard to the district as a whole but suggest that other areas that have been only sparsely prospected and where the structure is not known in detail may be worthy of investigation. We do not believe that the relation of mineralized zones to fold structures in the Belmont and Calamine quadrangles is the same as that which has been reported for some other parts of the mining district (West and Klemic, 1961). Lead and zinc mineralization has been so widespread in the Upper Mississippi Valley district that theories of relationship of ore bodies to specific structures should not deter prospectors from investigating any section in which the host formations of the district remain untested.

A broad band of high ground extending southeastward from the northwest corner of the Belmont quadrangle to Seymour Corners and eastward across the south-central part of the Calamine quadrangle may be considered as untested ground favorable for prospecting. Much of the Galena Dolomite and the entire thickness of the Decorah and Platteville Formations underlie this section. A few scattered prospect holes and a few old surface diggings are the only signs of prospecting. Traces of lead and zinc minerals have been found in a few holes drilled for geologic information in the area between Ames Branch and Wood and Vinegar Branches in Seymour and Darlington townships, and what may be a significant amount of lead and zinc sulfides was found in one drill hole in Darlington township (Carlson, 1956).

Until some geophysical method or other technique of locating subsurface zinc-lead deposits in the district is found to be successful, grid drilling of test holes will remain the most practical method for locating concealed ore bodies.

Zinc and lead mineralization is so widespread in the district that geochemical prospecting for these metals would be extremely difficult to apply successfully. In a search for copper deposits, however, geochemical prospecting may be feasible if molybdenum or some other metal associated with the copper can be used as a correlating tracer. Evidence of copper mineralization appears to be limited mainly to localities containing fairly sizable zinc-lead deposits or copper deposits containing high concentrations of copper. Unlike galena and sphalerite—particularly galena, which may be found in sparse disseminations in many places in the district—copper minerals are not noticeable and probably do not occur as disseminations far from the ore bodies. However, along subterranean water courses traversed by waters that have moved through copper-bearing deposits, some copper anomalies can possibly be detected and traced to their approximate source by geochemical methods.

Well water from farms near the copper prospect was sampled and analyzed for copper and molybdenum to try to determine whether significant amounts of these elements occur in rocks permeated by the well waters. The results of these analyses, in parts per billion, are given in the following table:

Serial No. (field No.)	*Cu*	*Serial No. (field No.)*	*Cu*
59–55W (HK–59–WA)	4	59–58W (HK–59–WD)	<2
56W (HK–59–WB)	2	59W (HK–59–WE)	<2
57W (HK–59–WC)	12	60W (HK–59–WF)	<2

NOTE.—Mo<10 parts per billion in all analyses. Locations of wells sampled are shown on plate 22; analyses made by H. H. Mehnert and C. E. Thompson of the U.S. Geol. Survey.

Although each sample was about 200 ml, the amount was insufficient for a more sensitive determination of molybdenum. If a correspondingly higher molybdenum content exists in the water samples that are higher in copper, the differences may indicate copper mineralization and not contamination by well-pumping equipment. Without some such correlation, the significance of the variations in copper content cannot be evaluated, but the data presented in the foregoing table may be useful for future geochemical prospecting.

DRILLING DATA

Twenty-four churn drill holes aggregating 3,897 feet were drilled for geologic information in the Belmont and Calamine quadrangles, Lafayette County, Wis., as part of the cooperative program of geologic studies by the U.S. Geological Survey and the Wisconsin Geological and Natural History Survey. The holes were drilled in areas of sparse outcrop and subsurface information to provide basic data for stratigraphic study and for the determination of geologic structures. Locations of the holes are shown on plate 22, and logs of the cuttings are given in the following pages. Most of the cuttings were examined by Larry Dixon under the direction of Harry Klemic. W. S. West and J. W. Allingham studied the cuttings from the Ross and McKillip drill holes in the Calamine quadrangle. Generalized descriptive logs of these holes were prepared by J. E. Carlson (1956). His field estimates of the abundance of sulfide minerals in the drill cuttings from some holes are given along with our estimates from splits of the samples studied.

Marine carbonate rocks of the Platteville and Decorah Formations and Galena Dolomite, all of Middle Ordovician age, were drilled. Most of the holes went through the Quimbys Mill Member of the Platteville Formation and bottomed in the McGregor Member of the Platteville Formation. The altitude and thickness of the Quimbys Mill Member were sought for purposes of structural interpretation.

We have used four categories of carbonate rock—dolomite, calcareous dolomite, dolomitic limestone, and limestone—in classifying the drill cuttings. The dominant types of rock fragments in each sample were tested for reaction to dilute hydrochloric acid, and several samples were X-rayed to determine relative amounts of calcite and dolomite. There is very little distinction between calcareous dolomite and dolomitic limestone in some of the samples, but in many of the samples one or the other of the rock types definitely predominates. Colors mentioned are of wet rock fragments. White crystalline calcite that occurs in veins and vugs is noted as distinct from the calcite of the limestone or from the interstitial calcite in the dolomite.

BELMONT QUADRANGLE

Property owner. Adickes.
Location. SE¼SE¼NW¼ sec. 22, T. 3 N., R. 1 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 9–11, 1955.

Collar altitude. 1052.8 ft.
Total depth. 150 ft.

	Depth (feet)
Surficial material:	
Reddish clay, loess, and cherty residuum	0–5
Galena Dolomite:	
Cherty unit:	
Dolomite, tan to light-brown, limonite-stained; gray to white chert; traces of calcite. Minor amounts of iron sulfides in interval 50–115 ft, and about 5 percent iron sulfide in interval 80–85 ft. Sparse quartz-sand grains	5–115
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray-brown; traces of green shale, calcite, iron sulfides, and limonite	115–126
Dolomite and calcareous dolomite, gray; traces of green shale, calcite, iron sulfides, limonite, and clear grains of quartz sand	126–132½
Guttenberg Limestone Member:	
Limestone and dolomitic limestone, brown, fossiliferous; minor amounts of green and brown shale; traces of calcite, iron sulfides, quartz	132½–149½
Spechts Ferry Shale Member:	
Limestone, gray; shale, white, gray, and brown; traces of iron sulfides	149½–150

Lead and zinc mineral content, in percent

[Carlson (1956, p. 45) estimated that the cuttings in the 45–65 ft interval contained 20 percent iron minerals]

Depth (feet)	*Galena*	*Sphalerite*
75–80	Trace	Trace
80–85	0. 5	----------
130–132½	----------	Trace

Property owner. Edwards.
Location. NE¼NW¼NE¼ sec. 28, T. 3 N., R. 1 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 12–14, 1955.
Collar altitude. 1057.5 ft.
Total depth. 187 ft.

	Depth (feet)
Surficial material:	
Soil and loess, dark brown; cherty residium	0–5
Galena Dolomite:	
Noncherty unit:	
Dolomite, tan; traces of calcite and limonite	5–35
Cherty unit:	
Dolomite, tan; buff and reddish-gray chert; traces of calcite iron sulfides, and limonite	35–70
Dolomite gray; gray shale; chert; traces of iron sulfides and limonite	70–75
Dolomite, brown; chert; traces of iron sulfides, calcite, and limonite; some dolomitic limestone and calcareous dolomite; traces of quartz sand in lower 18 ft; traces of green shale near base	75–138

	Depth (feet)
Decorah Formation:	
Ion Dolomite Member:	
Calcareous dolomite, gray; traces of calcite, iron sulfides, and limonite; fossiliferous	138–142½
Limestone, brownish gray at top, gray below; traces of green shale, calcite, iron sulfides, and limonite; fossiliferous	142½–155
Guttenberg Limestone Member:	
Limestone, dolomitic limestone, brown; minor yellow-green shale; traces of calcite, iron sulfides, limonite, and quartz sand	155–172½
Platteville Formation:	
Quimbys Mill Member:	
Limestone, dolomitic limestone, and calcareous dolomite, brown; minor yellow-green shale; traces of calcite, iron sulfides, limonite, and quartz sand; fossiliferous	172½–182½
McGregor Limestone Member:	
Limestone and calcareous dolomite, gray and dark brown; minor brown shale; traces of calcite, iron sulfides, and limonite	182½–187

Property owner. Harms.
Location. SE¼SE¼SW¼ sec. 26, T. 3 N., R. 1 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 12–13, 1955.
Collar altitude. 1059.7 ft.
Total depth. 162 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–14
Galena Dolomite:	
Cherty unit:	
Dolomite and calcareous dolomite, tan, light-brown to grayish-brown; gray to white chert; minor amounts of brown shale, calcite, and limonite. Traces of pyrite in the 45–110 ft interval	14–110
Decorah Formation:	
Ion Dolomite Member:	
Calcareous dolomite, gray, grayish brown at top; traces of calcite and iron sulfides	110–125
Limestone and dolomitic limestone, gray; fossiliferous; traces of green shale, calcite, iron sulfides, and limonite	125–133
Guttenberg Limestone Member:	
Limestone and dolomitic limestone, gray and gray-brown; minor amount of brown shale; traces of calcite and iron sulfides	133–137½
Limestone, brown and gray; minor amount of green shale near bottom; traces of calcite and iron sulfides	137½–152½
Platteville Formation:	
Quimbys Mill Member:	
Dolomitic limestone and dolomite, brown to gray-brown; traces of calcite and iron sulfides	152½–161

	Depth (feet)
Platteville Formation—Continued	
McGregor Limestone Member:	
Dolomitic limestone, gray; traces of calcite and iron sulfides	161–162

Property owner. J. Hillery.
Location. SE¼SE¼NW¼ sec. 4, T. 3 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 23–24, 1955.
Collar altitude. 1063 ft.
Total depth cased. 160 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–15
Galena Dolomite:	
Cherty unit:	
Dolomite, tan and light brown; gray to white chert; minor amounts of brown and green shale near bottom; traces of calcite, limonite, and iron sulfides	15–120
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray; minor amount of green shale near top; chert, possibly from the Galena Dolomite; trace amounts calcite, iron sulfides, limonite, and quartz sand	120–138
Guttenberg Limestone Member:	
Dolomite, dark-gray and brown; minor amounts of brown shale; traces of calcite and iron sulfides; phosphate nodules near base	138–148
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, calcareous near top, brown; minor amounts of brown shale; traces of calcite and iron sulfides	148–157½
McGregor Limestone Member:	
Dolomite, gray and brown; traces of calcite and iron sulfides	157½–160

Property owner. Ervin Johnson.
Location. SW¼SW¼NW¼ sec. 33, T. 3 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 19–20, 1955.
Collar altitude. 1076.4 ft.
Total depth cased. 170 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena dolomite:	
Noncherty unit:	
Dolomite; minor amount of gray shale and limonite	5–15
Cherty unit:	
Dolomite, light-brown; chert, gray to white; minor amounts of brown and green shale and calcite; traces of iron sulfides in lower 50 ft.; limonite	15–120

	Depth (feet)
Decorah Formation:	
Ion Dolomite Member:	
Dolomite and calcareous dolomite, gray to dark-gray; chert, possibly from Galena dolomite; minor amounts of green and gray shale, calcite, and iron sulfides	120–142½
Guttenberg Limestone Member:	
Dolomite and calcareous dolomite, brown and grayish-brown; minor amount of green shale near base; minor amounts of calcite and iron sulfides; trace of sphalerite	142½–155
Platteville Formation:	
Quimbys Mill Member:	
Dolomite and calcareous dolomite, brown; minor amounts of calcite and iron sulfides	155–168
McGregor Limestone Member:	
Dolomite, brownish-gray; minor amounts of calcite, iron sulfides, and limonite	168–170

Property owner. Knebel.
Location. NW¼NW¼SE¼ sec. 23, T. 3 N., R. 1 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 16–19, 1955.
Collar altitude. 1079.2 ft.
Total depth. 172 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–10
Gelena Dolomite:	
Noncherty unit:	
Dolomite, tan; minor amount of limonite	10–20
Cherty unit:	
Dolomite, tan; chert, gray to white; minor amounts of calcite and limonite; traces of iron sulfide near base	20–135
Decorah Formation:	
Ion Dolomite Member:	
Dolomite and calcareous dolomite in upper and middle part and limestone in lower part, gray and brown; minor amounts of calcite, iron sulfides, and limonite; traces of galena and sphalerite in lower part	135–150
Guttenberg Limestone Member:	
Limestone and calcareous dolomite, brown and gray; minor amounts of calcite and iron sulfides	150–157½
Platteville Formation:	
Quimbys Mill Member:	
Dolomitic limestone and calcareous dolomite, brown; minor amounts of calcite and iron sulfides	157½–167½
McGregor Limestone Member:	
Calcareous dolomite, gray and brown; minor amounts of calcite and iron sulfides, limonite, and gray clay	167½–172

Property owner. D. McNett.
Location. SW¼NW¼SW¼ sec. 8, T. 3 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 8–9, 1955.
Collar altitude. 1053.2 ft.
Total depth. 132 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Cherty unit:	
Dolomite, tan; gray to white chert; minor amounts of limonite. Minor amounts of yellow calcite at 40–55 ft. and 70–80 ft.	5–85
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, brown and gray; chert, possibly from Galena Dolomite; minor amounts of green shale, yellow calcite, iron sulfides, and limonite; traces of quartz indicated by X-ray pattern	85–105
Guttenberg Limestone Member:	
Dolomite, brown; minor amount of green shale, yellow calcite, iron sulfides, and limonite; white to gray chert, possibly from Galena Dolomite	105–117½
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, brown; white to gray chert, possibly from Galena Dolomite; minor amounts of green shale, calcite, iron sulfides, and limonite; traces of quartz sand	117½–130
McGregor Limestone Member:	
Dolomite, tan and gray; minor amounts of green shale, calcite, iron sulfides, and limonite; traces of quartz sand	130–132

Property owner. D. Miller.
Location. NW¼SW¼SW¼ sec. 29, T. 3 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 18–19, 1955.
Collar altitude. 1077.4 ft.
Total depth cased. 168 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–10
Galena Dolomite:	
Cherty unit:	
Dolomite, tan in upper 40 ft, grayish brown and light brown in remainder; gray to white chert; minor amounts of calcite and limonite; some reddish-gray shale at 55 ft; traces of iron sulfides in 50–75 ft interval. Some brown shale at 115 ft	10–120

	Depth (feet)
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, dolomitic limestone at top, gray; minor green shale, calcite, and iron sulfides. Dark specks in rock; traces of limonite	120–139
Guttenberg Limestone Member:	
Dolomite, calcareous at top and base, brown; white to gray chert, possibly from Galena Dolomite; minor amounts of brown shale, calcite, and iron sulfides; dark carbonaceous matter in lower part	139–152
Platteville Formation:	
Quimbys Mill Member:	
Limestone at top, underlain by dolomite, limestone, and dolomitic limestone, brown; minor amount of chert, possibly from Galena Dolomite; minor amount of brown shale, calcite, and iron sulfide	152–163
McGregor Limestone Member:	
Limestone, brown; minor amounts of calcite and iron sulfides	163–168

Property owner. H. Riter.
Location. SE¼SE¼NE¼ sec. 25, T. 3 N., R. 1 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 14–15, 1955.
Collar altitude. 1076.9 ft.
Total depth. 185 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–20
Galena Dolomite:	
Noncherty unit:	
Dolomite, tan; minor amounts of calcite and limonite	20–35
Cherty unit:	
Dolomite, calcareous dolomite in 50–75 ft interval, tan at top, light-brown, brown, and gray; gray and white chert; minor amounts of calcite, iron sulfides, and limonite; some red shale in 70–110 ft interval; traces of quartz sand	35–140
Decorah Formation:	
Ion Dolomite Member:	
Calcareous dolomite and limestone, gray; minor amounts of calcite, iron sulfides, and limonite; black specks in rocks; traces of quartz sand and green shale	140–160
Guttenberg Limestone Member:	
Calcareous dolomite and limestone, gray-brown and brown; minor amount of brown shale, calcite, limonite, and iron sulfides; gray and white chert, possibly from Galena Dolomite; traces of quartz sand	160–174
Platteville Formation:	
Quimbys Mill Member:	
Dolomite and dolomitic limestone, brown; minor amount of brown shale near base; buff chert and minor amounts of calcite, iron sulfides, and limonite	174–183
McGregor Limestone Member:	
Dolomitic limestone and dolomite, gray brown; minor amount of green shale, yellowish calcite, and limonite and iron sulfides	183–185

Property owner. L. Riter.
Location. NE¼NW¼NW¼ sec. 9, T. 2 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 21–22, 1955.
Collar altitude. 1076.7 ft.
Total depth cased. 171 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Noncherty unit:	
Dolomite, tan; minor amounts of limonite; traces of pyrite	5–25
Cherty unit:	
Dolomite, tan; light-brown and gray calcareous dolomite at 65–110 ft, gray dolomite at base; gray and white chert, minor amounts of calcite, limonite, and iron sulfides; some yellow shale at 45 ft	25–125
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray; chert, possibly from Galena Dolomite; minor amounts of calcite, iron sulfides, and limonite; some green shale at 135 ft	125–148
Guttenberg Limestone Member:	
Dolomite, brown; gray and white chert, possibly from overlying beds; minor amounts of calcite and iron sulfides	148–155
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, brown; gray and white chert, possibly from overlying beds; minor amounts of calcite, iron sulfides, and limonite; some gray shale at 163 ft	155–169
McGregor limestone Member:	
Dolomite, gray; minor amounts of calcite and iron sulfides	169–171

Lead and zinc mineral content

[Carlson (1956, p. 54) reported trace amounts of zinc and lead minerals in the drill cuttings from a depth of 55–169 ft, except that cuttings were barren at 125–148 ft]

Depth (feet)	Galena	Sphalerite	Depth (feet)	Galena	Sphalerite
55–60	Trace	Trace	100–105	------	Trace
60–65	Trace	Trace	115–120	Trace	-------
65–75	Trace	-------	160–162½	------	Trace
85–90	Trace	-------			

Property owner. W. M. Riter.
Location. NW¼SE¼SE¼ sec. 19, T. 3 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 17–18, 1955.
Collar altitude. 1078.1 ft.
Total depth. 182 ft.
Depth to water. 45 ft.
Cased.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5

	Depth (feet)
Galena Dolomite:	
Noncherty unit:	
Dolomite, tan; minor amounts of calcite, limonite, and iron sulfides	5–40
Cherty unit:	
Dolomite, tan; gray and white chert; minor amounts of calcite and limonite; traces of iron sulfides at 120–125 ft; traces of quartz sand near base	40–143
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray; minor amounts of calcite and limonite; traces of quartz sand	143–160
Guttenberg Limestone Member:	
Calcareous dolomite, brown; some green and gray shale; minor amounts of calcite, iron sulfides, and limonite	160–172
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, calcareous in upper part, brown; minor amounts of calcite, iron sulfides, and limonite; traces of quartz sand; some gray shale in lowest cuttings	172–181
McGregor Limestone Member:	
Dolomite, gray-brown; minor amounts of calcite, iron sulfides, and limonite; traces of quartz sand	181–182

Property owner. Speth.
Location. SE¼NE¼NE¼ sec. 26, T. 3 N., R. 1 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 10–11, 1955.
Collar altitude. 1040 ft.
Total depth. 150 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–18
Galena Dolomite:	
Cherty unit:	
Dolomite, calcareous near base, brown; gray and white chert; red-stained chert in 45–50 ft and 60–70 ft intervals; minor amounts of calcite, iron sulfides, limonite, and brown and white clay	18–105
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray; gray and white chert, possibly from overlying beds; minor amounts of calcite, iron sulfides and limonite; black specks in rock; traces of quartz sand; some orange clay in 110–112½ ft interval	105–123
Guttenberg Limestone Member:	
Dolomite at top, dolomitic limestone and limestone below, brown; rose and tan chert in uppermost cuttings, and gray chert in lower cuttings, possibly from Galena Dolomite; brown shale at 132½–135 ft interval; gray clay at 135–137½ ft interval; minor calcite, iron sulfides, and limonite	123–137½

	Depth (feet)
Platteville Formation:	
Quimbys Mill Member:	
Calcareous dolomite in upper part, dolomitic limestone next, dolomite in lower part, brown; gray and white chert, possibly from Galena Dolomite; minor calcite, iron sulfides, and limonite	137½–148
McGregor Limestone Member:	
Calcareous dolomite, gray; minor iron sulfide and limonite	148–150

Property owner. Von Glahn.
Location. SW¼SW¼SW¼ sec. 7, T, 3 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 5–6, 1955.
Collar altitude. 1045.9 ft.
Total depth. 134 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Cherty unit:	
Dolomite, tan; gray and white chert; minor amounts of calcite and limonite	5–90
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray in upper part and dark gray in lower; minor amounts of green shale, calcite, and limonite; traces of iron sulfides	90–105
Guttenberg Limestone Member:	
Dolomite, brown; some brown shale; gray and white chert, possibly from Galena Dolomite; minor amounts of calcite, iron sulfides, and limonite	105–117½
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, brown; some brown shale; minor amounts of calcite, iron sulfides, and limonite; chert, possibly from overlying beds	117½–129
McGregor Limestone Member:	
Dolomite, brown and gray; gray shale; minor calcite; chert, possibly from overlying beds	129–134

CALAMINE QUADRANGLE

Property owner. Arnsmeier.
Location. SW¼SE¼SE¼ sec. 5, T. 2 N., R. 3 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilling. Nov. 30, Dec. 1, 1955.
Collar altitude. 1019.6 ft.
Total depth. 180 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–15

	Depth (feet)
Galena Dolomite:	
Noncherty unit:	
Dolomite, yellow-tan; trace of galena and disseminated pyrite	15–30
Cherty unit:	
Dolomite, tan; gray and white chert; black specks in rock; minor amounts of pyrite partly altered to limonite	30–133
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray and tan; chert, possibly from overlying beds; black specks in rock; minor amount of limonite; trace of pyrite	133–152
Guttenberg Limestone Member:	
Dolomite, brown and tan; white chert; fossiliferous; minor amounts of iron sulfides	152–165
Platteville Formation:	
Quimbys Mill Member:	
Calcareous dolomite, brown and tan; light-gray chert; minor amount of iron sulfides and limonite	165–179
McGregor Limestone Member:	
Dolomite, gray and tan; minor amount of brown shale, iron sulfides, and limonite	179–180

Property owner. Bonjour.
Location. SW¼SW¼SW¼ sec. 27, T. 3 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 21–23, 1955.
Collar altitude. 1049.5 ft.
Total depth cased. 133 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Cherty unit:	
Dolomite, tan; gray and white chert; black specks in rock; minor amounts of calcite and limonite; minor iron sulfides in lower 10 ft	5–85
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, limestone in lower part, gray; black specks in rock; minor amounts of calcite and iron sulfides	85–102½
Guttenberg Limestone Member:	
Limestone, gray and tan, brown and green shale; white chert; black streaks in rock; minor amounts of calcite, iron sulfides and limonite	102½–115
Platteville Formation:	
Quimbys Mill Member:	
Limestone at top, calcareous dolomite, tan and pale-brownish-gray; green shale; minor amount of calcite; iron sulfides abundant in lower 5 ft	115–129
McGregor Limestone Member:	
Dolomite, brownish-gray; green shale; black streaks in rock; minor amounts of calcite and iron sulfides	129–133

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Property owner. Hillery.
Location: NW¼NE¼SW¼ sec. 12, T. 2 N., R 2 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 28–30, 1955.
Collar altitude. 1036.7 ft.
Total depth. 186 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–15
Galena Dolomite:	
Noncherty unit:	
Dolomite, tan; minor amounts of calcite, iron sulfides and limonite	15–30
Cherty unit:	
Dolomite, tan and gray-brown; gray and white chert; minor amounts of calcite, iron sulfides, and limonite; traces of sphalerite and galena as noted in the following table	30–138
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, brownish-gray; some yellow and green shale; chert, possibly from overlying beds; minor calcite and iron sulfides; traces of sphalerite as noted in the following table	138–157½
Guttenberg Limestone Member:	
Dolomite above, calcareous dolomite below, tan; minor amounts of calcite and iron sulfides; traces of sphalerite as noted in the following table	157½–169
Platteville Formation:	
Quimbys Mill Member:	
Calcareous dolomite at top, dolomite, tan; some green shale; minor amounts of calcite and iron sulfides; traces of sphalerite as noted in the following table	169–182½
McGregor Limestone Member:	
Limestone, tan; traces of iron sulfides	182½–186

Lead and zinc mineral content

[Carlson (1956, p. 61) reported traces of sphalerite in cuttings from most of the intervals listed]

Depth (feet)	Galena	Depth (feet)	Galena
50–60	--------	145–150	--------
60–70	Trace	152½–157½	--------
80–95	--------	162½–170	--------
125–130	Trace	177½–182½	--------
130–142½	--------		

NOTE.—Sphalerite in trace amounts found at all depths listed.

Property owner. McKillip.
Location. SE¼SE¼NW¼ sec. 10, T. 3 N., R. 3 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 25–26, 1955.
Collar altitude. 1030.7 ft.
Total depth. 117 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Cherty unit:	
Dolomite, tan; gray and white chert; green shale partings; traces of iron sulfides	5–74
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, tan in upper part, gray in lower; black flakes in rock; traces of green shale	74–93
Guttenberg Limestone Member:	
Calcareous dolomite, tan; minor amount of brown shale	93–107
Platteville Formation:	
Quimbys Mill Member:	
Calcareous dolomite, tan; trace of chert, possibly from overlying beds; trace of brown shale at base	107–115½
McGregor Limestone Member:	
Calcareous dolomite, gray; mottled rock; green streaks	115½–117

Property owner. McWilliams.
Location. NW¼NW¼NW¼ sec. 22, T. 2 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 23–24, 1955.
Collar altitude. 1002 ft.
Total depth. 158 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–20
Galena Dolomite:	
Cherty unit:	
Dolomite, tan; gray and white chert; brown and green shale partings; traces of calcite, iron sulfides, and limonite; traces of sphalerite at 45–50 ft and 80–90 ft intervals	20–110
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray; gray and white chert, possibly from overlying beds; black carbonaceous material; minor amounts of green shale, calcite, iron sulfides, and limonite; traces of sphalerite at 127½–130 ft interval	110–130
Guttenberg Limestone Member:	
Dolomite, brownish gray; chert, possibly from overlying beds; minor amount of green shale; traces of disseminated grains that resemble sphalerite; minor amounts of calcite and iron sulfides	130–142½

	Depth (feet)
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, tan in upper part, brown below; chert possibly from overlying beds; minor amounts of green shale, calcite, and iron sulfides	142½–157
McGregor Limestone Member:	
Dolomite, gray; minor amounts of green shale and calcite	157–158

Property owner. Merriam.
Location. SE¼SW¼SE¼ sec. 16, T. 2 N., R. 3 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Dec. 1–2, 1955.
Collar altitude. 961.8 ft.
Total depth. 145 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Cherty unit:	
Dolomite, tan, iron-stained; gray and white chert; minor amounts of green shale, calcite, and iron sulfides	5–105
Decorah Formation:	
Ion Dolomite Member:	
Dolomite and calcareous dolomite, tan, greenish-brown, and gray; black flecks in rock; green shale partings; minor amounts of calcite, iron sulfides and limonite; traces of quartz sand	105–125
Guttenberg Limestone Member:	
Calcareous dolomite in upper part, dolomite below, dark-brown; minor brown shale, calcite, and iron sulfides; traces of sphalerite in lower part	125–130
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, brown, gray near base; white to gray chert; minor amounts of green shale, calcite, and iron sulfides; traces of sphalerite near top and bottom	130–144
McGregor Limestone Member:	
Dolomite, tan; white to gray chert; minor amounts of iron sulfides	144–145

Property owner. L. Mill.
Location. SE¼SW¼NW¼ sec. 17, T. 2 N., R. 3 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Dated drilled. Dec. 2–3, 1955.
Collar altitude. 994.5 ft.
Total depth. 176 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5

	Depth (feet)
Galena Dolomite:	
Noncherty unit:	
Dolomite, yellow-tan; minor amounts of calcite and limonite	5–30
Cherty unit:	
Dolomite, tan; white to gray chert; black flecks and iron-stained rock; minor amounts of calcite and limonite; galena as noted in the following table	30–135
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray, with black specks; minor amounts of green shale, calcite, and iron sulfides; chert, possibly from overlying beds	135–153
Guttenberg Limestone Member:	
Dolomite, calcareous at top, light- to dark-brown; brown shale; minor amounts of chert, calcite, iron sulfides, and limonite; traces of galena and sphalerite	153–162
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, brown; chert, possibly from overlying beds; minor amounts of calcite and iron sulfides; traces of quartz sand	162–172½
McGregor Limestone Member:	
Dolomite, brown; minor amounts of calcite and iron sulfides; traces of sphalerite	172½–176

Lead and zinc mineral content

[Carlson (1956, p. 65) noted galena and sphalerite in most of the above intervals and in a few others in between]

Depth (feet)	*Galena*	*Sphalerite*
110–130	Trace	---------
155–157½	--------	Trace
157½–160	Trace	Trace
170–172½	Trace	---------
172½–176	--------	Trace

Property owner. Noble and Shaw.
Location: SW¼SE¼NW¼ sec. 18, T. 2 N., R. 3 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Dec. 3–5, 1955.
Collar altitude. 1002 ft.
Total depth. 165 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Noncherty unit:	
Dolomite, yellow-tan	5–10
Cherty unit:	
Dolomite, calcareous dolomite near bottom, tan; gray and white chert; black specks in rock; minor amounts of brown shale and limonite; trace of galena at 110–115 ft. interval	10–117

	Depth (feet)
Decorah Formation:	
Ion Dolomite Member:	
Calcareous dolomite, tan and gray; chert, possibly from overlying beds; minor amounts of calcite, iron sulfides, and limonite; black specks in rock	117–135
Guttenberg Limestone Member:	
Dolomitic limestone, calcareous dolomite at top, tan; brown shale; minor amount of iron sulfides; chert, possibly from overlying beds	135–149
Platteville Formation:	
Quimbys Mill Member:	
Dolomitic limestone, tan; greenish-gray chert; iron stains; minor amounts of brown shale and iron sulfides; trace of sphalerite near bottom	149–162
McGregor Limestone Member:	
Dolomitic limestone, grayish-brown; traces of iron sulfides	162–165

Property owner. Olson.
Location. NW¼NE¼SE¼ sec. 10, T. 2 N., R. 2 E.
Contractor. J. D. Judd.
Drill operator. W. Pahnke.
Date drilled. Nov. 25–28, 1955.
Collar altitude. 1018.9 ft.
Total depth. 188 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Noncherty unit:	
Dolomite, tan; minor amounts of brown shale, calcite, iron sulfides, and limonite	5–30
Cherty unit:	
Dolomite, buff near top, grayish brown to brown in most cuttings; gray and white chert; minor amounts of buff and yellow shale, calcite, iron sulfides, and limonite; iron stains	30–140
Decorah Formation:	
Ion Dolomite Member:	
Dolomite and calcareous dolomite in upper part, dolomitic limestone and dolomite in lower, gray; chert, possibly from overlying beds; minor amounts of yellow and green shale, calcite, and iron sulfides; black material in thin flakes; iron stain	140–157½
Guttenberg Limestone Member:	
Limestone, dolomitic limestone at top, brown; minor brown and green shale, calcite, and iron sulfides; iron stains; black material in thin flakes	157½–170
Platteville Formation:	
Quimbys Mill Member:	
Dolomite in upper part, calcareous dolomite below, brown; minor amounts of brown and green shale, calcite and iron sulfides	170–184

	Depth (feet)
Platteville Formation—Continued	
McGregor Limestone Member:	
Limestone, gray; chert, possibly from overlying beds; minor amounts of green shale and calcite; iron stains	184–188

Property owner. Ross.
Location. NE¼NW¼SW¼ sec. 15, T. 3 N., R. 3 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 28–30, 1955.
Collar altitude. 1043 ft.
Total depth. 149 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Cherty unit:	
Dolomite, buff; gray to white chert; minor amounts of gray shale, calcite, and limonite	5–107½
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, gray; green shale partings; black specks in rock; traces of iron sulfides	107½–123
Guttenberg Limestone Member:	
Dolomitic limestone, light-brown; traces of galena and sphalerite at 132½–135 ft interval	123–135
Platteville Formation:	
Quimbys Mill Member:	
Calcareous dolomite, some dolomitic limestone at top, light-brown; traces of iron sulfides	135–148
McGregor Limestone Member:	
Dolomitic limestone, gray and tan; traces of iron sulfides; dark specks in rock	148–149

Property owner. Sauer.
Location. NE¼NE¼SE¼ sec. 7, T. 2 N., R. 3 E.
Contractor. J. D. Judd.
Drill operator. C. Komprood.
Date drilled. Nov. 25–26, 1955.
Collar altitude. 1015.9 ft.
Total depth. 177.5 ft.

	Depth (feet)
Surficial material:	
Soil, loess, and residuum	0–5
Galena Dolomite:	
Noncherty unit:	
Dolomite, tan; black specks in rock; minor amounts of limonite	5–30
Cherty unit:	
Dolomite, tan; black specks in rock; gray and white chert; iron sulfides, galena, and sphalerite abundant in lower part; minor amount of limonite	30–137½

	Depth (feet)
Decorah Formation:	
Ion Dolomite Member:	
Dolomite, tan and greenish-gray; chert, possibly from overlying beds; minor amounts of green, brown, and white shale; iron sulfides, galena, and pyrite in upper part, as noted in following table; minor amount of iron sulfide and sphalerite in lower part; some limonite	137½–153
Guttenberg Limestone Member:	
Dolomite, gray and tan; minor amounts of iron sulfides; iron stains	153–157½
Platteville Formation:	
Quimbys Mill Member:	
Dolomite, tan; chert, possibly from overlying bed; black specks in rock; minor amounts of iron sulfides	157½–167
McGregor Limestone Member:	
Dolomite, gray and tan; black specks in rock; minor amounts of yellowish-brown shale, iron sulfides and limonite	167–177½

Lead and zinc mineral content

Depth (feet)	Galena	Sphalerite
110–115	Minor	Minor
120–142½	Minor	Minor
147½–150	--------	Trace

Lead and zinc content, in percent

[Determined by Carlson (1956, p. 70). Figures are assays; other notations are visual estimates. Assay figures are of original cuttings and are considered to be representative]

Depth (feet)	Zinc	Lead	Depth (feet)	Zinc	Lead
110–115	0.50	2.30	132½–135	3.70	0.45
115–120	3.65	.60	135–137½	------	Shine
120–122½	1.30	.40	137½–140	Trace	Trace
122½–125	.50	.35	140–147½	------	Trace
125–127½	5.2	.40	150–157½	------	Trace
127½–130	1.70	.35	157½–165	------	Trace
130–132½	3.30	.40			

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