WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

E. A. BIRGE, Ph. D., Sc. D., Director

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REPORT

ON THE

LEAD AND ZINC DEPOSITS

OF

WISCONSIN

WITH AN ATLAS OF DETAILED MAPS

BY

ULYSSES SHERMAN GRANT

Professor of Geology in Northwestern University

MADISON, WIS.

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PREFACE.

In the summer of 1902 the writer made a preliminary examination of the lead and zinc deposits of southwestern Wisconsin, and the results of this work were published as Bulletin IX of this survey. In that report a suggestion was made as to the kind of geological work which it would be wise to do in this district, and the present report presents the results of part of this suggested work. These results are the detailed maps of most of the important areas in the lead and zinc region. It was thought at the time that the preliminary work was done that such detailed maps would be of great assistance to those engaged in mining in the district and would also aid in the solution of problems concerning the origin and relation of the ores. The use of these maps to the mining men of the district can be determined only by them, and the maps are given to them with the hope that they will be found to be of much use. As to the results brought out by these maps in regard to the relations and origin of the ores, it should be stated that these results are extremely satisfactory, in that they show conclusively that a large portion of the ore deposits are confined to the structural basins, or small synclines. This idea was first suggested by Chamberlin in one of the early reports of the Wisconsin Geological Survey, but was not worked out in detail.

The United States Geological Survey has undertaken a far-reaching investigation of all the lead and zinc deposits in the Mississippi valley. An integral part of this work is a discussion of the lead and zinc deposits of the Upper Mississippi region, i. e. those included in the southwestern part of Wisconsin, the northwestern part of Illinois and adjoining portions of Iowa. As the Wisconsin district includes only a part, although a large part, of this field, it was soon seen that a general discussion of the ore deposits of this particular district could be written more easily from the standpoint of the United States Survey than from the standpoint of any individual state, and so this part of the work has been, under an informal scheme of co-operation between the Federal Survey and the Wisconsin Survey, turned over to the former organization. This report is to be prepared by Dr. H. Foster Bain.

The Potosi map (plates XVII and XVIII of this Bulletin) is furnished by the U. S. Geological Survey.

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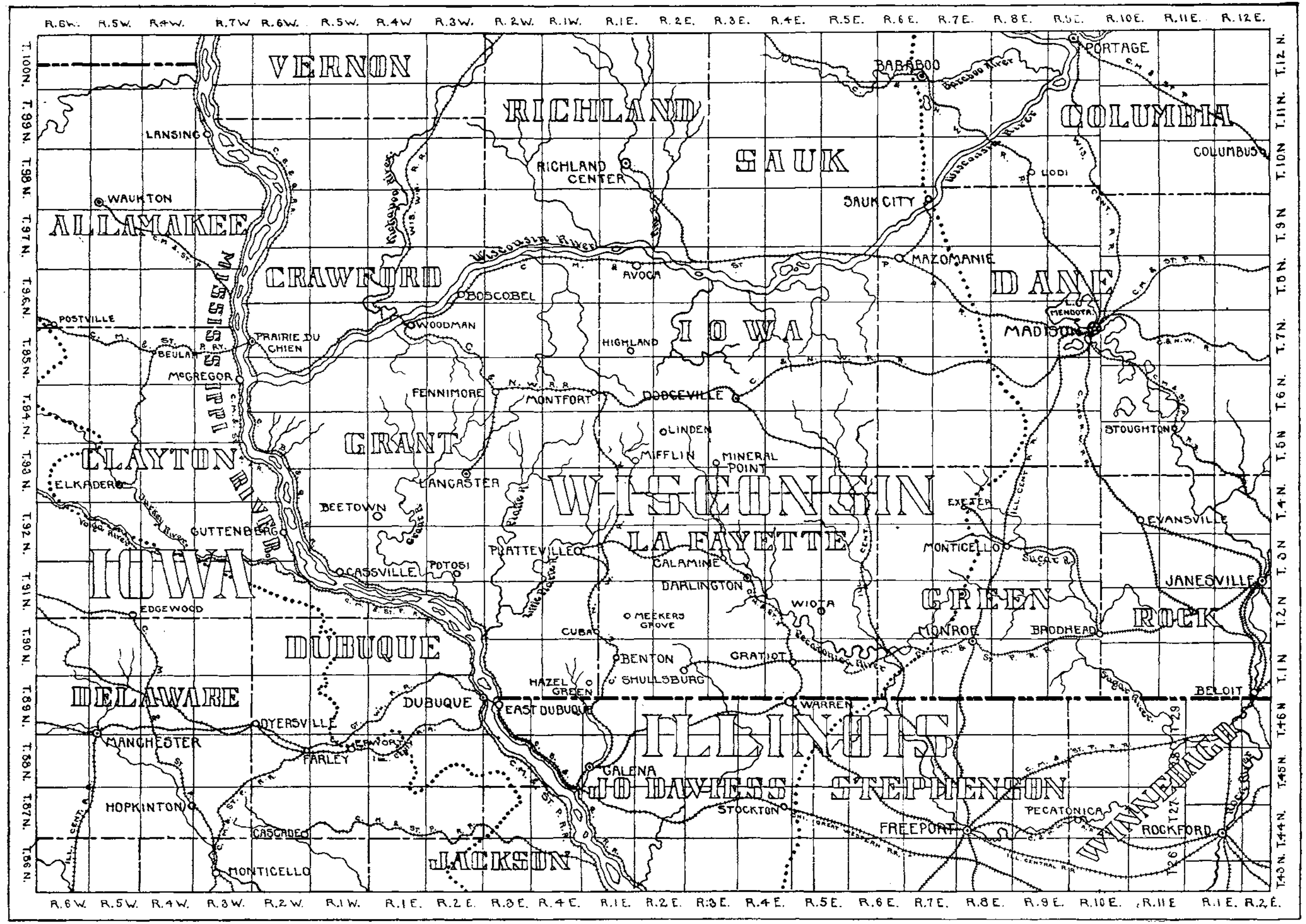
ILLUSTRATIONS.



General map of southwestern Wisconsin and parts of adjoining states.
The dotted line is the boundary of the driftless area.

REPORT, WITH DETAILED MAPS, ON THE LEAD AND ZINC DEPOSITS OF WISCONSIN.

CHAPTER I.

INTRODUCTION.

HISTORICAL.

The lead and zinc mines of the Mississippi valley may be grouped into three divisions:[1] (1) Those of the Ozark region; (2) those of the Upper Mississippi valley; and (3) those of outlying districts including (a) southwestern Arkansas and (b) an area in Kentucky and southern Illinois. The Upper Mississippi Valley district comprises: (1) Grant, Lafayette, and Iowa counties, Wisconsin, (2) Jo Daviess county, Illinois; and (3) Dubuque county, Iowa. From certain other counties adjoining these five, small amounts of ore have been produced, and the main production has come from the three Wisconsin counties mentioned. The lead and zinc deposits of these Wisconsin counties form the subject of this report.[2]

In the Upper Mississippi valley lead seems to have been discovered by Nicholas Perrott about 1692.[3] This metal was also noted by Le Sueur in 1700 or 1701, and by John Carver in 1766. The first mining in the district was done on the

[1] C. R. Van Hise and H. F. Bain: "Lead and zinc-deposits of the Mississippi valley, U. S. A.," Trans. Inst. Mining Engineers (England), vol. xxiii, p. 378, 1902.

[2] See frontispiece, plate XIX.

[3] Arthur Winslow: "Lead and zinc deposits," Mo. Geol. Survey, vol. vi, p. 145, 1894.

site of the present city of Dubuque in 1788 by Julien Dubuque, who obtained from the Indians land on which lead had been discovered a few years previously. After Dubuque's death in 1810, little was done until after 1820, and before 1830 mining had become quite general in the vicinity of Dubuque and Galena and also in southwestern Wisconsin. From this time down to the present day mining has been carried on continuously in the Upper Mississippi Valley district, with certain periods in which the district figured prominently as a producer of lead and zinc.

The early work, and in fact that for years afterward, was devoted entirely to the mining of lead, the zinc ores being unrecognized or, when recognized, regarded as of little value. It was not until some forty years ago that zinc ores were mined in this region, and the amount of these ores produced rapidly increased until the district became more important as a source of zinc than of lead. Of late years, due to a number of causes, the activity of the district has decreased but the past four years have seen a marked revival in mining interest,—a revival which promises well to continue.

The ores mined are galena or "mineral" (sulphide of lead), smithsonite or "dry-bone" (carbonate of zinc), and sphalerite or "black-jack" (sulphide of zinc). In relative amount of production sphalerite is the most important, galena of less importance, and smithsonite less still. The future will undoubtedly witness a continued increase in the importance of sphalerite.

PREVIOUS REPORTS AND MAPS.

In addition to some earlier reports by Daniels, Percival and Whitney,[1] the former Geological Survey of Wisconsin issued two important papers dealing with the lead and zinc deposits. The earlier of these was by Moses Strong,[2] and the later by

[1] A list of these reports will be found on a later page.

[2] "Geology and topography of the lead region," Geol. of Wis., vol. ii, pp. 643–752. 1877.

the Chief Geologist, T. C. Chamberlin.[1] The report by Chamberlin is a very complete and exhaustive account of the district under consideration,—by far the best account yet written. The Survey also issued an atlas of maps, included in which are a number relating directly to the lead and zinc region. These are (1) geological maps of the counties, (2) geological and topographical maps, scale about one inch to one mile, of the important ore-producing districts, and (3) large scale crevice maps of the different districts. The latter show in detail a large number of the crevices from which lead, or lead and zinc, ores have been obtained.[2]

Three of the sheets of the Topographic Atlas of the United States, published by the United States Geological Survey, include a large part of the territory in the Wisconsin lead and zinc district. These are the Elkader, Lancaster, and Mineral Point sheets; the scale of these is one-half inch to the mile and the contour interval is twenty feet.[3]

Bibliography.

Below will be found a partial list of the papers dealing with the Upper Mississippi Valley lead and zinc district. This list does not contain papers which treat solely of the paleontology and the Pleistocene geology.

1842

J. T. HODGE: "On the Wisconsin and Missouri lead region," Amer. Jour. Sci., ser. i, vol. xliii, pp. 35-72.

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[1] "The ore deposits of southwestern Wisconsin," Ibid., vol. iv. pp. 365-571, 1882.

[2] The reports and atlas of the former Geological Survey are unfortunately out of print, but they can be obtained at times from dealers in second-hand books. The atlas plates of importance in the lead and zinc districts are: V to IX (sometimes numbered III to VII), XIII, XVI, XXXI to XL. The atlas plates of Vol. II, containing the detailed maps of the lead and zinc district, may still be obtained from the Superintendent of Public Property, Capitol, Madison. The price of this atlas is $5.

[3] These sheets may be obtained from the Director of the U. S. Geological Survey, Washington, D. C. The price is five cents each.

1854

EDWARD DANIELS: "Some features of the lead district of Wisconsin," Proc. Boston Soc, Nat. Hist., vol. v, pp. 387–389.

EDWARD DANIELS: First Ann. Rept. Geol. Survey of Wis., pp. 7–66.

J. D. WHITNEY: "Metallic wealth of the United States," pp. 403–417.

1855

J. G. PERCIVAL: Ann. Rept. Geol. Survey of Wis., pp. 7–101.

1858

J. D. WHITNEY: Geol. of Iowa, vol. i, pt. i, pp. 422–471.

1862

J. D. WHITNEY: "Report on the lead region of Wisconsin," Geol. Survey of Wis., vol. i, pp. 73–420.

1866

J. D. WHITNEY: "Geology of the lead region," Geol. Survey of Ill., vol. i, pp. 153–207. Also in Economical Geol. of Ill., vol. i, pp. 118–162, 1882.

1870

C. A. WHITE: "Lead and zinc," Geol. Survey of Iowa, vol. ii, pp. 339–342.

1873

JAMES SHAW: "Geology of northwestern Illinois," Geol. Survey of Ill., vol. v, pp. 1–24. Also in Economical Geol. of Ill., vol. iii, pp. 1–20, 1882.

JAMES SHAW: "Geology of Jo Daviess county," Geol. Survey of Ill., vol. v, pp. 25–56. Also in Economical Geol. of Ill., vol. iii, pp. 20–54, 1882.

1877

MOSES STRONG: "Geology and topography of the lead region," Geol. of Wis., vol. ii, pp. 643–752.

1882

T. C. CHAMBERLIN: "The ore deposits of southwestern Wisconsin," Geol. of Wis., vol. iv, pp, 365–571.

1883

Moses Strong: "Lead and zinc ores," Geol. of Wis., vol. i, pp. 637-655.

1893

W. P. Blake: "The progress of geological surveys in the state of Wisconsin—a review and bibliography," Trans. Wis. Acad. Sci., Arts and Letters, vol. ix, pp. 225-231.

Arthur Winslow: "Notes on the lead and zinc deposits of the Mississippi valley and the origin of the ores," Jour. of Geol., vol. i, pp. 612-619.

1894

W. P. Blake: "Wisconsin lead and zinc deposits," Bull. Geol. Soc. of Amer., vol. v, pp. 25-32.

W. P. Blake. "The mineral deposits of southwestern Wisconsin, Trans. Amer. Inst. Mining Eng., vol., xxii, pp. 558-568. Also in Amer. Geol., vol. xii, pp. 237-248.

W. P. Blake: "Discussion on lead and zinc deposits of the Mississippi valley," Trans. Amer. Inst. Mining Eng., vol. xxii, pp. 621-634.

W. P. Blake: "Discussion on genesis of ore deposits," Trans. Amer. Inst. Mining Eng., vol. xxxiii, p. 587.

T. C. Chamberlin: "Discussion on Wisconsin lead and zinc deposits," Bull. Geol. Soc. Amer., vol. v, p. 32.

W. P. Jenney: "Lead and zinc deposits of the Mississippi valley," Trans. Amer. Inst. Mining Eng., vol. xxii, pp. 171-225, 642-646; especially pp. 208-212.

A. G. Leonard: "Occurrence of zinc in northeastern Iowa," Proc. Iowa Acad. Sci., vol. i, pt. iv, pp. 48-52.

Arthur Winslow: "Lead and zinc deposits," Mo. Geol. Survey, vol. vi and vii; especially vol. vi, pp. 135-149.

Arthur Winslow: "Discussion of lead and zinc deposits of the Mississippi valley," Trans. Amer. Inst. Mining Eng., vol. xxii, pp. 634-636.

1895

W. H. Hobbs: "A contribution to the mineralogy of Wisconsin," Bull. Univ. of Wis., sci. ser., vol. i, pp. 109-156. Also in Zeitsch. f. Kryst., vol. xxv, pp. 257-275.

A. G. Leonard: "Origin of the Iowa lead and zinc deposits," Amer. Geol., vol. xvi, pp. 288-294.

A. G. Leonard: "Lansing lead mines," Proc. Iowa Acad. Sci., vol. ii, pp. 36-38.

1896

A. G. LEONARD: "Lead and zinc deposits of Iowa," Eng. and Mining Jour., vol. lxi, p. 614.

A. G. LEONARD: "Lead and zinc. A description of the mines of Iowa in the Upper Mississippi region." Colliery Eng., vol. xvii, pp. 121–122.

1897

A. G. LEONARD: "Lead and zinc deposits of Iowa," Iowa Geol. Survey, vol. vi, pp. 9–66.

1900

SAMUEL CALVIN and H. F. BAIN: "Geology of Dubuque county," Iowa Geol. Survey, vol. x, pp. 379–622; especially pp. 480–597.

G. D. HUBBARD: "The Blue Mound quartzite," Amer. Geol. vol. xxvi, pp. 163–168.

1901

S. H. BALL and A. F. SMITH: "The geology and ore deposition of the Benton district, Lafayette county, Wisconsin," Thesis, Univ. of Wis. Not published, but in University library.

C. R. VAN HISE. "Some principles controlling the deposition of ores," Trans. Amer. Inst. Mining Eng., vol. xxx, pp. 27–177; especially pp. 102-109.

1902

H. F. BAIN: "Preliminary report on the lead and zinc deposits of the Ozark region, with an introduction by C. R. Van Hise, and chapters on the physiography and geology by G. I. Adams," 22nd Ann. Rept. U. S. Geol. Survey, pt. ii, pp. 23–227.

C. R. VAN HISE and H. F. BAIN: "Lead and zinc deposits of the Mississippi valley, U. S. A.," Trans. Inst. Mining Engineers, (England), vol. xxiii, pp. 376–434; especially pp. 409–420.

1903.

U. S. GRANT: "Preliminary report on the lead and zinc deposits of southwestern Wisconsin," Wis. Geol. and Nat. Hist. Survey, Bull. ix, viii, and 103 pp.

FRANK NICHOLSON: "The Wisconsin zinc fields," Engineering and Mining Journal, vol. 76, pp. 847–849.

1904

H. F. BAIN. "Lead and zinc deposits of Illinois," U. S. Geol. Survey, Bull. 225, pp. 202-207.

1905

H. F. BAIN: "Zinc and lead deposits of northwestern Illinois," U, S. Geol. Survey, Bull. 246, 56 pp.

U. S. GRANT: "Zinc and lead deposits of southwestern Wisconsin," U. S. Geol. Survey, Bull. 260, pp. 304-310.

E. E. ELLIS: "Zinc and lead mines near Dodgeville, Wis.," U. S. Geol. Survey, Bull. 260, pp. 311-315.

ACKNOWLEDGMENTS.

The writer wishes to acknowledge his indebtedness to a number of reports already published on this district, and especially to that published by Chamberlin. It seldom happens that a worker in a district of this sort has the help of so many detailed earlier reports, and this general acknowledgment of indebtedness to these reports is made at this place, for it is practically impossible to refer to the earliest source of many of the statements made in this volume.

To the Director of the Survey, Dr. E. A. Birge, and to the President of the University of Wisconsin, Dr. C. R. Van Hise, thanks are due for many kindnesses. The work was carried on under the general supervision of the latter and the assistance and helpful suggestions derived from him were a very important aid. During the last two years the writer has been constantly in consultation with Dr. H. Foster Bain, who has charge of the general investigation of the lead and zinc deposits of the Mississippi valley for the United States Geological Survey. It has been possible to visit with Dr. Bain many of the critical localities and to discuss fully with him facts of importance. The writer's special thanks are due to him for this help and for many kindly criticisms.

In the field work of the last two years, in which the detailed maps herein presented were made, the writer was ably as-

sisted by a number of men, mostly students in Northwestern University, and to these his thanks are due for efficient services. The list of men who took part in this work is included in the chapter devoted to the detailed maps.

CHAPTER II.

PHYSICAL FEATURES.

TOPOGRAPHY.

The surface of this district (including Grant, Lafayette, and Iowa counties) is fairly uniform in its general features throughout these three counties, with the exception of the immediate valley of the Wisconsin on the north and that of the Mississippi on the west. Away from the vicinity of these two large valleys the topographic features may be grouped under three heads: (1) the mounds, (2) the uplands, and (3) the valleys.

The mounds.

The important mounds are the Blue, Platte, and Sinsinawa. These are roughly circular elevations of small extent, usually with flat tops, which rise some 200 feet above the surrounding country. These mounds closely resemble others of the same character which are found to the east of the lead and zinc district in Wisconsin, and also to the south in Illinois. In general the mounds are capped by Niagara limestone, which has acted as a protection to the underlying softer Maquoketa (Hudson River) shale. This limestone frequently contains large amounts of flints, and at the west of the Blue mounds the upper rock layer is of a flinty or quartz-like nature.[1] These caps of Nia-

[1] Moses Strong: "Geology and topography of the lead region," Geol. of Wis.. vol. ii, p. 661, 1877.

G. D. Hubbard: "The Blue Mound quartzite," Amer. Geol., vol. xxvi, pp. 163-168, 1900.

gara limestone are all that is now left of a layer of this formation which has been removed by erosion from over a large part, if not from the whole of the district.

The uplands.

The uplands consist of rather level-topped elevations or ridges which separate the valleys. In fact the whole upland surface may be considered as a gently undulating plain which slopes gradually to the southwest. Above the plain rise the scattered mounds and in it have been cut the numerous valleys. The general features of this plain may be seen from almost any of the larger stream divides of the region. A very good view of the topographic features of the district can be had from the Chicago and North-Western railroad which traverses the plain from Blue Mounds to Fennimore along what is known as the Military ridge; also along the Lancaster branch of this railroad and along the Galena branch north of Cuba City.

The valleys.

Each valley, as one descends it, is seen to consist first of a sag with gently sloping convex sides which merge gradually into the general surface of the upland plain. Lower down the valley floor has a steeper slope and the sides also are steeper, but still of gradual slope. Still farther down the narrow valley widens out, has a less marked slope and acquires a rather wide flat bottom. These flat-bottomed valleys are characteristic of all the larger streams and also of many of the smaller ones. At times the valley is bounded by steep slopes or cliffs, and these cliffs are commonly of Trenton limestone. Sometimes they are of Galena limestone, and much less commonly of St. Peter sandstone. A good example of these sandstone cliffs may be seen just west of Mineral Point, where the St. Peter is more consolidated than usual. The bottoms of the valleys are from 100 to 400 feet, in places more, below the general level of the district, and continuous slopes of 200 feet in altitude are common along the valley sides.

The peneplain.

The present topography of the district is due to sub-aerial erosion acting on approximately horizontal strata. The general history of the erosion may be summed up as follows: After the deposition of the Niagara limestone there is no absolute proof that other and later formations were deposited. If such were deposited they have been entirely removed by erosion, and of such earlier erosion we have no certain records. There is, however, one period of erosion which has left marked records, and this is the period in which the land stood in a uniform position long enough for streams to reduce the whole district to a nearly level region or peneplain. This peneplain is now represented by the level uplands already described. The only parts of the district which were not reduced to the general level are the mounds, which rise as monadnocks above the peneplain. The date of the formation of this peneplain is not certainly known, but it may be of Tertiary age, and if so is thus later than the possibly Cretaceous peneplain which is exhibited farther north in central Wisconsin.[1] After the formation of this peneplain the land was elevated, and the erosion again began its work cutting into the surface and forming the present valleys. This elevation took place before Glacial time. Since the revival of erosion a large portion of the district has been lowered, and the region is now in a stage where the streams are not so rapidly deepening their valleys as the valleys are widening. The district has passed through the stage of most marked relief and has entered on the stage where future erosion will tend to subdue rather than to accentuate the present differences of topography. The district may thus be said to be intermediate between maturity and old age, although much nearer the former than the latter.

[1] C. R. Van Hise: "A central Wisconsin baselevel," Science, new ser., vol. iv, pp. 57–59, 1896. "A northern Michigan baselevel," Ibid., pp. 217–220.

Amount of erosion.

As an approximate estimate of material which has been removed from the district since the formation of the peneplain and the subsequent re-elevation of the land it may be said that the bulk of the hills, or the uplands between the streams, equals approximately the cubic contents of the valleys. In other words, if the district were to be leveled off the resulting surface would be about half way between the bottoms of the main valleys and the uplands (not the hills formed by the mounds). If the main valleys average 300 to 400 feet below the peneplain surface, we have a sheet of material, 150 to 200 feet in thickness and extending over the whole district, which has been removed by erosion since the elevation of the land subsequent to the formation of the peneplain. This period of elevation dates late in geological time, although antedating the Glacial period. That erosion may have removed a greater thickness than this is probable from a consideration of the soils.[1]

THE DRIFTLESS AREA.[2]

Covering the northern states is a layer of unconsolidated material known as the glacial drift, or simply as the drift. This varies in thickness from nothing up to a few hundred feet and is composed of sometimes stratified and sometimes unstratified mixtures of clay, rock flour, sand, gravel, and boulders of various sizes. Beneath the drift the solid rock is commonly scratched, smoothed or polished, and there is a sharp line of demarcation between this rock and the overlying material. The surface of the drift is now rough and hilly, now undulating, and now smooth. There is a lack of system in the arrangement of the topographic features and the streams, which wander about often apparently aimlessly. Moreover, none but the larger streams

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[1] T. C. Chamberlin and R. D. Salisbury: "Preliminary paper on the driftless area of the Upper Mississippi valley," 6th Ann. Rept. U. S. Geol. Survey, p. 257, 1885.

[2] For a detailed account of the driftless area consult the paper by T. C. Chamberlin and R. D. Salisbury just cited. The area is enclosed by a dotted line on plate XIX.

have well defined valleys, and there are numerous swamps and lakes. The district is topographically young,—very young, at least away from the southern edge of the drift. These features are due to a great continental glacier which came from the north and extended as far south as the Ohio and Missouri rivers.

Lying well north of the southern limit of this drift-covered area, and completely surrounded by it, is a district which has no drift and which possesses features markedly different from those just mentioned. This is known as the driftless area.[1] There is no drift here; the underlying rock is not scratched or smoothed and it is not sharply marked off from the unconsolidated material above; the topographic features are systematized, and even the smaller streams have well defined valleys and comparatively straight courses; there are no swamps, except along river bottoms, and no lakes; the district is topographically mature. This driftless area, comprising some 10,000 square miles in the Upper Mississippi valley, lies mostly in southwestern Wisconsin but enters adjacent portions of Minnesota, Iowa, and Illinois.[1] Grant, Lafayette, and Iowa counties, Wisconsin, lie wholly within the driftless area.

The reason, or reasons, why this district, which is not of higher altitude than the surrounding region,—even lower than much of it,—escaped glaciation while the surrounding country was covered by ice, has been a subject for speculation and investigation. It is generally conceded that the lack of glaciation is chiefly due to the fact that the ice, coming from the north and northeast, had its main currents deflected by the large valleys of lake Superior and lake Michigan and by the high lands in Wisconsin to the north and northeast of the driftless area. The possibility of local glacial deposits in this district has been noted,[2] and the fact that the district was never covered by mov-

[1] See plate XIX.

[2] G. H. Squier: "Studies in the driftless area of Wisconsin," Jour. of Geol., vol. v, pp. 825–836, 1897. Ibid., vol. vi, pp. 182–192, 1898. Ibid., vol. vii, pp. 79–82, 1899.

F. W. Sardeson: "On glacial deposits in the driftless area," Amer. Geol., vol. xx, pp. 392–403, 1897.

ing ice, while the entire surrounding country was thus deeply covered, is one of the most peculiar and striking phenomena in the whole range of glacial history.

SOILS.

Unlike the soils of the northern states in general, which are composed of material which has no immediate relationship to the underlying rock, the soils of the driftless area have the most intimate connection with subjacent rock. In fact these soils are derived by a process of decay from the country rock, and for this reason the character of the soil in any particular part of the driftless area is conditioned by the character of the underlying rock. The soil in a limestone area will thus differ widely from the soil in an area underlain by sandstone. In the latter the soil is composed largely of silica, in the former the soil does not closely resemble the original limestone but is mainly clay derived from this limestone. In other words, the limestone soils do not have the composition of the original rock, but are made up of the non-essential constituents, or what might be termed the impurities, of that rock.

Composition of the soils.

The main limestone of the district,—the Galena,—consists essentially of a mixture of calcium carbonate and magnesium carbonate, together with certain impurities. These impurities are chiefly three substances: (1) quartz, (2) oxide (and probably carbonate) of iron, (3) clay. When the limestone is exposed to the agents of weathering the two carbonates just mentioned are dissolved and carried away by percolating waters, while the impurities of the rock in general remain. The chemical composition and the relative percentages of the components of the rock and those of the soils thus differ materially. Chemically the soils contain a very large percentage of silica which comes, first, from the flint, which is abundant in the limestone, and, second, from the clay which is a hydrous aluminous silicate.

No series of analyses of the Galena limestone are available.

The accompanying analysis[1] of selected fresh samples of this rock shows nearly 96 per cent. of soluble material (calcium

Analysis of Galena Limestone.

Carbonate of lime, $CaCO_3$	54.33
Carbonate of magnesia, $MgCO_3$	41.56
Sesquioxide of iron, Fe_2O_3	.90
Alumina, Al_2O_3	.99
Silica, SiO_2	2.10
Total	99.88

carbonate and magnesium carbonate), which is carried away in the complete weathering of the rock to soil, and only 4 per cent. of impurities, which in the main remain in the soil after the removal of the above carbonates. The samples from which this analysis was made contained no flint nodules, which are so abundant in some parts of the limestone, and no noticeable clayey laminæ. So the average of the whole bulk of the Galena limestone would contain considerably more silica and alumina than is shown by this analysis. There are no collected data by which an accurate estimate of the percentages of these substances, and other impurities, in the limestone could be made, but a rough estimate will show approximately 10 per cent. of impurities and 90 per cent. of the carbonates. In other words, from the weathering of a thickness of 100 feet of the limestone a thickness of approximately 10 feet of soil would result. Actually this thickness of soil would be greater than just stated, for the soil is less compact than the limestone and contains other material (such as water and organic matter) than that which was derived from the limestone.

The accompanying analyses of clays, known as residual clays because they are formed from the underlying rock, from this district will give a good idea of their general composition.

[1] Made by Professor W. W. Daniels of the University of Wisconsin.

Analyses of residual clays from the driftless area.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
SiO_2	71.13	49.59	53.09	49.13	70.48	70.79
Al_2O_3	12.50	18.64	21.43	20.08	13.26	12.87
Fe_2O_3	5.52	17.19	8.53	11.04	4.20	4.50
FeO	.45	.27	.86	.93	......	......
TiO_2	.45	.28	.16	.13	.50	.50
P_2O_5	.02	.03	.03	.04	......	......
MnO	.04	.01	.03	.06	Trace	Trace
CaO	.85	.93	.95	1.22	.81	.98
MgO	.38	.73	1.43	1.92	1.11	.88
Na_2O	2.19	.80	1.45	1.33	1.18	1.52
K_2O	1.61	.93	.83	1.60	1.84	2.26
H_2O	[1]4.63	[1]10.46	[1]10.79	[1]11.72	[2]6.98	[2]5.93
CO_2	.43	.30	.29	.39	......	......
C	.19	.34	.22	1.09	......	......
Totals	100.39	100.50	100.09	100.68	100.36	100.23

Of these analyses Nos. 1 and 2 are from the same vertical section, the former being four and one-half feet from the surface and the latter eight and one-half feet and in contact with the underlying limestone. Nos. 3 and 4 are related in the same way, the former being three feet from the surface and the latter four and one-half feet and lying in contact with the rock.[3] Nos. 5 and 6 are from the brickyard of John Grindell at Platteville.[4]

Thickness of the soils.

The thickness of the soils of the driftless area varies greatly. It is greater on the hill tops and in the bottoms of the valleys and less on the slopes. The following is an accurate statement concerning the average thickness of the soil:

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[1] Contains H of organic matter. Dried at 100° C.

[2] Contains also some C.

[3] T. C. Chamberlin and R. D. Salisbury: Sixth Annual Report U. S. Geol. Survey, p. 250, 1885.

[4] E. R. Buckley: Wisconsin Geol. and Nat. Hist. Survey, Bull. vii, pt. i, p. 273, 1901.

"The following general averages are based on measurments which include the residuary earths and that portion of the residuary rock which is intermingled with them, but which do not include the disintegrating rock which underlies the clay but is not commingled with it. The average depth of the residuary material thus defined, as shown by the eighteen hundred measurements, is 7.08 feet. The amount varies widely in different topographic situations. It is greater on ridges and in valleys than on slopes, and is deeper the wider the ridges and the valleys. Of about one thousand measurements on slopes, steep and gentle, the average depth is 4.61 feet. On ridges, not including broad tracts of upland, the average, as shown by three hundred and sixty measurements, is 8.06 feet. Two hundred and nineteen measurements on broad upland tracts give an average of 13.55 feet. The average for broad ravine bottoms, or short, wide valleys unoccupied by streams, is 6.93 feet, as indicated by one hundred and twenty-three measurements. The average of fifty-five valley measurements is 18.17 feet. In this last class are included only the measurements made in valleys which have a notable flat, and the average here given may not very well represent the average depth of loose material in such situations, since measurements in the large valleys, as those of the Mississippi, Wisconsin and Pecatonica rivers, were rarely obtainable, but would have served to swell the average result. The extremes of depth are zero on the one hand and 70 feet on the other, the maximum being on uplands. It is not certain that in this instance the excavation was not in a crevice. Measurements exceeding 25 feet are, in this topographic situation, exceedingly rare."[1]

Amount of rock represented by the soils.

When the chemical composition of the original rock is conpaired with the chemical composition of the soils derived from it and the thickness of these soils, it is readily seen that the amount of soil which is now present in any given locality is

[1] T. C. Chamberlin and R. D. Salisbury: Op. cit., p. 254.

the equivalent of a very much greater thickness of rock,—just how great a thickness it is impossible to say without complete analyses, but a very good general estimate can be made.

The analyses given show that the carbonate of lime and magnesia have practically disappeared from the soil. In the original rock these carbonates make up probably 90 per cent. of the total. In some residual soils which have been carefully studied it has been found that over 97 per cent. of the original limestone has been removed in the process of weathering; in other words, in such a case a present thickness of three feet of soil would represent an original thickness of 100 feet of rock.[1] In this district, assuming that 90 per cent. of the rock has been removed by weathering, a thickness of ten feet of soil would represent an original thickness of 100 feet of rock. The results of the numerous measurements already quoted show an average thickness of about thirteen and one-half feet on the broad uplands. It is thus clear that at least 100 feet of rock have disappeared slowly by weathering from this district.

Amount of erosion.

This brings us back, however, to another statement which was made on a previous page[2] regarding the amount of material which had been removed from this district since the formation of the peneplain. With the above facts concerning the soils in mind, we can easily add 100 feet to the 150 or 200 feet there mentioned, and thus have a layer 250 to 300 feet thick which has been removed from the whole district. Of course it is possible that some of this soil was formed at the time the peneplain originated, and how extensive the soil thus formed was, we cannot say. But it seems doubtful, however, that a large thickness of this old soil has continued to the present day. Moreover, it is extremely unlikely that none of the soil formed on these broad uplands has been removed by erosion; and, if the amount thus removed can be balanced against that

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[1] G. P. Merrill: "Rocks, rock weathering and soils," p. 233, 1897.

[2] P. 12.

formed by decay at the time the peneplain originated, the above estimate of the amount of erosion in the district since the formation of the peneplain still stands.

If then at least 100 feet (the actual amount seems quite likely to be considerably greater than this) can be added to the amount of erosion accomplished directly by the streams, it will bring the surface of the original peneplain in general close to the top of the Galena limestone, In other words, it seems that, as far as the three counties here discussed are considered, the hard Galena limestone played an important part in determining the position of this peneplain. For it acted as a hard basement from above which were removed the much softer Hudson River shale. Thus, if it were not for other facts, there might be some question whether the level upland plain is a true peneplain, or is more likely a structural plain. However outside the areas of these three counties, especially to the north and northeast, this peneplain bevels other formations, and its true nature is thus evident. To the south, in the northern part of Illinois (near Galena), the peneplain is seen well up in the Maquoketa (Hudson River) shale, while to the north the location of this plain has not been fully determined. It does, however, north of the Wisconsin river, apparently lie in the Lower Magnesian and, still farther north, in the Potsdam.

Loess and alluvium.

It should be added that there are some soils in the district which are not of a residual character. Such are (1) the loess, (2) the alluvium on many of the river bottoms, and (3) the overwash glacial deposits which are found along the Wisconsin and Mississippi rivers, but not along the smaller rivers. The two larger rivers head without the driftless area and thus brought down the drainage from the ice sheet, while the other rivers of the district head well within the driftless area and so were not carriers of glacial waters.

The uppermost layer of unconsolidated material over a considerable part of the lead and zinc region is a light buff-colored clay, which is rather porous in texture. This is the loess and in this district it apparently is of æolian origin. This loess mantles the general surface, covering the broad upland areas and extending down the sides of the valleys. It thus seems to have been deposited since the origin of the present topographic features of the district, and can be regarded as in general of the age of the more extensive loess mantle associated with the edge of the Iowan drift. At the same time, in this district there is nothing yet seen to preclude the idea that some of this loess may be of later than Iowan date.

The loess is frequently seen in roadside exposures, and it is commonly sharply marked off from the residual soil below, as the latter is of a reddish or much darker brown color, is more compact and clay-like, and contains quite frequently angular fragments of flint. In thickness the loess varies from west to east, being thicker to the west (especially in the vicinity of the Mississippi river), and thinner toward the east. A few miles southwest of Platteville a thickness of three or four feet of loess is sometimes seen, but this is exceptional for most of the lead and zinc district, the average thickness being probably not over a foot.

All along the permanent streams of the district, and even along many of the intermittent streams, there are well developed flood plains, which are made of alluvial deposits, and which are even yet in times of flood receiving additions of this nature. The alluvium consists of fine clay, gravels, and at times of coarse rock fragments. In a few places these gravels, which are composed of angular to sub-angular fragments of flint, occur higher than the present flood plains,—thus representing deposits made before the rivers reached their present levels. Such deposits do not form well marked terraces, though they do at times resemble such forms. Most, if not all, of these terrace-like forms can be explained either as rock terraces marking the top of the Lower Magnesian limestone, or else as of the nature of alluvial fans at the mouths of side streams, which fans now have their down stream sides cut into by the shifting of the main stream.

Where the Fever river nears the Mississippi there is a marked terrace, as at Galena, Illinois,[1] and this terrace extends up the Fever for several miles north of Galena but dies out before reaching the southern boundary of Wisconsin. This terrace is regarded as of Wisconsin age (i. e., as deposited during the last or Wisconsin epoch of glaciation), being formed when the Mississippi was raised above its present, and its former, height. Similar terraces exist along the Mississippi and run up some of its tributaries for several miles, but the main part of the lead and zinc district of Wisconsin was beyond the influence of the glacial waters, which made these terraces possible, and so does not show marked terraces.

DRAINAGE.

The main stream of the district is the Mississippi, forming its western boundary, and its main tributary is the Wisconsin which forms the northern boundary of the district under consideration. These two trunk streams receive all the drainage of the region. The divide between the streams which flow north into the Wisconsin and those flowing south into the Mississippi is along the Military ridge. This divide is only some fifteen miles south of the Wisconsin, so the northward flowing streams are much shorter and of much steeper gradient than the southward flowing ones. The important streams of the latter class are, from west to east, the Grant, Platte, Little Platte, and Pecatonica rivers.

As the district has been so long subjected to erosion the streams have reached every part of it and the interstream areas are thus well drained, the ground-water on the uplands being a number of feet below the surface.

[1] H. F. Bain: U. S. Geol. Survey, Bull. 246, p. 24, 1905.

CHAPTER III.

GENERAL GEOLOGY.

The rocks of the lead and zinc district consist entirely of sedimentary deposits laid down in the early part of the Paleozoic era. No igneous and metamorphic rocks are exposed anywhere in the district, although such rocks exist below the base of the flat lying Paleozoic series and have been reached in a number of deep borings. To the north and northeast of the lead and zinc district these older rocks outcrop, first, in isolated areas, as for instance in the bluffs of quartzite about Baraboo and Devils lake, and still further north in central and northern Wisconsin they form practically the whole surface. These underlying, igneous and metamorphic rocks are of an age far antedating the overlying sedimentary rocks. The older rocks were practically in their present position and condition long before the formation of the ore deposits.

The sedimentary rocks occurring in the lead and zinc district are readily separated into the formations shown in the accompanying table, in which table the average thickness in feet of each formation is given. The areal distribution of the different formations is shown on the general geological map of the region,—plate XX.

Section of formations in the lead and zinc district.

System.	Formation.	Lithological Character.	Average thickness in feet.
Quaternary.		Residual soil. Alluvium. Loess.	7
Silurian.	Niagara.	Dolomite.	100
Ordovician.	Maquoketa (or Hudson River.)	Shale.	160
	Galena.	Dolomite.	230
	Platteville (or Trenton.)	Limestone and dolomite.	55
	St. Peter.	Sandstone.	70
	Lower Magnesian.	Dolomite and some sandstone.	200
Cambrian.	Potsdam.	Sandstone, with some shale and dolomite.	700
Pre-Cambrian.		Various metamorphosed sediments and igneous rocks.	

During the deposition of the Cambrian to Silurian rocks southwestern Wisconsin was covered by the sea, and land areas from which the clastic formations were derived existed to the north. The different formations are in a broad sense continuous one with another, there being no great unconformity in the whole series. There are, however, indications that part ot the district, at least the part adjoining the shore line on the north, was at various times below the sea level and again above it, and the rapid changes from sandstone to limestone, and from limestone to sandstone, indicate changes of importance in the sea level. In addition to this certain facts have been brought forward to show that there is a possible unconformity within the Cambrian, and the evidence that the Lower Magnesian limestone was subjected to subaerial erosion, before the deposition of the overlying St. Peter sandstone, is pretty conclusive.

The rocks of the district dip in general towards the southwest at a very low angle. There are, however, localities where this general southwestern dip is interrupted by northerly and northeasterly dips, showing that the district has been slightly folded by a force acting from north to south or from northeast to southwest. At the same time, some of these irregularities in dip may be explained, not by deformation since the beds were deposited but by the deposition of sediment on an irregular sea bottom. This is especially the case in regard to the St. Peter sandstone which was deposited on the undulating surface of the Lower Magnesian limestone. Nevertheless, as will be noted in the description of the ore deposits, rock deformation in this district has been more prominent than is generally supposed.

The lead and zinc deposits of the district are not confined to any one particular horizon, but have been found from the Niagara limestone to the Potsdam sandstone; nevertheless, by far the larger number of these deposits, and in fact practically all of those yet discovered of economic importance, lie in the Galena limestone or towards the top of the underlying Platteville (Trenton).

POTSDAM SANDSTONE.

The lowest and oldest formation exposed in the district is a thick body of sandstone known as the Potsdam. Interbedded with this great sandstone formation are certain shaly and limy layers, but these make up only a small percentage of the total thickness. The Potsdam sandstone reaches a maximum thickness of about 1,000 feet, and the average thickness is about 700 feet. Within the lead and zinc district the total thickness of this sandstone is nowhere exposed; in fact, the exposures of this formation are confined to the valley of the Wisconsin and its immediate tributaries. The greatest thickness of the Potsdam exposed in the district is about 300 feet of the upper part of the formation. This sandstone is composed essentially of rounded grains of quartz, which as a rule are not firmly cemented; at the same time, the whole formation averages harder and more enduring than the St. Peter sandstone. The Potsdam sandstone, being a coarse-grained rock which is not fully cemented, having the requisite inclination, and being included between practically impervious beds, forms a very important source of water for artesian and deep wells.

LOWER MAGNESIAN LIMESTONE.

This formation, so named to distinguish it from the Galena and Niagara, both of which are in the main dolomites, is limited below by a sandstone formation (the Potsdam), and also limited above by a sandstone formation (the St. Peter). The Lower Magnesian is essentially a dolomite. It has been separated into three divisions as follows: (1) at the base a thick dolomite, or the main body of the formation; this has been called the Oneota; (2) a thinner division known as the New Richmond sandstone; (3) at the top a thin division to which the name Shakopee limestone has been applied. The sharp separation of this great dolomite formation (Lower Magnesian) into these three smaller divisions cannot always be made with ease.

The dolomite is gray to white in color and varies from a very compact fine-grained rock to one which is porous and coarse-grained, but on the average it is less porous and less coarse-grained than is the other thick dolomite of the district—the

Galena limestone. It also commonly weathers less roughly than does the Galena, though in localities the Lower Magnesian is a markedly rough-weathering rock, but in these cases this feature is due quite largely to the brecciated or semi-brecciated character of the rock. Small masses of flint, varying in size up to a foot or more in diameter, occur frequently in this dolomite, but the flints are commonly aggregated in certain layers rather than scattered indiscriminately through the dolomite. In general the coarser parts of the formation carry more flints and the finer compact portions are frequently entirely free from them. Not uncommonly small cavities exist in the dolomite, or in the flint masses, and these are lined with small crystals of quartz; in fact there are more quartz crystals in this formation than in any others of the district, which are noticeably deficient in silica in crystallized forms. At the very top of the formation, or possibly at the very base of the St. Peter sandstone, there is frequently a marked development of oölite, which is a rock consisting of small rounded bodies, about the size of a pin's head, imbedded in a siliceous cement. These bodies have a concentric structure and are mainly siliceous, though some may be calcareous. This oölite may be seen in fragments along the wagon road just west of the bridge across the Pecatonica river in the N. E. ¼ of Sec. 36, T. 4 N., R. 2 E., five miles south of Mineral Point; also along the road near the south side of Sec. 3, of the same township, some three miles west-southwest of Mineral Point. At the latter place are also some large masses of cellular flint associated with this oölite.

Exposures of the Lower Magnesian are confined to the valleys, especially to the Wisconsin valley, but exposures also occur in some of the deeper valleys in the heart of the lead and zinc district. The presence of this formation can sometimes be detected, even though outcrops are not at hand, by its effect on the form of the valley bottoms. In the St. Peter sandstone, which is commonly loosely cemented, the valleys have wide flat bottoms; where the valley bottoms pass from this easily eroded sandstone into the massive dolomite of the Lower Magnesian they become much constricted and a terrace occurs marking the location of this dolomite. Such features occur at several places on the Pecatonica river and its branches south and west of Mineral Point, and one very noticeable locality is in the southern part of Sec. 2, T. 4 N., R. 2 E., two miles west-southwest of that town.

One of the most extensive exposures of this formation near Mineral Point occurs along the streams in Secs. 2, 3, and 10, T. 4 N., R. 2 E., where some thirty feet is to be seen in one cliff. The upper 10 feet of this consists of rough-weathering, hard, more or less broken beds; while the lower part is more regular, less rough-weathering, and in heavy beds; some flints occur in both parts of the cliff. The exposures are mainly dolomite, sandstone exposures of this age being rather uncommon, especially among the southern exposures. Near the northeast corner of Sec. 24, T. 5 N., R. 2 E., on the east bank of the creek and two and a half miles north of Mineral Point, is the accompanying section of the upper part of the Lower Magnesian.

Section of the Lower Magnesian formation north of Mineral Point.

	Ft.	In.
12. Sandstone, crumbling, not clearly in place; regarded as base of St. Peter	5	
11. Fine grained dolomite		6
10. Sandstone	4	
9. Fine-grained dolomite in undulating beds one to three inches thick	1	8
8. Sandstone		1
7. Fine-grained dolomite		1
6. Sandstone, commonly pure, but in places with blue clay cement	2	
5. Soft calcareous shale or shaly limestone		2
4. Sandstone		3
3. Soft calcareous shale or shaly limestone		6
2. Sandstone	2	
1. Coarse dolomite		6
Total	16	9

Along the road which runs through Sec. 14 and into Sec. 10, T. 6 N., R. 2 E., the following section occurs:

	Feet.
4. Sandstone; St. Peter	70
3. Sandstone and dolomite apparently interbedded; at top is siliceous oölite; regarded as Shakopee	40
2. Sandstone	60
1. Dolomite with some greenish shale and a few thin bands of black shale	104

Near Dodgeville a drill record is reported as follows:

	Feet.
5. Galena limestone	70
4. Platteville limestone	58
3. St. Peter sandstone	52
2. Lower Magnesian formation, solid, no openings	191
1. Sandstone, probably Cambrian	8
Total	379

A complete discussion of the Lower Magnesian can be written only after more detailed work is done on this formation. From what information is at hand, however, it seems that this formation in the lead and zinc district consists of a lower massive dolomite and a less thick upper part in which sandstone predominates, with some dolomite (or dolomite interbedded with sandstone) at the very top. The fact that this sandstone is lacking, or apparently lacking, in places may be explained by the statement that erosion removed the upper part of the formation before the deposition of the St. Peter sandstone. The recognition of this more recent sandstone from that belonging to the Lower Magnesian formation can commonly be made by one or more of the following criteria: (1) the St. Peter is commonly a thick bedded, massive formation; while the lower sandstone is commonly a thinner bedded, rougher-weathering formation in which cross-bedding is common; (2) the St. Peter has little foreign matter, i. e., it is a pure quartz sand, while the lower sandstone is commonly highly charged with iron oxide, at times has a clay cement, and is at times interbedded with dolomite; (3) frequently at the junction of the St. Peter with the underlying rocks is a layer of siliceous oölite, and sometimes large masses of cellular flint which are not known to occur in the St. Peter itself.

ST. PETER SANDSTONE.

Unconformably overlying the Lower Magnesian is a comparatively thin sandstone long known as the St. Peter from the fact that it occurs along the lower course of the St. Peters (now known as the Minnesota) river. This sandstone varies considerably in thickness, averaging about 70 feet. Its maximum thickness is over 100 feet and its minimum probably as low as 40 feet, although actual measurements of so small a mass of this sandstone have not been made. The variation in thickness is due, at least in the main, to the irregular character of the surface of the immediately underlying formation, which appears to have suffered considerable erosion before the deposition of the sandstone. This point is considered further under the heading of structural geology.

Lithologically the St. Peter is a practically pure quartz sandstone, the percentage of silica in its composition being very high and sometimes reaching ninety-nine per cent. The grains are well water-worn and commonly very poorly cemented, so that the rock crumbles readily and does not stand up in marked exposures. An exception to this last statement should be made for the district along the streams immediately west of Mineral Point where this sandstone is better cemented and where it forms prominent cliffs along the valley sides. The cementing substances, when present, are quartz and iron oxides. In a few places the grains have been enlarged by the addition of silica and now present more or less perfect crystal faces which glisten in the sun-light. Commonly near the surface of an exposure the sandstone is stained yellow, brown, or red by iron oxides which have filtered down into the clean white sand; this coloration is, however, mainly superficial and does not usually occur where the sandstone has been protected from surface waters.

The transition from the St. Peter sandstone to the overlying Platteville (Trenton) limestone is marked by a bed of blue sandy shale which varies in thickness from a few inches to five feet or more. This shale is not commonly sharply separated from the sandstone, but grades into it. On the other hand the upper edge of the shale is sharply delimited by the overlying, massive beds of the lower part of the Platteville limestone. (See figure 2 of plate XXI.) The sand grains in the shale do not usually extend to its upper surface and very rarely are quartz grains found in the lower beds of the Platteville.

The St. Peter can be looked upon as a practically non-fossiliferous formation, though a few casts of fossils, mainly lamellibranchs, have been reported from it.

PLATTEVILLE LIMESTONE.

This formation is noticeably different from the other calcareous members of the Paleozoic section in this district in that it is in considerable part a pure limestone, or a magnesian limestone, rather than a dolomite. In the former reports on this district this formation has been called the Trenton limestone, but the name Platteville has recently been applied to it,[1] as it is now believed that these beds do not represent the exact equivalent of the Trenton in its type locality. This formation is typically exposed in the vicinity of Platteville, and its entire thickness may be seen along the Little Platte river west of that town.

The thickness of the Platteville averages 55 feet, and this average thickness is maintained over a considerable part of the quadrangle. Towards the eastern edge of the quadrangle the thickness increases, mainly due to the thickening of the upper part of the formation, and the maximum thickness is about 75 feet. At Mineral Point a measured section shows 69 feet of this formation. The minimum thickness as determined is 40 feet and this occurs in the southern half of Sec. 30, T. 5 N., R. 2 E., about three and one-half miles southwest of Linden.

[1] H. F. Bain, U. S. Geol. Survey, Bull. 246, p. 19, 1905.

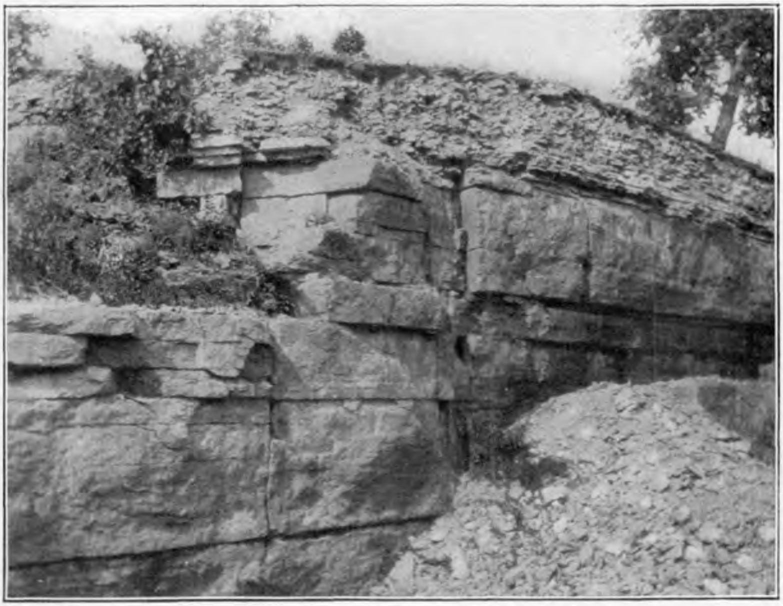

Fig. 1. Joint faces in buff limestone (lower part of the Platteville) in quarry on Little Platte river, west of Platteville. Limestone passing into soil above.

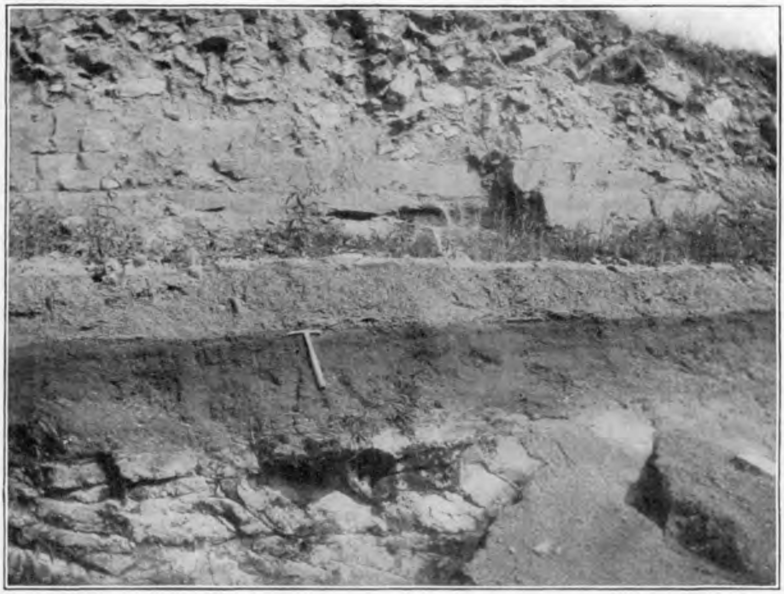

Fig. 2. Contact of St. Peter sandstone and Trenton limestone in quarry on Little Platte river, west of Platteville. The head of the hammer marks the contact; the upper part of the sandstone is iron stained, passing below into the almost white sandstone; the first layer above hammer handle is the shale at the base of the Trenton; above this is the buff limestone.

Divisions.

A generalized section of the Platteville includes the following divisions:

Generalized section of the Platteville limestone.

	Feet.
4. Thin beds of limestone and shale	10–20
3. Thin-bedded, brittle, fine grained limestone	15–25
2. Thick-bedded, magnesian limestone or dolomite	15–25
1. Blue shale, sometimes sandy	1–5

No. 1 of this section is a transition bed between the St. Peter and the Platteville and might be regarded as belonging to the lower rather than to the upper formation; it has been described above.

No. 2 of this section is in beds from six inches to two feet in thickness, and is a coarse, earthy, magnesian limestone or a true dolomite; It can be distinguished in the field from the more abundant, coarse, thick-bedded dolomite of the Galena by its more earthy nature and by its thin, irregular, dark partings. This member of the Platteville is buff on weathered surfaces, but where perfectly fresh is blue gray in color. It has been called the "lower buff limestone" and also the "quarry beds" and is the equivalent of the "lower buff" of the Wisconsin section. (See figure 1 of plate XXI.)

No. 3 of the Platteville section is commonly in thin beds, one to three inches in thickness. The beds are separated by very thin shale partings and have an undulating or wavy appearance. Commonly these beds are dense, of a very fine-grained, gray to light brown limestone which breaks with a more or less marked conchoidal fracture; on the weathered surfaces the rock is usually white or very light gray. When this member has the peculiar lithological character just mentioned it is sometimes called the "glass rock," though the main "glass rock" beds of the district lie higher up in the Platteville. This peculiar, thin, wavy-bedded character of this part of the formation is quite persistent and quite characteristic, and is noticeable as far east as Beloit, where this member becomes magnesian and is known as the "lower blue" of the Wisconsin section. Figure 1, of plate XXII, shows this thin-bedded member of the Platteville overlying the heavier quarry beds.

No. 4 of the Platteville section consists of limestone and shale. These are commonly in thin alternating beds, but there is comparatively little uniformity in this member in different parts of this district. In general it can be stated that the shale layers are better developed toward the west, while the limestone forms the main part of the member towards the eastern edge of the district. The shale beds are usually green or blue in color, though in places they are yellow, chocolate-colored, or even black. The chocolate-colored and black shales are highly carbonaceous and are locally termed "oil rock," though the main bed of chocolate-colored shale or "oil rock" proper of the lead and zinc district of Wisconsin, lies at the base of the Galena and just above No. 4 of the Platteville section.

Glass rock.

The most characteristic part of this member (No. 4) is composed of beds known as "glass rock." These are the typical glass rock beds of the lead and zinc district. They consist of dense, very fine-grained, hard, conchoidally-breaking limestone, which rings when struck with a hammer. This rock is of a light-chocolate color when fresh, but weathers rapidly to white or to a very light gray. In the following descriptions rock of this peculiar type of lithology is designated as glass rock. The typical glass rock beds are from three to eight inches in thickness and are separated by thin partings of chocolate-colored shale or oil rock. The lower beds at times have a peculiar mottled appearance. Together they have a thickness of from eighteen inches to four feet and form what is called the main glass rock. This is the most easily recognized horizon in the whole district; and the rock resists weathering markedly

Fig. 1. Platteville limestone in quarry at Mineral Point. The thin beds belong to No. 3 of the generalized section of the Platteville, while the lower thicker beds belong to No. 2 of this section.

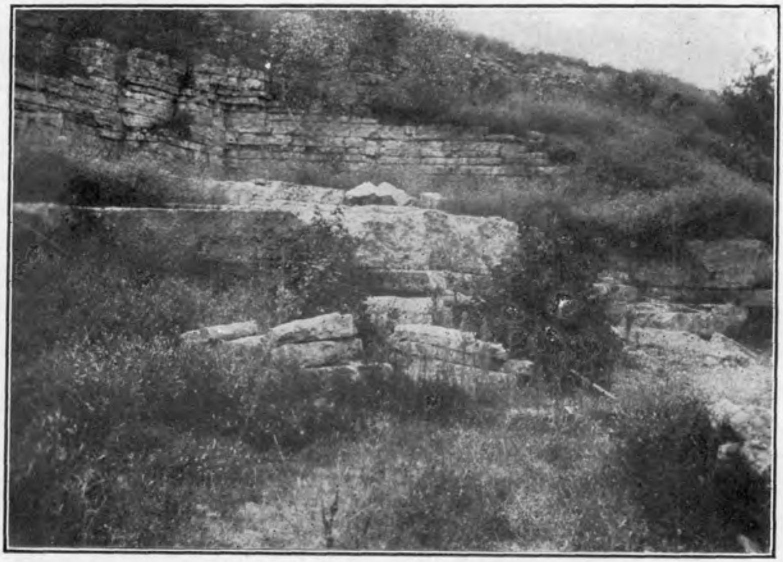

Fig. 2. Thin bedded upper part (No. 5 of the generalized section of the Galena) of the Galena limestone. Dubuque. Ia.

and so exposures and fragments are as a rule easily found. In the eastern half of the district this glass rock becomes coarser grained, somewhat magnesian and thicker, even up to 15 feet. It still has, however, some of its usual characteristics and is commonly designated as glass rock by the miners. In this portion of the quadrangle a few thin bands of oil rock commonly immediately underlie this glass rock. A chemical analysis[1] of some of the typical glass-rock gave the following results.

Analysis of the glass-rock.

Silica, SiO_2	6.160
Alumina, Al_2O_3	2.260
Sesquioxide of iron, Fe_2O_3	.950
Carbonate of lime, $CaCO_3$	85.540
Carbonate of magnesia, $MgCO_3$	3.980
Water, H_2O	.930
Phosphoric anhydride, P_2O_5	.055
Total	99.875

Blue shale.

The very top of this member (No. 4) of the Platteville, is commonly a blue shale or blue clay. The thickness of this bed varies from a few inches to four feet. In places it is gray, yellow, or even white in color. It is present in most of the mines in the western half of the district and frequently marks the lower limit of mining: It is known by the miners as "the clay bed". Immediately overlying this blue shale is the chocolate-colored, carbonaceous shale (or the oil rock) of the base of the Galena limestone. This blue shale is frequently not present in the eastern part of the lead and zinc district.

Fossils.

The Platteville is commonly highly fossiliferous, more so than any other formation within the region, excepting possibly the Maquoketa shale, which formation is highly fossiliferous in certain places outside of this part of the state. Within the lead

[1] Geol. of Wis., vol. 2, p. 681, 1877.

and zinc district, however, very few exposures of the shale occur and these contain comparatively few organic remains. The upper two members of the Platteville are commonly abundantly supplied with fossils, while practically none are preserved in the lowest member. and they are not very common in No. 2 of the section. The forms most common in No. 3 and No. 4 of the section are brachiopods, while bryozoans, trilobites, lamellibranchs, crinoids, and gastropods occur in less abundance. The most common and characteristic brachiopods are *Orthis deflecta* Conrad, *Orthis tricenaria* Conrad, and *Orthis subæquata* Conrad. The first is, as far as at present known, confined to this formation; the two others are not found below the Platteville, but extend in small numbers into the lower part of the overlying Galena limestone. A large variety of *Orthis subæquata* Conrad (*minneapolis* Winchell) is very abundant just above the main glass rock beds. This is a very characteristic form and is confined, as far as abundance and its large size are concerned, to a thickness of two or three feet of rock between the main glass rock beds and the base of the Galena. It thus furnishes an easy criterion for separating the Galena from the Platteville —a criterion which is of use in geological mapping as well as in determining a horizon of importance in mining operations. Other fossils occurring in the Platteville are listed in the detailed sections given below.[1]

Detailed sections.

The upper part of the Platteville limestone is exposed in a number of places, and at certain of these continuous sections from this formation up into the lower part of the Galena are available. The four sections given below are particularly well exposed and each exhibits a greater thickness of rock than is commonly available in one exposure. Section I is from an old quarry on the west bank of the Little Platte river, about one

[1] Mr. E. O. Ulrich, of the U. S. Geological Survey, has kindly helped in the determination of the fossils.

and one-half miles west-northwest of Platteville; the exact location is in the N. E. ¼ of section 8, T. 3 N., R. 1 W. Section II is at the City Quarry at Mineral Point. Section III is at a quarry about a quarter of a mile south of the last. Section IV is at a large quarry in the southern edge of Darlington.

I. Section near Platteville.

	Ft.	In.
13. Sub-crystalline, magnesian limestone at base, but in two or three feet grading into coarse, thick-bedded dolomite	20	
12. Blue to gray calcareous shale or shaly limestone		8
11. Thin-bedded, sub-crystalline limestone. A few specimens of *Orthis tricenaria* Conrad and *O. subæquata* Conrad	5	
10. Thin, wavy-bedded, glass rock-like limestone, becoming sub-crystalline above. Some beds are very fossiliferous. *Orthis tricenaria* Conrad, *O. subæquata* Conrad, and *O. testudinaria* Dalman	6	
9. Dark brown or chocolate-colored shale or oil rock		2
8. Thin, wavy-bedded glass rock-like limestone; commonly very fossiliferous; a few thin partings of oil rock. *Orthis tricenaria* Conrad, *O. subæquata* Conrad, *Strophomena incurvata* Shepard, *Rafinesquina alternata* Conrad, *Ctenodonta astartiformis* Salter, *Ceraurus pleurexanthemus* Green, *Isotelus gigas* Dekay, *Rhinidictya mutabilis minor* Ulrich	8	
7. Blue shale		8
6. Undulating, hard, sometimes glass rock-like limestone interbedded with blue shale. The limestone is very fossiliferous. This is the chief horizon for *Orthis subæquata* Conrad (var. *minneapolis* Winchell), which is here very abundant and of large size. *Stictoporella frondifera* Ulrich, occurs at top of this division	2	
5. Gray to yellow-brown to almost black clay		7
4. Dark gray shale and hard gray limestone interbedded	1	2
3. The main glass rock beds. Some oil rock bands occur in the lower part and in these are fern-like forms which are probably fossil algæ	2	6
2. Thin shaly layers of glass rock with oil rock partings; weathers to clay		3

1. Blue, gray-weathering limestone with dark partings. The upper part is separated by blue shale into 2 beds, each 21 inches thick. The upper of these beds has in places the appearance of thin wavy-bedded glass rock. *Orthis deflecta* Conrad, *Rafinesquina minnesotensis* Ulrich, *Thaliops ovata* Conrad, *Leperditia fabulites* Conrad, *Monotrypa magna* Ulrich..................	7	
Total..	54	

In the above section No. 1 belongs to the thin-bedded member (No. 3 of generalized section) of the Platteville. Nos. 2 to 7 belong to the upper member of the Platteville, while Nos. 11 to 13 clearly belong to the Galena. Nos. 8 to 10 are probably the equivalents of the main oil rock horizon which marks the base of the Galena; the division between the Galena and Platteville will then probably be drawn between Nos. 7 and 8, although it may more strictly be between Nos. 8 and 9.

II. Section at the City quarry, Mineral Point.

	Ft.	In.
10. Residual soil..	5	6
9. Decayed dolomite, called by the miners the "brown rock"	4	
8. Oil rock, with some cubes of lead and some decayed limestone..	1	6
7. Compact, brownish magnesian limestone..............	1	
6. Unexposed..	17	6
5. Thin, wavy-bedded limestone, much like glass rock	4	
4. Compact, magnesian limestone; brown on weathered surface, but blue on fresh surfaces; in beds 3 inches to 1 foot in thickness	10	6
3. Thin, wavy-bedded, hard, glass rock-like limestone	15	6
2. Coarser, thick-bedded dolomite.......................	20	6
1. Sandstone	3	
Total	83	

In the last section No. 1 represents the St. Peter sandstone. The shale (No. 1 of the generalized section of the Platteville) just above this is here very thin and not well exposed. No. 2 represents No. 2 of the generalized section of the Platteville, while Nos. 3 and 4 represent the next higher member; and Nos. 5 to 7 represent the upper member of the Platteville. Nos. 7 and 8 belong to the Galena.

III. Section at Mineral Point.

	Feet.
6. Debris of limestone, containing *Streptelasma corniculum* Hall and a few *Orthis subæquata* Conrad..........................	3
5. Compact, fine-grained magnesian limestone	2
4. Thin, wavy-bedded, glass rock-like limestone. *Orthis tricenaria* Conrad, *O. deflecta* Conrad, *Rafinesquina alternata* Conrad, *Rafinesquina minnesotensis* Ulrich, *Zygospira*, *Strophomena trentonensis* Winchell and Schuchert, *Rhynchotrema inæquivalvis* Castelnau, *Isotelus gigas* Dekay, *Monotrypa magna* Ulrich	25
3. Coarser, thick-bedded dolomite..............................	14
2. Unexposed..	6
1. Sandstone	10
Total	60

In this section No. 1 is St. Peter; No. 3 (and part of No. 2) is the second member of the Platteville; No. 4 is the third member of the Platteville, while Nos. 5 and 6 belong to the upper member of this formation.

IV. Section at Darlington.

	Ft.	In.
11. Coarse-grained, thick-bedded dolomite, with *Receptaculites oweni* Hall	4	
10. Coarse-grained, thick-bedded dolomite.................	3	
9. Coarse-grained, thick-bedded dolomite with flints	5	
8. Coarse-grained, thick-bedded dolomite	2	
7. No exposure	6	
6. Coarse-grained, thick-bedded dolomite with 3 shaly bands, ½ to 4 inches thick. Near base are a few *Orthis tricenaria* Conrad, *O. plicatella* Hall, *O. subæquata* Conrad	27	6
5. Thin-bedded dolomite.................................	4	6
4. Thin-bedded limestone with oil rock partings which are ¼ to 2 inches in thickness. *Orthis tricenaria* Conrad, *O. subæquata* Conrad	4	

3. Fine-grained, compact, magnesian limestone, with a few flints and a few oil rock partings. The upper surface is smooth—possibly waterworn. *O. subæquata* Conrad (var. *minneapolis* Winchell), *Streptelasma profundum* Owen..................................	15	6
2. Blue magnesian limestone with dark wavy partings	19	6
1. Bluer magnesian limestone with more prominent clay partings. *Pleurotomaria subconica* Hall, *Streptelasma profundum* Owen..................................	10	
Total	101	

In the above section No. 2, and possibly No. 1, belong to No. 3 of the generalized Platteville section, while No. 3 belongs to the upper member of that section. Nos. 4 to 11 belong to the Galena.

GALENA LIMESTONE.

This formation is the most important and the most extensively developed of any within the district. It is the main country rock, immediately underlying the surface everywhere except (1) in some of the valleys and (2) in some of the higher districts, as about the mounds. The Galena limestone is also by far the most important ore-bearing horizon in the district. In fact, nearly the whole of the lead ore which has been produced in this region, and the main part of the zinc ore, came from the Galena limestone, especially from the lower part of it.

The thickness of this formation averages about 230 feet. In some places, especially towards the north, the thickness seems to be less than this. On account of the lack of continuous exposures and the dip of the rock, exact measurements are not available, but in places it would seem not to exceed 200 feet in thickness. In the vicinity of Hazel Green some drillings to the bottom of the Galena limestone show a thickness of nearly 250 feet of this formation.

Lithologically the Galena is a dolomite. It is a granular, crystalline, coarse-grained, porous dolomite which weathers into exceedingly rough and irregular forms. Frequently in this weathering the rock breaks down into a coarse, yellow, dolomitic sand. This lithological character of the formation is practically continuous from top to bottom with the few exceptions which are noted below in the description of the lower part of the formation. The formation as a whole is massive in appearance; the average thickness of the beds is from 1 to 4 feet. Near the bottom and near the top, however, thinner beds occur. Frequently very thin seams or partings of clayey material, a little darker in color than the main mass of the dolomite, separate the formation into irregular layers. The dolomite, when unweathered, is usually of a light bluish-gray color, but sometimes, especially in the upper part, it loses the bluish tinge and becomes gray, while in the lower part this bluish shade is sometimes intensified. On weathering the dolomite changes to a light yellowish gray, or buff, and in the more weathered parts has a somewhat brownish to reddish color, the exact shade depending on the proportion and character of the iron oxide present in the residual material.

No series of chemical analyses of the Galena limestone is at hand, but the accompanying analysis, of selected fresh samples of this rock from several localities, will give a general idea of its composition. As these samples contain no flint nodules and practically none of the clayey partings, the average composition of the rock of the Galena formation would include a slightly larger proportion of alumina and silica than is here shown.

Analysis of Galena limestone.[1]

Carbonate of lime, $CaCO_3$	54.33
Carbonate of magnesia, $MgCO_3$	41.56
Sesquioxide of iron, Fe_2O_3	.90
Alumina, Al_2O_3	.99
Silica, SiO_2	2.10
Total	99.88

[1] By Professor W. W. Daniells of the University of Wisconsin

Divisions.

The Galena can be divided into five divisions, shown in the following generalized section.

Generalized section of the Galena limestone.

	Feet.
5. Dolomite, earthy, thin-bedded	35
4. Dolomite, coarse-grained, thick-bedded	60
3. Dolomite, coarse-grained, thick-bedded, with numerous flints.	90
2. Dolomite, thick to thin-bedded, coarse to fine-grained; sometimes in part a limestone	45
1. Chocolate-colored carbonaceous shale, known as oil rock	2

No. 1 of the above section varies considerably in thickness. Sometimes the actual material of this description has a thickness of only one or two inches, while in other places it runs up to four or five feet. In cases where it is so thin it is apparently replaced, at least in part, by layers of thin-bedded, fossiliferous limestone, as shown in Nos. 8 to 9 in section I and No. 4 in section IV given under the description of the Platteville. In the vicinity of the mines this member of the Galena is always present and is more markedly developed than in other places. As a rule this oil rock is thicker in the western part of the district and thinner in the eastern part.

This oil rock is a thin-bedded, at times rather porous, shale, which varies in hardness from a rather soft clay to a white or gray, compact, shaly limestone. In general, however, it has the softness of a shale and consequently does not form important outcrops. About the only places where it is seen are at quarries or in mines. While the shale is commonly dark chocolate color, it sometimes becomes much darker, even to black, and is then called by the miners "black slate". When dry this oil rock will frequently burn with a thick, smoky flame, slivers of it sometimes being easily lighted with a match. When burning it gives off the peculiar petroleum odor and consequently has received the name "oil rock". Partial analyses of three samples[1] gave respectively the following amounts of carbona-

[1] Geol. of Wis., vol. 2, pp. 680–681.

ceous matter in this shale: 40.60 per cent, 18.31 per cent, and 15.76 per cent. While there are near this particular horizon, and especially below it, other thin bands of oil rock, this particular bed (the main oil rock), which is taken as marking the base of the Galena limestone, can be recognized throughout practically the whole district where exposures occur, while the thin bands which occur below it, and more rarely above it, are not by any means always present. The oil rock is most commonly underlain by a bed of blue clay or shale, which is taken as marking the top of the Platteville limestone.

A generalized section running both above and below this oil rock, i. e., a typical section across the junction between the Platteville and Galena, would be as follows:

Generalized section between the Platteville and Galena.

	Feet.
5. Heavy-bedded, coarse-grained dolomite	10
4. Thin beds of limestone, or magnesian limestone, which is at times similar to the glass rock and at times carries thin partings of oil rock	5
3. The main oil rock horizon	2
2. Blue shale or clay	1
1. Thin-bedded limestone, sometimes with bands of blue shale. In this horizon occur the main glass rock beds	10

No. 2 of the generalized section of the Galena consists of thin-bedded to thick-bedded dolomite, the thin-bedded portions being at the base, although at times the heavy beds of dolomite run clear down to the oil rock. This member of the Galena formation varies in lithology more than any other. At the base, instead of dolomite beds, there are frequently thin beds of highly fossiliferous limestone. At other times the dolomitization extends clear to the very base; and on the other hand, in a few places this member is almost entirely limestone or magnesian limestone. Two of these localities where this member of the Galena has not become dolomitized are: (1) along the road north from Etna in the E. one-half of Section 11, T. 1 N., R. 1 E.; (2) the upper part of this member of the Galena has also been found only partially dolomitized at an old quarry immediately east of Benton. To the westward this lower part of the Galena is frequently non-dolomitic, and this character of the rock extends up to an indefinite distance, making a separation between the Platteville and Galena impossible on purely lithological data. But with few exceptions the dolomitic character of this part of the formation in the lead and zinc district is very marked.

No. 3 of this section is a coarse-grained, porous, thick-bedded dolomite which carries nodules and layers of flints. These flints vary in size up to masses which are a few inches to even a foot across, and these masses are very frequently lense-shaped in form and commonly distributed in layers,—in fact, in some places the flints become so abundant that layers an inch to three inches in thickness can be traced for some distance through the dolomite.

No. 4 of the above section is practically like No. 3 except for the absence of flints, and the separation between these two members of the section is not so easily made within the area under discussion.

No. 5 of the generalized section of the Galena consists of thinner-bedded, earthy dolomite. The thickness of the beds varies from a foot down to two inches, the thinner being near the top. This member is not commonly well exposed, but is seen in a quarry near the northeast corner of Sec. 23, T. 1 N., R. 2 E., one and a half miles southeast of Shullsburg. The thin-bedded upper member of the Galena is shown in figure 2 of plate XXII.

Fossils.

The Galena, being as a whole completely dolomitized, carries comparatively few recognizable fossils. There are, however, at times, as already shown in sections I and IV under the description of the Platteville limestone, places where the lower part of the Galena is non-dolomitic, thin-bedded and highly fossiliferous. In such places two brachiopods, namely *Orthis* *tricenaria* Conrad and *Orthis deflecta* Conrad are rather common, and with these are certain bryozoans and also other brachiopods, especially forms of *Strophomena*, and a few crinoids. The remains of a peculiar organism, known as *Receptaculites oweni* Hall, and commonly called "the lead fossil" and "the sun-flower coral," occur somewhat rarely throughout the whole of the Galena. There are, however, two important horizons in which these remains are especially abundant. These horizons are from one to four feet in thickness and can be used as a ready means of determining the position in the Galena of outcrops in which they occur. The lower horizon exists from 35 to 50 feet above the base of the formation. In other words, it marks rather closely the separation between Nos. 2 and 3 of the generalized section, the first flints in the formation being at this horizon, or just a few feet above or below it. This lower *Receptaculites* horizon is exposed in a number of places throughout the district. Among these may be mentioned: (1) the small quarry on the west side of Rountree branch, just south of the Chicago and North-Western railway trestle at Platteville; (2) along the east side of the road north of Etna, in the east half of Sec. 11, T. 1 N., R. 1 E.; (3) several occurrences along the streams north of Dodgeville; (4) at a quarry on the south side of the road near the southeast corner of Sec. 8, T. 1 N., R. 2 E., two miles west of Shullsburg; (5) at Darlington, near the top of section IV given under the Platteville. The upper horizon of these fossils occurs about 60 feet below the top of the formation. This horizon is even more marked than the lower one just mentioned, but as exposures of this part of the formation are not so common this horizon is not usually seen. What is probably this horizon occurs in a small quarry along the west side of the road in the east half of Sec. 13, T. 1 N., R. 2 E., southeast of Shullsburg. It is seen also in the quarry just east of the railroad station at Ridgeway.

At times a few specimens of a brachiopod of the genus *Lingula* are found in the Galena, but more especially in the upper thin-bedded parts, i, e. in No. 5 of the generalized section. With the exception, however, of the two horizons of *Receptaculites* just described, it is quite difficult to rely on fossil evidence for the separation of the Galena into different horizons.

Separation between the Platteville and Galena.

While a generalized section of the strata marking the top of the Galena and the bottom of the Platteville has already been given,[1] it is thought best to add other and detailed sections of this horizon, as in mining operations it is important to determine just where certain beds lie in referrence to the bottom of the Galena. In the sections which follow the bottom of the main oil rock horizon (printed in italics) is regarded as marking the base of the Galena.

I. Section at the Graham and Stevens mine. This mine is situated about two miles west of Platteville and just east of the Little Platte river (Sec. 18, T. 3, N., R. 1 W.) Here the following section can be made out:

11. Yellow-gray limestone, typical Galena	10 feet.
10. Blue shale, not seen but reported by the miners	1 ft., 6 in.
9. Yellow-gray limestone, similar to No. 11 above	8 feet.
8. Thin beds of blue limestone, separated by narrow bands of oil rock. Frequently this blue limestone is turning brown along the cracks and edges of the bands. This is the chief ore horizon, the blende and Galena being disseminated through these blue limestone bands	4 feet.
7. Oil rock mixed with sandy shale and some thin bands of blue limestone which carries ore in the same manner as No. 8	8 inches.
6. *The main oil rock*, also containing ore	1 ft., 6 in.
5. Blue shale	1 ft., 6 in.
4. Oil rock	3 inches.
3. A soft yellow to white clay, called "pipe clay"	1 foot.
2. Black carbonaceous shale or slate	2 inches.
1. Buff limestone	1 foot.

[1] P. 31.

Below this are some other exposures of limestone similar to No. 1, but no uniform layers of typical glass rock were found here although they occur in several places within the distance of a mile to the south on the east side of the Little Platte river.

II. Section at the Capitola mine. At this mine, which is about one-fourth of a mile west of the Graham mine, but on the west side of the Little Platte river, is the following section:

4. Ordinary buff Galena limestone	3 feet.
3. Thin beds of limestone, some of which look much like the typical glass rock, separated by thin bands of oil rock	5 feet.
2. *The main oil rock*	1 foot.
1. Blue shale	1 foot.

III. Section at the Tippecanoe mine. At this mine, which is about a mile southwest of the Graham and Stevens and the Capitola mines, the following section can be seen along the opening to a tunnel:

5. Thin beds of blue limestone and narrow beds of oil rock; this is the ore horizon	5 feet.
4. *The main oil rock*	1 foot.
3. Blue shale; in places, some of this is closely like the oil rock and at the bottom there is a fairly continuous layer of blue to gray-yellow soft clay	4 feet.
2. Black carbonaceous shale or slate	2 inches.
1. Hard blue limestone	3 feet.

IV. Section at the Enterprise mine. At the Enterprise mine at Platteville near the bottom of the shaft the following section occurs:

4. Hard blue or grayish blue limestone, the Galena.	
3. Thin beds of hard blue limestone with narrow bands of oil rock	7 feet.
2. *Oil rock*	1 ft. 6 in.
1. Hard blue limestone	1 foot.

V. Section at the Gritty Six mine. At the Gritty Six mine (S. W. ¼ Sec. 21, T. 2 N., R. 1 E.) southwest of Meekers Grove, the following section is shown at the bottom of the mine:

4. Blue limestone, Galena.	
3. Layers of yellow and blue limestone with narrow bands of oil rock and some yellow sandy shale	4 feet.
2. *The main oil rock*	2 feet.
1. Blue shale and blue limestone, the shale being rather hard	2 feet.

VI. Section at the Kennedy mine near Hazel Green, At the Kennedy mine (S. W. ¼ Sec. 29, T. 1 N., R. 1 E.) the following section is seen at the bottom of the shaft and along a level running west from the shaft:

7. Blue Galena limestone.	
6. Bands of highly fossiliferous limestone, some of which is typical glass rock, with narrow bands of typical oil rock	8 feet.
5. *The main oil rock*	2 feet.
4. Blue shale, rather soft and almost like clay in pláces..	10 inches.
3. Oil rock	10 inches.
2. Shale similar to No. 4	10 inches.
1. Typical glass rock	2 feet.

VII. *Section at Mineral Point.* At Mineral Point some dry bone mining is going on on the land of Mr. W. S. Ross (S. W. ¼ Sec. 31, T. 5 N., R. 3 E.). Here the following section is made out near the bottom of one of the shafts:

7. Yellow Galena limestone.	
6. Thin layers of limestone full of fossils and much like typical glass rock; thin seams of oil rock	4 feet.
5. *Decaying oil rock*	6 inches.
4. Gray limestone, compact and looking somewhat like glass rock but not typical	9 feet.
3. Decaying and sandy limestone with 4 to 8 inches at the bottom of rock closely like oil rock	2 ft. 6 in.
2. Fossiliferous limestone closely like typical glass rock..	1 foot.
1. Decayed sandy rock and clayey material	9 inches.

This section is above the water level and consequently the rocks are mostly decayed and do not show their customary condition.

VIII. Section at the Penitentiary mine. At this mine, just south of Mifflin, water makes it impossible to get the complete section, but the following is shown:

4. Gray Galena limestone.	
3. Sandy *oil rock* with some bands of limestone	4 feet.
2. Blue clay	8 inches.
1. Hard limestone called glass rock but not like the typical glass rock	4 feet.

There is said to be a greater thickness of glass rock here, and below that it is stated that there is a layer of black slate or shale 18 inches in thickness.

IX. Section at the Ellsworth mine. At the Ellsworth mine (N. E. ¼ Sec. 29, T. 5 N., R. 1 E.), west of Mifflin, the general section is as follows:

5. Hard gray Galena limestone.	
4. Thin layers of limestone with fossils and narrow seams of oil rock. This limestone is at times very similar to the typical glass rock	7 feet.
3. *Oil rock*, which is here called "liner"	1 ft. 6 in.
2. Blue clay	2 inches.
1. Hard blue limestone	

X. Section at the Glanville mine. At the Glanville mine near Linden, is the following section:

6. Gray Galena limestone.	
5. Sandy limestone with some thin bands of oil rock: there is no glass rock or rock like glass rock here....	8 feet,
4. *Oil rock* rather hard and sandy	2 feet.
3. Blue shale or clay	3 inches.
2. Hard brownish compact limestone. This limestone is here called glass rock but it is coarser grained than the typical glass rock and does not have the conchoidal fracture	8 feet.
1. Bluish clay with narrow seams of oil rock	6 inches.

Below this it is reported that there is a hard blue limestone.

XI. Section at the Kennedy mine at Highland. At the Kennedy mine, just north of Highland, is the following section:

7. Hard Galena limestone	15 feet.
6. Bands of hard gray limestone with thin seams of rock which resembles oil rock, but harder than customary. This is called the lower opening	6 feet.
5. *Oil rock*, which is here more compact and harder than usual	1 foot.
4. Gray to yellow soft clay	6 inches.
3. Very hard, fine grained gray limestone. This is called the glass rock opening, but the rock is not like the typical glass rock	4 feet.
2. Oil rock	2 inches.
1. Hard limestone.	

XII. Section at the Little Giant mine. At the little Giant mine (S. ½ Sec. 4, T. I N., R. 2 E.), west of Shullsburg, a shaft has been put down through the oil rock and here the following section can be made out:

6. Yellow decayed limestone	1 foot.
5. Soft sandy material, *oil rock* and soft yellow sandy clay confused, with the oil rock mainly in the lower half	3 ft. 6 in.
4. Blue shale	2 feet.
3. Blue shale with thin layers of oil rock	1 foot.
2. Very hard, compact, fine-grained limestone resembling, but coarser than the typical glass rock	6 feet.
1. Same as the last but holding small flats and fractures which are filled with ore	7 feet.

Below this bed, twenty-two feet of rock similar to Nos. 1 and 2, with two or three narrow beds of shale, are said to have been penetrated. In the tunnel of the Galena level, which is a short distance to the west, several feet of rock similar to this,—i. e., similar to Nos. 1 and 2,—are found above the oil rock.

MAQUOKETA (HUDSON RIVER) SHALE.

Overlying the Galena dolomite is a formation of shale, which has been described from Iowa under the name of Maquoketa. It is the same formation which is known in the reports on the Wisconsin district as the Hudson River shale. This shale is confined to the higher land of the district, and its complete thickness occurs only on the mounds. The most extensive area underlain by the Maquoketa is near the southern edge of the State,south and southeast of Shullsburg; here there are a number of square miles of high land covered by this shale. Another area is in the vicinity of Hazel Green and westward to Sinsinawa mound. Other areas are at and in the vicinity of the Platte mounds. A small area of this shale occurs on a hill top four miles east-northeast of Mineral Point.

The average thickness is taken at 160 feet, although, because of the difficulty in finding outcrops to determine the lower and upper limits of the shale, careful measurements in this district have not been made. It would seem as though the minimum thickness, especially at the Platte mounds, is less than 160 feet, but this may be due to the fact that the heavy limestone above has settled down and the shales have been lessened in thickness by squeezing out. There are no good exposures of any considerable thickness of the shale within the district. Partial exposures of the base of the formation occur in a few places, as mentioned below in the section devoted to fossils, and other, but rather poor exposures occur: (1) on the Chicago and North-Western railway about a quarter of a mile south of the crossing of this road and the Chicago, Milwaukee and St. Paul railway between Platteville and Belmont; (2) on the road in the northeast quarter of Sec. 22, T. 1 N., R. 2 E., two miles south of Shullsburg.

Lithologically the Maquoketa consists of blue shale interbedded with thin layers, one-half to three inches in thickness, of earthy limestone, which limestone readily disintegrates on exposure to the atmosphere. Locally the formation is in small exposures all blue shale or clay, and in other places nearly all earthy limestone.

Fossils.

The Maquoketa shale in general throughout the Upper Mississippi valley forms a markedly fossiliferous horizon, but as exposures are so rare in the lead and zinc district, comparatively little is known concerning the fossils which occur in this formation within this immediate region. There is, however, at the very base of the formation a thickness of two to five feet of shale which contains rather abundant fossils, and this particular horizon, or rather the fossils which occur in this horizon and which seem to be preserved after the rest of the rock has weathered away, occur in a number of places, especially along roadsides. They can be seen: (1) in a few of the gullies running down from the Platte mounds; (2) along the east-west road through the center of section 18, T. 3 N., R. 1 E., about 3 miles east of Platteville; (3) along the road which marks the boundary line between Wisconsin and Illinois near the southeast corner of sec. 36, T. 1 N., R. 1 W., about two miles south of Hazel Green; (4) in the debris thrown out from a shallow well in the northeast part of the town of Hazel Green; (5) in the debris thrown out from a cistern at the first house on the north side of the road east of the Little Platte mound.

In this fossiliferous zone at the base of the Maquoketa the following forms occur, all of small size: a cephalopod of the genus *Orthoceras;* a pteropod, *Hyolithes parviusculus* Hall; two gastropods, *Liospira micula* Hall and *Pleurotomaria depauperata* Hall; two lamellibranchs, *Clidophorus neglectus* Hall and *Ctenodonta fecunda* Hall.

NIAGARA LIMESTONE.

This is the only formation of the Silurian found within the limits of the area and it is exposed: (1) on the top of the Platte mounds, (2) on the top of two mounds south of Shullsburg, almost at the southern limits of the state, and (3) on the top of Sinsinawa mound west of Hazel Green. In all the total outcrop of this formation within the lead and zinc district west of Blue mound is not to exceed a square mile in area. Undoubtedly at one time the Niagara extended over the whole district, but erosion has removed all but the small remnants just mentioned. The best exposures occur on the West Platte mound. On this mound over 100 feet in thickness of the lower part of the Niagara limestone exists, and there may be a greater thickness than this, for the lower portion of the formation is not exposed, As far as the exposures go, this formation can be divided into two parts: a lower, thin-bedded, light gray to white, fine-grained dolomite, some 40 feet in thickness; and above this, a thicker-bedded, somewhat coarser dolomite which carries abundant flints. These flints are especialy large and numerous towards the top of the mound and the upper surface of the mound seems to owe its existence in large part to a very resistant flint-bearing horizon of this dolomite.

Fossils.

The remains of organic life in this formation, as exposed in the lead and zinc district, are not very abundant, but on the top of the West Platte mound three compound corals,—i. e. *Halysites catenulatus* Linnæus, *Favosites favosus* Goldfuss, and *Favosites niagarensis* Hall,—occur rather commonly. There are also rather commonly casts of a brachiopod, *Pentamerus oblongus* Sowerby. These last occur in the flint masses, which are loose and so may belong to a horizon higher than the corals mentioned above, which occur in place in the dolomite.

LATER FORMATIONS.

After the deposition of the Niagara limestone there is no positive evidence that other stratified rocks were laid down in this district. It is of course possible that the region was still below sea level as late as the end of the Paleozoic time and received the deposits of Devonian and Carboniferous age. No remnants of these rocks are found anywhere in the district and it seems rather improbable that the Carboniferous rocks extended this far north between the Mississippi river and lake Michigan. There is, however, more possibility that the Devonian may have once covered this territory, for the fact that rocks of this age were more extensive than has heretofore been supposed is shown by the finding of Devonian fossils in cracks in the Niagara limestone of northeastern Illinois.[1]

Rocks of Cretaceous age are found to the west both in Iowa and Minnesota, but it has not yet been proved that the Cretaceous ocean extended as far east as southwestern Wisconsin; at the same time it is not improbable that outliers of Cretaceous age may yet be found in this part of the state. Of rocks later than the Cretaceous age, we have no knowledge in this immediate district; in fact, deposits of Tertiary age are known no nearer than Missouri and southern Illinois and the Great Plains district. At the same time there are certain isolated deposits of gravel which have been found in Illinois and at one or two points in Wisconsin which possibly may be regarded as the remnants of a once extensive deposit of Tertiary gravel.[2]

Residual soil, loess, and alluvium are the last deposits in the district. These have already been discussed.[3]

STRUCTURAL GEOLOGY.

The work which has been done in the last two years in making detailed geologic and topographic maps of important portions of the Wisconsin lead and zinc district has brought out much information concerning the structure of the region, and it is thus possible to speak now with more certainty concerning the minor structural details than has before been possible.

Throughout the district as a whole the rocks have a gentle inclination towards the south-southwest. This general dip averages about twenty feet per mile, as measured from a point a few miles north of Dodgeville to the southern border of the State near Hazel Green. This gentle dip is so small that it can be recognized in no single exposure. There are, however, exposures which show dips of one or two degrees not uncom-

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[1] Stuart Weller: "A peculiar Devonian deposit in northern Illinois," Jour. of Geol., vol. vii, pp. 483-488, 1899.

[2] R. D. Salisbury: "Pre-Glacial gravels on the quartzite range near Baraboo, Wisconsin," Jour. Geol., vol. iii, pp. 655-667, 1895.

[3] Pp. 14-21.

monly, and sometimes considerably larger dips, but such exposures are parts of small folds rather than parts of this general inclination which is characteristic of the whole district.

Folds.

Aside from the general inclination just spoken of, we find that the district is crossed by a series of gentle rolls of the strata whose axes run approximately east-west. Many of these minor folds are shown in considerable detail on the maps which accompany this report. It is impossible to state at the present time just how many of these gentle rolls are due to actual folding of the rocks and how many are due to inequalities in deposition. It is quite probable, however, that in very many cases inequalities in deposition have been accentuated by folding since the rocks have solidified. These gentle folds consist of minor anticlines and synclines which in some instances are parts of broader anticlines. Two particularly noticeable uplifts occur in the district. The axis of one of these is roughly parallel with the boundary line between Lafayette and Iowa counties, and extends from the Dodge branch south of Jonesdale, westward past Mineral Point to the vicinity of Lancaster and Bloomington. Along this region of uplift the lower rocks, such as the St. Peter sandstone and the Lower Magnesian limestone, are brought to the surface in the bottoms of the valleys, while along these valleys higher rocks outcrop both to the north and to the south. Another broad anticlinal uplift runs from the vicinity of Redrock westward towards Cuba, and brings up the St. Peter sandstone in the vicinity of Redrock and also along the Fever river just south of Meeker's Grove.

In addition to these folds of larger and smaller size whose axes run in an east-west direction, it is seen that some, especially of the smaller folds, have a pitch either to the west or to the east, showing that the district has been compressed somewhat by a force acting in an east-west direction as well as by one acting in a general north-south direction.

The general character of the anticlinal folds consists in a longer gently rising southern limb, and a shorter northern limb of steeper dip. A very marked instance of this kind occurs along the Fever river south of Meeker's Grove, where the St. Peter sandstone first appears in the southern edge of Sec. 34, T. 2 N., R. 1 E., and rises gradually as the outcrop is traced northward for two and one-half miles, the ascent in this distance being from 815 feet A. T. to 900 feet A. T. In the next quarter of a mile the top of this sandstone descends rapidly towards the north falling about ninety feet, and within a half a mile falling 130 feet. The details of this fold are brought out on the Meeker's Grove sheet, plate XVI.

Another marked instance of the same sort, where both sides of a syncline occur, rather than an anticline as in the case just given, is immediately northwest of Mifflin (see plate VIII) where the bottom of the Galena limestone on the south side of the synclinal basin descends over fifty feet in a distance not to exceed a quarter of a mile, and then rises to the north a like amount in over a mile. Other instances of this particular type of folding occur in other parts of the district as shown on the detailed maps.

In addition to the type of folds just described, there is another of a monoclinal character. Districts of this sort, when examined on the geological map, seem in many cases to represent anticlines rather than monoclines, for a lower-lying horizon, usually the Platteville limestone, is brought to the surface along a stream valley for a short distance and then disappears both to the north and to the south. Many of these cases, however, are not anticlines, but simply monoclinal folds. Examples of these may be seen along the stream north of Mifflin where the Platteville limestone comes to the surface in Sec. 22, T. 5 N., R. 1 E. (see plate VIII). Another locality where the same feature is brought out even more markedly is in the southwest corner of the Meeker's Grove sheet (plate XVI), where also the Platteville is brought to the surface. Another instance is along the three streams in secs. 4 and 5, T. 1 N., R. 2 E. (see plate XIV).

Fig. 1. Openings in the Galena limestone. East Dubuque, Ill.

Fig. 2. Dipping joints in the Galena limestone. East Dubuque, Ill.

Joints.

All the formations in the district, with the exception of the St. Peter sandstone and the Maquoketa shale, very commonly show pronounced series of joints. These are especially well developed in the massive beds of the Galena dolomite and they play an important role in the deposition of the ores. There are several directions of jointing; but the main joints are practically vertical. The most pronounced system strikes a few degrees north of west. Crossing this are other less important systems, the one more commonly developed striking a few degrees east of north.

In addition to the vertical joints just mentioned, there occurs at times, especially in the vicinity of the mines, a series of pitching joints. These usually have the same strike as the main vertical joints and are confined to the smaller synclines. (See figure 2 of plate XXIII). These dipping joints, which are inclined at from 20 to 60 degrees to the horizontal, are especially important in some of the mines, for in them occur the deposits known as "pitches".

CHAPTER IV.

THE ORES AND ASSOCIATED MINERALS.

The minerals of the lead and zinc district of Wisconsin are not as numerous, so far as species go, as one would naturally expect in a mining district; in fact, the minerals which are here to be ordinarily seen are confined to a few of the commoner forms. The most important minerals are galenite, sphalerite, smithsonite, marcasite, and calcite. These are by far the most abundant, most noticeable and most important. A number of other minerals, found associated with these, are of considerable interest and importance in a study of the ore deposits themselves.

THE ORES.

Lead ores.

Galenite. (PbS; lead 86.6 per cent., sulphur 34.4 per cent., specific gravity 7.4 to 7.6.) This ore is the only important lead ore of the district. It is known as galena, as lead sulphide, and the miners usually term it "mineral". Galenite commonly occurs in the form of crystals which are usually cubes, and less commonly octahedrons. Sometimes a combination of these two forms is seen. These large crystals of galenite sometimes reach a size of several inches or a foot across, and the miners have applied the term "cog mineral" to such large crystals. When the substance occurs in small crystals, especially when it is disseminated through the rock, it has been designated as "dice mineral." Galenite also occurs in peculiar reticulated form, when it assumes the shapes of various tree-like branches. This is the original lead ore of the district and from it have been formed other minor ores, but none of them are important. Unlike the galena of most mining districts, this mineral found in the Upper Mississippi valley lead and zinc district contains practically no silver.

Cerussite. ($PbCO_3$; carbon dioxide 16.5 per cent., lead oxide 83.5 per cent., metallic lead 77.5 per cent., specific gravity 6.46 to 6.57). It is known as lead carbonate and also as white lead ore. It occurs sometimes in minute, colorless crystals on the surface of the larger crystals of galena, as for instance at the Robarts mine near Linden. More commonly, however, it occurs as a white to yellowish powder-like coating on altered galena crystals. It is a secondary mineral derived from the alteration of the galena in the zone of weathering. It does not occur in any large amount and is not used as an ore of lead.

Anglesite. ($PbSO_4$; sulphur trioxide 26.4 per cent., lead oxide 73. 6 per cent., metallic lead 68.3 per cent., specific gravity 6.3.) This mineral has been mentioned in some of the earlier reports on this district, but it is of rare occurrence and examination of some of the so-called anglesite from Mineral Point shows that it is not a lead mineral, but is really selenite or gypsum.[1]

In fact, it may be questioned whether this mineral really exists in southwestern Wisconsin, but at the same time there is no apparent reason why it may not occur.

Zinc ores.

Sphalerite. (ZnS; zinc 67.15 per cent., sulphur 32.85 per cent., specific gravity 3.9 to 4.1.) It is known as zinc blende, zinc sulphide, and the miners commonly refer to it as "black jack," or simplyas "jack". This is by far the most important

[1] W. H. Hobbs: "A contribution to the mineralogy of Wisconsin." Bulletin of the University of Wisconsin, Science Series, vol. i, pp. 135-136, 1895. In this paper are descriptions of a number of the minerals of the lead and zinc district.

ore of the district and it is the original zinc mineral. It is found commonly below the level of the ground water and so was not discovered in the early explorations of the district, and it was not made use of until some years after its first discovery. It varies in color from a light straw-yellow through brown to jet black, this black color being due to impurities, especially iron. Sphalerite occurs most commonly in sheets lining the sides of the veins. On free surfaces there are small and rather poorly formed crystals. At times small nodules of sphalerite, ranging in size from those quite minute up to others which have a diameter of an inch or more, are found imbedded in the clays, especially in the clay bed which marks the top of the Platteville limestone. This form of sphalerite is frequently spoken of as "strawberry jack". It is seen at the Penitentiary mine near Mifflin, and also at the Capitola mine west of Platteville. From the alteration of this sphalerite the other zinc minerals of the district have been formed.

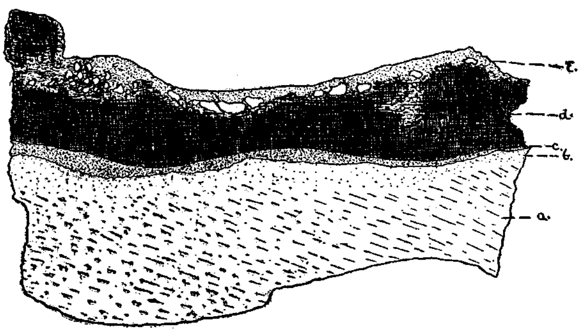

FIG. 1.—Specimen showing the usual order of deposition of the ores and their alteration. *a*, Compact, fresh limestone passing into altered, partly porous limestone, *b*; c, thin layer of marcasite altered in part to limonite; *d*, fresh sphalerite; *e*, smithsonite formed from the sphalerite.

Smithsonite. ($ZnCO_3$; carbon dioxide 35.2 per cent., zinc oxide 64.8 per cent., metallic zinc 52.06 per cent., specific gravity 4.3 to 4.4.) Smithsonite is known by the miners as carbonate, or more commonly as "dry bone," the latter name being given it in reference to its light, porous condition which roughly resembles the inside of a bone. This mineral occurs most frequently in the porous masses just spoken of, which are usually brownish or yellowish in color, and have a decided earthy appearance. At other times it forms thin coats or crusts on the rock and especially on calcite crystals, and not uncommonly the calcite is found to be replaced by a porous mass of smithsonite. Near the level of ground water it is very frequently possible to find specimens which show beautifully the alterations from sphalerite to smithsonite; in such cases the inside of a mass of smithsonite will be found to be made up entirely or partially of unaltered zinc sulphide. (See Fig. 1.) This ore of zinc in the early mining of the district was neglected, and it is now produced in considerably less amounts than formerly and in decidedly lesser amounts than is sphalerite. During the early period of zinc mining this was about the only ore of zinc mined, sphalerite not being used. At the present time most of the smithsonite is burned into zinc white at Mineral Point, and none of it is used in the production of spelter.

Hydrozincite. (A basic, hydrous carbonate of zinc; specific gravity 3.58 to 3.8.) This is known as zinc bloom. When pure it contains 60 per cent. of metallic zinc. Hydrozincite is frequently associated with smithsonite and it is often difficult to distinguish one from the other. In fact this mineral is rarely recognized in this district and no definite statements can be made as to its occurrence.

Calamine. (H_2ZnSiO_5; silica 25 per cent., zinc oxide 67.5 per cent., water 7.5 per cent., metallic zinc 54.23 per cent., specific gravity 3.4 to 3.5.) This ore of zinc is common in some districts; but it has not been certainly recognized in the Upper Mississippi valley district, although, because of its close resemblance at times to the massive, non-porous variety of smithsonite, it may possibly have been overlooked.

Other ores.

Iron ores. These exist in considerable abundance but are not of economic importance, so far as this district is concerned, with the exception of the iron sulphide (pyrite and marcasite) which is used in the manufacture of sulphuric acid. These two minerals are so intimately associated with the lead and zinc sulphides that they are described under the minerals associated with the ores.

Limonite is a hydrous oxide of iron and is known as brown hematite, yellow ocher, and by the miners it is frequently called "iron". Chemically it is a compound of iron, oxygen, and water. It exists in large amounts and is a product of the alteration of marcasite in the belt of oxidation.

Hematite is an oxide of iron and is known as red iron ore and red ocher. It is not as common as limonite, but the red clays which occur so abundantly with the lead ores owe their color mainly to the presence of hematite.

Melanterite is known as copperas, iron vitriol, and green vitriol. Chemically this is sulphate of iron. This is frequently formed in the decomposition of the sulphide of iron (marcasite), and very commonly heaps of this latter mineral are found covered with a white coating which is melanterite. This material, however, is soon dissolved and carried away and does not accumulate in large amounts.

Copper ores. While ores of copper are not abundant, they occur in places and have at times proved of economic importance. The original copper ore is chalcopyrite (a sulphide of copper and iron), and quite probably oxide of copper also occurs. In the belt of oxidation the copper ores have been altered to the green copper carbonate (malachite) and also less frequently to the blue copper carbonate (azurite).

Manganese ores. It is probable that some original sulphide of manganese exists in the district, from which has been derived the secondary mineral known as wad or black oxide of manganese. This latter is not common, but occurs at times and is called black ocher.

ASSOCIATED MINERALS.

Marcasite and pyrite. (FeS_2; iron 45.78 per cent., sulphur 54.22 per cent.; specific gravity 4.67 to 5.2.) These two minerals are intimately associated with the galena and the sphalerite, especially with the latter. Marcasite is sometimes known as white iron pyrites, and crystallizes in the orthorhombic system, while pyrite crystallizes in the isometric system and takes commonly the form of cubes and octahedrons. Marcasite is by far the most common form of the iron sulphide in this district and in the descriptions which follow it is assumed that all of the iron sulphide is in the form of marcasite. Pyrite is very much less common, although it does occur, and at times, as for instance at the Western mine, a short distance northwest of Mineral Point, the two minerals occur side by side. Marcasite is important economically from its association with the sphalerite and from the fact that in milling it is separated with some difficulty from this zinc ore. Above the level of ground water marcasite is commonly altered to limonite.

Calcite. ($CaCO_3$; carbon dioxide 44 per cent; lime 56 per cent.; specific gravity 2.7.) This is known commonly as calc spar and simply as spar, and the miners usually designate it as "tiff". It is the most common mineral in the district. It is almost always associated with lead and zinc ores and occurs frequently lining the inside of the veins, being deposited after the metallic sulphides already mentioned. It also commonly occurs in veins or in any kind of cavity throughout the limestones and dolomites of the district, especially in the Galena and Platteville formations.

Dolomite. ($MgCaCO_3$; carbon dioxide 47.9 per cent., lime 30.4 per cent., magnesia 21.7 per cent; specific gravity 2.8 to 2.9.) While this mineral is the important constituent of most of the Galena formation, it still almost never occurs in crystals of any size and it does not seem to have been deposited in the veins.

Selenite. ($CaSO_4$, $2H_2O$; sulphur trioxide 46.6 per cent., lime 32.5 per cent., water 20.9 per cent.; specific gravity 2.3.) This occurs in small crystals, but is not very common. It undoubtedly owes its origin to certain chemical reactions taking place between the calcium carbonate of the rocks and sulphuric acid due to the breaking down of the marcasite.

Barite. ($BaSO_4$; sulphur trioxide 24.3 per cent., baryta 65.7 per cent.; specific gravity 4.3 to 4.6.) This is commonly known as heavy spar. When it does occur, barite appears in the main in the vicinity of the oil rock and, although it is not common, in certain of the mines it is quite abundant. Aside from occuring with the oil rock, it also occurs lining cavities in the veins, being the last mineral deposited.

Sulphur. (S; specific gravity 2.) Native sulphur, though not abundant, is occasionally found in the lead region in a pulverulent or minutely crystalline form in crevices or small cavities in the mines. It is undoubtedly due to decomposition of the iron sulphides, marcasite and pyrite. It is never found in sufficient abundance to be of any importance.

Quartz. SiO_2; oxygen 53.3 per cent., silicon 46.7 per cent; specific gravity 2.6. This occurs chiefly in the form of flints, which are so abundant in certain parts of the Galena formation. Notwithstanding the large amounts of silica in the ore bearing rocks, it is rarely found in crystalline form, except in cavities in the Lower Magnesian limestone, and here the crystals are commonly quite small.

CHAPTER V.

THE ORE DEPOSITS.

The ores of the lead and zinc district of southwestern Wisconsin consist in: (1) lead sulphide or galena, the "mineral" of the miners; (2) zinc sulphide or sphalerite, the "black jack" of the miners; (3) zinc carbonate or smithsonite, the "dry-bone" of the miners. With the last seems to be more or less hydrozincite, but this is not easily separated from smithsonite, under which name in this report is included all the carbonate of zinc.

The only other original metallic mineral which occurs in considerable quantity intimately associated with the ores is the sulphide of iron; this takes the forms of pyrite and of marcasite, the latter being more common, and all the iron sulphide is here spoken of as marcasite. An oxide of iron (hematite) of an hydrous oxide (limonite) also occurs associated with the galena and smithsonite.

The original minerals of the ore deposits are the three sulphides just mentioned, galena, sphalerite and marcasite. The smithsonite and iron oxides are secondary minerals, having been formed from the alteration of the original sulphides. Small amounts of secondary lead minerals are also found, but not in sufficient quantity to form ores of importance.

The secondary minerals occur in the rocks above the level of ground water or extend a short distance below this level, i. e., they are confined to, and are a product of, the belt of weathering. The original minerals, with the exception of galena which is closely associated with both the original and secondary minerals, occur below the level of ground water.

Intimately associated with the foregoing metallic minerals are considerable quantities of carbonate of lime or calcite, and much less common than this is the sulphate of barium or barite. At times small amounts of chalcopyrite, a sulphide of iron and copper, occur with the other sulphides.

The minerals here mentioned are almost the only ones found in the ore deposits of the district.

FORMATIONS IN WHICH THE ORES OCCUR.

Very minor amounts of lead and zinc have been found in all the formations of the district, from the Niagara limestone down to the Cambrian sandstone. In the Maquoketa shale near the south edge of the State a little work for zinc ore has recently been done, but apparantly with no very encouraging results; and in the Lower Magnesian formation some ore has been mined, although none is being mined at the present time.

The productive ore bodies are confined to the Galena limestone and to the Platteville limestone. The deposits occur in all the divisions of the Galena, but the most important deposits, i. e., the peculiar flats and pitches, and the disseminated deposits, occur at, or near, the base of this formation. Some of the crevice deposits (rarely some of the flats and pitches, however,) run as high as the upper half and even close to the top of the Galena. In the Platteville the ore is confined to the upper member of the formation, and occurs most commonly in the shales immediately underlying the oil rock, in the main glass rock beds (as for instance, at the Little Giant mine near Shullsburg), and at times near the base of the glass rock associated with some narrow bands of oil rock. Ore in this last location is found at several points in the eastern part of the district, but especially around Linden, and particularly at the Mason mine.

Considerable attention has been devoted by the miners in the district to the question of prospecting for ore in the Lower

Magnesian formation. In regard to this matter it may be stated that some ore has been found in that formation, especially towards the north, but the ore bodies known in this formation are not anywhere nearly as extensive as those which occur in the Galena and the Platteville, and it is doubtful whether ore deposits of economic value exist in the Lower Magnesian where that formation is under a considerable cover of higher rocks. Moreover, prospecting for ore in the Lower Magnesian by deep drillings, or by shafts, is a very expensive operation compared with prospecting in the Galena or the Platteville, where each reaches the surface. All things considered, it is clear that it is not advisable to expend effort and time in drilling or in sinking deep shafts into the Lower Magnesian with the hopes of finding ore. The chances for thus finding ore are poor indeed, although there is still a possibility that such ore bodies may occur, but the small chance of finding them and the expense of the search ought practically to forbid work in this direction.

FORM OF DEPOSITS.

The lead and zinc ores occur quite commonly associated with each other, and they both occur in the same kinds of formations and in the same horizons. These ore deposits may be grouped into two divisions according to their form: First, those which occur in cracks or crevices in the rocks and which are in the nature of vein deposits; here are included the vertical crevices and the flats and pitches to be described below. Second, those which are disseminated in small particles throughout the rock and which do not occur in fissures which were once, or are now, open. These can be called disseminated deposits.

Crevice deposits.

These deposits occur in cracks or fissures, which have very commonly been enlarged by solution before the ore was deposited, but the ore minerals seem to have been in all cases deposited in open cavities, and are not in the nature of replacements.

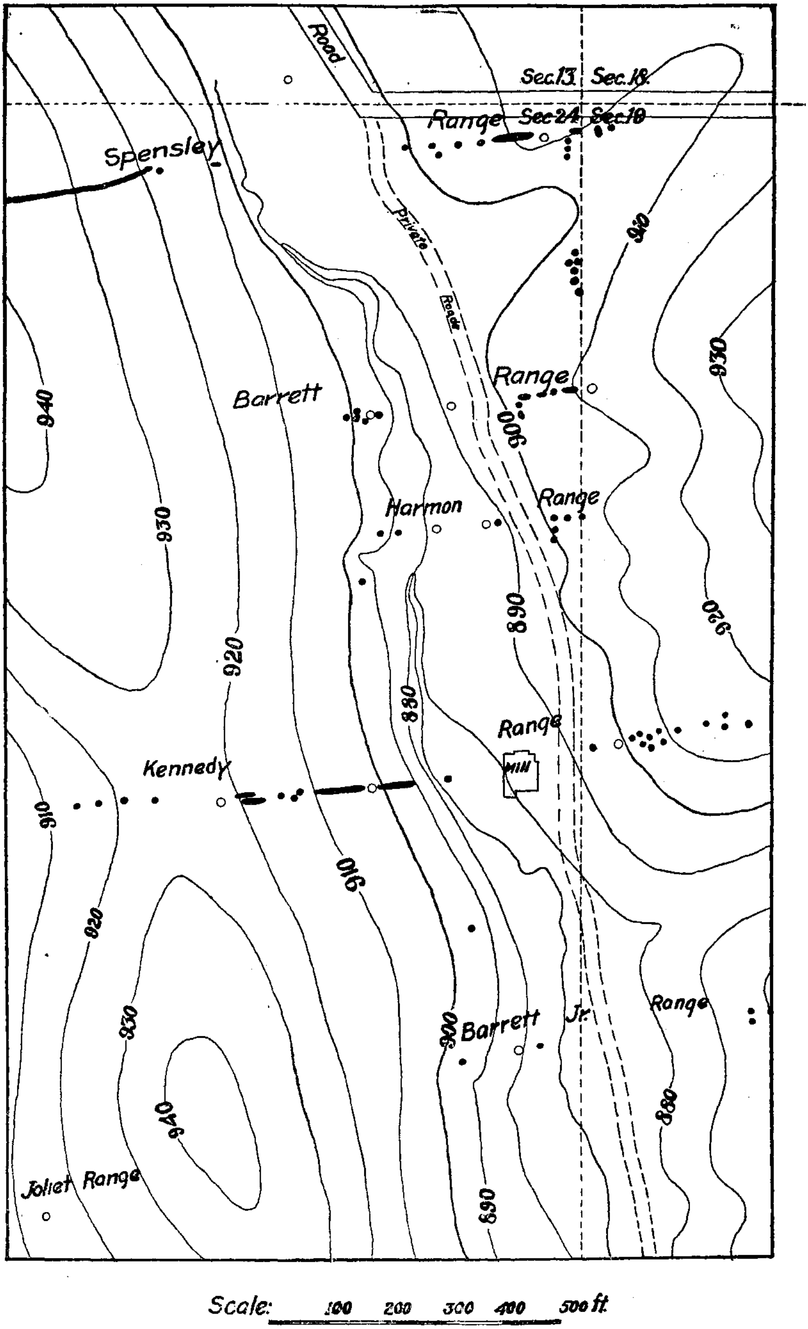

FIG. 2.—Map of Hazel Green mine, July, 1903. Contour interval, 10 feet. Circles represent test pits; heavy black dots and lines represent old workings.

These crevices occur along joint planes, or joint planes which have been enlarged by solution.

The direction of these crevices is in the main east-west, or a little north of west and south of east. They are crossed frequently by other crevices, the main series of the latter running a little east of north and south of west. To the first of the series of crevices the miners apply the term "east and wests," and to the second, "north and souths." In addition to these there are smaller crevices, crossing the main crevices at various angles, which are called quartering crevices, and to these the names "two o'clocks," "ten o'clocks," etc., have been applied, depending upon whether they run in the direction cast by the shadow of the sun at two o'clock or ten o'clock. The main ores have come from the east-west crevices, but it frequently occurs that where there is a crossing of crevices particularly rich deposits occur.

The general term "range" is applied by the miners of the district to a crevice, or a series of parallel crevices close together which carry ore, and these ranges can sometimes be traced for several hundreds of feet, and in some instances apparently for a few miles. The ranges are usually located in groups, i. e. several lying close together. An example of several ranges occurring near together is shown at the Hazel Green mine, near Hazel Green. Here (see figure 2) are five distinct ranges, while another range begins at the southwest corner of the area and runs westward. In some other localities the different ranges are much nearer together.

Along these vertical crevices it is found that the ore deposits sometimes extend horizontally out a short distance along certain beds, where solution of dolomite has occurred. It is thus that irregular cavities are found more or less filled with ore, and to these cavities the term "openings" has been applied. (See figure 1 of plate XXIII.) These openings occur more commonly in the upper half of the Galena, while the flats and pitches are in the main confined to the lower part of the formation. A good example of one of these crevices containing openings is shown in the accompanying sketch (Fig. 3).

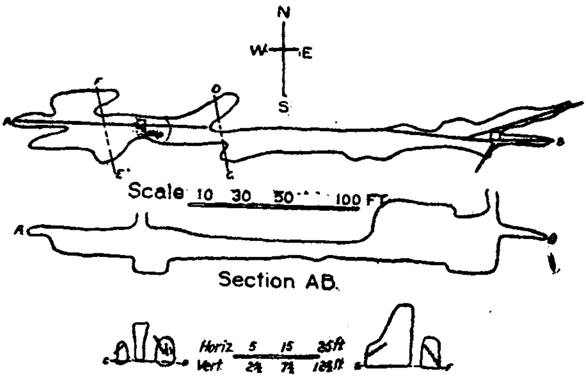

FIG. 3.—Plan and sections of one of the crevices at the Hazel Green mine. In the sections the dots connected by lines represent the ore (sphalerite). Mapped by E. E. Ellis for the U. S. Geological Survey.

In the lower part of the Galena formation, especially in No. 2 of the generalized section, these vertical joints are frequently replaced by a series of pitching joints which dip away on either side of the main vertical crevice. (See figure 2 of plate XXIII.)

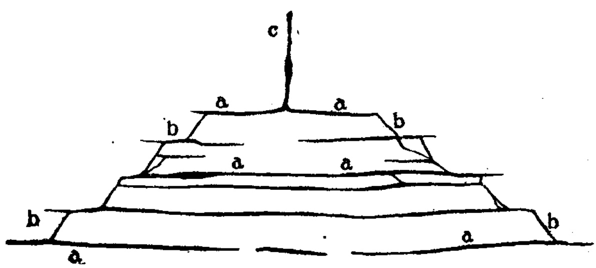

FIG. 4.—Diagram illustrating flats and pitches. *a*, flats; *b*, pitches; *c*, vertical crevice.

These pitching joints which carry ore are connected with horizontal openings, or joints, running along the bedding, which also carry ore, and to these peculiar forms of deposits the name "flats and pitches" has been given, the flats being the horizontal parts of the deposit, and the pitches the inclined parts. A diagram of this particular kind of deposit is shown in the accompanying sketch (Fig. 4), in which the black lines

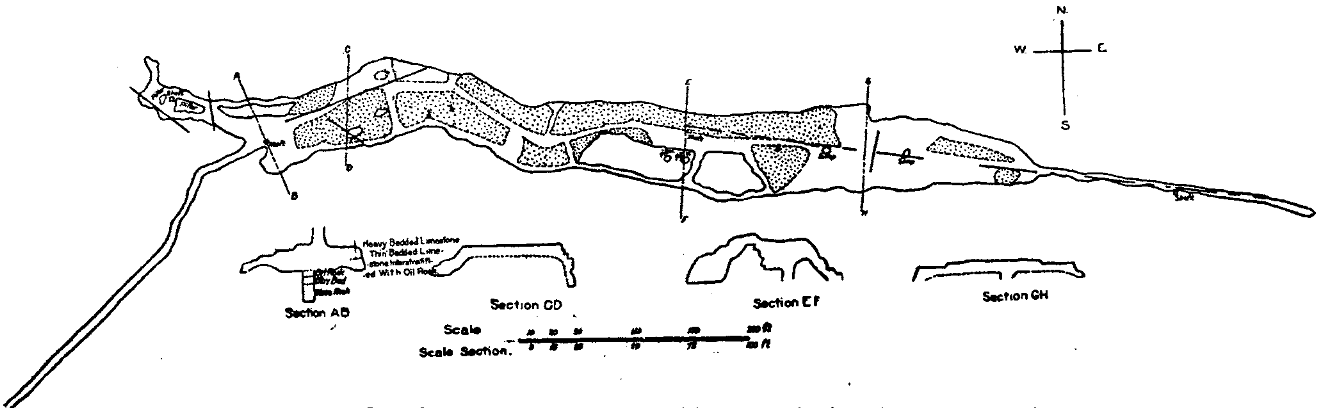

FIG. 5.—Map of the Empress mine, east of Benton. The dotted areas represent parts of the mine which are more or less filled with refuse rock. By E. T. Hancock.

represent the joints or cracks which are now filled, or nearly filled, with ore. These series of flats and pitches are usually connected with vertical east-west crevices, and they end commonly on the oil rock. The crevices usually do not extend below this latter horizon, although in some places, notably at the Little Giant mine at Shullsburg, the main glass rock beds contain numerous fractures filled with ore. At times such a series of flats and pitches may be 100 feet to 200 feet across, and where the flats run back from the pitches into the foot wall

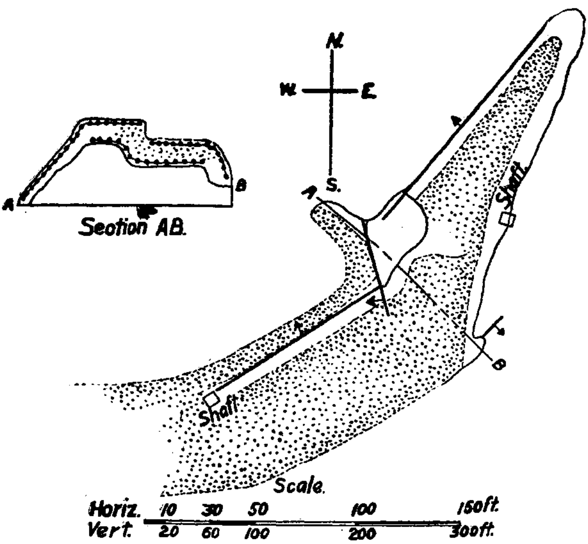

FIG. 6.—Map of part of the Robarts mine, near Linden. The dotted areas represent parts of the mine which are more or less filled with refuse rock. Straight lines with arrows indicate pitching crevices. In the section the heavy dots connected by lines represent the ore (galena) which is in flats and pitches. Mapped by E. E. Ellis for the U. S. Geological Survey.

there is a considerable mass of rock, extending from one pitch to the other, which can be mined out. Such a case occurs in the Hoskin and Kennedy mines near Hazel Green, and is represented on a smaller scale at the Empress mine east of Benton, a map of which, with sections, is shown in Fig. 5. This shows a typical case of the flats and pitches on a rather small scale. Another example of flats and pitches is shown in the Robarts mine near Linden, as illustrated by Fig. 6, and also in the

Ellsworth mine, northwest of Mifflin, as shown in Fig. 7. The Robarts is a lead mine, the others zinc mines.

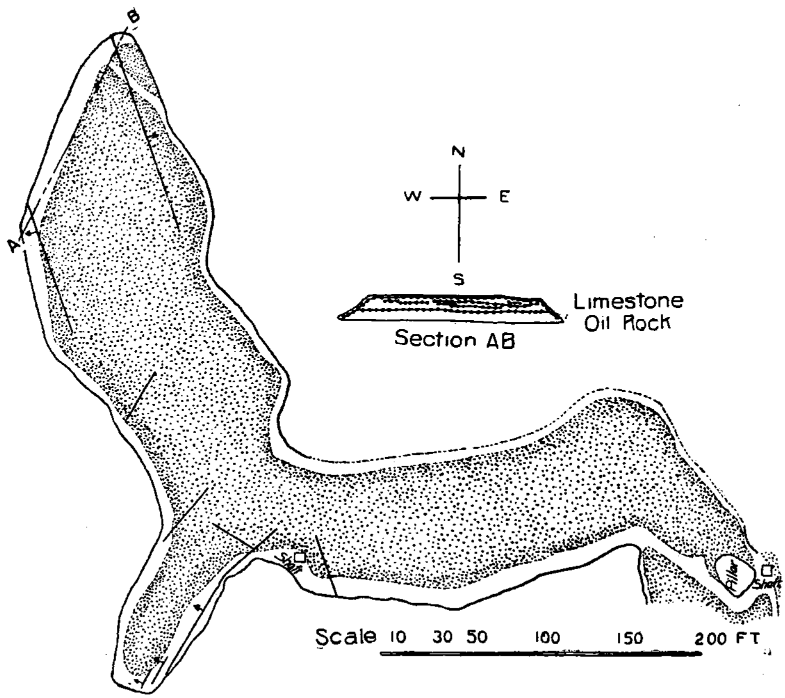

FIG. 7.—Map of part of the Ellsworth mine, northwest of Mifflin. The dotted areas represent parts of the mine which are more or less filled with refuse rock. In the section the heavy dots connected by lines represent the ore (sphalerite), which is in flats and pitches, mainly the former. Mapped by E. E. Ellis for the U. S. Geological Survey.

While the general type of pitches in any one mine strike approximately parallel with each other and also parallel with the vertical crevice, there are at times secondary pitches which carry ore and which have a direction markedly different from the main system of pitches. In the earlier workings of the Enterprise mine at Platteville the main pitches dipped to the south, while a subordinate series of pitches, near the east end of the mine, dipped to the east-northeast. (See Fig. 8.) Similar occurrences have been seen in other mines.

Associated with these crevice deposits are others, to which the name "honey-comb" deposits has been applied. Under this name are included certain apparently brecciated and very porous parts of the Galena limestone in which the cavities have been more or less filled by the ores. In some cases the brecciation of the limestone is very evident, but in other cases it is quite clear that the limestone was not brecciated but owes its present form mainly to solution. The two cases, i. e. cavities produced by brecciation and by solution, pass into each other in the same deposits. It seems quite likely that originally the rock was brecciated or partly brecciated, allowing free access to circulating waters and that these waters have enlarged and added to

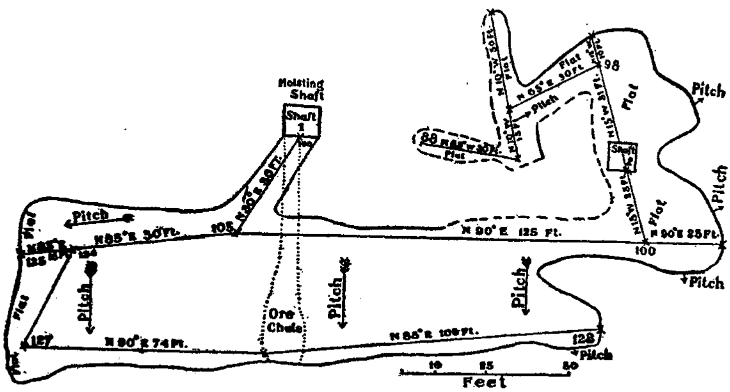

FIG. 8.—Map of the Enterprise mine at Platteville, Sept., 1902. Rock walls of workings shown by full lines; filled walls by broken lines. Figures near crosses indicate approximate distances, in feet, from surface of ground at top of hoisting shaft.

the cavities by solution of the semi-brecciated or strained limestone. These honey-comb deposits occur sometimes as small openings or enlargements of a crevice, but their main importance lies in the fact that they make extensive deposits, first along vertical fissures, and second along flats. As an example of the vertical deposits of this class may be mentioned the Oldenburg mine near Galena. As examples of these deposits in the form of flats may be mentioned the Strawberry Blonde mine at Strawbridge and parts of the upper flats of the Enterprise mine at Platteville; also parts of the Hazel Green mine,

PLATE XXIV.

FIG. 1.—Disseminated ore in the blue limestone just above the oil rock, St. Rose mine west of Platteville. The stippled areas represent blue limestone, the clear areas calcite, and the dark areas sphalerite.

FIG. 2.—Cross section of a stalactite-like mass, New Deal mine. The solid black in the center represents Galena; the small clear areas represent marcasite; the finely radiating lines show black radiating sphalerite; outside of which is yellow sphalerite in coarse, radiating and concentric structure.

FIG. 3.—Disseminated ore in the oil rock, Klondike mine west of Platteville. The dark-lined areas represent the usual oil rock; the stippled areas porous, lighter colored oil rock; and the dark areas sphalerite.

FIG. 4.—Blue limestone showing barite, sphalerite and galena, Enterprise mine. The stippled areas represent limestone; the clear areas with radiating lines represent barite; the double lined areas, sphalerite; the single lined areas, galena.

Fig. 1.

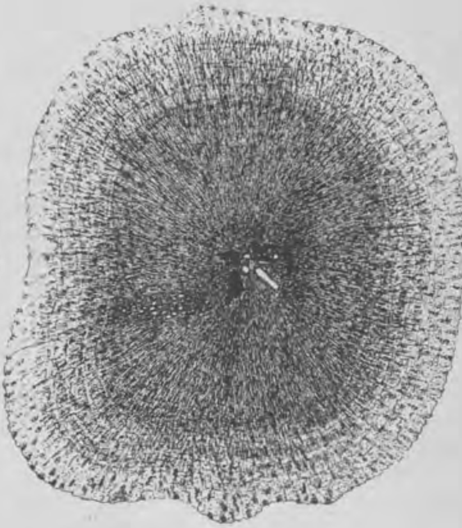

Fig. 2.

Fig. 3.

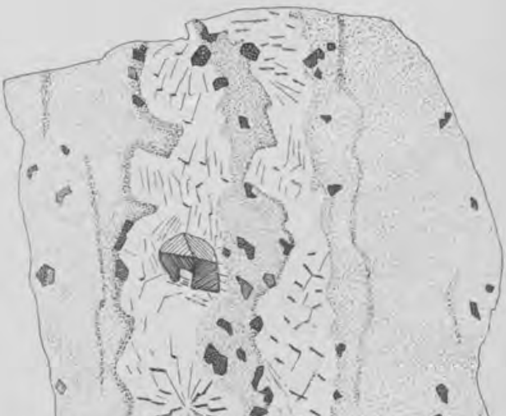

Fig. 4.

near Hazel Green, and the Dawson mine near Benton. The order of deposition of the ore minerals in deposits of this class is the same as in the ordinary crevice deposits, but galena appears to be usually lacking or is present in only small amounts. The honey-comb deposits are genetically connected with the ordinary crevice deposits and pass into them.

As before stated, the vertical crevices filled with ore exist at times not in connection with the flats and pitches. We find also that at times flats occur without pitches. These flats are chiefly found at, or just above, the horizon of the oil rock, and they also occur, especially around Linden, just below the main glass rock beds, where there is also another small band of oil rock. The ore in these flats in certain cases has been deposited in open cavities that were made by solution, but in other cases it seems to be a replacement deposit, and thus grades directly into the next class, called disseminated deposits.

Disseminated deposits.

These are horizons in the rock which have been more or less permeated or impregnated by crystals of sphalerite and of galena. The actual separation of these disseminated deposits from the flats found in connection with the oil rock just mentioned cannot always be sharply made. The particular horizons for these disseminated deposits are (1) thin beds of limestone or dolomite which immediately overlie the oil rock, (2) in the oil rock itself, (3) in the clay bed, which in some of the mines immediately underlies the oil rock, and (4) at the base of the main glass rock beds associated with some thin layers of oil rock. Deposits of this character are especially well developed west and south of Platteville, as for instance at the Graham and Stevens, the Klondike, the Tippecanoe, and the Capitola mines. The mode of occurrence of the ores and their relation to the containing rock is shown in figures 1, 3 and 4 of plate XXIV.

While the flats and pitches and the vertical crevices usually carry noticeable amounts of marcasite (sometimes the marcasite is in great abundance) it can be stated as a general rule that the disseminated deposits carry less marcasite than do the flats and pitches and the vertical crevices.

ORDER OF DEPOSITION OF THE ORES.

In the crevice deposits, as already stated, the ore has been deposited in open fissures. The usual order is as follows, beginning from the wall and going to the center of the vein: (1) marcasite, (2) sphalerite, at times containing some galena, (3) galena, (4) calcite, (5) barite. This may be called the universal order of deposition of those ores and the minerals associated with them. In not every case, however, are all five of these bands observable, but practically everywhere the wall rock is coated by a layer, either thin or thick, of marcasite, and outside of this is sphalerite which may, or may not, carry a little galena, and which may, or may not, have galena outside of it. The richest ore of the district, and that which is quite important in a number of the larger mines working in the flats and pitches, is this second layer made up essentially of sphalerite with at times some little galena. In places a layer of ore on either side of the open crevice is from three to six inches in thickness.

While the order given above for the deposition of the ores is the general rule of the district, it is found that sometimes a second period of marcasite deposition has taken place; and rarely all of these metallic sulphides are mingled together.

CHANGE OF ORES IN DEPTH.

While there is a marked arrangement of ores from the wall rock out to the center of the vein, there is a still more marked and more important arrangement in a vertical direction. Three distinct zones are noticeable in this connection. At the top and frequently near the surface of the ground, there is a zone containing large crystals and masses of galena. This, of course, is above the level of the ground water, and it is a zone which is being continually lowered by erosion. Below this is a zone in which smithsonite is the important ore. This extends down to, and in some cases a few feet below, the level of ground water. The third zone, existing below ground water level, is essentially a sphalerite zone.

While the three zones just mentioned are each characterized by its own peculiar mineral, the galena of the first zone extends down into the second zone with the smithsonite, and galena is found also to some extent in the zone of the sphalerite, especially near the top of this lower zone. It is here that there are frequently found small or large crystals of galena deposited on the sphalerite in the open center of the veins. But a short distance below the top of this lower zone these galena crystals become very much less important and in the deeper part of this zone the main galena exists intimately mingled with the sphalerite.

The smithsonite of the whole district is an alteration product from the original sphalerite and this alteration has taken place everywhere in the zone above the level of ground water, and in some cases oxidizing waters have brought about this alteration a few feet below the top of the water table. The lower part of this second zone commonly contains specimens showing all stages of alteration from sphalerite to smithsonite. (See figure 1.)

The depth of the ground water level in this quadrangle varies markedly. It is from zero to ten feet below the surface in the valleys, while on some of the broad interstream areas water is not reached within one hundred feet from the surface.

RELATION OF ORE DEPOSITS TO STRUCTURE.

The fact that the crevice deposits occur in joints, or more usually in joints which have been enlarged by solution, has already been mentioned. These joints bear a close relation to the folding which the district has undergone, the principal joints running approximately parallel to the main axes of folding.

The detailed mapping, the results of which are presented with this report, has demonstrated conclusively that very many of the lead and zinc deposits of the region are in synclinal basins. This is especially true of the disseminated deposits and the flats which are associated with the main oil rock and with the thin seams of oil rock which lie just below the glass rock. For examples of these deposits lying in structural basins it may be stated that practically all of the mining in the vicinity of Dodgeville is confined to a wide, shallow, basin-shaped, rock depression which slopes off towards the southwest. (See plate IV.) West of Platteville at the Graham mine and at the Capitola mine, both of which are in disseminated deposits, this basin-like character in the rocks is also apparent (see plate X); and it comes out even more markedly in the Highland mining district. (See plate II.)

Not only are there disseminated deposits in these structural rock basins, but in certain instances, at least, the well known and important flats and pitches have been demonstrated to occur in basins of this character. Examples of this sort are seen in the Blende and the Ida mines just southeast of Benton (see plate XII), and the Rowley mine north of Buncombe (see plate XII), the Sally Waters mine near New Diggings (see plate XII), while the important deposits of the Empire and Enterprise mines at Platteville (see plate X) also seem to lie in another basin of this description. In the vicinity of Hazel Green the Hoskin and the Kennedy mines are in a synclinal basin and this same basin apparently extends westward to include a number of the mines worked in former years just south and east of Hazel Green. (See plate XII.)

Sufficient data are not at hand to show that all of the deposits occurring in flats and pitches do exist in these synclinal basins, but there can be no question as to their general relation to these basins, and it is confidently expected that future and more detailed mining exploration will show that other of the mines are intimately connected with these structural basins. As has been stated, it is not possible to always separate these synclinal basins into two classes as to their origin, that is, some of them may be due to original inequalities in sedimentation, while others, especially those which are quite marked, are undoubtedly due to folding.

One of the best illustrations of the important ore deposits in synclinal basins is shown at the mines in the vicinity of Linden. (See plate VI.) It will here be seen that the Mason mine, one of the most important in the past history of the district, and one which is still producing today, lies very close to the axis of a syncline. The same can be said of the Milwaukee and the Glanville mines, just to the east of the Mason, while the Robarts mine lies in a minor syncline included in the large synclinal basin about Linden. It is quite probable that the old workings which are so abundant just west and northwest of the Robarts mine are also in a minor southward plunging syncline which is not well brought out by the structural contours.

ORIGIN OF THE ORE DEPOSITS.

The United States Geological Survey is now carrying on a careful study of the ore deposits of the Upper Mississippi Valley lead and zinc district, and it is not possible at the present time to discuss fully the question of the origin of these ores Some few facts, hovever, may well be mentioned here.

It is now commonly believed by geologists that the ore deposits of this district are derived entirely from the country rock, i. e. in the main from the Galena dolomite. There is no evidence whatever that the ores have been brought up from deeper seated areas, as is the case in many metalliferous mining districts. The ore substances were, in all probability, brought in solution from the crystalline rocks existing to the north and were precipitated by some means, possibly by plant life, in the Ordovician ocean. The ore deposits as they exist today are due to the circulation of waters in these Ordovician rocks; these waters have dissolved the minute particles of these metallic substances scattered through the rocks, and have redeposited them in their present position. Some idea of the very minute quantity of lead and zinc necessary in the country rock to form ore deposits of importance, can be had from the following account of the Potosi district.

"At my suggestion, Mr. I. M. Buell made an estimate of the amount of impregnation of the rock that would occur, if the entire quantity of ore taken from the Potosi district were uniformly distributed through the adjacent rock. This district was selected because (1) it has been one of the most productive, (2) has definite outlines, (3) a somewhat uniform distribution of crevices, and (4) is withal one of the most concentrated districts of the whole region. In determining the limits of the district, a margin outside the outermost crevices was allowed equal to half the average distance between the crevices, i. e. the outside crevice was supposed to draw only as much from the territory outside as from that between it and its neighbor crevice. As the basin occupied by the district extends some distance on every side, this is a very moderate assumption. Furthermore, it was assumed that only 100 feet in depth had been leached in the derivation of the ores, although probably twice that amount of rock originally lay about the base of the deposit. The result was *one fourteenth-hundredth of one per cent.*, or a little more than seven-millionths part of the rock, a quantity that may seem surprisingly small to those who, by dwelling on the relative value of the ores magnify their relative quantity, a quantity certainly small enough to answer certain inconsiderate objections to the theory of derivation of the ores from the enclosing rock, based on the want of ocular evidence of their metalliferous character."[1]

As has already been stated, the ore deposits in many cases are intimately related to the structural basins. These structural basins are floored, at least as far as the Galena dolomite is concerned, by practically impervious layers, i. e. the oil rock and shale just below it. It seems quite clear then that these basins with impervious floors have acted as channels for water circulation, that the water has descended to the impervious floors and then has flowed along in the direction of the pitch of these synclines. In the case of the disseminated deposits it seems very clear indeed that the organic matter found in the oil

[1] T. C. Chamberlin, Geol. of Wis., vol. 4, p. 538, 1882.

rock has had an important role to play in the precipitation of the metallic substances held in solution. The agency of precipitation in the crevices higher up in the formation is not so clear.

Returning to a consideration of the vertical arrangement of the ores in different zones, it can be stated that there is evidence to show that the ore minerals are continually migrating downward along the crevices. Sphalerite is quite readily altered to smithsonite and part of this is dissolved and carried downward to be precipitated close to the water level as smithsonite, or to be carried still further down and precipitated as sphalerite. The galena on the other hand, is not so easily dissolved and so does not travel downward as rapidly, a large part of it remaining close to the surface, and probably traveling downward only a little faster than erosion lowers the surface. The lead which is dissolved and carried down is commonly precipitated at, or a short distance below, the level of ground water, and this gives rise to the large crystals of galena which frequently line the veins in the upper part of the lower ore zone.

CHAPTER VI.

GENERAL CONSIDERATIONS.

MINING.

Mining in this district has been carried on for the last seventy years and is today in many parts of the district done in the same primitive manner that it has been for years past. There still are many lead and dry-bone diggings which are worked only a few weeks or a few months in the year, when the owners are not engaged in the work of farming. In these small mines the work is of a very primitive character and will probably continue to be such. At the same time these mines have produced, are producing, and in all probability will continue to produce for a long time to come considerable quantities of zinc carbonate and galena.

In many places the early workings in the district were carried on very thoroughly within limited areas and the evidences of extensive former operations are today quite noticeable. A large amount of this early mining was confined to shallow workings in search of lead. In certain places the ground down to a distance of twenty feet from the surface has been literally honey-combed by this early work, so that now there are tracts of many acres in extent, the surfaces of which are rough and broken areas of knolls and hollows. An example of this early work in the district is shown on the accompanying sketch (Fig. 9), where the irregular circular areas represent old pits and the crevices are represented by heavy lines. It was custom-

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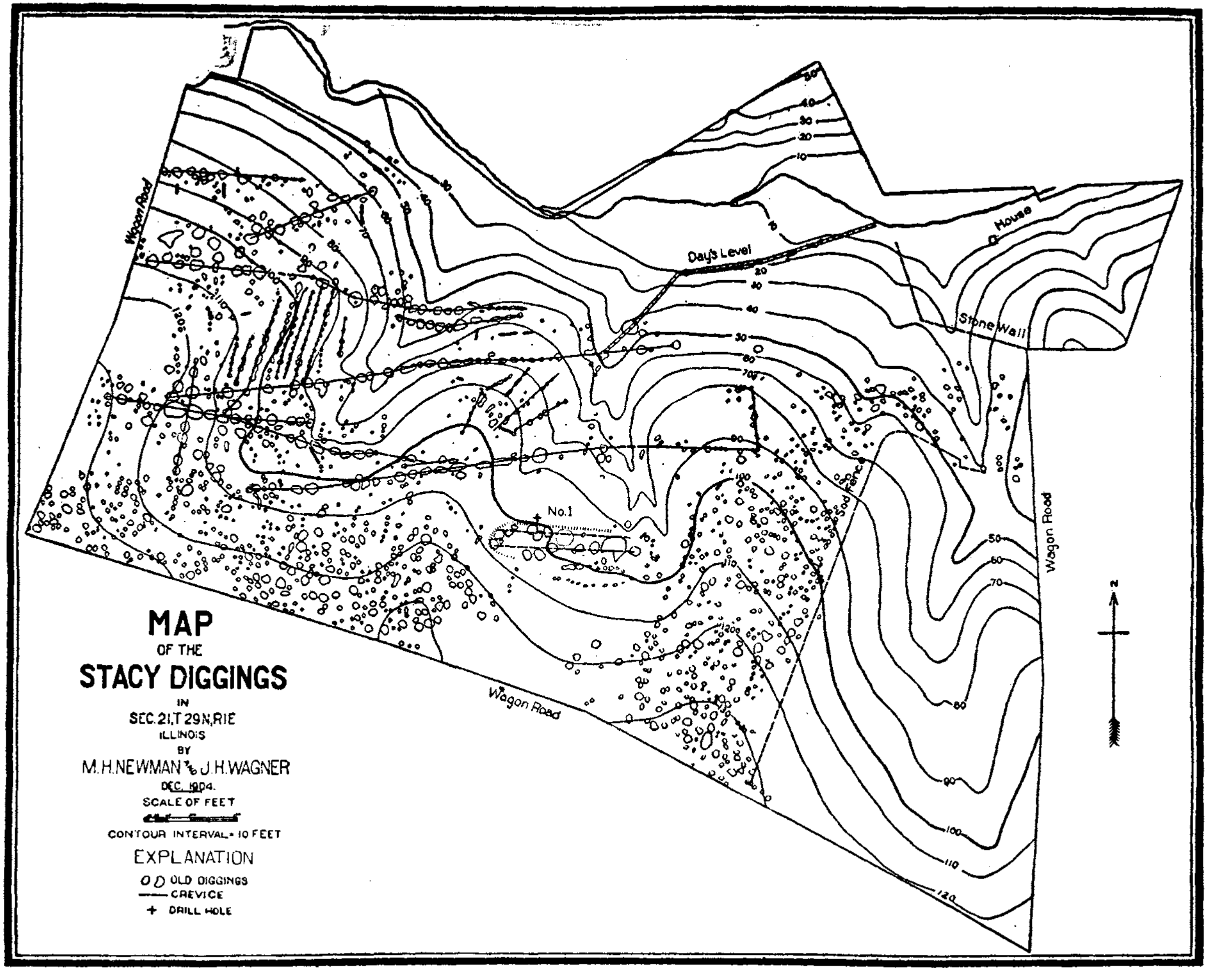

FIG. 9.—Map of Stacy diggings.

ary to sink pits very close together along crevices, and frequently from the bottoms of these pits tunnels were run out. At the present time practically all of the old workings are caved in. These old workings furnish at the present time the very best places for prospecting, and in fact it may be said that practically all of the larger mines working today are operating on the lower portions of deposits which were worked close to the surface in years gone by. There are most excellent reasons for believing that within the lower 75 feet of the Galena limestone and the upper part, perhaps the upper 15 feet, of the Trenton limestone, there exists such a quantity of lead and zinc ore, especially zinc ore, that the supply will not be exhausted for a number of years to come. This statement is made after a careful consideration of the facts in the case and a study of the mines which have been recently opened up. It is only within the last few years that much mining has been done at levels below the water table. And what mining has been done seems to have demonstrated in a large number of cases that below the old ranges, which were worked in past years for large quantities of lead ore, are other deposits of zinc ore with minor quantities of lead. While it is not probable that each one of these lead bearing crevices traced down will develop into a series of flats and pitches carrying large quantities of lead and zinc, still there is every reason to believe that very many of these crevices do this. In this connection it might be well to quote the statement made by Chamberlin some twenty years ago, a statement which work in the district since that time, and especially that which has developed within the last two years, has shown to be eminently true.

"*Probabilities of ore below given horizons.*—Where lodes have been mined in the upper measures of the Galena limestone, and work has been suspended by reason of water or other practical difficulties, there is strong presumption of valuable deposits below. These may be shifted along the crevice or to one side, according to the drift of subterranean drainage. The relation of the 'twelve foot opening' deposits to the 'sixty-five foot opening' at Muscalunge may be studied with profit on this point.

"In the middle and lower portions of the Galena limestone where lead ore alone has been found at higher horizons, we deem it altogether probable that mixed lead and zinc ores occur. The progress of mining seems to indicate that zinc ores are more widely and abundantly distributed in the lower beds than has been heretofore supposed. It may be quite unsafe to assume that beneath all the lead deposits there is a corresponding formation of zinc, and that every crevice that is lead-bearing in its upper reaches will develop zinc below, but such is the general tenor of evidence, and the general presumption is in favor of this as a rule. It would manifestly be of the greatest importance, if it were possible, to determine any definite ratio between the amount of lead in the upper beds and that of zinc below. In our previous discussions, pages 472, 488, we have alluded to this subject and have given some facts bearing upon it, facts which, we think, have not been generally known, or appreciated, in their bearing upon this important practical question. If the results of experience in a few of the most important mines of the whole region, from which the most of reliable statistics have been obtained, are to be taken as fair representatives of the general fact, which may be doubted, we shall be justified in concluding that an amount of zinc equivalent to that of lead might not be far from the general rule. But I must say, candidly, that I deem such a deduction too uncertain to be much trusted. But that greater richness in zinc in the lower beds is being, and is likely to be developed, than has heretofore been indicated by some of my official predecessors seems to me scarcely questionable. I incline to the judgment, therefore, that this region, in which the annual zinc product already surpasses that of lead, and which should rather be called now the zinc district than the lead region, will continue to develop an increasing relative importance in the latter resource."[1]

[1] Geol. of Wis., vol. iv, pp. 567-568, 1882.

As to the question of the discovery of large numbers of other ranges, especially in the areas which have yet produced no ore, no complete answer can be made. It is of course true that new ranges are being discovered from time to time, and old ranges are being extended. But the facts (1) that there are hundreds of these ranges already known, only the upper parts of which have been mined, and (2) that below at least many of these there are very good reasons to expect as rich or richer deposits of zinc and of lead ore, are sufficient reasons for believing that the future will see more zinc ore produced from this district than has been produced in the past; but it is doubtful if the same statement can be made in reference to lead.

The recent revival of activity in mining in this district has developed a considerable number of mines which are operated on a more extensive plan than was formerly the case, and which have been able by the introduction of machinery to mine a considerable distance below the level of ground-water. The present development of the region is due in a large part to these more modern methods of mining and concentrating the ores. The plants are, from the nature of the deposits, comparatively small, but are well adapted to the needs of the region. Within the last four years some thirty or more mines have opened up with modern machinery. (See plates XXV and XXVI.)

CONCENTRATION.

In the early days, and still to a considerable extent in the smaller mines, the ores were concentrated by hand sorting, by cobbing and by hand jigging. In the larger mines these primitive methods have been done away with and the metallic sulphides are removed from the surrounding rock in concentrating mills, which are built on the plan of those used in the Joplin zinc district. In these mills series of jigs are used to make a successful separation of the galena from the sphalerite and marcasite, but these two latter minerals, because of a somewhat similar specific gravity, cannot be successfully separated

Fig. 1. Kennedy mine (in center) and Hoskins mine (to the right), near Hazel Green.

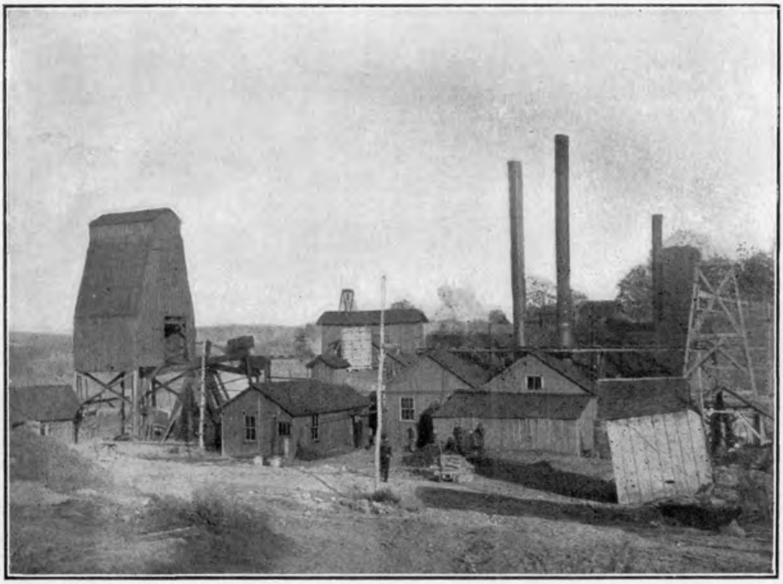

Fig. 2. Trego mine, Meekers Grove.

entirely from each other by ordinary jigging. Still the marcasite percentage in the cleaned ore is frequently so low as to allow the ores to be purchased for the making of spelter and in cases where the marcasite percentage is higher the ores are sold to the Mineral Point Zinc Company for use in the manufacture of sulphuric acid and zinc oxide. Some of the mines have installed rotary roasters and magnetic separators. In these the ore is roasted until the outer parts of the grains of marcasite are changed to iron oxide, and then the ore is passed under electric magnets which extract the iron mineral from the sphalerite. This method has proved very successful,—so much so that at the present time large quantities of ore of high grade are being sent out from the district. In fact this method has overcome the main handicap from which the district has suffered, and with this question settled the future seems exceedingly bright.

Some experiments have been carried on in the district looking towards the separation of marcasite from the sphalerite by static electricity, and if this can be successfully and economically done the marcasite, which after the roasting process is now unsalable, can be sold also.

In a few of the mills concentrating tables have been introduced with the expectation that much of the finer part of the ore which now escapes from the jigs can be saved and that in some cases a better separation between the sphalerite and the marcasite can be made. At the present time these concentrating tables are not in common use.

PROSPECTING.

In the matter of prospecting it is wise to carry in mind the fact that, other things being equal, the ranges and the districts which produced in early days close to the surface of the ground large quantities of lead, or lead and zinc, are the most favorable locations. The chances are, as has been stated above, that a range which has borne considerable quantities of these materials in its upper part will continue to bear large quantities in its lower part, the main difference being that below the level of ground water there will be less lead, practically no smithsonite, and probably much sphalerite. In selecting an area for prospecting, however, one should be taken in which there is below the level of ground water a considerable thickness of the Galena limestone, i. e. a considerable thickness of rock which may carry ore, for the deposits in many cases are limited by the base of the Galena limestone, and in nearly all other cases are limited by the oil rock bands at the base of the main glass rock horizon of the Platteville formation.

Bearing in mind the two points just mentioned, a third should be added, and that is, that a range, or a series of ranges, or a district, which can be shown to lie in a synclinal basin, is a more favorable place for prospecting than one which is not so situated.

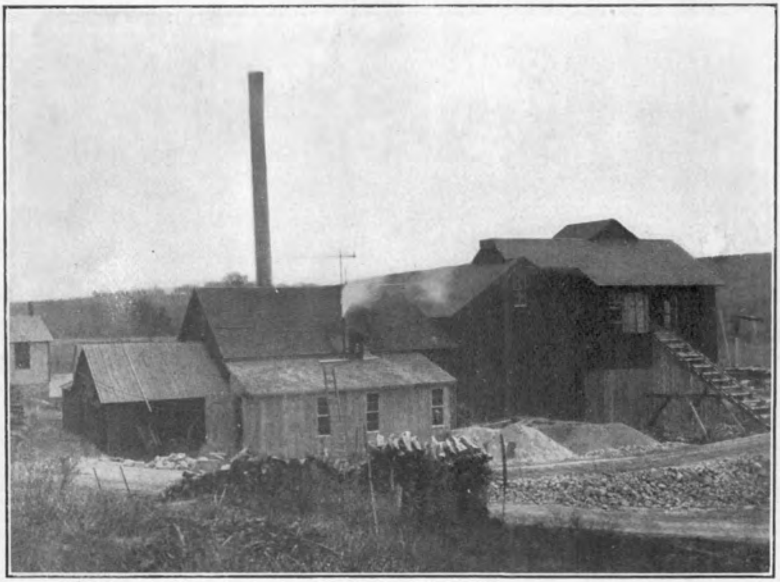

Fig. 1. Concentrating mill of the Enterprise mine. Platteville.

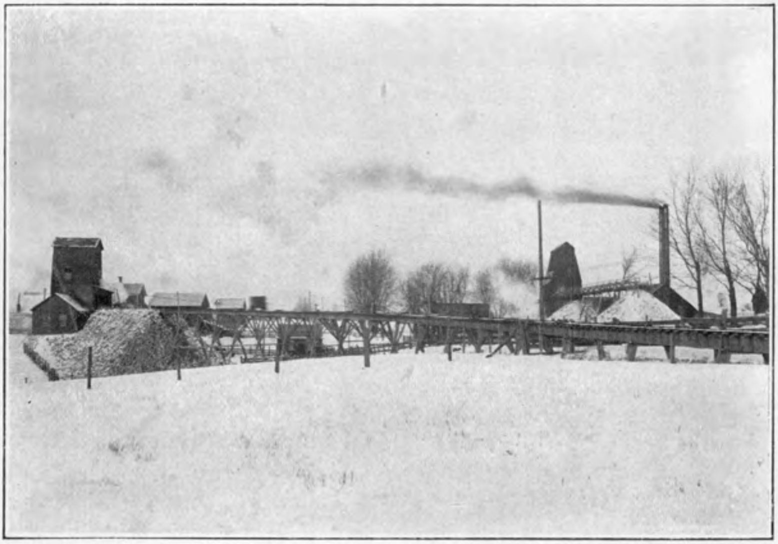

Fig. 2. Shafts of the Empire mine, Platteville.

CHAPTER VII.

THE DETAILED MAPS.

INTRODUCTION.

Following the suggestions made in an earlier report,[1] the Survey carried on during the summers of 1903 and 1904 field work which resulted in the careful and detailed mapping of most of the important mining areas in the lead and zinc district.

In this field work the topographic and geographic mapping of the district were conducted at the same time. Each individual doing part of the mapping was furnished with a small planetable, an alidade sight ruler, an aneroid barometer, and a Locke hand level. Preliminary to the mapping bench-marks had been established at intervals of one-fourth mile or less along the roads of the district mapped, the data for these bench-marks being obtained by leveling from established bench-marks of the United States Geological Survey. As the roads are rarely more than a mile apart—usually within half a mile of each other—the opportunity for careful topographic mapping was good, and the use of the aneroid barometer was made satisfactory by the ability to check on the bench-marks at short intervals of time. For general locations the mapping depended on the roads of the district, which usually run along section lines, and on the subdivisions of the farms, which usually correspond to the fractional section lines. Locations, aside from these, were drawn in by intersections and by pacing.

[1] Wisconsin Geol. and Nat. Hist. Survey, Bull. ix, p. 95, 1903.

Along with the topographic work geological mapping was done, all the important outcrops being located and the contacts between the different formations being determined as to elevation by the barometer and in some cases by leveling. The field maps were made on the scale of 8 inches to the mile, which is reduced to 4 inches to the mile on the published map. The contour interval used was 10 feet.

During the summer of 1903 the following persons were engaged in this mapping:

E. F. Burchard, geology and topography (for part of the season).
E. T. Hancock, geology and topography.
E. E. Ellis, geology and topography.
M. J. Perdue, geology and topography.
A. F. Crider, geology and topography (for part of the season).
R. I. Dugdale, levelman (for part of the season).
G. S. Fulcher, levelman (for part of the season).
L. Smith, rodman (for part of the season).
J. C. Harcleroad, rodman (for part of the season).

In the summer of 1904 the following persons carried on this work:

M. J. Perdue, geology and topography.
E. E. Ellis, geology and topography (for part of the season).
G. H. Cox, geology and topography.
G. S. Fulcher, geology and topography.
J. R. Banister, geology and topography.
G. H. Cady, geology and topography (for part of the season).
B. J. Spence, levelman.
C. S. Blair, levelman.
W. J. Reed, rodman.
J. L. Moss, rodman (for part of the season).

THE TOPOGRAPHIC MAPS.[1]

In the topographic mapping a large number of temporary bench marks were established along the roads and frequently along section lines. These bench marks were usually on telegraph poles, bridge rails and fence posts. They are commonly

[1] Description taken largely from the U. S. Geological Survey folios of the Geologic Atlas of the United States.

marked by a blaze on the pole and a horizontal line or a cut at the bottom of the blaze, which indicates the position (vertically) of the bench mark. The figures on these bench marks soon disappear, but the bench marks themselves in many cases remain and their elevations can be obtained from the maps. On the maps the bench marks are located by small black crosses and their elevations are given in figures in brown.

The features represented on the topograpic map are of three distinct kinds: (1) inequalities of surface, called relief, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called drainage, as streams, lakes and swamps; (3) the works of man, called culture, as roads, railroads, boundaries, villages and cities.

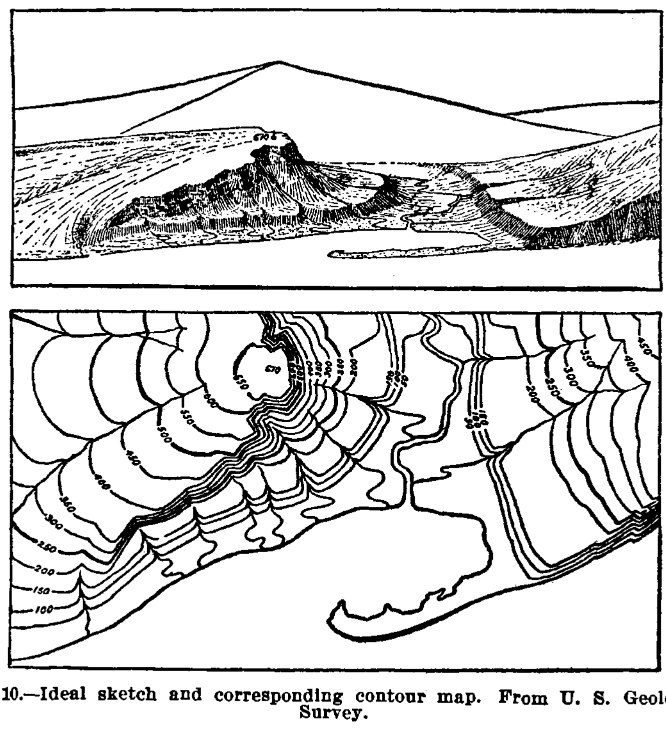

FIG. 10.—Ideal sketch and corresponding contour map. From U. S. Geological Survey.

Relief. All elevations are measured from mean sea level. The heights of many points are accurately determined, and, as has been stated above, most of these are shown on the maps. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the horizontal outline, or contour of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical space between each two contours is called the *contour interval.* Contours and elevations are printed in brown.

The manner in which contours express elevation, form and grade is shown in the accompaning sketch and corresponding contour map. (Fig. 10).

The sketch represents a river valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sandbar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply in a precipice. Contrasted with this precipice is the gentle descent of the slope at the left. In the map each of these features is indicated directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form and grade:

1. A contour indicates approximately a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain con-

tours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour. In the detailed maps accompanying this report the contour interval is 10 feet and each fifth line is heavier.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

Drainage. Water courses are indicated by blue lines. If the streams flow the year around the line is drawn unbroken, but if the channel is dry a part of the year the line is dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs. Springs are shown by small circles.

Culture. The works of man, such as roads, railroads and towns, together with boundaries of townships, counties and states and artificial details are printed in black.

THE GEOLOGIC MAPS.

The geology is shown by a series of patterns in color. Each of the formations represented in the district is given a different pattern or a different color. Where an area is covered by any particular pattern it indicates that rock of that particular formation exists at the surface, or immediately beneath the surface below the soil and decayed rock. The geological boundaries are indicated by dotted black lines, and it will be noted that while these boundaries very frequently run approximately parallel with the contour lines, as is the case when the rocks are practically horizontal, in many instances they cross the contour lines, thus indicating that the rocks are not horizontal, but are dipping.

On the maps an attempt has been made to represent by a series of contour lines in green the position of the base of the Galena formation, i. e. the bottom of the main oil rock bed. These lines are drawn at vertical intervals of ten feet and the figures on them refer to altitudes above the sea-level. By means of these contour lines it is possible to indicate the elevation above sea level of the base of the Galena limestone, a very important horizon in mining. And at any particular point, by a comparison of the elevation of the surface of the ground and the elevation of the base of this formation, one can determine how far it is from the surface to the bottom of the oil rock. It is not expected that these contour lines on the base of the Galena are accurate throughout the whole district. This would be impossible with the information which is available, but where these contour lines are closely associated with outcrops, or with the junction line between the Platteville and the Galena formations, they can be relied upon as being quite accurate. The farther away from these junction lines the green contour lines are, the less accurately do they represent the elevation of the base of the Galena limestone. It is confidently expected, however, that even in districts removed a mile or farther from these outcrops that these contour lines will give a closely approximate indication of the elevation of the base of the Galena limestone.

SPECIAL CASES.

To refer to some detailed iustances of the formation represented on these maps reference is made to the Dodgeville sheet, plate IV. On this sheet the large cross marked "U. S. G. S. B. M." is a permanent bench mark established by the United

States Geological Survey. This is a brass cap on an iron post in the front yard of the court house. It is marked 1220; the corrected elevation however, of this brass cap is 1221.107 feet above sea mean level. This furnished the datum plane for the temporary bench marks established by leveling throughout the Dodgeville district.

On this map (Plate IV), if reference be made to the road crossing at the southeast corner of section 26, T. 6 N., R. 3 E., a small cross at this place, with figures in brown near it, will be noticed. This indicates that the crossing of the roads at that point is 1143 feet above sea level; and running almost directly through this road crossing is a contour line ten feet below the 1150 foot line, which 1150 foot line is much heavier than the others. The original level of the ground here, then, is 1140 feet above sea level.

In going eastward from this road crossing one passes downward into a small valley, the bottom of which is between 1120 and 1130 feet above sea level, and then ascends more gradually to the next black cross, which indicates an elevation of 1160 feet. In continuing further eastward to the stream which flows past the Williams mine a considerable hill is descended to this stream, and before reaching the stream the junction between the Galena formation and the Platteville formation is crossed at an elevation, as shown by the geological boundary referred to the contour lines, of approximately 1095 feet. The contour lines show that this stream valley has a flat bottom.

Going back now to the first road crossing mentioned (i. e., at the southeast corner of section 26, which is close to 1140 feet above sea level), we find that this place is about half way between the green contours of 1100 and 1090. Assuming that the slope southward (the arrows on the green contour lines indicate the direction of slope of the bottom of the Galena formation) of the bottom of the Galena (i. e. the base of the main oil rock) is uniform from the 1100 to the 1090 contour line, the elevation of this geologic horizon is 1095 feet above sea level at this particular place. Subtracting 1095 (the elevation of the base of the oil rock) from 1140 (the elevation of the ground at this point), the result is 45; in other words, a pit sunk at this place to the bottom of the main oil rock would be 45 feet deep. In a similar manner the depth to the base of the oil rock at any particular point can be determined with considerable certainty. In places far removed from stream valleys that cut into the Platteville limestone, these determinations are of course less accurate.

INDEX.

PUBLICATIONS

OF THE

Wisconsin Geological and Natural History Survey.

The publications of the Survey are issued as (1) bulletins, which are numbered consecutively, (2) biennial reports, and (3) hydrographic maps. These publications are independently paged and indexed, no attempt being made to group them in volumes.

1. Bulletins.

The bulletins are issued in three series:

Scientific Series.— The bulletins so designated consist of original contributions to the geology and natural history of the state, which are of scientific interest rather than of economic importance.

Economic Series.— This series includes those bulletins whose interest is chiefly practical and economic.

Educational Series.— The bulletins of this series are primarily designed for use by teachers and in the schools.

The following bulletins have been issued:

Bulletin No. I. Economic Series No. 1.

On the Forestry Conditions of Northern Wisconsin. Filibert Roth, Special Agent, United States Department of Agriculture. 1898. Pp. vi, 78; 1 map. *Out of print.*

Bulletin No. II. Scientific Series No. 1.

On the Instincts and Habits of the Solitary Wasps. George W. Peckham and Elizabeth G. Peckham. 1898. Pp. iv, 241; 14 plates, of which 2 are colored; 2 figures in the text. Sold at the price of $1.50 in paper and $2.00 bound.

Bulletin No. III. Scientific Series No. 2.

A Contribution to the Geology of the Pre-Cambrian Igneous Rocks of the Fox River Valley, Wisconsin. Samuel Weidman, Ph. D., Assistant Geologist, Wisconsin Geological and Natural History Survey. 1898. Pp. iv, 63; 10 plates; 13 figures in the text. *Out of print.*

Bulletin No. IV. Economic Series No. 2.

On the Building and Ornamental Stones of Wisconsin. Ernest Robertson Buckley, Ph. D., Assistant Geologist Wisconsin Geological and Natural History Survey. 1898. Pp. xxvi, 544; 69 plates, of which 7 are colored, and 1 map; 4 figures in the text. Sent on receipt of 30 cents.

Bulletin No. V. Educational Series No. 1.

The Geography of the Region About Devil's Lake and the Dalles of the Wisconsin, with some notes on its surface geology. Rollin D. Salisbury, A. M., Professor of Geographic Geology, University of Chicago, and Wallace W. Atwood, B. S., Assistant in Geology, University of Chicago. 1900. Pp. x, 151; 38 plates; 47 figures in the text. Sent (bound) on receipt of 50 cents.

Bulletin No. VI. Economic Series No. 3. Second Edition.

Preliminary Report on the Copper-bearing Rocks of Douglas county, and parts of Washburn and Bayfield counties, Wisconsin. Ulysses Sherman Grant, Ph. D., Professor of Geology, Northwestern University. 1901. Pp. vi, 83; 13 plates. Sent on receipt of 10 cents.

Bulletin No. VII. Economic Series No. 4.

The Clays and Clay Industries of Wisconsin. Part I. Ernest Robertson Buckley, Ph. D., Geologist, Wisconsin Geological and Natural History Survey. 1901. Pp. xii, 304; 55 plates. Sent on receipt of 20 cents.

Bulletin No. VIII. Educational Series No. 2.

The Lakes of Southeastern Wisconsin. N. M. Fenneman, Ph. D., Professor of General and Geographic Geology, University of Wisconsin. 1902. Pp. xv, 178; 36 plates; 38 figures in the text. *Out of print.*

Bulletin No. IX. Economic Series No. 5.

Preliminary Report on the Lead and Zinc Deposits of Southwestern Wisconsin. Ulysses Sherman Grant, Ph. D., Professor of Geology, Northwestern University. 1903. Pp. viii, 103; 2 maps; 2 plates; 8 figures in the text. *Out of print.*

Bulletin No. X. Economic Series No. 6.

Highway Construction in Wisconsin. Ernest Robertson Buckley, Ph. D., State Geologist of Missouri, formerly Geologist, Wisconsin Geological and Natural History Survey. 1903. Pp. xvi, 339; 106 plates, including 26 maps of cities. Sent on receipt of 30 cents.

Bulletin No. XI. Economic Series No. 7.

Preliminary Report on the Soils and Agricultural Conditions of North Central Wisconsin. Samuel Weidman, Ph. D., Geologist, Wisconsin Geological and Natural History Survey. 1903. Pp. viii, 67; 10 plates, including soil map. Sent, paper bound, on receipt of 10 cents; cloth bound, 20 cents.

Bulletin No. XII. Scientific Series No. 3.

The Plankton of Lake Winnebago and Green Lake. C. Dwight Marsh, Ph. D., Professor of Biology, Ripon College. 1903. Pp. vi, 94; 22 plates. Sent, paper bound, on receipt of 10 cents; cloth bound, 25 cents.

Bulletin No. XIII. Economic Series No. 8.

The Baraboo Iron-bearing District of Wisconsin. Samuel Weidman, Ph. D., Geologist, Wisconsin Geological and Natural History Survey. 1904. Pp. x, 190; 23 plates, including geological map. Sent, paper bound, on receipt of 10 cents; cloth bound, 20 cents.

Bulletin No. XIV. Economic Series No. 9.

Report on Lead and Zinc Deposits of Wisconsin, with an Atlas of detailed maps. Ulysses Sherman Grant, Ph.D., Professor of Geology, Northwestern University. 1906. Pp. x, 94; 5 plates, 2 maps; 10 figures n the text; and an atlas containing 18 detailed topograpical and geological maps.

In Preparation.

The Geology of North Central Wisconsin. Samuel Weidman, Ph. D., Geologist, Wisconsin Geological and Natural History Survey.

The Clays of Wisconsin. Heinrich Ries, Ph. D., Professor of Economic Geology, Cornell University.

2. Biennial Reports.

The Survey has published four biennial reports, which relate to administrative affairs only and contain no scientific matter.

First Biennial Report of the Commissioners of the Geological and Natural History Survey. 1899. Pp. 31.

Second Biennial Report of the Commissioners of the Geological and Natural History Survey. 1901. Pp. 44.

Third Biennial Report of the Commissioners of the Geological and Natural History Survey. 1903. Pp. 35.

Fourth Biennial Report of the Commissioners of the Geological and Natural History Survey. 1904. Pp. 42.

3. Hydrographic Maps.

There have been prepared hydrographic maps of the principal lakes of southern and eastern Wisconsin. This work is in charge of L. S. Smith, C. E., Assistant Professor of Topographic and Geodetic Engineering, University of Wisconsin.

		Size of Plate, Inches.	Scale, Inches per mile.	Contour Interval, Feet.
No. 1.	Lake Geneva	17.5x10.8	2	10
No. 2.	Elkhart Lake	15.5x13.1	5	10
No. 3.	Lake Beulah	22.5x20.0	6	10
No. 4.	Oconomowoc-Waukesha Lakes	29.8x19.1	2	10
No. 5.	The Chain of Lakes, Waupaca	21.7x20.6	6	10
No. 6.	Delavan and Lauderdale Lakes	22.5x16.8	4	10
No. 7.	Green Lake	26.0x17.8	3.2	20
No. 8.	Lake Mendota	23.7x19.5	6	5
No. 9.	Big Cedar Lake	18.0x13.5	2.9	10
No. 10.	Lake Monona	17.6x17.3	4	5

In press:

No. 11. Lake Kegonsa.
No. 12. Lake Waubesa.

In all of these maps the depth of the lakes is indicated by contour lines, and by tints in all except No. 1. They are sent on receipt of 15 cents each, except Nos. 4 and 8, for which 20 cents are required. They may be had either mounted in a manilla cover, or unmounted.

All correspondence relating to the Survey should be addressed to

E. A. Birge, *Director*,
Madison, Wis.

Wisconsin Geological and Natural History Survey

E. A. BIRGE. Director
W. O. HOTCHKISS, Economic Geologist

GEOLOGICAL MAPS OF THE LEAD AND ZINC DISTRICT.

Supplement to Bulletin XIV.

These maps extend the area covered by detailed geological maps to include those parts of the district which have become important since Professor Grant's work was completed. As funds become available it is proposed to extend this mapping over the entire lead and zinc district of southern Wisconsin.

The maps are similar to those prepared under the direction of Professor Grant with several additional features, which it is believed will make them more useful to the people of the state who are interested in the lead and zinc district.

The most important of these additions is the names of the owners of the properties. Another addition is the mapping of the positions and directions of the old ranges. A third addition is the location of drill holes with the elevation above sea level at which the clay bed was found in each hole, thus furnishing a definite guide to the drilling that has been done on a property and the thickness of the principal ore bearing formation, the Galena limestone. The detailed records of as many of these drill holes as could be obtained are on file in the survey office.

Other additions are the showing of rock outcrops and the directions of jointing in the rocks.

The question of intelligent prospecting in this district is one of examining all the factors that enter into the formation of a water-deposited ore body and selecting a location to prospect where most of these factors are favorable.

According to our present knowledge we can say that there are three highly probable sources, any one or all of which might have originally supplied the ore. (1) The lead and zinc minerals may have been originally deposited in the oil rock at the base of the Galena limestone. (2) They may have been deposited either as finely disseminated particles all through the Galena limestone or in more or less segregated patches of ore bearing limestone separated by barren areas, and afterward concentrated by circulating waters. (3) They may have been deposited in the overlying formations, either evenly disseminated or in rich patches and carried downward and deposited in the present ore bodies by the circulating waters.

From the above statement it is apparent that one of the most important factors in the formation of workable deposits is the circulation of the water. A second factor consists of the influences that have caused the circulating water to deposit the ore it has carried. Each of these factors is complex.

(1) The circulation of the water through the rock depends on many things and has not as yet been studied in as detailed a manner as it should be, but we can say in general that the following factors control it. (a) The relief of the surface—the height of the hills above the valleys, and their shape—is a very important factor. (b) The presence of impervious beds, such as the clay bed, serves to concentrate the circulation in depressions in these impervious beds. (c) The joints and fissures and porous portions of the rock serve to collect the circulating waters and give direction to their flow.

(2) The limestone itself is capable of causing the water to deposit its zinc, lead and iron. These metals are carried in acid waters which are neutralized by the lime carbonate. The waters thereupon deposit the ore they carry and take up lime in its place. From the chemical principles involved it seems very improbable that acid waters bearing ore could carry that ore for very great distances through a limestone formation. The organic matter of the oil rock also has probably played a part in precipitating the ore from solution.

Use of the Accompanying Maps.

The maps are designed to indicate as many as possible of the above factors. The brown contours give the shape and elevations of the surface of the country. A definite idea of their significance can be obtained if the reader will imagine that the sea should begin to rise over the land. When it had risen about 800 feet above its present level it would begin to cover the zinc district. If the shore line (which would be an irregular line on the surface of the country every part of which would be at the same elevation as every other part—a "contour" in other words), were to be mapped for each 10 foot rise we would get the series of "shore lines" or contours—shown on the map in brown. If the land surface were steep the sea would advance but little in rising 10 feet and the contours would be close together. If the surface were gently sloping the sea would advance a long distance over the land in rising 10 feet and the contours would be far apart. Consequently closely spaced contours on the maps represent steep slopes and the contours having wide spaces between represent gentle slopes.

The green contours show in the same manner the elevations above sea level of the clay bed at the base of the Galena limestone. These are drawn as nearly accurate as the best information obtainable from rock outcrops and from drill records would permit, and their probable accuracy is indicated by drawing those based on meager information with dashed lines and those based on good information with full lines. The approximate thickness of the Galena limestone at any point where it is the surface rock can be found by subtracting the elevation of the clay bed as shown by green contours from the elevation of the surface—shown by brown contours.

The water circulating through the Galena formation would in general tend to collect in the places where the clay bed is low, since this clay bed acts as an impervious blanket almost entirely preventing the water from finding its way into the formations below. These low places are shown on the maps by the green contours.

The maps also show the directions of the old ranges and the major and minor joints in the rock. The direction of flow of the water in particular cases can be judged from these and from the occurrence of springs.

Having as good an idea of the flow of underground water as can be thus obtained for a particular locality we may ask what are the chances that this flow has resulted in an ore body. If the original source is evenly and widely disseminated material in the limestone or formerly overlying formations, the flow must be extensive enough to collect the ore from a fairly large area. If the original source is in richer areas of the limestone or formerly overlying formations the circulation may not happen to be located on one of the rich areas and consequently drilling would be profitless. The surest indication of the presence of a rich area—whether original or due to later concentrations—is the presence of float mineral or old ranges or diggings which indicate that float or surface mineral was formerly present. These old diggings and ranges are shown on the maps.

This statement is recognized to be brief and necessarily incomplete but it will serve to indicate some of the uses to which these maps may be put. For a more complete discussion of the principles governing the deposition of the lead and zinc ores of southwestern Wisconsin reference is made to bulletin 294 of the U. S. Geological Survey which can be obtained free of charge by writing the Director at Washington, D. C., or to bulletin XIV of the Wisconsin Geological and Natural History Survey, which with the atlas of maps can be obtained from the Director at Madison by sending 20 cents for postage.

W. O. HOTCHKISS.

Madison, Wis.
Mch. 15, 1909.

Insert in Bulletin XIV facing p. VIII.

SUPPLEMENTARY PLATES

GEOLOGICAL AND TOPOGRAPHIC MAPS