Stratigraphy of Middle Ordovician Rocks in the Zinc-Lead District of Wisconsin, Illinois, and Iowa

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 274-K

Prepared in cooperation with the Wisconsin Geological and Natural History Survey

Stratigraphy of Middle Ordovician Rocks in the Zinc-Lead District of Wisconsin, Illinois, and Iowa

By ALLEN F. AGNEW, ALLEN V. HEYL, Jr., C. H. BEHRE, Jr., *and* E. J. LYONS

A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 274-K

Prepared in cooperation with the Wisconsin Geological and Natural History Survey

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1956

UNITED STATES DEPARTMENT OF THE INTERIOR

Fred A. Seaton, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 60 cents (paper cover)

CONTENTS

ILLUSTRATION

A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

STRATIGRAPHY OF MIDDLE ORDOVICIAN ROCKS IN THE ZINC-LEAD DISTRICT OF WISCONSIN, ILLINOIS, AND IOWA

By Allen F. Agnew, Allen V. Heyl, Jr., C. H. Behre, Jr., and E. J. Lyons

ABSTRACT

Stratigraphic studies, both outcrop and subsurface, of Ordovician rocks of the zinc-lead district in Wisconsin, Illinois, and Iowa form the basis for a more accurate means of delimiting potentially ore-bearing areas from less favorable localities. Detailed stratigraphic subdivisions of the Platteville, Decorah, and Galena strata have permitted the mapping of folds with structural relief of 30 feet or less in areas smaller than a quarter of a mile square. Such relatively small flexures and their associated fractures have caused the localization of the ore-bearing solutions.

Lithologic characteristics provided the basis for subdividing the rocks into mappable units—formations and members. No systematic paleontologic study has been made; age assignments, therefore, are only general

Although the investigation initially dealt with relatively local areas, certain members of the rock units and their subdivisions are mappable regionally.

Rock units below the Platteville formation include sandstone and shale of the St. Peter sandstone; shale, dolomite, and sandstone of the Prairie du Chien group, sandstone, siltstone, and dolomite of Cambrian age, and the Pre-Cambrian granitic rocks. The Galena strata are overlain by the shale and dolomite of Maquoketa age, upon which rests Silurian dolomite.

Because the Platteville, Decorah, and Galena strata include the currently producing ore zone, the detailed investigation was restricted to those units.

The Platteville formation regionally includes the green sandy Glenwood shale member at its base, as much as 3 feet thick; the brown Pecatonica dolomite member, 20–24 feet thick; the gray limestone and dolomite of the McGregor limestone member, totalling 30 feet; and the uppermost member, the brown limestone dolomite, and shale of the Quimbys Mill member, as much as 18 feet thick.

In the mining district the Decorah formation includes at the base green shale and limestone of the Spechts Ferry shale member, with a maximum thickness of 8 feet; the brown limestone, dolomite, and shale of the Guttenberg limestone member, 12–16 feet thick; and the uppermost member, the grayish-green limestone, dolomite, and shale of the Ion dolomite member, 20 feet thick. In the western part of the mining district and to the west is an unnamed limestone member that underlies the Spechts Ferry.

To the east, the Platteville and Decorah strata are dolomite of similar lithologic character, and have been called the Beloit dolomite.

The Galena dolomite is generally coarsely crystalline massive vuggy dolomite or limestone divisible regionally into two units, a cherty lower unit 105 feet thick and a noncherty upper one 120 feet thick. The cherty unit is divided into four zones, *A*, *B*, *C*, and *D* in descending order, based primarily upon relative chert content and the presence of *Receptaculites*. The noncherty unit is divided on the basis of thinness of bedding and the amount of interbedded shale into Dubuque at the top and the more massive, less shaly Stewartville and zone *P* of the Prosser below; the latter is divided less precisely on the basis of *Receptaculites* which are abundant in the Stewartville, but not in zone *P*, below. The name Dubuque is applied much as it has been in the past; the name Stewartville is applied more or less as it has been in the past; and the name Prosser includes the cherty unit and probably all of zone *P* of the overlying noncherty unit. Because of paleontologic deficiencies and because of the distinct lithologic differences, in this paper the Galena is subdivided into the cherty and noncherty units rather than into the Prosser, Stewartville, and Dubuque members of common, although not precise usage.

A bentonite layer is present near the base of the Spechts Ferry shale member; less commonly bentonite seams are found 30–32 feet below and 18 feet above the contact between the cherty and noncherty units. West of the mining district the unnamed lower member of the Decorah formation includes bentonite at its base. Locally bentonite is present in the Decorah.

All members of the Platteville formation except the Glenwood decrease in thickness toward the west, whereas all members of the Decorah formation thicken toward the west.

In general the Platteville, Decorah, and Galena strata represent a marine environment of a relatively shallow-water platform.

Facies analysis of the Platteville, Decorah, and Galena formations shows a regional change from shale (Decorah formation) and limestones (Galena and Platteville formations, excluding the Glenwood member) west of the mining district eastward into dolomite (all three formations) east of the district. Chert is characteristic of the upper two members of the Platteville formation to the east. To the northwest, in southeastern Minnesota the Decorah formation is green shale, and the lower two zones of the Galena dolomite are interbedded shale and limestone; the Galena has very little chert in Minnesota. The increase in dolomite and chert to the east is probably due to the influence of the Wisconsin arch.

Leaching, dolomitization, and silicification, due to the zinc-lead mineralizing solutions, have altered some of the carbonate strata

especially the Quimbys Mill member ("glass rock" of local usage) and the Guttenberg member (oil rock of local usage); in places either of these units may have been reduced from 15 feet of argillaceous limestone with a small amount of shale, to less than 5 feet of shale and argillaceous residuum.

Zinc-lead bearing strata include the cherty unit of the Galena dolomite, the Decorah formation, and the Quimbys Mill and McGregor members of the Platteville formation; the zinc-lead ore occurs in veins and breccia along inclined fracture zones ("pitches and flats"), in more or less interconnected vugs ("brangle"), and disseminated in the more shaly beds. Lead ore is found also in vertical joints ("crevices") especially at favorable horizons ("openings") in the upper or noncherty member of the Galena dolomite.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

In late 1942, when lead and zinc were in great demand because of the requirements of World War II, the U. S. Geological Survey began a project in Wisconsin, Illinois, and Iowa, hoping thereby to aid prospectors and mine operators in the discovery of additional lead and zinc ore.

Production from the mining district, which was considered by most geologists to be almost completely worked out, was being maintained in a limited way by several small mining operations; most of the ore was being concentrated in one relatively small custom mill, and two smaller mills shipped the rest of the concentrates from the district. None of the companies had geologists on their staffs, nor were consulting geologists working in the area. It seemed plausible that a detailed restudy of the geology of the district might result in a renewed interest in its ore-bearing potentialities, and thus might contribute materially to the supply of lead and zinc at that critical wartime period.

LOCATION AND GEOGRAPHIC SETTING

The zinc-lead district in Wisconsin, Illinois, and Iowa lies mainly within the Driftless Area (fig. 31), on generally southwestward-dipping lower Paleozoic strata. As a result of the absence of glacial drift and because of the mature dissection, there are many natural exposures; they are supplemented by quarries, by roadcuts, and by railroad cuts and tunnels. Because of the regional dip the outcrop pattern of the Platteville, Decorah, and Galena strata (Middle Ordovician) is mapped as a generally northwestward-trending band that is limited on the southwest by the apron of Maquoketa rocks (Upper Ordovician) flanking the cuesta formed by rocks of Silurian age and on the northeast by the exposure of pre-Platteville beds. Within this band of outcropping Platteville, Decorah, and Galena strata are a few "mounds"—knobs of Silurian rocks with their aprons of Maquoketa shale; in addition some upland areas contain relatively thin but rather extensive patches of Maquoketa under the omnipresent mantle of loess and residual material. Pre-Platteville strata are exposed along parts of the valleys especially in the more deeply dissected areas in the district.

FIELD WORK

The geologic study of the zinc-lead district in Wisconsin, Illinois, and Iowa was begun by the U. S. Geological Survey in October 1942, and was still in progress in 1955. The initial investigation was an analysis of the structural control of the ore deposits in an area of many open mine workings and drill holes and some exposures and included a cooperative prospecting program with the U. S. Bureau of Mines. This study was soon extended and expanded to a general geologic mapping program of the mining district, including the areal geology, stratigraphy, structure, economic geology, and the larger geologic features, which was started in 1943 and has continued without interruption since that time.

It was soon evident that the rock units of Platteville, Decorah, and Galena ages, which contain the ores, should be restudied because the published stratigraphic work of the preceding 10 to 15 years did not agree with the rock units recognized underground by the miners and in drill cuttings by prospect drillers. Furthermore, the miners and drillers were not always consistent in the recognition of the rock units in a restricted area, nor was there adequate correlation of rock units from area to area within the mining district. The writers therefore made a detailed examination of the Platteville, Decorah, and Galena formations and subdivided them into relatively thin units so that the rather small ore-localizing structures could be mapped more accurately.

A. F. Agnew has been responsible for the direction of the stratigraphic study, the description of most of the sections, the regional stratigraphy, and the preparation of the present report. The other writers described stratigraphic sections and in addition contributed much helpful discussion. The writers jointly described stratigraphic sections and acquired additional stratigraphic information in the course of the mapping of geologic structure.

The writers' stratigraphic study included the examination of exposures, mine workings, and drill-hole cuttings and cores within the mining district, by hand lens and binocular microscope. Later, more information of a regional nature was desirable; as a result exposures and cuttings from holes drilled in nearby areas of Wisconsin, Illinois, Iowa, and Minnesota were investigated in 1944 and 1945, mainly by Agnew. The stratigraphic description presented herein was originally written in 1945 and is a result principally of the work from 1942 through 1945, although additional studies by

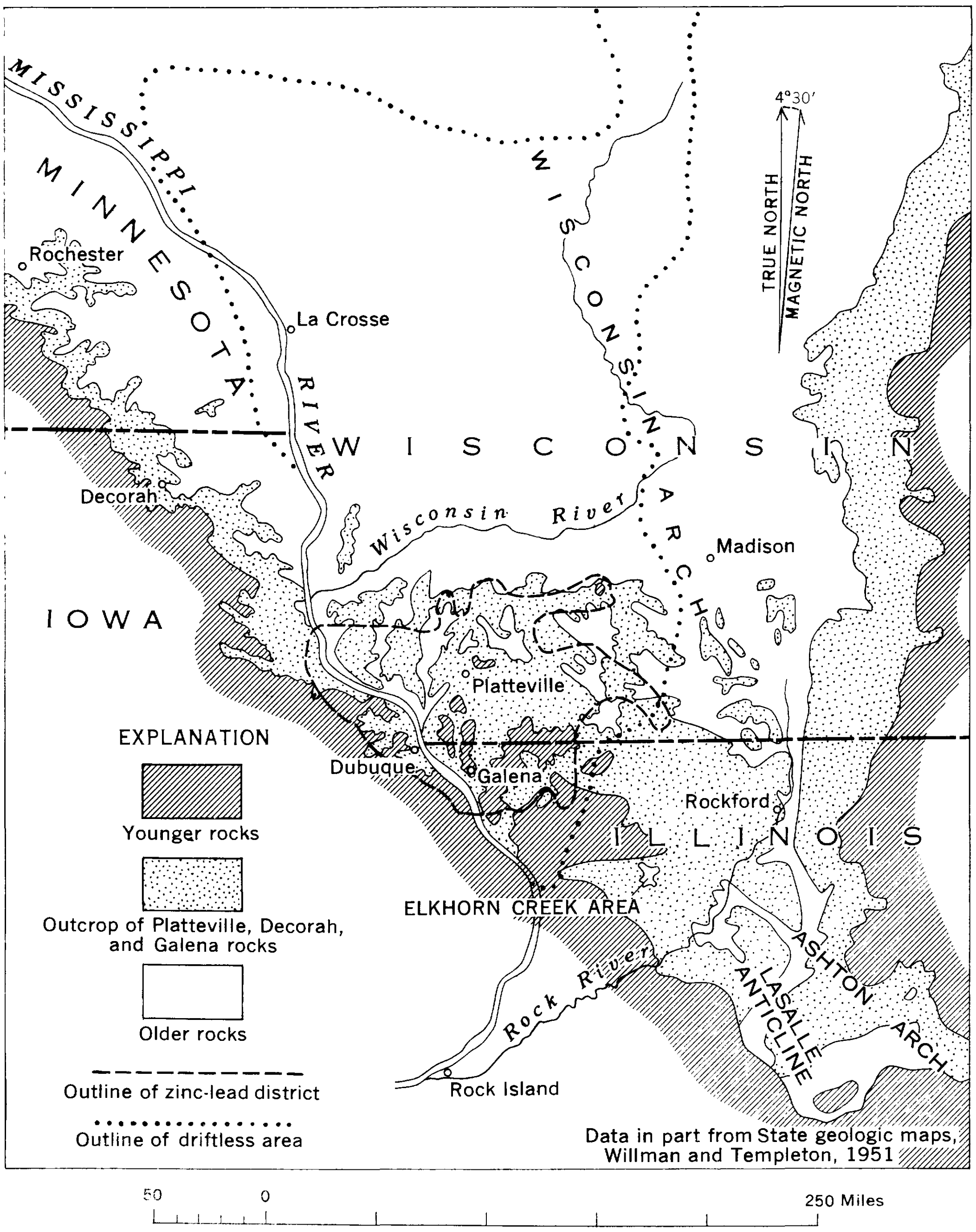


FIGURE 31.—Upper Mississippi Valley region, showing Driftless Area, zinc-lead district, and bedrock distribution of Platteville, Decorah, and Galena strata.

Agnew since 1949, based in part upon his work dealing with the subsurface Ordovician rocks of Iowa in 1946 and 1947 while engaged in ground water studies for the U. S. Geological Survey in cooperation with the Iowa Geological Survey, have modified considerably some of the earlier concepts and terminology. The report was completely rewritten in 1953–54, to incorporate a revised approach to the problem and to include pertinent information and published references acquired since 1945.

Comprehensive reports on the geology, structure, ore deposits, and mineral resources of the district have been prepared for readers interested in other phases of the study (Heyl, Lyons, Agnew and Behre, 1955; Heyl, Agnew, Lyons, Behre, in preparation).

The geologic study was instigated in 1942 by C. H. Behre, Jr., who had been supervising research in the mining district by students of Northwestern University since 1933. A. F. Agnew was in charge of the work from 1942 to the end of 1945, and again since July

1950; A. V. Heyl, Jr., was in charge from 1946 to July 1950, except for part of 1948–49 when E. J. Lyons was in charge. A. E. Flint was in charge of the work in Iowa in 1951–1953, and since that time, C. E. Brown. The members of the party consisted of A. F. Agnew from October 1942 to December 1945 and also during the summer of 1948 and since June 1949; A. V. Heyl Jr., from February 1943 to August 1950; E. J. Lyons as a part-time member of the party from February 1944 to June 1948, and a full-time member from June 1948 to October 1949; C. H. Behre, Jr., as a part-time member and project advisor from October 1942 to October 1945; A. E. Flint, 1949–53; R. M. Hutchinson, 1944–45; Dorothy J. West, 1948; J. W. Allingham, 1950–55, C. E. Brown since 1951; Percy Crosby, 1953–54, J. E. Carlson, since 1951; W. A. Broughton 1950–55; L. G. Collins, 1953. Harriette A. Burris, R. W. Chartraw, J. F. Coulthard, R. P. Crumpton, D. C. Dixon, Catherine M. Fulkerth, H. L. Hefty, Maxine L. Heyl, M. A. Husted, J. H. Moor, D. W. Ressmeyer, H. F. Seeley, J. C. Spradling, C. W. Tandy, Jr., J. J. Theiler, Mary C. Wheeler, L. A. Ziech served as field assistants, and Marge B. Hake and Mary J. MacCulloch as scientific aids, during various stages of the program until 1954. A. E. Flint and R. P. Crumpton, in particular, added to the knowledge of the Platteville, Decorah, and Galena sequence during their mapping of the geologic structure.

ACKNOWLEDGMENTS

The study of the zinc-lead district in Wisconsin, Illinois, and Iowa has been done in cooperation with the Wisconsin Geological and Natural History Survey since 1945 and the Iowa Geological Survey since 1951. The Wisconsin Survey, directed by E. F. Bean and later by G. F. Hanson, contributed funds for the work in Wisconsin and a large amount of data including stratigraphic information and logs of deep wells, supplied by F. T. Thwaites. The Iowa Geological Survey gave financial support to the work in Iowa and permitted the use of subsurface data that had been used in groundwater studies by Agnew for the U. S. Geological Survey in 1946–47. A. C. Trowbridge and H. G. Hershey, State Geologists of Iowa, freely contributed information.

Our work was aided by the free interchange of data with the field party of the Illinois State Geological Survey during the summer of 1943 and from the spring of 1944 until 1954.

The U. S. Bureau of Mines maintained a party from December 1942 to 1954, except for a few months in 1946, to explore deposits in the district. The cores and churn-drill samples were logged by U. S. Geological Survey geologists, and in most instances the explorations were planned and interpreted in close cooperation by members of both organizations. We wish to acknowledge their invaluable aid in carrying out our studies.

Acknowledgment for their valuable aid and contributions is made to Paul Herbert, Jr., and R. R. Reynolds, formerly of the Illinois State Geological Survey; H. B. Willman, of the Illinois State Geological Survey; W. C. Bell, formerly of the University of Minnesota; J. R. Ball, formerly of Northwestern University; representatives of mining companies, especially the Vinegar Hill Zinc Co., The New Jersey Zinc Co., and the American Zinc, Lead, and Smelting Co.; to C. W. Stoops, an ore buyer, mine operator, and geologist at Platteville; and drillers of water wells and prospect holes and the many mine operators who supplied useful data. Particular thanks is due to M. A. Melcher, president of the Wisconsin Institute of Technology. The school furnished office and laboratory space for many years and gave us much valuable data and use of its facilities. We wish to thank the Geology Departments of the University of Wisconsin and Northwestern University for use of binocular microscopes and theses.

REGIONAL GEOLOGY AND STRATIGRAPHIC RELATIONS

STRUCTURE

The zinc-lead district in Wisconsin, Illinois, and Iowa lies on the southwestern slope of the Wisconsin arch (fig. 31).

The regional dip of the rocks is to the south-southwest but it has been modified by folds which are directed easterly, northwesterly, and northeasterly. Joints and generally high angle faults are associated with the folds, and in the mining district bear zinc-lead ore.

REGIONAL STRATIGRAPHIC SUMMARY

Because this report deals primarily with rocks related to the major zinc-lead ore deposits—the Platteville, Decorah, and Galena strata (Middle Ordovician)—pre-Platteville and post-Galena rocks are discussed only briefly.

Pre-Cambrian rocks underlie the mining district, as granite gneiss and other granitic rocks have been penetrated in wells at several localities. Cambrian strata consist of sandstone, siltstone, and dolomite, of Late Cambrian age (fig. 32). The Mount Simon sandstone, which unconformably overlies the pre-Cambrian, is succeeded conformably by sandstone and siltstone of the Eau Claire sandstone, and that by the Dresbach sandstone; the latter is overlain conformably by the glauconitic sandstone and siltstone of the Franconia sandstone, which is succeeded conformably by sandstone, siltstone, and dolomite of the Trempealeau formation. There are many facies changes. The

System	Series	Group or formation	Description	Average thickness, in feet	
SILURIAN	Lower and Middle		Dolomite, buff, cherty; *Pentamerus* at top,	90	200
			Dolomite, buff, cherty; argillaceous near base	110	
ORDOVICIAN	Upper	Maquoketa shale	Shale, blue, dolomitic; phosphatic depauperate fossils at base	108–240	
	Middle	Galena dolomite	Dolomite, yellowish-buff, thin-bedded, shaly	40	225
			Dolomite, yellowish-buff, thick-bedded; *Receptaculites* in middle	80	
			Dolomite, drab to buff; cherty; *Receptaculites* near base	105	
		Decorah formation	Dolomite, limestone, and shale, green and brown; phosphatic nodules and bentonite near base	35–40	
		Platteville formation	Limestone and dolomite, brown and grayish; green, sandy shale and phosphatic nodules at base	55–75	
		St. Peter sandstone	Sandstone, quartz, coarse, rounded	40+	280–320
	Lower	Prairie du Chien group (undifferentiated)	Dolomite, light-buff, cherty; sandy near base and in upper part; shaly in upper part	0–240	
CAMBRIAN	Upper	Trempealeau formation	Sandstone, siltstone, and dolomite	120–150	
		Franconia sandstone	Sandstone and siltstone, glauconitic	110–140	
		Dresbach sandstone	Sandstone	60–140	700–1050
		Eau Claire sandstone	Siltstone and sandstone	70–330	
		Mount Simon sandstone	Sandstone	440–780	

FIGURE 32.—Generalized stratigraphic column for zinc-lead district.

thickness of the Cambrian rocks increases southward across the district from 960 to 1,310 feet.

Rocks of the Prairie du Chien group (Lower Ordovician) in many places are dolomite, with a sandstone formation or sandy zone near the middle; in other localities, however, this group is represented by a large amount of red and green shale, silicified limestone, and limestone. The overlying St. Peter sandstone (Middle Ordovician) is normally 40 feet thick, but unconformable relations between it and the Prairie du Chien below, coupled with leaching of the dolomite in the latter, cause sandstone of this type to be present to a depth of at least 320 feet below the top of the St. Peter. Because of this the Prairie du Chien reaches a maximum thickness of 250 feet; together the two units aggregate 280-320 feet.

The outcropping band of the southwesterly dipping Platteville, Decorah, and Galena strata (Middle Ordovician), which contain the zinc-lead deposits, strikes generally northwesterly across the district; facies changes are evident both toward the northwest and toward the southeast. These changes are marked by differences in the lithologic character of the equivalent rocks, and by differences in thickness.

As viewed within the confines of the mining district, especially the eastern part, the beds designated Platteville, Decorah, and Galena by earlier writers fall naturally, because of general lithologic similarity, into three groups, as follows:

Grouping of Platteville, Decorah, and Galena rocks in district

[Local terminology in parentheses]

Group 1	Noncherty unit (buff) Cherty unit (drab) Ion dolomite member (gray and blue)
Group 2	Guttenberg limestone member (oil rock) Spechts Ferry shale member (clay bed) Disconformity Quimbys Mill member ("glass rock")
Group 3	McGregor limestone member (Trenton) Pecatonica dolomite member (quarry beds) Glenwood shale member (shale)

Because the stratigraphic guides for the practical miner are the different lithologic characteristics, such a classification might be the most practical locally, insofar as the eastern, or main part of the mining district is concerned.

Group 2 is a lithologic entity within this part of the mining district, for the rocks composing all three of its subdivisions were deposited under generally similar conditions and they also reacted similarly under the stress of later geologic solutional and structural processes. Furthermore, in the mining district the basal beds of Group 2 are distinct lithologically from the uppermost beds of Group 3, and the upper beds of Group 2 are equally distinct lithologically from the lowest beds of Group 1.

When considered regionally, on the other hand, to the east the dolomite of the Quimbys Mill member is lithologically more similar to that of the McGregor member below than it is to the Spechts Ferry above. Moreover, the Quimbys Mill pinches out to the west as does the Pecatonica, whereas the Spechts Ferry pinches out and the Guttenberg thins to the east. Furthermore, in its western facies the shale character of the Ion member is more similar lithologically to that of the Guttenberg and Spechts Ferry below than it is to the limestone of the Galena above.

In addition to the facies and convergence factors mentioned above, a disconformity marked by a corrosion surface and associated closely with a bentonite layer lies within, rather than at the top or bottom of Group 2. Thus the available regional evidence suggests a different grouping of the beds, as follows (fig. 33):

Regional grouping of Platteville, Decorah, and Galena rocks

Galena dolomite	Noncherty unit Cherty unit
Decorah formation	Ion dolomite member Guttenberg limestone member Spechts Ferry shale member —Disconformity—
Platteville formation	Quimbys Mill member McGregor limestone member Pecatonica dolomite member Glenwood shale member

FIGURE 33.—Platteville (*Op*), Decorah (*Od*), and Galena (*Og*) strata in 200 foot bluff west of State Route 81, in Grant County, Wis. (fig. 35, loc. 9).

Similarly, 300 miles away in Missouri, Groshskopf (1948, p. 354) has shown that the Decorah as used in eastern Missouri is coincident in extent with the overlying Kimmswick and overlaps various parts of the Plattin; this suggested to him that the Decorah is related more closely to the Kimmswick than to the underlying Plattin and that a hiatus exists between the Decorah and the Plattin.

For these reasons the classification given on the preceding page is the one used in the upper Mississippi Valley region, which includes the zinc-lead mining district.

Except for the Glenwood shale member the Platteville formation is limestone and (or) dolomite, with thin shale partings. The dolomite facies as mapped generally includes part of the mining district and extends toward the east, whereas the limestone facies extends toward the west (fig. 34).

Significant regional changes in the stratigraphic character of the Platteville formation are not present in the Glenwood shale (basal) member. The overlying Pecatonica dolomite member thins northwesterly from 20–24 feet in the mining district, to 10 feet in northeastern Iowa, and less than 2 feet in southeastern Minnesota; it maintains a thickness of 26 feet in the vicinity of Beloit (fig. 35) and Janesville, Wis., along and east of the Wisconsin arch, although Bays and Raasch (1935, p. 297) reported only 18 feet of Pecatonica dolomite member over the Wisconsin arch.

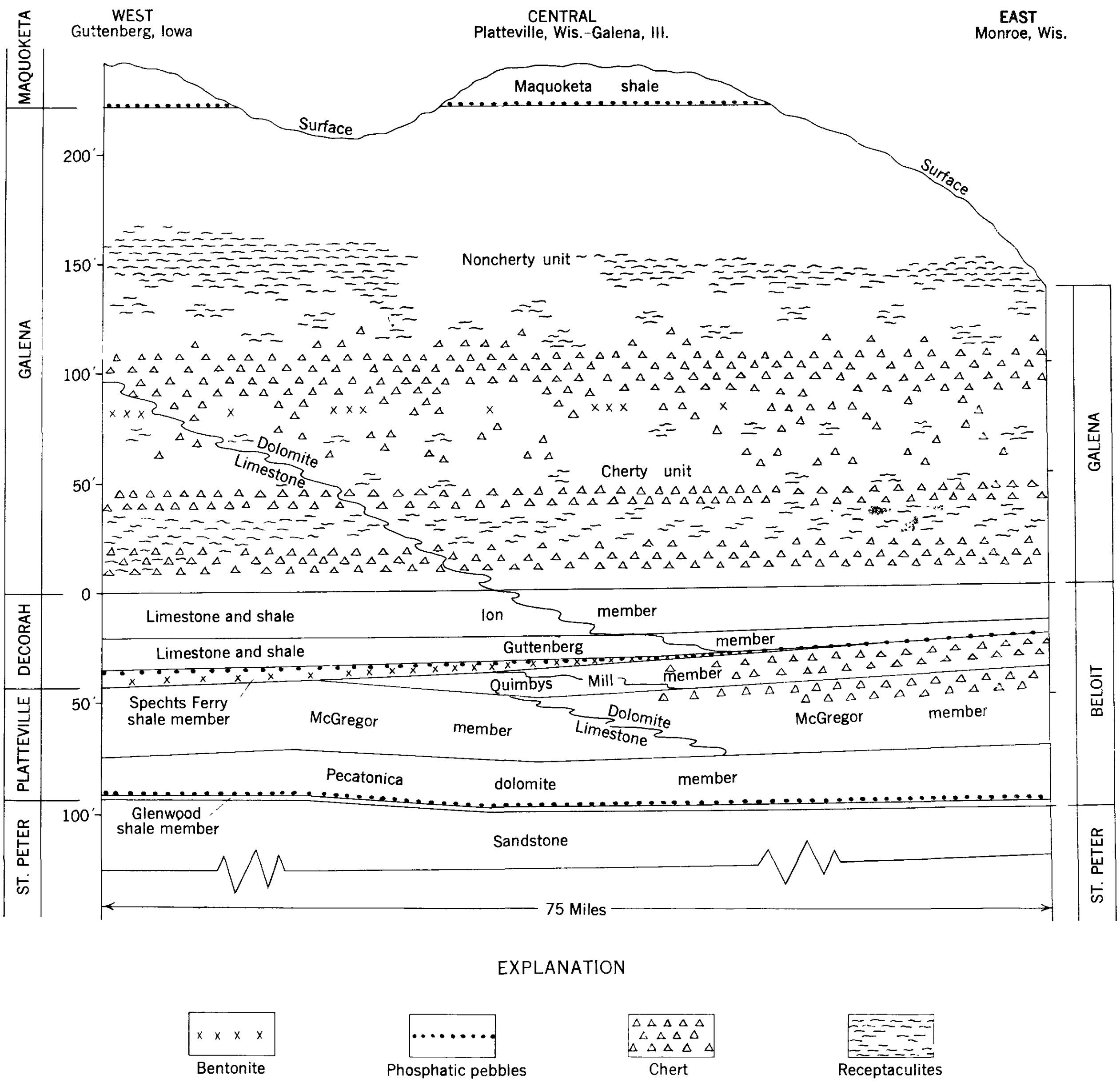


FIGURE 34.—Diagrammatic cross section of Platteville, Decorah, and Galena strata eastward across the mining district, showing facies relationships.

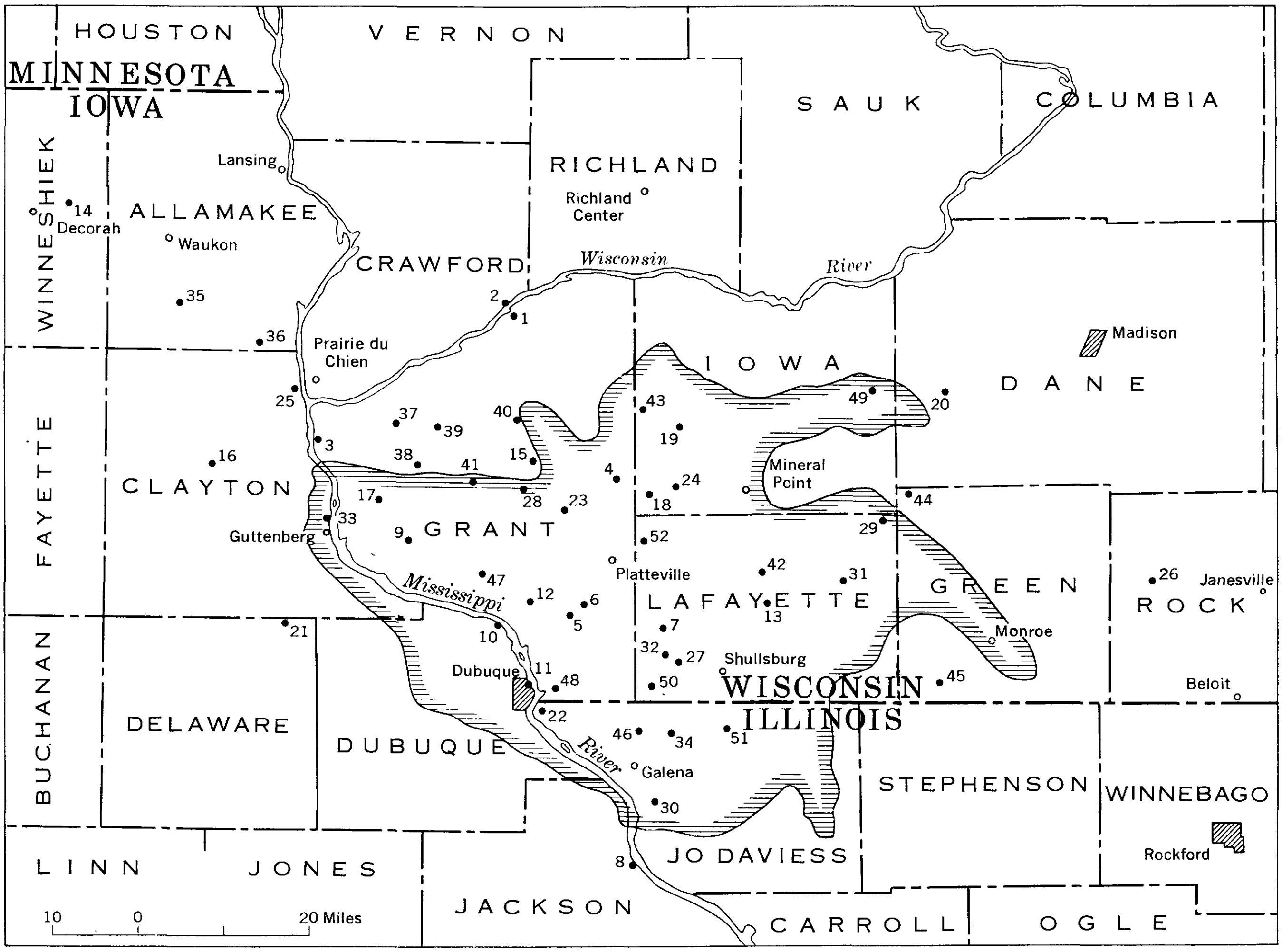


FIGURE 35.—Map of part of the upper Mississippi Valley region, showing outline of zinc-lead district. Localities cited in the text are listed below.

1 Borden Whey Plant well 2, sec. 33, T. 8 N., R. 3 W., Boscobel, Wis.
2. Roadcut, sec. 22, T. 8 N., R. 3 W., junction of State Routes 60 and 61, Wisconsin.
3. Quarry, sec. 31, T. 6 N., R. 6 W., and sec. 36, T. 6 N., R. 7 W., north edge of Wyalusing, Wis.
4. Crow Branch diggings, sec. 22, T. 5 N., R. 1 W., Wisconsin.
5. Roadcut, sec. 15, T. 2 N., R. 2 W., U. S. Highway 151, Wisconsin.
6. Roadcut, secs. 1 and 12, T. 2 N., R. 2 W., U. S. Highway 151, Wisconsin.
7. USGS-Raisbeck hole 2, sec. 21, T. 2 N., R. 1 E., Wisconsin.
8. City well, sec. 18, T. 86 N., R. 5 E., Bellevue, Iowa.
9. Bluff, sec. 36, T. 4 N., R. 5 W., near State Route 81, Wisconsin.
10. Quarry, sec. 4, T. 90 N., R. 2 E., Spechts Ferry station, Iowa.
11. Eagle Point Quarry, sec. 7, T. 89 N., R. 3 E., Dubuque, Iowa.
12. Roadcut, sec. 7, T. 2 N., R. 2 W., U. S. Highway 61, Wisconsin.
13. Quarry, sec. 3, T. 2 N., R. 3 E., Darlington, Wis.
14. Type section of Glenwood, sec. 6, T. 98 N., R. 7 W., Iowa.
15. Roadcut, sec. 18, T. 5 N., R. 2 W., U. S. Highway 61, Wisconsin.
16. Clayton County Home well, sec. 7, T. 93 N., R. 4 W., Iowa.
17. Cheese factory well, sec. 6, T. 4 N., R. 5 W., North Andover, Wis.
18. Village well, sec. 5, T. 4 N., R. 1 E., Rewey, Wis.
19. School well, sec. 26, T. 6 N., R. 1 E., Cobb, Wis.
20. City well, sec. 12, T. 6 N., R. 6 E., Mount Horeb, Wis.
21. City well 1, sec. 4, T. 90 N., R. 3 W., Colesburg, Iowa.
22. City well, sec. 29, T. 29 N., R. 2 W., East Dubuque, Ill.
23. Roadcut, near center N½ sec. 10, T. 4 N., R. 2 W., County Road A, Wisconsin.
24. Roadcut, near center of S½ sec. 35, T. 5 N., R. 1 E., Wisconsin.
25. Type section of McGregor, NE¼ sec. 28, T. 95 N., R. 3 W., Iowa.
26. Type sections (of Bays and Raasch 1935) of Magnolia, NW¼ sec. 26, T. 3 N., R. 10 E., Wisconsin.
27. Type section of Quimbys Mill, SE corner, sec. 11, T. 1 N., R. 1 E., Wisconsin.
28. Roadcut, center E½ sec. 1, T. 4 N., R. 3 W., County Road A, Wisconsin.
29. Quarry, near center sec. 23, T. 4 N., R. 5 E., County Road F, Wisconsin.
30. Bautsch mine, sec. 10, T. 27 N., R. 1 E., Illinois.
31. Quarry, NW¼ sec. 30, T. 3 N., R. 5 E., Wisconsin.
32. Ravine, center of east line sec. 4, T. 1 N., R. 1 E., Wisconsin.
33. Type section of Guttenberg, SW¼ sec. 5, T. 92 N., R. 2 W., Iowa.
34. East bank of Galena River, near center sec. 34, T. 29 N., R. 1 E., Illinois.
35. Ravine, NE¼ sec. 32, T. 97 N., R. 5 W., State Route 51, Iowa.
36. Type section of Ion, NW¼ sec. 35, T. 96 N., R. 4 W., Iowa.
37. Roadcut, NW¼ sec. 33, T. 6 N., R. 5 W., U. S. Highway 18, Wisconsin.
38. Quarry, SW¼ sec. 24, T. 5 N., R. 5 W., Wisconsin.
39. Quarry, NE¼ sec. 32, T. 6 N., R. 4 W., Wisconsin.
40. Roadcut, center sec. 21, T. 6 N., R. 3 W., U. S. Highway 18, Wisconsin.
41. Roadcut, SW¼ sec. 31, T. 5 N., R. 3 W., County Road A, Wisconsin.
42. Quarry, SW¼ sec. 9, T. 3 N., R. 3 E., Calamine, Wis.
43. Quarry, SE¼ sec. 19, T. 6 N., R. 1 E., Montfort, Wis.
44. Quarry, sec. 5, T. 4 N., R. 6 E., York Church, Wisconsin.
45. Quarry, along Honey Creek, SW¼ sec. 23, T. 1 N., R. 6 E., Wisconsin.
46. Ginte mine, sec. 30, T. 29 N., R. 1 E., Illinois.
47. Quarry, SE¼ sec. 18, T. 3 N., R. 3 W., County Road U, Wisconsin.
48. Roadcut, NW¼ sec. 34, T. 1 N., R. 2 W., State Route 11, Wisconsin.
49. Quarry, SE¼ sec. 3, T. 6 N., R. 5 E., U. S. Highway 151, Wisconsin.
50. Old railroad tunnel, SE¼ sec. 21, T. 1 N., R. 1 E., Wisconsin.
51. T. T. Redfern well, SE¼ sec. 34, T. 29 N., R. 2 E., Illinois.
52. Quarry, NW¼ sec. 5, T. 3 N., R. 1 E., Platte Mound, Wis.

In southeastern Minnesota, where the Pecatonica is less than 2 feet thick, it consists of very sandy limestone above calcareous sandstone that contains phosphatic nodules. This phase is exposed in the long roadcut along U. S. Highway 16 in sec. 35, T. 103 N., R. 10 W., just south of Lanesboro, Minn. (about 40 miles north of Decorah, Iowa; fig. 35).

The McGregor member, a limestone in the western and central parts of the district, changes laterally, becoming progressively more dolomitic eastward near the crest of the Wisconsin arch, where it is dolomite (fig. 34). This dolomitization affects the upper beds of the McGregor farther west than it does the lower strata. Chert is present in the McGregor from Shullsburg, Wis., eastward.

The Quimbys Mill (upper) member of the Platteville formation is limestone or limestone and dolomite in the central part of the mining district, and is cherty dolomite to the east (fig. 34). The unit wedges out to the west, as is shown by its thickness of only 1 foot in the roadcut 10 miles southwest of Platteville, Wis., (fig. 35, loc. 12), and of only a few inches in a roadcut 10 miles northwest of Platteville, in sec. 1, T. 4 N., R. 3 W. (loc. 28). The Quimbys Mill averages 14 feet thick in localities several miles east of the type section (loc. 27) and at Mount Horeb (loc. 20), and is more than 18 feet thick in an area southeast of Shullsburg.

All members of the Platteville formation are conformable except the Quimbys Mill. The Quimbys Mill strata do lie conformably on the McGregor, and a dark shale bed commonly marks the contact. However, the Quimbys Mill member and the overlying Decorah strata, whether the Spechts Ferry shale member or the unnamed limestone member (p. 264), regionally show disconformable relationships.

In the central part of the mining district the upper surface of the Quimbys Mill is corroded and pitted by solution; clots of greenish shale and of sandy limestone similar to that in the overlying Spechts Ferry fill these pits, giving the appearance of involutions in vertical cross section. East of the mining district, where the Spechts Ferry is absent, the pits are filled with sandy dolomite and phosphatic pebbles of the Guttenberg that farther west mark the upper part of the Spechts Ferry. Similar features were noted by Chamberlin (1882, fig. 8), Sardeson (1898, p. 322), and Ulrich (1924, fig. on p. 96). This corrosion surface marks the upper limit of the Quimbys Mill member.

The Decorah formation at its type locality, 80 miles northwest of the mining district, is 25–30 feet of greenish calcareous shale with nodular limestone, overlying a 2-foot basal limestone unit that wedges out to the east. In the western part of the mining district the Decorah is divisible into the following three members: at the base is the 8-foot thick greenish shale with limestone nodules of the Spechts Ferry, next above is the brown limestone and some shale of the Guttenberg 15½ feet thick, and at the top is the grayish limestone and shale of the Ion, 19 feet thick (fig. 34). In the eastern part of the mining district the Spechts Ferry has wedged out, the brown dolomite of the Guttenberg has thinned to 8 feet thick, and the overlying grayish buff dolomite of the Ion is only 15 feet thick and difficult to distinguish from the lower zone of the overlying Galena dolomite.

The Decorah rests disconformably on the Platteville; it grades upward into the Galena (Agnew, 1950), contrary to previous statements (Kay, 1932; Kay and Atwater, 1935) that an unconformity exists at the latter contact.

The Galena dolomite is rather uniform in thickness across the mining district—averaging 225 feet—and is generally a dolomite. The lower part, however, is limestone in the western part of the district and to the west, and also locally in the central part of the district; The formation is divisible regionally into two subdivisions of about equal thickness, a cherty unit below and a noncherty one above. The cherty unit includes the lower two-thirds of the Prosser member of established stratigraphic usage, whereas the noncherty unit consists of the upper third of the Prosser, the Stewartville, and the Dubuque members. As the Prosser, Stewartville, and Dubuque members are not everywhere recognizable in the regional area embraced in this study, and because the noncherty and cherty units are distinctive throughout its extent, the twofold subdivision of the Galena based on the presence or absence of chert is employed in the present report (p. 265).

The Maquoketa shale (Upper Ordovician) is generally grayish dolomitic shale and dolomite in the mining district, although its lower one-third is commonly brownish in color. The Maquoketa is as thin as 110 feet in the southern part of the mining district, and thickens toward the northeast to 240 feet in a locality 25 miles west of Madison, Wis. (fig. 31); it likewise thickens to the northwest, 220–260 feet being common in the area northwest of Dubuque, Iowa. The Maquoketa is characterized by facies changes, especially west of the mining district. It appears to lie conformably on the Galena, although regionally the contact seems to be disconformable.

Dolomite of Early Silurian age is present up to 200 feet thick in the mining district. The lower 20 feet or so is argillaceous dolomite; this is succeeded by 65 feet of cherty strata, 20 feet of noncherty dolomite, and the upper 90 feet is somewhat cherty and contains *Pentamerus*. Dolomite of the Silurian generally lies unconformably on the Maquoketa, although locally the contact appears to be gradational.

Post-Silurian deposits found locally in the mining district include boulders of quartz sandstone, boulders of hematite, boulders of quartzite and greenstone, and poorly cemented conglomerate. In addition, in the southern, eastern, and western fringes of the district, glacial drift occurs generally in local patches (fig. 31). Pleistocene terrace deposits and loess are common in the mining district.

STRATIGRAPHIC PRINCIPLES

Because the geologic investigation that gave rise to the present report had as its major purpose the delineation of geologic structure, the rocks were studied in terms of mappable units—formations and members. Initially the investigation was concerned with relatively local areas (maximum width 10 miles), but more regional relationships were scrutinized as areas 15 or 20 miles or more distant from the initial one were mapped. In local areas 5 to 10 miles wide, differences in lithofacies were observed, and the recognition of facies relationships was found to be even more important in the regional correlation of the strata than in local correlation..

Despite these lateral changes in lithologic features, from the standpoint of the structural mapping it was desirable to picture the rocks as correlative units, provided that upper and lower limits of the mapped unit were recognizable. Thus a liberal interpretation of the facies concept was applied.

Regionally and even locally all lithologic criteria were evaluated and a top or base was assigned to a particular unit, although the gross lithology of that unit in places may have been atypical, as for example the regional lithology of the Guttenberg limestone member, and locally the Ion member of the Decorah-Galena contact. As another example, the Decorah formation at its type locality is indivisibly green shale with limestone nodules, overlain by limestone of the Galena, and underlain by limestone of the Platteville. Thirty-five miles closer to Platteville, at the type locality of the Ion the upper (Ion) member of the Decorah is still green shale and limestone in almost equivalent amounts; it is overlain by buff limestone of the Galena dolomite and underlain by tan limestone of the Guttenberg (middle member of the Decorah). At Platteville the Ion is light-brown dolomite with greenish argillaceous mottlings and partings; it is overlain by light-brown dolomite of the Galena and is underlain by light-brown Guttenberg limestone. In gross lithology the Ion at Platteville is more like the overlying than it is like the underlying strata, although at Decorah, Iowa, the reverse is perhaps true. The recognition of one persistent and other less-persistent bentonite beds aided in the regional tracing of the strata across facies changes.

A "formation" in this study is a locally mappable unit consisting of rocks mainly of one dominant lithologic type, with boundaries based upon objective criteria. It is extended regionally, despite facies changes, from local areas on the basis of all the lithologic criteria (including fossils) available; and its boundaries, although in this extension somewhat subjective, are drawn at the same stratigraphic positions relative to units above and below, as where the formation was initially mapped. Stratigraphic purists may object, for example, to calling the Ion a part of the Decorah formation at Platteville, Wis., where actually it is more similar in lithology to the overlying Galena dolomite. However, the philosophy presented herein permits the use of workable stratigraphic units locally, permits the correlation of these units regionally, and permits the stratigraphic nomenclature to be held at a minimum.

Geologic time rock classification is another matter, entirely (see the discussion of this problem as related to Cambrian strata of the upper Mississippi Valley by Bell, Feniak, and Kurtz, 1952, p. 175–176).

Fossils in the Platteville, Decorah, and Galena strata of the upper Mississippi Valley have not been adequately studied, nor have most of the many fossil collections been gathered with adequate attention to principles of stratigraphic geology. As a result the faunal characteristics of the strata are as yet not completely known.

No systematic paleontologic study of the strata has been attempted during the course of the present project. However, fossils have been observed as rock characters, and it is believed that because the faunas are related closely to environmental conditions, and because they recur in succeeding strata of similar lithologic facies, they are generally facies faunas. Thus only general assignments to the larger time-stratigraphic subdivisions (systems and series) is made herein.

Furthermore, dolomitization can destroy evidence of fossils originally entrapped in the limestone (Bucher, 1953, p. 292); therefore, relatively unfossiliferous dolomitic rocks such as the Pecatonica may originally have been characterized by a much greater abundance and diversity of forms.

Most of the fossils observed in the Galena, Decorah, and Platteville beds seem to be facies faunas (as should be expected, but commonly is not). As Allan so concisely stated (1948, p. 7),

> the practice of matching faunas—usually faunas determined in a museum by one person but collected by someone else—is quite illogical; and the widely accepted views that dissimilarity of

faunal content indicates difference of age, and that similarity of faunal content establishes chronological equivalence, are extremely unsafe generalizations.

Allan's views were forecast by Sardeson (1907, p. 190), who stated that "the identity of fossils does not prove strictly contemporaneous deposits, but only related faunas." (See also Williams, 1952; Rich, 1951, p. 17.) Regionally these faunas transgress lithologic units, they recur with ecologically recurring rock-depositing environments, or they are absent where their particular environment was absent. For example, Bell (1950, p. 493) ventures the

suspicion that the widespread Eden-Maysville "hiatus," the physical evidence for which is so infrequently demonstrated, records the absence of a biotic environment—not the absence of a depositional record.

The writers agree heartily with Bell, for there is no physical evidence that a "hiatus" exists between the Stewartville and Dubuque members of the Galena; yet because the fauna of the limestone and dolomite of the Stewartville is Trenton in aspect, and the fauna of the shale and limestone of the Dubuque is Richmond in appearance, a hiatus representing Eden and Maysville "time" is commonly postulated between the Stewartville and Dubuque members (see also Lattman, 1954, p. 268; McFarlan and White, 1948, p. 1642). Because the object of this study was the mapping of geologic structure, therefore, and because of the reasons stated above, the fossils have not yet been studied in detail and only general assignments to the geologic time scale are made.

The faunal relationships of these strata remain to be worked out; this constitutes an extremely interesting problem whose solution will contribute materially to our knowledge of stratigraphy, paleontology, ecology, and general geologic history of the Middle Ordovician of the upper Mississippi Valley.

STRATIGRAPHIC PROBLEMS

PLATTEVILLE-DECORAH BOUNDARY

Bain's (1905, p. 19) original description of the beds of Platteville age at the type locality recorded an average thickness of 60 feet, consisting of:

	Feet
4. Thin beds of limestone and shale	10–20
3. Thin-bedded brittle limestone, breaking with a conchoidal fracture	25–30
2. Buff to blue magnesian limestone, heavy bedded, (frequently a dolomite)	20–25
1. Shale, blue	1–5

According to Bain, unit 4 consists of limestone and shale commonly in thin alternating beds, but

there is comparatively little uniformity in this member in different parts of the district * * * the shale layers are better developed toward the west, while the limestone is the main part or the whole of the member in the eastern portion of the lead and zinc district. The shale beds are usually green or blue in color, though some of the beds are at times yellow, chocolate colored, or even black. The green shales are especially developed in Iowa. The chocolate-colored and black shales are highly carbonaceous, and are locally termed "oil rock," though the main bed of chocolate-colored shale, or the "oil rock" of the lead and zinc district, lies just at the base of the Galena. The limestone is commonly a thin-bedded, fine-grained, blue rock, rich in fossils. At times it is subcrystalline, and, while usually nonmagnesian, becomes markedly magnesian toward the east, where it seems to be the equivalent of the "upper buff" of the Wisconsin section. The most marked beds of No. 4 in the type locality of the Platteville occur near the base of this member, and are termed "glass rock." These are the typical glass-rock beds of the lead and zinc district.

These "green or blue" shales and the "thin-bedded, fine-grained, blue rock [limestone] rich in fossils" belong in the Spechts Ferry, which is here referred to the Decorah formation, as is discussed later (p. 286). The "chololate-colored and black shales" and the subcrystalline limestone that becomes dolomitic toward the east belong in the Quimbys Mill member of the Platteville formation. It is therefore evident that the grouping of the two members together as facies of the same unit led to Bain's impression that unit 4 of his description lacked uniformity.

Bain (1905, p. 21) described the Galena as follows:

Generalized section of the Galena limestone, Illinois

	Feet
5. Dolomite, earthy, thin-bedded	30
4. Dolomite, coarsely crystalline, massive to thick bedded	60
3. Dolomite, thick to thin bedded, coarsely crystalline, chert bearing	90
2. Dolomite, thick bedded, coarsely crystalline	60
1. Thin bedded limestone with shaly partings which are highly fossiliferous and, in part, at least, carbonaceous—the 'oil rock' of the miners	2

The basal member of the Galena, No. 1 of the above section, is well known throughout the zinc district. It receives its name from the large amount of carbonaceous material which it contains, often sufficient to cause it to burn when lighted with a match. In the mining district it is everywhere recognized as the oil rock; and as there are usually several bands of shale interbedded with thin-bedded brittle limestone, the most important band is there discriminated as the main oil rock. Away from the mining district the horizon is occupied by a soft green clay. Usually the shaly element is most important at the top, and ordinarily—in southwestern Wisconsin, at least—a particularly bituminous parting is recognized as belonging to the oil rock.

It is apparent that Bain considered the carbonaceous oil rock and the "soft green clay" as different facies, thus implying that the "glass rock," "clay bed," and "oil rock" are all facies of the same stratigraphic unit. They belong to three separate members (Quimbys Mill, Spechts Ferry, Guttenberg) of two different formations (Platteville, Decorah), as is demonstrated in the discussions of those units in succeeding pages.

In a later publication Bain (1906, p. 22, 23) placed all of the "bluish or greenish" shale at Spechts Ferry, Dubuque County, Iowa (fig. 35, loc. 10) in the Platteville formation, and stated that in a quarry about 2 miles northwest of Platteville, Wis., "the equivalents of the main oil-rock horizon which marks the base of the Galena" were present, and that the unit immediately below "represents the clay bed usually found beneath it." It is not clear from the above statement whether he meant the clay bed to be assigned to the Galena or to the Platteville, but presumably the latter.

Two pages later, however, he (1906, p. 25) wrote as follows:

General section of basal Galena beds

	Ft.	In.
4. Thin-bedded magnesian limestone, variable in thickness, which depends upon the extent of dolomitization	0–15	15
3. Thin-bedded limestone or dolomite with partings of oil rock	5–8	
2. Brown, shaly material, with minor lenses of limestone; the main oil-rock horizon	½–2	
1. Shale or blue clay containing black phosphatic pebbles	½–3	

In places dolomitization extends down to the top of No. 3 of the above section; in other places No. 1 of the section cannot be distinguished from the shaly limestone beds at the top of the Platteville, in which black and brown shale, indistinguishable from the oil rock of the Galena, occurs.

Bain's earlier concept that the green shales and brown carbonaceous shales are merely different facies of the same beds is thus again evident. His described section (1906, p. 28) at Eagle Point quarry, Iowa, shows 3 feet of green argillaceous fossiliferous shales as the basal unit of the Galena.

Ellis (1905, p. 313), who worked closely with Bain on the Wisconsin and Iowa parts of the study, wrote as follows:

The base of the Galena is marked by a constant shale bed varying from 1 to 3 feet in thickness. This shale consists of blue clay and of brown carbonaceous material, which gives it the name of "oil rock" * * * [The underlying "glass rock," which comprises the upper beds of the Platteville] carries varying amounts of magnesium carbonate, although not approaching a dolomite.

Cox (1911, p. 431) likewise interpreted this relationship as one of facies:

The base of the main body of oil rock occurring from 8 to 12 feet above the glass rock is taken as the division between the Platteville limestone below and the Galena dolomite above. * * * Interbedded with, or just below, there is often a greenish clay bed a foot or so in thickness.

It is uncertain whether he meant the "greenish clay bed" to be basal Galena or uppermost Platteville.

Grant (1903, p. 35–36; 1906, p. 33) had likewise noted the stratigraphic recurrence of the oil rock, with the bluish or greenish shale between. However, he termed the oil rock above the blue shale the "main oil rock." He found that this bed of oil rock in every case overlies the clay bed, which in turn overlies the "glass rock." He signified the "main oil rock" as the basal unit of the Galena, and the clay bed as the uppermost unit of the underlying Platteville. Later he was not consistent, however, for he and Burchard (1907, p. 6) placed within the Galena the green shale beds occurring below the oil rock in the Eagle Point quarry at Dubuque, Dubuque County, Iowa (fig. 35, loc. 11), although in other sections (1907, p. 5) the blue and green shale was consistently put in the Platteville.

Although Davis (1906, p. 548) had noted that the clay bed and the oil rock are separate and superimposed units and not facies, his lead was not followed until Trowbridge and Shaw (1916, p. 39) and Boericke and Garnett (1919, p. 1218–1219) likewise distinguished them.

The Platteville-Decorah boundary was shown recently (Agnew, Heyl, 1946) to be one of regional disconformity. The upper member of the Platteville formation pinches out to the west, whereas the members of the Decorah formation thin and are absent to the east. Furthermore, locally the upper surface of the Quimbys Mill is pitted and corroded, and contains involutions of sedimentary rocks of the overlying unit. The presence of a bentonite layer near the base of the Spechts Ferry is evidence that these relationships are not facies, because the bentonite layer remains just above the contact of the limestone and shale as the beds are traced eastward beyond the area of Spechts Ferry strata (fig. 36).

BELOIT DOLOMITE

In the eastern part of the mining district and farther east the strata of Platteville, Decorah, and Galena age are dolomite, and the gross lithology of the three formations is somewhat similar. A marked difference, however, is the fact that the Galena maintains its characteristic honeycomb (wormy) weathered appearance, which the lower two formations do not share. This eastern area is the type for Sardeson's Beloit formation, which name he (1896b, p. 360) suggested to replace "'Trenton' or Lower Trenton," as the overlying Galena strata are more probably the "equivalent to the Trenton limestone of New York." The Beloit was made up of the four divisions: "lower buff beds," "lower blue beds," "upper buff beds," and "upper blue beds" (Chamberlin, 1877, p. 293, 295, 296).

The Beloit was distinguished first on lithologic criteria, having "thinner, more compact strata" in

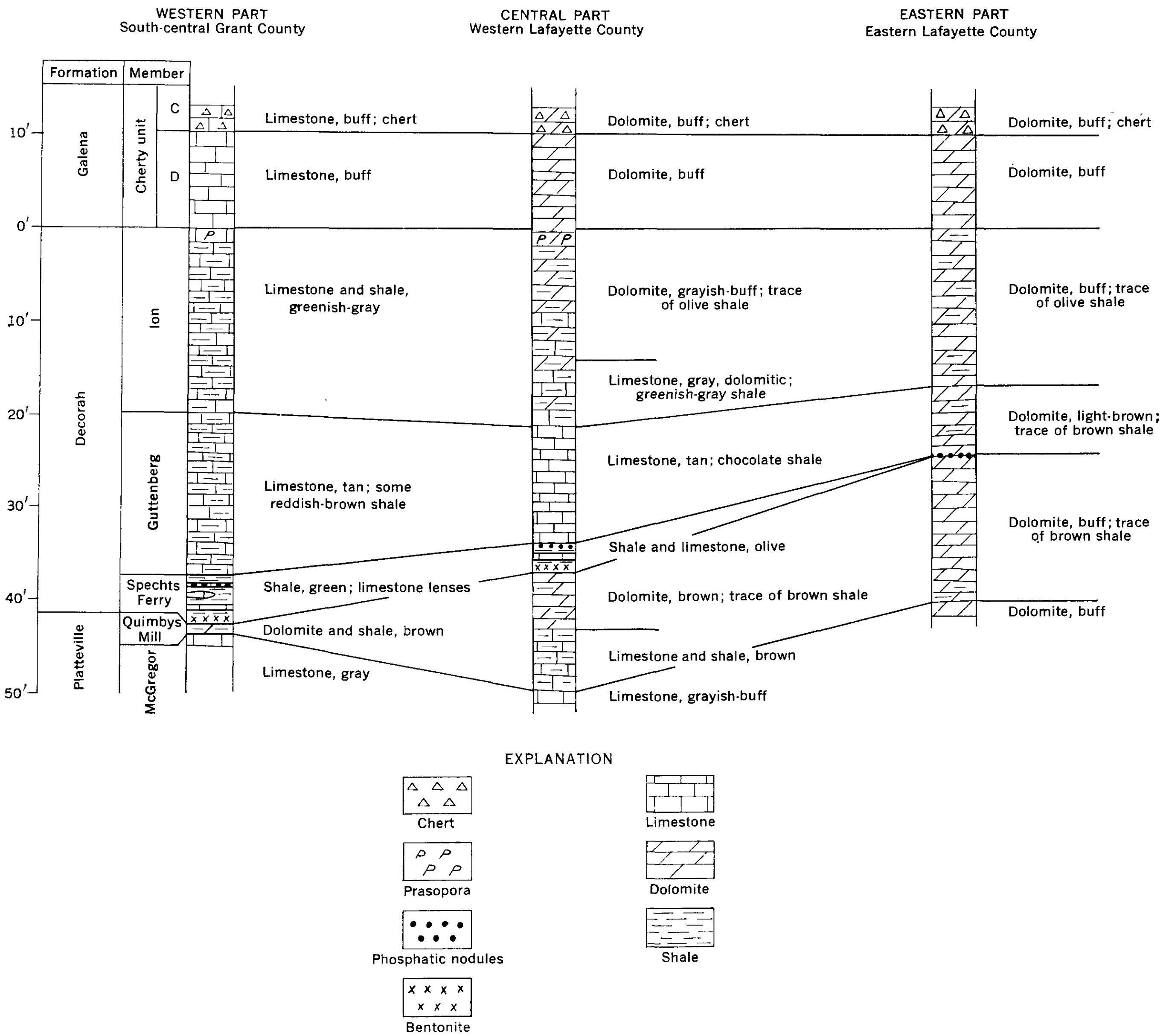


FIGURE 36.—Generalized west-east cross section of the Decorah formation and adjacent strata.

contrast with the overlying Galena's "thick porous ones" (Sardeson, 1897a, p. 23). Sardeson felt that a faunal distinction also was needed, however, as the lithologic differences best recognizable in the "lead region" are not quite satisfactory, because "local alteration of the rock has produced the typical Galena facies in the top of the Beloit formation." The addition of faunal criteria made the Beloit formation the "zone of *Orthis subaequata* Con. (*O. perveta* Con., etc.), and the Galena is the zone of *Receptaculites oweni* H." Sardeson's (1897a, p. 29) correlation placed the top of the Beloit at the top of the Fucoid bed (Ion) of Minnesota (fig. 37), which he had traced to the vicinity where the Beloit is exposed by the presence of fossils including *Prasopora contigua* Ulrich.

This makes the Beloit equivalent to the Platteville and Decorah formations of the present classification, as noted first by Sardeson (1907, p. 187, 193). The lithologic unity of the Beloit formation is characteristic eastward from the mining district to the vicinity where the Beloit is exposed. The lithologic subdivisions of the Beloit are likewise most characteristic in that area. However, certain miscorrelations (especially of the lower blue beds) which Sardeson perpetuated (1896b, p. 362) causes one to avoid those subdivisions as stratigraphic units.

Classification used in this paper		Minnesota		
Formation	Member	Winchell and Ulrich, 1897, p. lxxxvi	Sardeson, 1897a; 1907, p. 185	Hall and Sardeson, 1892, fig. 5
Galena	Dubuque	Maquoketa (Utica)	*Triplecia* bed *	Maquoketa (Utica)
	Stewartville	*Maclurea* zone	*Maclurea* bed	*Maclurea*
	Prosser	*Fusispira*	*Lingulelasma* bed	*Lingulasma*
			Camarella bed	*Camarella*
		Nematopora / *Clitambonites*	*Orthisina* bed	*Orthisina*
Decorah	Ion	*Phylloporina* / *Ctenodonta*	Fucoid bed	*Zygospira* Fucoid
	Guttenberg	*Rhinidictya* bed	*Stictopora* bed	*Stictopora*
	Spechts Ferry	*Stictoporella* bed	*Stictoporella* bed	*Stictoporella*
Platteville	Quimbys Mill			
	McGregor	*Vanuxemia* bed	Blue, or *Bellerophon* bed	Blue
	Pecatonica	Buff limestone	Buff limestone	Buff
	Glenwood			

* Sardeson (1897a) also referred to the *Triplecia* bed as the "Transition formation" and as the Maquoketa shales

FIGURE 37.—Correlation of Platteville, Decorah, and Galena strata with units in Minnesota.

Furthermore, in the area where the Beloit is exposed it is difficult to distinguish the uppermost strata of the Beloit from the overlying Galena strata. Conversely, the Platteville and Galena formations are distinct in the area of their type localities in the mining district; the Decorah formation, though mainly shale in its type locality 80 miles northwest of the mining district, and mainly dolomite at the eastern edge of the mining district, nevertheless is traceable lithologically across these facies changes; therefore, the Decorah is a distinct unit in the mining district.

Moreover, the terms Platteville and Decorah have been in use consistently since 1906, whereas the term Beloit has been virtually forgotten. The names Platteville and Decorah are therefore used in this paper.

UNNAMED[1] LIMESTONE MEMBER, DECORAH FORMATION

Northwest of the mining district is a thin limestone unit that is similar in lithologic character to the underlying McGregor there, but separated from that member by bentonite. It is typically exposed in the quarry at the north end of Ice Cave Bridge (called Halloran's quarry by Calvin, 1906, p. 85), in NE¼NW¼ sec. 15, T. 98 N., R. 8 W., in Decorah, Winneshiek County, Iowa (see section 6, p. 306), where it consists of 2½ feet of limestone above half a foot of bentonitic shale and siltstone. Other exposures near Decorah that show this member well are the Coon Creek ravines in SW¼ sec. 13, T. 98 N., R. 7 W., the Conners roadcut along the north line of sec. 13, and the roadcut along the south line of the SW¼ sec. 13, all about 8 miles east of the Ice Cave Bridge quarry. The thickness has diminished to 2 feet at these localities, but otherwise the strata are similar to those at Ice Cave Bridge quarry.

Twelve miles to the southeast, in a ravine 2 miles north of Forest Mills (fig. 35, loc. 35) these limestone strata are thinner and have changed somewhat in color to bluish gray (see section 7, p. 307). Similar lithology was observed in the type section of the Ion, 11 miles farther east, in NW¼ sec. 35, T. 96 N., R. 4 W. (loc. 36), except that the limestone bed is only 0.9 foot thick and the bentonite bed is overlain and underlain by dark brown shale. Near McGregor, 5–8 miles farther southeast, roadcuts, in the NE¼ sec. 9 and the NE¼ sec. 34, and the (type locality of the McGregor) NE¼ sec. 28, T. 95 N., R. 3 W. (loc. 25) showed 0.4–0.7 foot of purplish limestone overlying 0.3–0.5 foot of bentonite and bentonitic siltstone.

[1] Although the writers originally intended to name this distinctive unit the Ice Cave Bridge member from an exposure in Decorah, Iowa, because of the greater thickness in Fillmore County, Minn. (30 miles to the northwest) M. P. Weiss is naming and defining the unit from exposures near Carimona in that county.

The bentonite bed in the Spechts Ferry member in the McGregor-Ion area is 0.3–0.5 foot above the top of the limestone of the unnamed member, whereas in the Coon Creek to Conners area east of Decorah it is 0.8–1.3 feet above the limestone; at Decorah the bentonite layer is 2.5 feet above.

East of the Mississippi River the relations of this unnamed member of the Decorah with the overlying Spechts Ferry in Grant County, Wis., are not completely clear, as the tabulation below shows:

Relations of unnamed member of Decorah formation in Grant County, Wis.

Exposures	Lithologic character	Thickness between bentonite beds (feet)	
		Units	Total
Roadcut, U. S. Highway 18 (loc. 37)[1]	Shale, olive, and brown limestone.	0.5	0.5
Bloomington quarry (loc. 38)[1]	Shale, olive	1.6	1.6
Mount Hope quarry (loc. 39)[1]	Shale, olive Limestone, buff	.2 .8	1.0
Roadcut, U. S. Highway 18 (loc. 40)[1]	Limestone, buff	.6	.6
Roadcut, County Trunk A (loc. 41)[1]	Shale, olive Limestone, buff to brown	.1 .7	.8
Shriners Park quarry, SE¼SW¼ sec. 34, T. 5 N., R. 3 W. (midway between locs. 41 and 28).	Shale, olive Limestone, buff	.6 .6	1.2
Roadcut, County Trunk A (loc. 28)	Limestone, buff Limestone, pink Shale, olive Limestone, buff	.7 .1 .2 .5	1.5
Liberty Ridge quarry, NW¼SE¼ sec. 19, T. 5 N., R. 2 W. (1 mile south of loc. 15).	Shale, olive Limestone, pink Shale, olive	.1 .8 .3	1.2

[1] Locality numbers and section, township, and range are given on figure 35.

At the Liberty Ridge quarry lenses of limestone similar in lithology to the Quimbys Mill are present in the basal part of the lower bentonite bed. Six miles east of this quarry (roadcut, County Trunk E, center E½ sec. 18, T. 5 N., R. 1 W.) 1.5 feet of typical limestone of the Quimbys Mill member is overlain by 0.9 foot of pinkish limestone, which may possibly represent the eastern feathering out of the unnamed member, although the lower bentonite bed is absent. Moreover, 4 miles southeast of the Bloomington quarry in a roadcut along State Route 35 (SE¼ sec. 8, T. 4 N., R. 4 W.), where the Quimbys Mill is absent, the McGregor is overlain in ascending sequence by a 0.1-foot mottled brown and green shale, a 0.1-foot olive shale, a 0.1-foot greenish limestone, a 0.3-foot olive shale, and that by the bentonite bed of the Spechts Ferry. As the bentonite bed at the base of the unnamed limestone member is elsewhere overlain by a mottled brown and green shale, the unnamed limestone and its basal bentonite bed are considered to be absent at this roadcut south of Bloomington.

The western edge of the Quimbys Mill is an approximate north-south line about 5 miles west of the east line of Grant County, Wis. (fig. 35). Recognizable beds of the unnamed limestone unit are seen as far east as the mouth of the Wisconsin River, which is 30 miles west of the Quimbys Mill pinchout. Between the mouth of the Wisconsin River and the central part of Grant County, there are beds of indeterminate assignment, although presently they are recognized as having some of the characteristics of the unnamed limestone member.

Although these limestone beds at Decorah were excluded from the Decorah of Calvin, in their eastern occurrences (Grant County, Wis.) they are more characteristic of Decorah strata than of the underlying Platteville. Furthermore, the members of the Platteville formation thin to the west whereas those of the Decorah formation thin to the east. The unnamed limestone member, therefore, is here referred to the Decorah formation. This was apparently the assignment made by Stauffer (1925, p. 616–619) at an exposure in St. Paul, Minn., as he determined the top of the Platteville to be below 1.5 feet of brown dolomitic limestone, which was overlain by a thick bentonite bed that was succeeded above by 2 feet of gray to bluish limestone. These limestone beds, which Stauffer placed in the Decorah, rested on a corrosion surface, probably the same as the one that Sardeson (1898, pl. 9) recognized at the top of the *Bellerophon* bed (fig. 37).

No systematic paleontologic study has been made of these strata (p. 289). Such a study should be valuable, as would similar studies through the Platteville, Decorah, and Galena sequence of the upper Mississippi Valley. Because the unnamed member is better exposed in Winneshiek County, Iowa, and Fillmore County, Minn., than in the mining district, further study of this member should be concentrated in that general area.

SUBDIVISIONS OF GALENA DOLOMITE

Galena is the name applied by Hall (1851, p. 146) to the rocks exposed in the vicinity of the town of Galena, Ill.

In the upper Mississippi Valley region the Galena has been divided into the following three members on the basis principally of paleontologic criteria:

Dubuque (Sardeson, 1907, p. 193)—limestone and shale, bounded below by the "cap rock" of the Stewartville; named from Dubuque, Iowa (fig. 35).

Stewartville (Ulrich, 1911b, pl. 27)—the *Maclurea* zone (Winchell and Ulrich, 1897, p. lxxxiii–lxxxvii) of Minnesota; named from Stewartville, Fillmore County, Minn., 65 miles northwest of Waukon, Iowa.

Prosser (Ulrich, 1911a, p. 257)—The *Fusispira* (above), *Nematopora* and *Clitambonites* (below) beds of Minnesota (Winchell and Ulrich, 1897, p. lxxxiii–lxxxvii); named from Prosser's ravine, near Wykoff, Minn., 50 miles northwest of Waukon, Iowa.

The Prosser member was named by Ulrich (1911a, p. 257) as including the *Clitambonites* (*Vellamo*), *Nematopora*, and *Fusispira* beds (fig. 37) of the Minnesota reports, apparently from the exposures in "Prosser's ravine, near Wykoff," (sec. 20?, T. 103 N., R. 12 W.).

The member was not adequately described in 1911, nor is the type section properly located. However, Winchell and Ulrich (1897, p. lxxxv–lxxxvii) had previously given a section at "Prosser's ravine," near Wykoff, Fillmore County, "which Ulrich undoubtedly intended as the type section" (Stauffer and Thiel, 1941, p. 86). About 185 feet of limestone occurs at this locality, of which the lower 110 feet or so were assigned to the Prosser. As described by Stauffer and Thiel the beds are fairly thick, composed of hard compact drab limestone with a small amount of shale. Several zones are cherty.

The name Stewartville was applied by Ulrich (1911b, pl. 27) to the "*Maclurea* zone" of the earlier Minnesota reports, apparently from exposures near the town of Stewartville, Minn. (sec. 34?, T. 105 N., R. 14 W.).

In southeastern Minnesota, as elsewhere in the upper Mississippi Valley region, the Stewartville is a dolomite or dolomitic limestone. It was originally described as having a thickness averaging 50 feet. Stauffer and Thiel (1941, p. 87) described a section from the type region of the Prosser member, in Prosser Creek, 2½ miles west of the town of Wykoff (15 miles southeast of Stewartville) as follows:

	Feet
Maquoketa Formation:	
Dubuque Member:	
18. Limestone, shaly, gray to buff, fossiliferous	20. 0
Galena Formation:	
Stewartville Member:	
17. Dolomite, cavernous, yellow to buff, fossiliferous. Common fossils include *Maclurina manitobensis* and *Hormotoma major*	16. 0
16. Dolomite, very porous, yellow from weathering, in thin, knotty layers. Common fossils are *Receptaculites oweni*, *Maclurina cuneata*, *M. manitobensis*, *Hormotoma major*, *Endoceras* sp., *Illaenus americanus*	10. 5
15. Dolomite, thick-bedded, gray to yellow. Common fossils are *Receptaculites oweni*, *Maclurina manitobensis*, *Hormotoma major*, *Westonoceras minnesotense*	12. 3
Galena Formation—Continued.	
Stewartville Member—Continued	
14. Dolomite, gray to brown, weathering yellow. Common fossils are *Receptaculites oweni*, *Rafinesquina alternata*, *Maclurina manitobensis*, *M. crassus*, *Hormotoma major*, *H. trentonensis*, *Illaenus americanus*, *Isotelus gigas*	14. 5
13. Shale, argillaceous, yellow to gray	1. 0
	54. 3
Prosser Member:	
12. Limestone, compact, drab, subcrystalline, with some thin, argillaceous layers	11. 0
11. Limestone, compact, hard, drab, thin-bedded, with numerous graptolites	1. 0
10. Limestone, compact, hard, drab, very fossiliferous. Common fossils include *Rafinesquina deltoidea*, *Catazyga uphami*, *Plectambonites gibbosus*, *Byssonychia intermedia*	8. 0
9. Limestone, bluish, compact, partly crystalline, thin-bedded to shaly. Common fossils include *Streptelasma corniculum* and *Rafinesquina deltoides*	8. 0
8. Limestone, compact, drab, with some chert or flint. Fossiliferous	13. 3
7. Limestone, compact, drab, with numerous fossils. Common forms are *Ischadites iowensis*, *Hesperorthis tricenaria*, *Plectambonites sericeus*, *Rafinesquina alternata*, *Vellamo diversa*, *Endoceras annulatum*, *Isotelus gigas*	19. 3
6. Limestone, thick-bedded, compact, drab, with some chert. Common fossils include *Hesperorthis tricenaria* and *Plectorthis plicatella trentonensis*	10. 3
5. Limestone, compact, drab, with shaly beds at the base, forming bottom of small caves and line of springs. Graptolites common	9. 2
4. Limestone, argillaceous, massive, but weathering into thin, knotty beds, blue to gray in color. *Receptaculites oweni* common	17. 8
3. Limestone, compact, drab, passing into argillaceous beds. *Receptaculites oweni* and *Plectambonites sericeus* common	10. 3
2. Limestone, compact, light drab in color. Abundant fauna includes *Dinorthis meedsi germana*, *Rafinesquina alternata*, *Rhynchotrema increbescens*	3. 2
1. Covered interval to level of Deer Creek at outlet of Prosser Creek	5. 3

The strata above the Stewartville and underlying the Maquoketa were named Dubuque by Sardeson (1907, p. 193) from their outcrops at Dubuque, Iowa.

Sardeson described the Dubuque as consisting of those "strata of irregular limestone and interlaminated carbonaceous shales" which lie above the "cap rock" of the Stewartville and below the "blue shales of the Maquoketa proper." Kay (1935c, p. 571) stated that this "cap rock" falls within the Stewartville both lithologically and faunally, and as the "cap rock" occurs within bed 14 of the following section (Calvin, Bain, 1900, p. 429), Kay redefined the Dubuque, restricting it to bed 15:

	Feet
15. Thin-bedded Galena limestone, earthy, non-crystalline, the layers ranging from ten or twelve inches near the base to less than three inches in thickness near the top; upper part of this member very shaly; carries as fossils *Lingula iowensis*, *Liospira lenticularis*, and *Conularia trentonesis*	30
14. Well dolomitized Galena in layers ranging from one to two and a half feet in thickness; with softer beds near the middle, which frequently disintegrate so as to form caverns; basal part only, of this member, represented above the Receptaculites beds at Eagle Point	30

Recent work by the writers (see also Flint and Brown, 1955), however, has lent support to a subdivision based upon the description by Calvin and Bain.

Because the descriptions of the Prosser and Stewartville in their type areas (southeastern Minnesota) are incomplete, these names cannot be used precisely in stratigraphic work in the general upper Mississippi Valley region without further study of the stratigraphy and paleontology of the Galena in southeastern Minnesota. Such a study should result in the validation of the names Prosser and Stewartville and thus in their continued use, because they are well-established in the literature. This is preferable to renaming these strata from different, although perhaps more representative localities regionally, as Templeton and Willman (1952, p. 6 and fig. 3) have done. During the past few years W. C. Bell and his students have been examining the rocks of this area, and M. P. Weiss' report, The stratigraphy and stratigraphic paleontology of the upper Middle Ordovician rocks of Fillmore County, Minn.,[2] contains descriptions of type sections and additional material that give precise stratigraphic meaning to the units described by Ulrich.

In the zinc-lead district the beds of the Galena are dolomite and are only sparsely fossiliferous; the fossils that are present in exposures are poorly preserved. Furthermore, where seen in the mines and in cuttings from prospect drill holes, local rock alteration and the pulverization by drilling have destroyed most of the fossils that survived the effects of regional dolomitization. As a result, during the current study it was necessary to subdivide the Galena on the basis of lithologic criteria. The units that can be recognized in exposures in the mining district are as follows, in descending order:

	Thickness (feet)
Noncherty unit:	
Dolomite and dolomitic limestone, yellowish-gray, finely granular, argillaceous, thin- to medium-bedded; thin partings of dolomitic yellowish-gray shale; lower contact gradational	35–45
Dolomite, yellowish-buff, coarsely granular to crystalline, vuggy, medium- to thick-bedded; *Receptaculites* common 35–55 ft above base	75–85
Cherty unit:	
Zone *A*. Dolomite, buff to drab, otherwise as above; chert bands common in upper 44 ft and 50–56 ft below top; locally a thin bentonite about 32 ft below top; *Receptaculites* 35–40 ft below top and 10 ft above base	70
Zone *B*. Dolomite as above, except more brownish; chert bands rare; *Receptaculites* common	15
Zone *C*. Dolomite as above; chert bands common	10
Zone *D*. Dolomite as above, except with streaks of greenish argillaceous material; no chert	10
Total	225

By definition the Prosser extends upward to the base of the upper *Receptaculites* zone, which has been called the base of the Stewartville member (fig. 38). However, it has been found extremely difficult to place this boundary with any degree of reliability, especially in subsurface work. The contact is normally not characterized by a marked and easily recognizable lithologic change. In fact, the delimitation of the Prosser member in the mining district depends solely upon the finding of *Receptaculites oweni* Hall, a difficult task in weathered or largely covered outcrops and in drill cuttings and cores. Furthermore, *Receptaculites* individuals have been found downward to within a few feet above the topmost chert, or about 25 feet lower than the normal position of the base of the upper *Receptaculites* zone.

The highest appearance of the chert bands within the described Prosser affords a useful lithologic key horizon (see also Willman and Reynolds, 1947, p. 10). In many places an observable color change in the dolomite occurs at the appearance of the chert bands. This change in lithology, striking in all outcrops and even more so in subsurface study, is found in southwestern Wisconsin, northeastern Iowa, and northwestern Illinois. The highest chert horizon is readily recognized farther south and west in Iowa (Agnew, 1955) and farther south in Illinois. (Workman, L. E., and Herbert, Paul, Jr., formerly with the Illinois Geological Survey, oral communication, August 18, 1945.) The stratigraphic continuity of the cherty and noncherty units is well established, and the contact between them is so dependable as a key horizon that structure contour maps using it as a datum have been prepared during

[2] Unpublished Ph. D. thesis, Minn. Univ., Minneapolis, 1953.

Formation	Member and subdivision		Local terminology	Description	Unaltered thickness, in feet		
Maquoketa			Shale	Shale, blue or brown, dolomitic; with dolomite lenses; phosphatic depauperate fauna in lower few feet	108–240		
Galena	Dubuque —?—	Noncherty unit	Buff or sandy	Dolomite, yellowish-buff, thin- to medium-bedded; with interbedded dolomitic shale	35–45	120	225
Galena	Stewartville —?—	Noncherty unit	Buff or sandy	Dolomite, yellowish-buff, thick-bedded, vuggy; *Receptaculites* in lower part	37–47	120	225
Galena	Prosser	Noncherty unit, P	Buff or sandy	Dolomite as above; bentonite rarely at midpoint	38	120	225
Galena	Prosser	Cherty unit, A	? Drab	Dolomite, drab to buff, thick- to thin-bedded; cherty; bentonite at base	32	105	225
Galena	Prosser	Cherty unit, A	Drab	Dolomite as above; *Receptaculites* at top	6	105	225
Galena	Prosser	Cherty unit, A	Drab	Dolomite as above; cherty	6	105	225
Galena	Prosser	Cherty unit, A	Drab	Dolomite as above; some chert; *Receptaculites* at midpoint	26	105	225
Galena	Prosser	Cherty unit, B	Drab	Dolomite as above; little chert; *Receptaculites* abundant	15	105	225
Galena	Prosser	Cherty unit, C	Drab	Dolomite as above; much chert	10	105	225
Galena	Prosser	Cherty unit, D	Drab	Dolomite as above;	10	105	225
Decorah	Ion		Gray	Dolomite and limestone, light-gray, argillaceous; grayish-green, dolomitic shale	11–15	20	32–44
Decorah	Ion		Blue	Dolomite, limestone, and shale as above, but darker	5–9	20	32–44
Decorah	Guttenberg		Oil rock	Limestone, brown, fine-grained, thin-bedded, nodular, conchoidal; dark-brown shale	12–16		32–44
Decorah	Spechts Ferry		Clay bed	Shale, green, fossiliferous; greenish-buff, fine-grained limestone; phosphatic nodules near top; bentonite near base	0–8		32–44
Platteville	Quimbys Mill		Glass rock	Dolomite and limestone, dark-brown, fine-grained, sugary, medium-bedded, conchoidal; dark-brown shale especially at base	0–18		55–75
Platteville	McGregor	Magnolia (of Bays and Raasch, 1935)	Trenton	Limestone and dolomite, light-gray, fine-grained	13–18	30	55–75
Platteville	McGregor	Mifflin (of Bays, 1938)	Trenton	Limestone, light-gray, fine-grained, thin-bedded, nodular, conchoidal	12–17	30	55–75
Platteville	Pecatonica		Quarry beds	Dolomite, brown, medium-grained, sugary, thick-bedded	20–24		55–75
Platteville	Glenwood		Shale	Shale, green, sandy	0–3		55–75
St. Peter			Sand rock	Sandstone, quartz, medium- to coarse-grained poorly cemented, crossbedded	40+		

FIGURE 38.—Stratigraphic column of Platteville, Decorah, and Galena strata in zinc-lead district.

the past several years by members of the Iowa Geological Survey.

West of the mining district the Stewartville and Dubuque members can generally be distinguished by lithologic features in the outcrop; however, in the mining district and to the east the differences are more subtle. Furthermore, in drill cuttings, which constitute a major source of information in the mining district, the separation of the Dubuque and Stewartville is generally difficult.

ORIGIN AND APPLICATION OF THE NAMES

The origin of most of the stratigraphic terms employed in this report is discussed by Wilmarth (1938); names that have been applied since 1938 or older names that for various reasons merit additional treatment are discussed in the paragraphs that follow.

MADISON SANDSTONE

The term Madison (Howell, 1944; Raasch, 1935) is not used in the present report, as the writers believe that it is not consistently recognizable in the zinc-lead district.

PECATONICA DOLOMITE MEMBER

Hershey (1894, p. 175) named the Pecatonica from exposures in the Pecatonica River valley "near the Wisconsin line, and northward," in southwestern Green County (fig. 35). As originally defined the Pecatonica included the sandy and shaly "insensible gradations" (beds of Glenwood age) downward into the St. Peter sandstone. Although Hershey (1897, p. 67) intended the name to be applied chiefly to the Elk Horn Creek area (fig. 31), and although Sardeson (1897c, p. 333) and Bays and Raasch (1935, p. 297) objected to its use, the name Pecatonica as restricted by Kay (1935a, p. 286) to exclude the "insensible gradations" at its base has received wide adoption, even by Bays (1938). This unit was called the "Lower Buff" by early writers because of its color when weathered.

McGREGOR LIMESTONE MEMBER

The McGregor limestone member was named by Kay (1935a, p. 286) from beds exposed in a ravine a mile west of McGregor, Clayton County, Iowa (fig. 35, loc. 25). The name was applied to the "limestone succeeding the Pecatonica member of the Platteville formation, and underlying the Spechts Ferry member." This is unit 3 of Bain's (1905) type section of the Platteville, as described on page 261.

The McGregor was divided by Bays and Raasch (1935, p. 298) into the McGregor, sensu stricto, below and the Magnolia above. Later Bays (1938) renamed the lower beds Mifflin from their exposure in "the roadcuts and stream banks of the Pecatonica River, at Mifflin, Iowa County, Wis." in the NE¼ sec. 34, T. 5 N., R. 1 E. (1 mile northeast of loc. 18, fig. 35). The Mifflin (of Bays, 1938) is characterized by thinly bedded nodular limestone that weathers light gray, and is 17½ feet thick at Mifflin, Wis. The type exposure of the Magnolia (of Bays and Raasch, 1935) is "on and near Highways 13 and 14," 1 mile south of the town of Magnolia, Wis., in the NW¼ sec. 26, T. 3 N., R. 10 E., Rock County (loc. 26).

In the type outcrops the Magnolia is reported (Bays and Raasch, 1935, p. 298) to consist of 39 feet of light-buff, moderately thick bedded dolomite, with conspicuous fucoidal markings on the bedding planes in the upper part of the member. The type section consists of several roadcuts and a quarry as much as a quarter of a mile apart, each exposing only a small part of the Magnolia (of Bays and Raasch, 1935); thus a measurement of thickness can be only an estimate. Other disadvantages of this selection are the lack of a complete exposure of the typical lithology, and the lack of exposure of the stratigraphic relations with the Mifflin (of Bays, 1938) beds below. No acceptable section in the vicinity of Magnolia, Wis., could be found during the course of the present study.

QUIMBYS MILL MEMBER

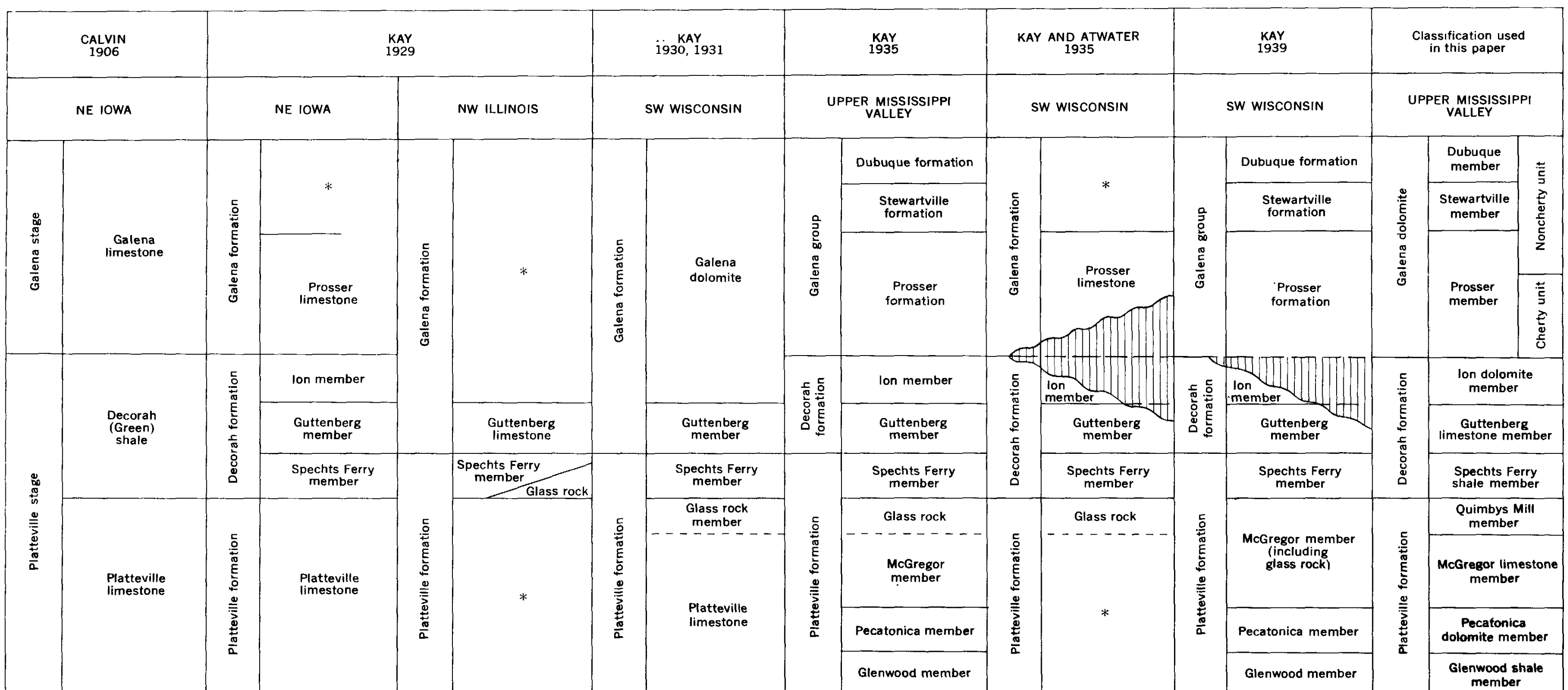
Agnew and Heyl (1946, p. 1585) named the Quimbys Mill member from its exposure in the quarry at Quimby's Mill, 5 miles west of Shullsburg, Wis. (fig. 35, loc. 27), including all the beds between the top of the McGregor (Trenton) and the base of the Spechts Ferry (clay bed) there. The Quimbys Mill strata are the "glass rock" of the miners.

Kay (1928) included the "glass rock" beds in his description of the type section of the Spechts Ferry which more or less agreed with Shaw and Trowbridge (1916, p. 4). Later Kay (1929, p. 644) described this assignment as possible, but shortly thereafter he (1931, p. 370) felt it desirable to omit these beds from the Spechts Ferry classification. He retained this point of view in later publications (1935a, p. 287) but at no time defined the exact position and nature of the "glass rock" (fig. 39).

Bays and Raasch (1935, p. 298) apparently included the "glass rock" beds in the Spechts Ferry but without describing them. These authors appear to have referred to the "glass rock" as a lithologic facies, for they stated:

> The Spechts Ferry varies from one district to another. It may be a soft calcareous shale, a limestone, or a dolomite.

Bays (1938) stated that it "passes laterally from shales to limestones to dolomites to cherty dolomites." The latter two are facies of the "glass rock" or Quimbys Mill member, as recognized in this report.



* Not mentioned in reference cited

FIGURE 39.—Classifications of Platteville, Decorah, and Galena sequence of the upper Mississippi Valley since 1906.

STRATIGRAPHY OF THE MINING DISTRICT

PRE-PLATTEVILLE ROCKS

Because this report deals primarily with rocks related to the ore deposits, pre-Platteville strata will be discussed only cursorily. Furthermore, as a detailed investigation of pre-Platteville strata was not attempted, information regarding those rocks is taken partly from the work of others, from rather brief studies of outcrops by the writers, and from recent drilling data.

PRE-CAMBRIAN ROCKS

Pre-Cambrian rocks were reported (Thwaites, 1923, p. 553) in a well at Platteville, Wis. (City well 2, sec. 15, T. 3 N., R. 1 W.), where the drill penetrated "granite" at a depth of 1,714 feet (fig. 35). Wells at the north margin of the district, in Richland Center, Wis. (sec. 16, T. 10 N., R. 1 E.), reached similar pre-Cambrian material at depths ranging from 665 to 678 feet, and the Borden Whey Plant well 2 at Boscobel, Grant County, Wis., reportedly struck "granite" at 837 feet (loc. 1). Information for these wells is in the files of Wisconsin Geological and Natural History Survey, Madison, Wis.

Pre-Cambrian rocks in the subsurface of this general area have been discussed by Thwaites (1931) and Grogan (1949). In the Baraboo area just northeast of the zinc-lead district, and in northern Wisconsin the pre-Cambrian rocks are separated from the overlying Cambrian sedimentary rocks by an unconformity of considerable relief.

CAMBRIAN ROCKS

The oldest Paleozoic rocks known in the upper Mississippi Valley (fig. 32) are sandstone, siltstone, and dolomite of Late Cambrian age (Twenhofel, Raasch, Thwaites, 1935; Trowbridge, Atwater, 1934). These rocks are exposed only along the northern edge of the zinc-lead district, and farther south they are found in deep wells drilled for water and as oil tests. An excellent exposure of much of the upper 150 feet of Cambrian is seen in the bluff at the intersection of State Routes 60 and 61 in Crawford County, 2 miles north of Boscobel, Wis. (fig. 35, loc. 2).

The thickness of the Cambrian increases southward from about 1,000 feet at the north fringe of the district (locs. 1, 2) to 1,284 feet at Platteville.

The Mount Simon sandstone, which rests unconformably upon the pre-Cambrian rocks, ranges from 440 to 780 feet in thickness in the mining district. It is generally light gray, but locally reddish. In the mining district few wells have intersected this sequence; however, Templeton (1950) has shown that near Rockford, Ill., (fig. 31) and to the south, different lithofacies are characteristic of the formation.

The Eau Claire shale overlies the Mount Simon sandstone conformably. In the mining district the Eau Claire is mainly sandstone, and its relations with the underlying and overlying strata are gradational. It ranges from 70 to 330 feet in thickness.

The Dresbach sandstone is light gray, and is 60–140 feet thick. The Mount Simon, Eau Claire, and Dresbach together aggregate 700–1,050 feet in thickness in the mining district. Part of this variation is due to the unconformity at the base of the Mount Simon; part to a southward increase in the thickness of the Mount Simon; and part is due to the gradational lithologic relationships of the three formations.

Above the Dresbach is the Franconia sandstone, 110–140 feet thick. The glauconite in the Franconia is the principal feature by which these strata can be distinguished from the similar overlying and underlying sandstone. Recently Berg (1953, 1954) has published the results of a thorough study of the facies of the Franconia; because the Cambrian strata are discussed only briefly in this report, however, no attempt was made by the writers to apply these subdivisions of the Franconia to the rocks in and bordering the mining district.

The Trempealeau formation, which overlies the Franconia, is principally sandstone and siltstone although commonly the lower strata are dolomite. The uppermost beds of the Trempealeau are called the Jordan sandstone, which is composed of clean well-sorted coarse quartz grains that are subangular to round. The Trempealeau formation is 120–150 feet thick.

Locally within the mining district and along its margins a sandstone unit called the Madison or Sunset Point (Raasch, 1951, p. 150) is said to overlie the Jordan sandstone of the Trempealeau formation. Raasch regards the Madison as a separate formation, basing this opinion primarily upon sedimentary and lithologic criteria, which Twenhofel and Thwaites (Twenhofel, Raasch, Thwaites, 1935, p. 1711, footnote 45) consider as having little weight. Raasch states that the Madison is poorly sorted silty or conglomeratic quartz sandstone, as much as 60 feet thick. It is not consistently recognized in the mining district.

In most places beds transitional in lithology fill the interval between the Jordan sandstone and the overlying dolomite of the Prairie du Chien group (Schuldt, 1943, p. 404). These transition beds consist of alternating dolomitic sandstones and arenaceous dolomites and are as much as 27 feet thick. In areas where the transition beds are lacking the contact of the Jordan and the Prairie de Chien appears conformable.

Lead minerals have been found in Cambrian rocks near Lansing, in northeastern Allamakee County, Iowa, sec. 10, T. 99 N., R. 4 W., and 35 miles to the north, at Dresbach, in southeastern Winona County, Minn., sec. 18, T. 105 N., R. 4 W.; both localities are marginal to the mining district (fig. 35). The galena at the Lansing occurrence is in the uppermost beds of the Cambrian, probably the dolomitic transition beds, whereas in the Minnesota locality the minerals were found in a shale 350–400 feet below the top of the Cambrian, probably in the Eau Claire sandstone.

Zinc minerals were seen (Heyl, Lyons, and Agnew, 1951, p. 9) in cuttings from a prospect hole near Montfort, in west-central Iowa County, Wis., sec. 30, T. 6 N., R. 1 E. (one mile south of loc. 43, fig. 35), from 149 to 159 feet below the top of the Cambrian in glauconitic sandstone called Franconia.

Evidences of iron mineralization in Cambrian strata are abundant, especially just north of the zinc-lead district. Iron sulfide estimated at 1–3 percent iron was found in the prospect hole at Montfort, from 141 to 179 feet below the top of the Cambrian, in the Franconia.

Water supplies ample for large industrial plants and municipalities are obtained from the Cambrian strata, especially from the Mount Simon and Dresbach.

ORDOVICIAN ROCKS

PRAIRIE DU CHIEN GROUP

The Prairie du Chien strata, which are commonly known in the upper Mississippi Valley by the old name of Lower Magnesian limestone, are seen above the Cambrian strata along the north fringe of the mining district and crop out in the more dissected areas in the central part of the district. Perhaps the most nearly complete exposure is in the quarry at the north edge of Wyalusing, Grant County, Wis. (fig. 35, loc. 3).

Rocks of the Prairie du Chien group are extremely variable in lithology. In places the group is divisible into three formations—the Oneota dolomite, which overlies the Cambrian, the New Richmond sandstone, and the Shakopee dolomite; the name Root Valley has been applied to a sandstone at the New Richmond position (Stauffer and Thiel, 1941, p. 59) and the name Willow River is used by many in place of Shakopee (Powers, 1935, p. 390). In other places, however, no recognizable sandstone unit is found; no threefold division could therefore be made. Furthermore, rocks that occupy the interval represented by the Prairie du Chien in places are sandstone, red shale, green shale, silicified limestone, and limestone. These strata have been assigned to the basal part of the St. Peter sandstone (Heyl, Lyons, Agnew, 1951, p. 5). Recent detailed study by Flint [3] ,on the other hand, has caused him to place them in the Prairie du Chien.

The dolomite of the Prairie du Chien group is light buff to light gray, finely to medium crystalline, in part vuggy, and thin to thick bedded, or irregularly bedded or massive. The dolomite is commonly oolitic, sandy with clear rounded quartz grains, and cherty. Locally, especially where evidences of iron-zinc-lead mineralization are abundant, the dolomite has been silicified. Thin green glauconitic shale lentils are found along bedding planes and in the dolomite. Mound-shaped *Cryptozoon* colonies are common at certain horizons. The sandstone is similar to that in the Cambrian below, and commonly contains stringers and beds of greenish glauconitic shale. The sandstone in most places has dolomitic cement. Because of the variation in lithology the bedding is irregular, and generally poor (fig. 40).

FIGURE 40.—Exposure of typical dolomite of Prairie du Chien group in quarry in NE¼NW¼NW¼ sec. 32, T. 7 N., R. 1 E., Iowa County, Wis. (4 miles north of loc. 43, fig. 35).

In local outcrops of the lower 40 feet of the Prairie du Chien, that rock can be zoned by lithology into several units, as Starke [4] has shown in the area north of the mining district; to these units Raasch (1952) has applied names in the Stoddard quadrangle (50 miles northwest of Platteville, Wis.), and Raasch has likewise given names to the succeeding 10–40 feet of strata in the Stoddard area. Because of the brief discussion of the Prairie du Chien in the present report, and because the correlative value of Starke's and Raasch's units and the value of Raasch's names have not been established in the mining district, the names and subdivisions are not used by the writers.

The Prairie du Chien attains a maximum thickness of about 240 feet in the zinc-lead district; it and the

[3] Flint, A. E., 1953, Stratigraphic relations of the St. Peter sandstone and the Shakopee dolomite in southwestern Wisconsin: unpublished Ph. D. thesis, Chicago Univ.

[4] Starke, G. W., 1949, Persistent litholcgic horizons of the Prairie du Chien formation from the type section eastward to the crest of the Wisconsin arch: unpublished M. S. thesis, Wis. Univ., Madison.

overlying St. Peter sandstone, from which it is separated by an unconformity, aggregate 280–320 feet.

Prairie du Chien strata have been correlated with the Canadian series of Missouri (Ulrich, Foerste, and Bridge, 1930; Twenhofel, and others, 1954).

The Prairie du Chien strata constitute one of the potential mining zones in the zinc-lead district. Although this potential has not been properly evaluated as yet, evidence of former mining of lead in these beds and recent testing by the U. S. Geological Survey, 1949–1951 (Heyl, Lyons, Agnew, 1951; Agnew, Flint, Allingham, 1953, p. 7–11) show that, with favorable economic conditions, these strata might possibly become a lower producing zone and thus prolong the industry in the district. Lead mining in the Prairie du Chien has been restricted to areas of its exposure along the northern fringe of the district. The drilling by the U. S. Geological Survey confirmed the presence of lead and iron minerals in these beds as far south as Mineral Point, Wis., and the Crow Branch diggings, in Grant County, Wis., (fig. 35, loc. 4). Although zinc minerals have been found in these beds, the only locality known to contain any great abundance is that 10 miles north of Waukon, Iowa (sec. 13, T. 99 N., R. 6 W.), where both zinc and lead were mined.

The permeability of the Prairie du Chien is such that it is a source of an adequate supply of water for farm use, especially where the overlying St. Peter sandstone is exposed and dry. Where the St. Peter sandstone is water bearing, commonly the Prairie du Chien is not a good source of water. Locally, the dolomites of the Prairie du Chien are permeable enough to be a reservoir rock and during drilling operations are able to absorb water rather than contribute it.

ST. PETER SANDSTONE

The St. Peter sandstone is exposed along the Wisconsin River and its tributaries, along the Mississippi River southward alomost to Dubuque, Iowa (fig. 35), and in areas of deep dissection within the zinc-lead district. Good exposures are seen along U. S. Highway 151 a few miles southwest of Platteville, Wis. (locs. 5 and 6).

The St. Peter consists of clear, fine to coarse, subangular to round quartz grains, as a rule poorly cemented; where the rock is indurated the cement is dolomitic, calcareous, or siliceous. Greenish argillaceous material is present in the upper few feet of the unit and near its base, particularly where the sandstone is abnormally thick; otherwise, it is relatively clean. The sandstone is thin-bedded to massive; crossbedding is characteristic (fig. 41). In many places, a variety of colors, brown and red being the most common, in

FIGURE 41.—Cross-bedded St. Peter sandstone in roadcut along State Route 39, near center of NW¼ sec. 1, T. 4 N., R. 5 E., Iowa County, Wis. (2 miles west of loc. 44, fig. 35).

the St. Peter is due to oxidation of iron sulfide in the cement.

The St. Peter is normally 40 feet thick. However, sandstone of this type has been found (fig. 35, loc. 7) at least 320 feet below the top of the formation (Heyl, Lyons, and Agnew, 1951, p. 33). Where green and reddish shales are present with the sandstone this association of sediments also is known to be more than 300 feet thick and to rest on strata as old as the Franconia, shown in the following wells (also see p. 272):

Abnormal thicknesses of the St. Peter sandstone

[Data in files of Wisconsin Geological and Natural History Survey, Madison, Wis.; Illinois Geological Survey, Urbana, Ill.; and Iowa Geological Survey, Iowa City, Iowa]

Wells	Thickness, St. Peter (feet)	Underlying strata
Dodgeville city well 3, sec. 28, T. 6 N., R 3 E., central Iowa County, Wis.	315	Trempealeau.
Linden city well 2, sec 8, T. 5 N., R. 2 E., 10 miles west of Dodgeville, Wis.	385	Franconia.
Belmont city well, sec. 14, T. 3 N., R. 1 E., northwestern Lafayette County, Wis.	303	?*
Shullsburg city well 3, sec. 10, T. 1 N., R. 2 E., Lafayette County, Wis. (fig. 35).	397	?*
Hanover city well, sec. 9, T. 26 N., R. 2 E., southwest corner Jo Daviess County, Ill.	340	Prairie du Chien.
Bellevue city well, Jackson County, Iowa (fig. 35, loc. 8).	345	Do.

*Not reached.

At least part of this difference in thickness is due to an unconformity at the base of the St. Peter, which is well shown in a quarry in Clayton County, Iowa (sec. 1, T. 93 N., R. 3 W.), directly across the Mississippi River from locality 3 in Grant County, Wis. (fig. 35).

Nearly everywhere the St. Peter is unfossiliferous. However, Sardeson (1896a, p. 79) found fossils in the formation in Minnesota and Wisconsin that showed greater similarity with the overlying Platteville than with the underlying Prairie du Chien. Because of its position, he (1896a, p. 83) correlated the St. Peter with the Chazy (see also Twenhofel, and others, 1954).

Lead and zinc minerals are almost unknown in St. Peter rocks. Small amounts have been found where mineralized fractures connect with zones of mineralization in higher beds, as at Mineral Point, Wis., and at Crow Branch, Grant County, Wis. (fig. 35, loc. 4). Iron minerals are characteristic of the St. Peter especially in the uppermost few feet, where pyrite cements the quartz sand grains. This evidence of iron mineralization appears to be more abundant in local areas that show zinc-lead deposits in overlying beds, and in larger areas where the iron minerals appear to be related to major structural features as at Red Rock, Wis. (sec. 17, T. 2 N., R. 4 E.) 10 miles northeast of Shullsburg, Lafayette County (fig. 35).

In most places the St. Peter sandstone provides an ample supply of water for small towns, for small industrial plants, and for farms.

PLATTEVILLE FORMATION

GENERAL FEATURES

Platteville strata are known throughout the mining district by exposures at the surface and in mines, and by cuttings from wells and prospect drill holes. Exposures are numerous; some of the best outcrops of the beds of Platteville age can be seen in the quarry at Spechts Ferry station, Dubuque County, Iowa (fig. 35, loc. 10); along U. S. Highway 151 southwest of Platteville, Wis. (loc. 6); along U. S. Highway 61 southwest of Platteville (loc. 12); and in the city quarry at Darlington, Wis. (loc. 13).

In the mining district the Platteville formation consists of the following four members in descending order (fig. 38): Quimbys Mill member, McGregor limestone member, Pecatonica dolomite member, and Glenwood shale member.

The Platteville formation ranges in thickness from 55

FIGURE 42.—Pecatonica (*Opp*) and McGregor (*Opm*) members of Platteville formation in roadcut, U. S. Highway 151, 8 miles southwest of Platteville, Grant County, Wis. (fig. 35, loc. 6).

feet, in the western part (Heyl, Lyons, Theiler, 1952) of the district, to 75 feet near Shullsburg. It apparently lies conformably on the St. Peter sandstone within the mining district, and is overlain disconformably by the Decorah.

There is an excellent exposure of the lower three members of the Platteville in the western part of the mining district about 8 miles southwest of Platteville, Wis. (fig. 35, loc. 6). This section, hereafter designated the reference for the Platteville formation, appears as follows (see fig. 42):

Roadcut, U. S. Highway 151, NW¼NE¼, sec. 12, T. 2 N., R. 2 W., Grant County, Wis.

[Described by A. F. Agnew and A. V. Heyl, Jr., Apr. 1, 1943; revised by Agnew, Oct. 4, 1945]

	Thickness (feet)
Decorah formation:	
Spechts Ferry shale member (clay bed), in part slumped:	
Shale, bluish-green	0.5+
Bentonite, white; weathering orange brown	.2
Shale, yellowish-green above to bluish-green below	.2
Shale, brown and olive, soft	.1
Platteville formation:	
Quimbys Mill member ("glass rock"):	
Limestone, dark-purple, fine-grained, dense, conchoidal fracture; very wavy upper surface; thin, dark-brown to black, fossiliferous platy shale parting at base	.3–.5
McGregor limestone member (Magnolia of Bays and Raasch, 1935):	
Limestone, light-gray, very fine grained, very dense, conchoidal fracture like "glass rock" above, fairly massive, very fossiliferous; wavy upper surface	0.9
Limestone as next above but less dense, medium bedded above to thin bedded below, fossiliferous; wavy upper surface	.7
Dolomite, light-olive-drab, fine-grained, "sugary," argillaceous, very thin bedded; nodular	1.6
Dolomite as next above but thick-bedded; calcite near middle	3.0
Limestone, thin-bedded yet stands massively as one unit; light-greenish-gray-brown, weathering brown, with a few argillaceous streaks; sparingly fossiliferous, but with fossils and fucoids on top surface	2.6
Limestone, thin-bedded as next above but the beds are distinct; nodular beds and shaly partings; argillaceous in upper 0.3 ft, which is very fossiliferous	3.4
Limestone, light-buffish-gray, in medium to thick beds; in places gradational into unit next below	3.6
Total, upper McGregor	15.8
McGregor limestone member (Mifflin of Bays, 1938):	
Limestone, light-greenish- to bluish-gray, in massive beds but composed of thin beds which are not separated; ample shaly material in wavy bands; fairly fossiliferous, argillaceous; a peculiar mottled light-gray and darker gray 0.1-ft zone, 1 ft below top	3.9

	Thickness (feet)
Platteville formation—Continued	
McGregor limestone member (Mifflin of Bays)—Con.	
Limestone, light-gray, very fine-grained, very dense, sublithographic, in extremely thin and nodular beds with thin calcareous shaly partings which become thinner below; the shale beds are light grayish blue, mottled, very fossiliferous; weathers slightly recessed	4. 0
Limestone as next above, but beds are not quite so thin; fossiliferous; poor gastropod zone 1.7 ft above base; shaly zone at base	3. 6
Limestone, dolomitic, light-gray, fine-grained, very slightly argillaceous, very fossiliferous, medium-bedded; indistinct argillaceous partings, not wavy; calcite and limonite, especially in basal 0.6 ft	3. 6
Total, Mifflin	15. 1
Pecatonica dolomite member:	
Dolomite, light-grayish-brown, very coarse grained and vuggy, upper 2 ft are a mixture of this lithology and a somewhat argillaceous fine-grained "sugary" laminated dolomite; a 1-ft bed of very vuggy dolomite from 1.8 to 2.8 ft above base, shaly in lower part; stylolitic partings 1 ft above base	4. 8
Dolomite, medium-gray, laminated, somewhat argillaceous, fine-grained "sugary", fossiliferous, especially in lower 0.9 ft; medium- to thick-bedded; shaly at top; weathers brownish in lower 2.5 ft	6. 9
Dolomite, medium-gray, laminated, argillaceous; very fossiliferous partings	3. 6
Dolomite, light-grayish-brown, very coarse grained and vuggy; thin brownish gritty dolomitic and platy shale parting at top	1. 4
Dolomite, medium-gray, laminated, somewhat argillaceous, fine-grained	2. 8
Dolomite, medium-gray, laminated, argillaceous, silty and sandy with fine to coarse quartz grains similar to those of the St. Peter sandstone, phosphate nodules abundant (especially in two zones, one at base, the other 1 ft above base)	2. 0
Total, Pecatonica	21. 5
Glenwood shale member:	
Shale, sandy with rounded quartz grains, khaki to drab, soft; phosphate nodules	0. 4
Shale, sandy, olive to grayish brown; mottled yellowish brown, friable	. 2
Shale, sandy, medium- to dark-gray, olive, blocky, very hard	. 6
Shale, medium-gray, blocky, hard, sandy; streak of carbonaceous material at top	. 3
Total, Glenwood	1. 5
Total, Platteville	54. 3
St. Peter sandstone:	
Sandstone, red and white; rounded, frosted, coarse to medium grains	. 1
Sandstone, gray, pinkish, very friable	. 2
Sandstone, brown, iron-cemented, hard	0–0. 1
St. Peter sandstone—Continued	
Sandstone, yellow to gray, very friable, with irregular lower surface	1. 3
Sandstone, light-gray, very friable	. 1
Sandstone, yellow to dark-brown, laminated, hard	. 2
Sandstone, gray and yellow; hard irregular lower surface	1. 1
Sandstone as next above, but medium- to fine-grained; spalls	7 +

The Platteville strata have been correlated with the Black River of New York (Kay, 1935a, p. 288).

GLENWOOD SHALE MEMBER

The Glenwood is unit 1 of Bain's (1905) Platteville (p. 261). The type section in Glenwood township, Iowa (fig. 35, loc. 14), where Calvin (1906, p. 74–75) described 15 feet of shale beds, is no longer well exposed. His description, which is generally applicable to exposures in Glenwood township, is as follows:

> The sandstone phase [of the St. Peter] is overlain by a bed of shale fully fifteen feet in thickness, and the lower eight or ten feet of this is highly arenaceous. Some thin bands at intervals of a foot or more are almost pure sand. The sand grains in the shale are of the same clear, worn and polished type as those making up the main body of the sandstone deposit. The upper part of the shale bed is quite free from sand and resembles the "basal shale" referred to the Trenton series in Allamakee and Dubuque [Counties]. The lower arenaceous part should, without any doubt, be regarded as the closing phase of the St. Peter stage.

LITHOLOGIC DESCRIPTION AND STRATIGRAPHIC RELATIONS

In the zinc-lead district the Glenwood consists of greenish sandy and dolomitic shale (fig. 43), varying locally with thin shaly or sandy dolomite beds. The grains are rounded frosted white quartz sand similar

FIGURE 43.—Glenwood shale member (*Opg*) of Platteville formation, in contact with the Pecatonica (*Opp*) above and the St. Peter (*Osp*) below, in roadcut. U. S. Highway 61, Grant County, Wis. (fig. 35, loc. 15).

to those of St. Peter sandstone. They are unsorted and range from fine to coarse. Almost everywhere pyrite cement is present in the Glenwood, and the glittering pyritic sandstone fragments are very conspicuous in well cuttings. Many large black or dark-brown phosphatic pebbles and fossils are found near the top of the member; these pebbles are dull, subround, and smooth.

The green sandy shale beds maintain an average thickness of 1–3 feet in the mining district, although in a few places (ledges, east bluff Little Platte River, in NE¼ sec. 4, T. 3 N., R. 1 W., 2 miles north of Platteville, Wis.; roadcut, County Trunk M, SW¼ sec. 10, T. 2 N., R. 6 E., 8 miles northwest of Monroe, Green County, Wis., see fig. 35) the basal sandy dolomite bed of the Pecatonica rests directly on somewhat argillaceous relatively unsorted sandstone that in turn rests on the cleaner sandstone of the St. Peter. In the study of subsurface samples it is not clear whether this sandy dolomite bed is truly Pecatonica or is a facies of the Glenwood.

Similarly, in the subsurface studies it has been found that a variable thickness of the upper part of the sandstone bed immediately underlying the green sandy shale bed is related almost as closely in lithology to the Glenwood shale member as it is to the St. Peter sandstone below. This sandstone, containing some greenish argillaceous lentils, is unsorted in the upper part in contrast with the more or less well-sorted St. Peter below, which moreover does not contain so much coarse sand. This statement is supported by the findings of Thiel (1937, p. 113), who related that in southeastern Minnesota the petrographic constituents of the upper part of the St. Peter are more characteristic of the Glenwood than of the major part of the St. Peter. He found that the upper 3–10 feet of St. Peter are thin bedded and not as well sorted and consist of coarser sand and more fine silt and clay than does the greater part of the formation. Thiel noted that garnet is very abundant in the upper third of the Glenwood and decreases toward the base, where there is none; on the other hand, the zircon content increases downward. Zircon is dominant in the underlying St. Peter beds.

Thiel's studies led him to conclude that the sea of early Mohawkian age reworked the upper part of the St. Peter sandstone and that additional clastic sediments from new source areas, differing texturally and petrographically from the St. Peter, were transported to the basin of deposition and mixed with the St. Peter. He concluded that the sandstone thus formed was therefore an early phase of the Glenwood and should be classified as such. Bevan's (1926, p. 13) earlier work had resulted in similar conclusions.

Studies with the binocular microscope of subsurface samples from wells in southwestern Wisconsin and northeastern Iowa show that the thickness and relationships of these lithologic facies are very irregular, as follows:

Thickness of different facies of Glenwood shale member

Location No. (fig. 35)	Name and location of well	Thickness (in feet)		
		Upper part—Shale	Middle part—Sandy dolomite	Lower part—Sandstone
16	Clayton County Home well, Elkader, Iowa, sec. 7, T. 93 N., R. 4 W	9		
17	Cheese Factory well, North Andover, Grant County, Wis., sec. 6, T. 4 N., R. 5 W	4		5
18	Rewey village well, Iowa County, Wis., sec. 5, T. 4 N., R. 1 E			5
19	Cobb School well, Iowa County, Wis., sec. 26, T. 6 N., R. 1 E	7		3+
20	Mount Horeb city well, Dane County, Wis., sec. 12, T. 6 N., R. 6 E		4	10
21	Colesburg city well 1, Delaware County, Iowa, sec. 4, T. 90 N., R. 3 W	8		
22	East Dubuque city well, Jo Daviess County, Ill., sec. 29, T. 29 N., R. 2 W		8	14
	Shullsburg city well 3, Lafayette County, Wis., sec. 10, T. 1 N., R. 2 E		5	10
	Monroe city well 4, Green County, Wis., sec. 34, T. 2 N., R. 7 E	5		18
	Coltman mine well, Lafayette County, Wis., sec. 10, T. 1 N., R. 1 E. (8 miles west of Shullsburg)	½	½	

Likewise Grant [5] recorded the following section "at the water reservoir on the spur of the bluff just east of Prairie du Chien," Wis. (fig. 35):

	Thickness (feet)	Present writers' term
Quarry rock, buff	2	Pecatonica.
Limestone, like quarry rock	0. 1–0. 2	Pecatonica.
Sandrock, green	. 1	Glenwood.
Sandrock, white	. 5	Glenwood.
Limestone, yellowish brown	. 3	Glenwood.
Sandrock, white	3. 5	Glenwood.
Limestone, gray-brown	1	Glenwood.
Sandrock, green	. 4	Glenwood.
Sandrock, brown to white, cemented to quartzite.	6	St. Peter.

This section shows 5.8 feet of sandstone and limestone which represents the Glenwood interval, and is rather similar to that at the type locality, 35 miles to the west.

Whether these differences in lithology are due to facies, as Bevan (1926), Bays (1938), and the present writers believe, or are due to the intermittent presence of one or more of the four members of the Glenwood formation of Templeton (1948)—or the four formations of the Glenwood subgroup of Templeton and William (1952, p. 21 and fig. 11)—the fact is that the Glenwood is rather inconsistent in lithology. Criteria for differentiating the four subdivisions of the Glenwood are not adequate nor are they useful in field mapping in the zinc-lead district. Sardeson (1933, p. 82, 90) recom-

[5] Field notes, U. S. Grant, September 3, 1902; in files of U. S. Geological Survey, Platteville, Wis.

mended that the term Glenwood be dropped, as the strata are vertically transitional and laterally variable. However, because the green shale beds themselves are easily distinguishable it would seem advisable to confine the term Glenwood in the zinc-lead district to that mappable unit consisting of green sandy and in part dolomitic shale that underlies the buff dolomite of the Pecatonica and overlies the sandstone containing the rounded frosted unsorted quartz sand grains.

The so-called bentonitic clays of the Glenwood (Sardeson, 1926a, p. 385–392, pl. 26), which are mainly recrystallized orthoclase, contain well-rounded detrital grains of garnet, zircon, and tourmaline (Thiel, 1937, p. 121). According to Thiel this fact, coupled with the facts that X-ray analyses fail to show bentonitic clay minerals and that chemical analyses show more potassium than normal in the average volcanic rock, does not favor a volcanic origin for the shale.

The Glenwood shale member is overlain apparently conformably by the Pecatonica dolomite member; the writers do not agree with Elder's (1936) view that a disconformity exists. Evidences for the transitional contact are the lenses of greenish sandy dolomite in the upper part of the Glenwood, and the abundance of rounded quartz sand grains in the base of the overlying Pecatonica.

The lower contact of the Glenwood is likewise transitional, for the shale grades downward into an argillaceous sandstone very similar to the underlying St. Peter except in the lack of sorting, the finer grain size, and the presence of argillaceous material.

Templeton (1948) found that, particularly in north-central Illinois (in the vicinity where Rock River crosses the LaSalle anticline and the Wisconsin arch; fig. 31), the Glenwood consists of four subdivisions, (1) sandstone and siltstone, (2) dolomite and sandstone, (3) sandstone, and (4) very argillaceous sandstone and shale, in ascending order. Whether Templeton's superposition of 4 members, or the facies concept of Bevan (1926, p. 10) is accepted, both of those authors recognized an unconformity at the base, separating sandstone of the Glenwood from the underlying St. Peter. This unconformity represents a greater span of geologic time farther east, for Pecatonica and even Mifflin beds of local usage rest directly on St. Peter sandstone (Willman and Payne, 1942, p. 61–62) in Ogle County, Ill., 20 miles southwest of Rockford (fig. 35).

In addition to differences in lithology, the presence of the unconformity at its base is physical evidence against including the Glenwood in the upper part of the St. Peter (Hershey, 1894, p. 174). Thus the Glenwood even as early as 1855 (Percival, 1855, p. 17; Chamberlin, 1877, p. 287, 293; Strong, 1877, p. 683; Sardeson, 1897a, p. 26) was included in what is now known as Platteville.

DISTRIBUTION

Because of the shaly and friable sandy character of the Glenwood, the strata are usually not well exposed. However, excellent outcrops are in the roadcut southwest of Platteville, Grant County, Wis., along U. S. Highway 151 (fig. 35, loc. 6), in the roadcut along U. S. Highway 61 northwest of Platteville (loc. 15), in a roadcut along County Trunk A northwest of Platteville (loc. 23), and in a roadcut in Iowa County, northeast of Platteville (loc. 24).

FAUNA AND CORRELATION

Stauffer (1935, p. 128) presented a list of genera of megafossils reported from the Glenwood in the Minneapolis–St. Paul region, and described 85–90 species of conodonts and scolecodonts from outcrops in southeastern Minnesota. According to him many of these are certainly forms of Mohawkian age, although there is an element of the conodont fauna that is decidedly older than the Platteville and never found indigenous in the Mohawkian; these may be residual forms weathered out of older beds and incorporated in the younger (Glenwood) beds as they were being deposited.

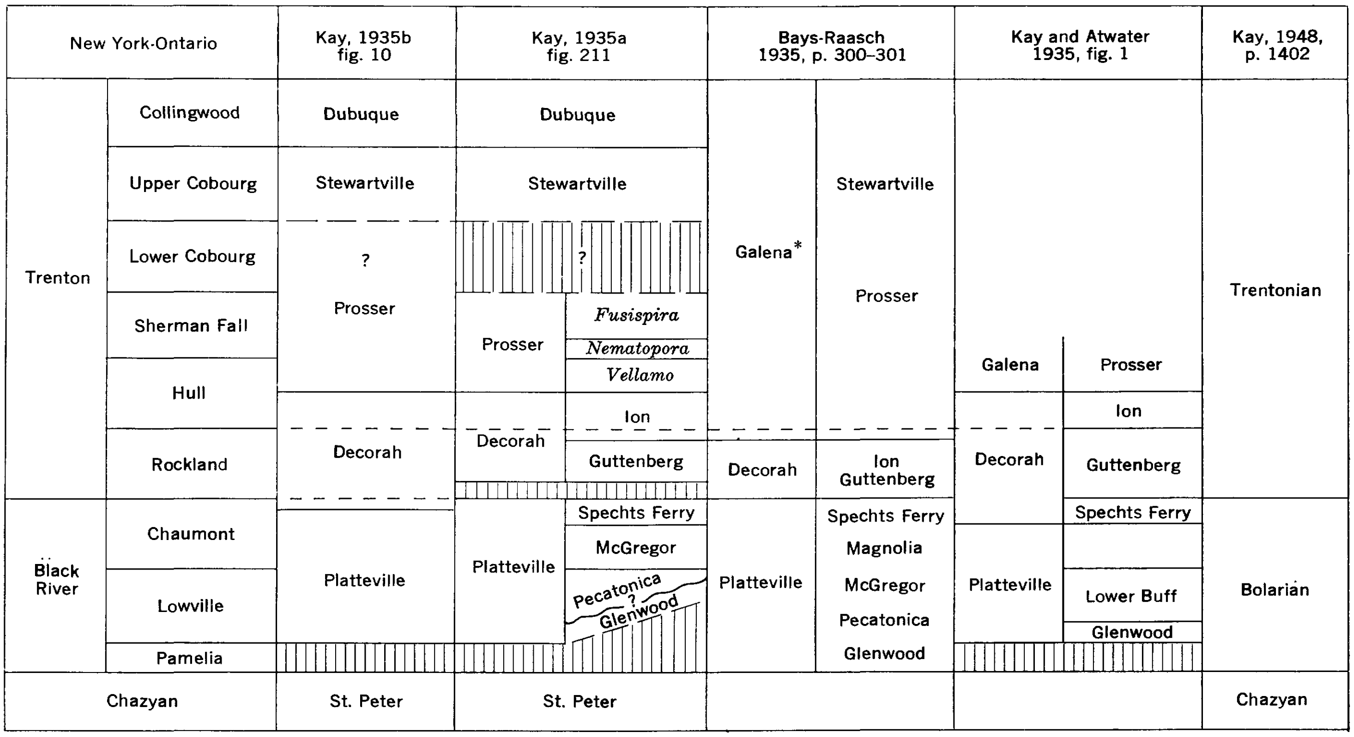
The Glenwood has been considered to be of Lowville (fig. 44) age (middle Black River of the standard New York section) by Kay (1935a, p. 288) because of its conodonts of Mohawkian age and stratigraphic position with regard to the Pecatonica (see also Twenhofel and others, 1954).

ECONOMIC PRODUCTS

Commonly the sand grains of the Glenwood are cemented by pyrite, and less commonly by iron oxide. The pyrite appears to be more abundant in areas where zinc, lead, and iron minerals are present in the beds above. Locally, minor amounts of zinc and lead minerals have been found in the Glenwood. None of these occurrences has proven commercial.

PECATONICA DOLOMITE MEMBER

The Pecatonica is unit No. 2 of Bain's (1905) Platteville (p. 261). There is no type locality described for the Pecatonica dolomite member, but its lithology is substantially uniform regionally. The lithology in the mining district is similar to that shown in the 20 feet of Pecatonica dolomite member exposed in the bluff along the Pecatonica River at Lattice Bridges (NW¼-NW¼ sec. 21, T. 1 N., R. 6 E.), Green County, Wis. (2 miles west of loc. 45, fig. 35), which may be designated as the type outcrop. The section about 8 miles southwest of Platteville, Wis. (loc. 6), will serve to convey a general picture of the sequence (p. 275).



* Bays and Raasch consider the Dubuque member of the Galena formation to be early Cincinnatian in age

FIGURE 44.—Suggested correlatives of Platteville, Decorah, and Galena strata, by various authors.

LITHOLOGIC DESCRIPTION AND STRATIGRAPHIC RELATIONS

The beds constituting the Pecatonica dolomite member of the Platteville formation are dolomite that is medium grained, sugary, buff to gray where freshly broken, weathering-brown, as a rule in fairly thick beds. Subordinate amounts of light-brownish platy shale occur along the partings, especially in the upper more thinly bedded part.

The Pecatonica is known locally by the name "quarry rock" (Strong, 1877, p. 682) because in almost all parts of the district building-stone blocks were obtained from quarries in these strata.

The thickness of the Pecatonica within the mining district is 20–24 feet.

The basal foot or so of the Pecatonica is usually marked by sandy dolomite with many phosphatic nodules and pebbles. The sand is clear quartz grains, coarse to medium in size, well-rounded, and somewhat frosted, typical of the St. Peter. A good exposure of this contact is in the roadcut in the SE¼NE¼SW¼ sec. 35, T. 5 N., R. 1 E., Iowa County, Wis. (fig. 35, loc. 18). Pettijohn (1926) has described the phosphatic pebbles in detail.

In the mining district the upper strata of the Pecatonica are, in most localities, thin and nodular bedded; in this respect they appear much like the lower beds of the McGregor above. This fact tends to make precise determination of the contact between the Pecatonica and McGregor difficult in certain areas; on the whole, however, the beds are distinctive, because throughout most of the mining district the Pecatonica is a medium-bedded dolomite whereas the overlying McGregor is generally a thin-bedded limestone (fig. 42).

Bays [6] stated that the dominant heavy minerals in the Pecatonica are garnet, tourmaline, and zircon in order of decreasing abundance, thus similar to the heavy mineral suite found in the Glenwood. Dake [7] found the Pecatonica to have a low percent of insoluble residue; the insoluble material is dolomoldic chert (Ireland, 1947, p. 1481), angular quartz, and feldspar.

DISTRIBUTION

The Pecatonica is normally resistant and forms cliffs and bluffs; for this reason, and because it has been quarried extensively, there are many good exposures. Some of the better outcrops are listed below:

Roadcut, U. S. Highway 151, Grant County, Wis. (fig. 35, loc. 6).
Roadcut, U. S. Highway 61, Grant County, Wis. (loc. 12).
Quarry, Potosi station, NW¼NE¼ sec. 9, T. 2 N., R. 3 W., Wis., Grant County, 3 miles southwest of above.
Quarry, 3 miles southwest of Mineral Point, NE¼NW¼ sec. 34, Iowa County, T. 4 N., R. 2 E., Wis.

[6] Bays, C. A., 1937, Stratigraphy of the Platteville formation. Unpublished Ph. D. thesis, Wis. Univ., Madison.
[7] Dake, L. F., 1937, Insoluble residues of the Mohawkian series of Wisconsin. Unpublished Ph. D. thesis, Wis. Univ., Madison.

City quarry, Mineral Point, SE¼SE¼ sec. 31, T. 5 N., R. 3 E., Iowa County, Wis.
Roadcut, 1 mile southeast of Mifflin, Iowa County, Wis. (loc. 24).
Ravine, 2 miles southeast of Meekers Grove, SE¼NE¼ sec. 27, T. 2 N., R. 1 E., Lafayette County, Wis. (1 mile southeast of loc. 7).

FAUNA AND CORRELATION

Contrary to its unfossiliferous appearance on the weathered surface at the outcrops, the Pecatonica is moderately fossiliferous. However, because the Pecatonica is dolomite throughout the district, its fossils are likewise dolomitic, and are preserved as molds and casts. The coarseness of grain and sugary nature of the dolomite result in most of the fossils being very poorly preserved, and they tend to crumble. The megafossils are mainly molluscan but have not been adequately described. No microfossils have been reported from the Pecatonica.

The Pecatonica has been correlated with the Black River of the standard New York section by Kay (1935a, p. 288), who stated that "inconclusive evidence suggests the correlation of the Glenwood and Pecatonica" with the Lowville, while Bays and Raasch (1935, p. 300) said that "the Lower Buff [Pecatonica] member is definitely pre-Lowville and equivalent to a part of the Stones River" of Tennessee. Bays (see p. 278) correlated the Pecatonica with part of the Plattin of Missouri, and Twenhofel, and others (1954) joined him in correlating the Pecatonica with part of the Pamelia (lower Black River) of New York (fig. 44).

ECONOMIC PRODUCTS

The Pecatonica strata were a poor host for lead and zinc minerals, and only locally are even small quantities of galena and sphalerite found. Evidence of iron mineralization is similarly uncommon, although significant amounts were seen (Agnew, Flint, Crumpton, 1954) in samples from holes drilled at the Alderson mine in SE¼ sec. 32, T. 2 N., R. 2 E., 2 miles northwest of Shullsburg (fig. 35). As noted earlier (p. 278), the Pecatonica has been quarried for building stone.

McGREGOR LIMESTONE MEMBER

Kay's (1935a, p. 287) description of the type section of the McGregor recorded:

> * * * 21′ 6″ of gray-blue, rather fine-textured, fossiliferous limestone with greenish shale partings and interbeds, the latter most prevalent in the middle part of the section. The thickness is normally from 20 to 25 feet, and is about 27 feet in the type section of the Platteville formation.

The type section is rather poorly exposed, as it is in a rather shallow ravine; thus measurements of thickness may not be accurate. A more complete description of the exposure is given in section 1, p. 305.

LITHOLOGIC DESCRIPTION AND STRATIGRAPHIC RELATIONS

The representative lithology of the beds of the McGregor limestone member in the central part of the district can be taken from the typical Platteville section (p. 274). A dolomite facies of the McGregor begins in the central part of the mining district (fig. 34) and continues eastward to the vicinity of Beloit, Wis. and Rockford, Ill.

These beds, called the Trenton in early reports (Hall, 1862, p. 33) and Blue and Lower Blue in others, are still known as Trenton by the well drillers and mining men of the district (fig. 45).

In describing the Mifflin beds of local usage Bays (1938) said that the unit consists of thin-bedded limestone that passes laterally into dolomitic limestone and dolomite, and at the type locality is 17½ feet thick. Furthermore, the rock is characterized by fossils preserved on bedding planes, and by a blue color when fresh (footnote p. 278). Weathering produces bluish-gray to grayish-buff colors. The thickness ranges between 16 and 18 feet in the mining district, and becomes greater to the east of the Wisconsin arch where, near Beloit, Bays found it "nearly 25 feet" thick. The dominant heavy mineral of the Mifflin is zircon, he said. Dake (footnote p. 278) found that the amount of insoluble material in the eastern facies of the Mifflin (of Bays 1938) is greater than that in the Pecatonica, and that this material consists almost wholly of light-gray shale, partly dolomoldic.

Referring once more to the typical Platteville section (p. 274), the limestone is typically light gray, very fine grained, very dense, and very fossiliferous; it is in thin nodular beds plastered with shale partings of light grayish blue. In many places these shales are brownish and resemble somewhat the oil-rock type of shale, discussed under the Guttenberg member (p. 290).

Bays (p. 278) stated that the basal contact of the Mifflin is well marked "in many quarries in the Lead and Zinc District" by a conglomerate bed about 1 foot thick, composed of "irregular and subangular pieces of buff dolomite in a bluish-gray, clayey, fine-grained limestone matrix." Bays stated further that over parts of the Wisconsin arch, in Dane, Green, and Iowa Counties, Wis., a calcareous green or blue shale, 10 inches to 1 foot thick, occurs as the basal bed of the Mifflin.

Observations made in the course of the present study, based on both outcrop and subsurface data, tend to corroborate the sporadic occurrence of the shaly bed at the contact of the McGregor and Pecatonica, but no exposure has been found that illustrates the "conglomerate," despite the fact that several of the conglomerate localities listed by Bays were visited by the present writers. We feel that the

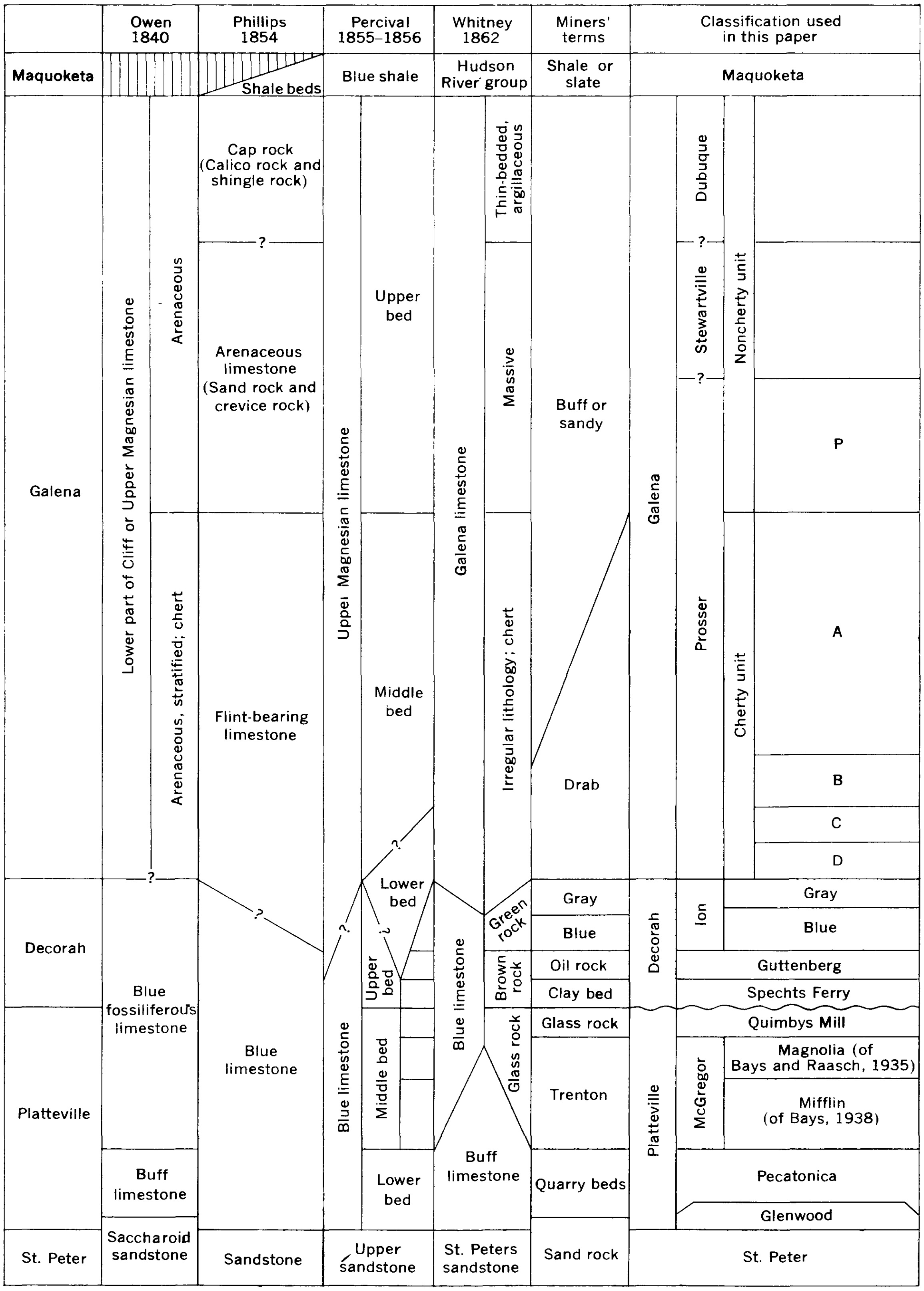


FIGURE 45.—Stratigraphic terminology of early geologists compared with that used by miners and drillers and with the classification used in this paper.

bed is not a sedimentary conglomerate; it might be due to secondary dolomitization along a favorable horizon, or might be the corrosion zone noted by Sardeson (1898, p. 318 and pl. 9) at the top of his Buff limestone in the St. Paul–Minneapolis area.

The lithologic distinction between the brownish argillaceous dolomite beds of the Pecatonica and the light-gray dense fossiliferous generally calcareous beds of the Mifflin (of Bays 1938) in the mining district is somewhat offset by the similarity in thickness of bedding in the upper part of the Pecatonica (p. 278; fig. 42).

The Mifflin (of Bays 1938) of local usage contains a fauna rich in gastropods; in the limestone facies bryozoa and microfossils are particularly abundant, but, except for ostracodes, are nearly always absent in the dolomitic facies.

In the lower part of the Magnolia (of Bays and Raasch 1935) the surfaces of the beds bear great numbers of the ostracode (*Leperditia* sp. aff. *L. fabulites* Conrad and large specimens of *Lambeophyllum profundum* (Conrad). An abundant molluscan fauna, remarkably similar to that in the Pecatonica, has been obtained from the Beloit region. Bays and Raasch (1935, p. 298) stated that in western Wisconsin the Magnolia is thinner and less conspicuous, and that in the "Lead Region it tends to be more limey and more thinly bedded than in the type area."

Referring to the typical Platteville section (p. 274), the limestone and dolomite of the Magnolia (of Bays and Raasch 1935) are typically light to medium gray, slightly mottled with dark-gray markings, fine to medium grained, and contain some soft dove-gray to olive-brown shale. The strata are thin or of medium thickness, and in the lower part look not unlike the Mifflin (of Bays 1938). In many places the upper 1–2 feet are very fine grained, very dense, light-gray fossiliferous limestone that breaks with a conchoidal fracture and is difficult to distinguish from the "glass rock" beds above, the difference in color being the principal distinctive feature, as the "glass rock" beds are purplish brown on a freshly fractured surface. Further stratigraphic study of this part of the Platteville formation to the east and southeast may show these "glassy" McGregor strata to be a distinctly recognizable lithologic unit.

Chert is present about 12 feet below the top of the Magnolia (of Bays and Raasch 1935) in the Calumet and Hecla mines in sec. 22, T. 1 N., R. 2 E., 2 miles south of Shullsburg, Wis. (fig. 35), and in exposures to the east.

Bays has recorded two localities in the mining district in which limestone conglomerate occurs at the base of the Magnolia (of Bays and Raasch 1935), one of these being in the small quarry south of the city quarry at Mineral Point. Nowhere was any such conglomerate observed during the studies here reported, all observations in the mining district pointing rather to a gradational and obscure contact between the Mifflin (of Bays 1938) and the Magnolia (of Bays and Raasch 1935).

According to Bays (p. 278) the heavy minerals of the Magnolia in order of decreasing abundance are garnet, tourmaline, and zircon. Dake (p. 278) found less insoluble material in the eastern facies of the Magnolia (of Bays and Raasch 1935) than in the Pecatonica. The lower part of the Magnolia has more residue than does the upper; the residue is principally quartz and feldspar.

The fauna of the Magnolia has not been adequately described. These strata are far less fossiliferous in the mining district than are those of the Mifflin (of Bays and Raasch, 1935).

It has been noted that the Magnolia is only poorly exposed in the type locality at Magnolia. However, where seen in and near the mining district, the thin dense nodular limestones of the Mifflin (of Bays 1938) are very distinctive, as are the thicker bedded less dense dolomite and limestone strata termed the Magnolia by Bays. But, commonly no definite lithologic break is present between the two units, and the beds just above or below the contact are transitional through a zone of 2–3 feet. Moreover, two adjacent outcrops may show the contact at somewhat different stratigraphic horizons.

These views regarding the transitional nature of the rocks are supported by the fact that in the mining district the combined thickness of the two sets of beds rarely departs appreciably from the average of 28–31 feet, yet the two lithologic types commonly show complementary thickness variations within these limits. The following table illustrates this relationship:

Thickness of Mifflin (of Bays, 1938), Magnolia (of Bays and Raasch, 1935), and McGregor

[Localities shown on fig. 35]

Location of outcrop	Thickness, in feet		
	Mifflin (of Bays 1938)	Magnolia (of Bays and Raasch 1935)	Total
Roadcut Grant County, Wis. (loc. 28)	19.5	9	28.5
Ravine, west side valley, in SE¼NE¼ sec. 25, T. 3 N., R. 3 W., Grant County, Wis. (3 miles north of loc. 12)	16.5	11	27.5
Quarry, Spechts Ferry station Dubuque County, Iowa (loc. 10)	15.7	13.3	29.0
Roadcuts, U. S. Highway 61, Grant County, Wis. (loc. 12)	15	14.5	29.5
Roadcut, U. S. Highway 151, Grant County, Wis. (loc. 6)	19	12	31.0
City quarry, Mineral Point, in SE¼SE¼SE¼ sec. 31, T. 5 N., R. 3 E., Iowa County, Wis.	18	12	30.0
Quarry, Darlington, Lafayette County, Wis. (loc. 13)	13	15	28.0

Thus it would appear that, although both the Mifflin and Magnolia have distinctive lithologic characteristics, the boundary between them is somewhat arbitrary. The retention in the mining district of the member term McGregor with the two facies, rather than substituting two member terms is therefore preferable for the beds above the Pecatonica member and below the Quimbys Mill member of the Platteville formation.

DISTRIBUTION

The beds of the McGregor are not so well exposed as the Pecatonica because of the thin-bedded character, but form bluffs where overlying and underlying strata are present. Quarries supplement outcrops along streams. Representative exposures are at the localities given on page 281.

FAUNA AND CORRELATION

The Mifflin and Magnolia faunas of the McGregor limestone member are clearly of Black River age, but there is disagreement among authors as to the precise position within the Black River. Kay (1935a, p. 288) stated that the McGregor (and the Spechts Ferry above) is equivalent to the Chaumont (upper Black River), whereas Bays and Raasch (1935, p. 300) implied that the McGregor should be placed in the Lowville (middle Black River). Bays (p. 278) later went even farther, in correlating his Mifflin with the upper Pamelia (lower Black River) and asserting that the Magnolia transgresses the Pamelia-Lowville time line (fig. 44). In the Missouri section a part of the Plattin is the equivalent of the McGregor (Twenhofel, and others, 1954). As for the Tennessee-Kentucky sequence, according to Bays the nearest equivalent of the Mifflin is found in the Stones River there. The McGregor also includes the *Vanuxemia* bed of Minnesota (fig. 37) as used by Winchell and Ulrich (1897).

ECONOMIC PRODUCTS

McGregor strata constitute a potential zinc-lead mining zone. Zinc-lead ore has recently (1948–1952) been found in these beds south of Shullsburg, Wis., and south of Galena, Ill. Within 2 miles northwest of Shullsburg these beds have been mined for zinc and lead at the old Mulcahy and the Lucky Hit mines (Agnew, Flint, Crumpton, 1954). Isolated occurrences of zinc-lead ore have been found at other places—Etna mine, a mile north of locality 27, figure 47 (Agnew, Flint, Crumpton, 1954) and Last Chance mine, 2 miles south of locality 4, (Lincoln, 1947). The ore-bearing potential of the McGregor member appears to be better in the eastern and central parts of the district than in the western part. In mineralized areas beds of the McGregor have been leached to a grayish clayey mass, with an accompanying reduction in thickness.

QUIMBYS MILL MEMBER

At its type locality (fig. 46) the Quimbys Mill member consists of 6 feet of dolomite above 6 feet of limestone, as follows:

Quarry, Quimby's mill, southeast corner, sec. 11, T. 1 N., R. 1 E., Lafayette County, Wis.

[Described by A. F. Agnew, August 25, 1944; revised November 20, 1945]

	Thickness (feet)
Decorah formation:	
Spechts Ferry shale member (clay bed):	
Shale, olive, calcareous	0. 3
Limestone as below, weathers very ropy	. 8
Limestone, light-grayish-buff, fine-grained, dense, very fossiliferous; phosphatic nodules	1. 5
Bentonite, a white plastic clay, weathers orange-brown	. 1
Limestone, light-olive-gray, very dense, very thin bedded	. 2
Total, Spechts Ferry	2. 9
Platteville formation:	
Quimbys Mill member ("glass rock"):	
Dolomite, light-brown, fine grained, "sugary," dense, thin-bedded	6. 0
Limestone, dark-purplish-brown, very fine grained, very dense, conchoidal fracture; in thin, nodular beds, with dark-brown shale partings; half an inch of platy fossiliferous dark-brown shale at base	6. 0
Total, Quimbys Mill	12. 0
McGregor limestone member (Magnolia beds of Bays and Raasch, 1935; "Trenton"):	
Limestone, light-gray, pinkish, fine-grained, dense; conchoidal fracture (the "glassy" McGregor)	1. 5
Limestone, light-gray, fine-grained, thin-bedded	5+

LITHOLOGIC DESCRIPTION AND STRATIGRAPHIC RELATIONS

Typically a dense sublithographic limestone, the Quimbys Mill is the "glass rock" of the miners, a clearly recognizable unit present in the eastern and central parts of the district.

Quimbys Mill strata in the western part of the mining district are limestone and subordinate amounts of shale, whereas in the eastern part of the district dolomite and a small amount of shale are characteristic. In a northeastward-trending area across the central part of the mining district the limestone and dolomite beds intermingle.

The name "glass rock" is probably derived from the characteristic fracture. The designation is found in the description of the quarry at Quimby's mill in early reports on the district (Whitney, 1862, p. 163). Until the geologic study (Grant, 1903, 1906; Bain, 1905, 1906) about the beginning of the present century, the term "glass rock" was loosely applied to a lithologic

FIGURE 46.—Type section of Quimbys Mill member (*Opq*) of Platteville formation, with Spechts Ferry (*Ods*) above and McGregor (*Opm*) below, in quarry at Quimbys Mill, Lafayette County, Wis. (fig. 35, loc. 27).

facies, sometimes to what is here called the Quimbys Mill member, sometimes to the underlying part of the McGregor called Mifflin (of Bays 1938), and often to the lower limy beds of the overlying Guttenberg. The surveys of Grant and Bain in the early 1900's applied the term "glass rock" especially to the Quimbys Mill beds but mentioned the fact that the lower beds of the McGregor had been and occasionally still were referred to as "glass rock."

From that time until the present, however, the custom has prevailed among the mining men of the district to designate as "glass rock" only those beds now known as Quimbys Mill. Thus in practice the "glass rock" beds are a generally recognized stratigraphic entity.

In the western part of the mining district the Quimbys Mill is less than a foot thick and is overlain by bentonite and interbedded limestone and shale of the Decorah formation (see section 2, p. 305). East of the mining district, where Spechts Ferry strata are absent, the Quimbys Mill is overlain by dolomite of the Guttenberg member of the Decorah formation. A regional disconformity therefore exists at the contact of the Quimbys Mill (Platteville) and Decorah. The Quimbys Mill rests conformably on the McGregor member.

Regional dolomitization eastward is shown by the complete dolomite section at Shullsburg and to the east (Agnew, 1950; Herbert, 1946).

The Quimbys Mill thickens locally to more than 18 feet in an area just southeast of Shullsburg, Wis. However, eastward from the central part of the mining district the unit is 13–14 feet thick and becomes somewhat cherty (see section 3, p. 305).

Locally the mineralizing solutions leached the calcareous elements from the Quimbys Mill, increased the relative brown shale content—called "oil shale" or "oil rock" by many geologists (Scott, Behre, 1935), although this term should be reserved for the Guttenberg member of the Decorah formation—and noticeably diminished the thickness of the unit (Agnew, 1950). For example, in diamond-drill holes (U. S. Bureau of Mines 20 and 17) only 75 feet apart at the Bautsch mine south of Galena, Ill. (fig. 35, loc. 30), thicknesses of 13 feet (near normal) and 4 feet, respectively, were recorded.

Dolomitization accompanying the zinc-lead mineralizing solutions notably affected the Quimbys Mill, resulting in a more granular or sugary texture (Agnew, 1950). In such dolomitized rock other primary lithologic characteristics still are present. Less commonly, silicification accompanying the zinc-lead-bearing solutions caused parts of the beds to be replaced by silica so faithfully that the only megascopic difference is in the hardness (Agnew, 1950). Rarely, secondary chert nodules were formed.

Bays (p. 278) stated that the cherty dolomite (eastern) facies contains a suite of heavy minerals with garnet dominant, similar to that in the underlying Magnolia (of Bays and Raasch 1935); this is in contrast to the overlying Spechts Ferry shale member, which is characterized by zircon. Dake (p. 278) found that the Quimbys Mill contains less insoluble material than does the Magnolia; the residue is silicified fossils and some buff to brownish-gray shale. Aberdeen [58] found almost no residue in Quimbys Mill strata near Platteville.

DISTRIBUTION

Because of their dense and resistant character the Quimbys Mill commonly crops out; moreover, because these beds are valuable as building stone, quarries in them are common. Several of the better exposures of the Quimbys Mill are listed below, together with the thickness and general lithology:

[58] Aberdeen, Esther J., 1931, The location of the break between the Galena and the Platteville limestones: unpublished M. S. thesis, Northwestern Univ., Evanston, Ill.

Thickness and general lithology of Quimbys Mill member

Location	*Lithology*	*Thickness (feet)*
Bluff, north side valley, in NW¼NE¼ sec. 7, T. 1 N., R. 2 E., Lafayette County, Wis. (2 miles east of loc. 27, fig. 35).	Limestone and dolomite	12
Quarry, Darlington, Lafayette County, Wis. (loc. 13).	Dolomite	10+
Quarry 1 mile north of Darlington, in SW¼SE¼ sec. 27, T. 2 N., R. 3 E., Lafayette County, Wis. (2 miles north of loc. 13).	do	14. 2
Quarry, ½ mile east of Calamine, Lafayette County, Wis. (loc. 42).	do	12
Quarry, Lafayette County, Wis. (loc. 31).	do	8. 4
Quarry, ¼ mile north of York Church, Green County, Wis. (loc. 44).	do	13
Quarry, along Honey Creek, Green County, Wis. (loc. 45).	do	13. 2
City quarry, Mineral Point, in SE¼ SE¼ sec. 31, T. 5 N., R. 3 E., Iowa County Wis.	do	11
Small ravine from north, at bend of Fever River, in SW¼NE¼ sec. 22, T. 2 N., R. 1 E., Lafayette County, Wis. (1 mile northeast of loc. 7).	Limestone and dolomite.[1]	8±
Ravine from east, east of farm house, in SW¼NW¼ sec. 26, T. 2 N., R. 1 E., Lafayette County, Wis. (1 mile southeast of loc. 7).	Limestone	8±
Steep ravines from east, in SE¼ sec. 27, T. 2 N., R. 1 E., Lafayette County, Wis. (1 mile south of loc. 7).	Limestone and dolomite.[1]	8±
Quarry, west bluff of valley, near center NE¼ sec. 8, T. 3 N., R. 1 W., Grant County, Wis. (2 miles northwest of Platteville).	Limestone	3
Roadcut, County Trunk E, near center W½E½ sec. 18, T. 5 N., R. 1 W., Grant County Wis. (3 miles northwest of loc. 4).	do	1. 5
Roadcut, County trunk O, in NW¼ NE¼ sec. 35, T. 3 N., R. 2 W., Grant County, Wis. (2 miles northwest of loc. 6).	do	2
Roadcut, U. S. Highway 61, Grant County, Wis. (loc. 12).	Limestone and dolomite.	1

[1] This dolomite is attributed to the lead-zinc mineralizing solutions.

FAUNA AND CORRELATION

Strata of the Quimbys Mill are fossiliferous, particularly in the limestone facies; the fauna has not yet been described, although Aberdeen (p. 283), Bays (p. 278), and Kay (1929, p. 657) prepared fossil lists.

Bays correlated beds of the Quimbys Mill with the Lowville (middle Black River) of the standard New York section (fig. 44), although Kay (1935a, fig. 11) shows its position to be equivalent to part of the Chaumont. Until further paleontologic work has been completed only tentative correlation of these strata with those in other areas can be accomplished.

ECONOMIC PRODUCTS

The Quimbys Mill ("glass rock") constitutes one of the ore-bearing zones and has been prospected and mined particularly since 1940 (Agnew, and Heyl, 1947, p. 228).

The limestone of the "glass rock" is suitable for a facing stone and has been used for that purpose in many areas, particularly in the central part of the district.

DISTRIBUTION OF FACIES OF PLATTEVILLE AGE AND CONDITIONS OF DEPOSITION

The Platteville strata are rather uniform in lithology, except for the Glenwood shale member whose facies relationships are not completely known as yet, and were products of a marine environment.

The Pecatonica is a dolomite or dolomitic limestone throughout the area of study. On the other hand, the McGregor and the Quimbys Mill are limestone to the west, limestone and dolomite in the central part of the mining district, and dolomite to the east. Both the Magnolia beds of the McGregor member, and the Quimbys Mill become cherty to the east. The chertification and dolomitization are apparently related to the major structural axis, the Wisconsin arch; similar relationships of dolomite and structure have been discussed for north-central Illinois by Willman and Payne (1942, p. 64–65), and in nearby states by Cohee (1948, p. 1432).

The clastic quartz sandstone, dolomite, and shale of the Glenwood shale member show evidence of relatively coarse deposition under rather shallow open-water "platform" conditions (Krumbein, 1947). The alternation of coarse clastic material with the finer clays and the thin bedding, which is commonly somewhat obscure, are both characteristic of shallow-water environment; the tendency toward crossbedding seen in southeastern Minnesota and the area south of Rockford, Ill., marks deposits formed under conditions prevalent in an environment of very shallow water.

Pecatonica strata may have been laid down as a clastic limestone platform deposit (Sloss 1947), although the massive bedding characteristic of the Pecatonica is cited by Rich (1951) as a criterion for deep-water deposition. The general absence of fossils also tends to support Rich's deeper water origin. Furthermore, although the Pecatonica is now a granular sugary dolomite, the original limestone may have been fine grained; if so, Rich's relatively deep water origin for the Pecatonica sediments gains credence.

Mifflin strata (of Bays 1938) of the McGregor member were generally of shallow-water platform origin

(Sloss, 1947), as shown by the thin nodular beds of limestone separated by silty and clayey fragments, although deeper water environment is suggested by fineness of grain and the sublithographic type of limestone, coupled with the slightly bituminous character of some of the shale partings. The highly fossiliferous nature of the Mifflin strata is characteristic of shallow-water deposits.

Magnolia strata (of Bays and Rausch, 1935) of the McGregor member are similar to the Mifflin strata except that the deep-water characteristics are absent; shallow-water environment is therefore indicated.

In the Quimbys Mill strata we find the same type of conflicting evidence as that seen in the Mifflin except that in these platform (Sloss, 1947) deposits shallow-water criteria are less abundant and apparently of less importance than the deep-water characteristics. The highly bituminous nature of the shale, the lithographic type of limestone, and the general absence of fossils (except on the shale partings) are dominant characteristics. However, thinness and evenness of bedding, reeflike concentrations of fossils, and interbedded shale strata suggest a shallow-water origin for these sediments.

DECORAH FORMATION

GENERAL FEATURES

An excellent exposure in the central part of the mining district of all but the upper few feet of Decorah is seen in a steep ravine from the west into the Galena River (locality 32, fig. 35) as follows:

Ravine, west side of Galena River, center of east line, sec. 4, T. 1 N., R. 1 E., Lafayette County, Wis.

[Described by A. F. Agnew, Aug. 22, 1949]

	Thickness (feet)
Galena dolomite:	
Cherty unit (zone *D*):	
Dolomite, brownish, medium-crystalline, thin-bedded; mottled with calcareous areas	2. 2
Limestone, buff to flesh-colored, thin-bedded	1. 0
Covered interval	6. 8
Decorah formation:	
Ion dolomite member (gray beds):	
Limestone, light-buffish-gray, argillaceous, thin-bedded	9. 4
Limestone, grayish-buff, coarsely crystalline, very fossiliferous; a 0.1-ft platy grayish shale at base	2. 0
Ion dolomite member (blue beds):	
Limestone, bluish-gray alternating with grayish-buff; thin-bedded in lower 0.5 ft; upper 0.7 ft is 1 bed	1. 2
Limestone, greenish-gray, shaly, platy	. 7
Limestone, fossiliferous	. 7
Limestone, grayish-buff and bluish, crystalline, mottled, argillaceous; upper 0.4 ft very fossiliferous	1. 4
Limestone, thin-bedded, lower part bluish-gray upper part flesh-colored	1. 0
Decorah formation—Continued	
Limestone, bluish-gray, medium- to coarsely crystalline, fossiliferous	1. 0
Total, Ion	17. 4+
Guttenberg limestone member ("oil rock"):	
Transition beds—limestone, buffish, medium-crystalline, fossiliferous	. 9
Limestone, brown, thin-bedded, fine-grained, fossiliferous, band of chert nodules 3.5-feet below top	5. 0
Limestone, brown, fine-grained, dense, nodular; interbedded brown platy shale	6. 3
Total, Guttenberg	12. 2
Spechts Ferry shale member (clay bed):	
Shale, olive, calcareous; trace of orange bentonite (?)	. 4
Limestone, light-brown to cream; fossil fragments and phosphate nodules	. 8
Shale, olive; brown and green mottled fine-grained argillaceous limestone; brown platy shale	. 1
Limestone, light-brown, fine-grained, dense, nodular	1. 1
Limestone, light-brown, dense, nodular, wavy-bedded; parting of tan platy shale at top	. 1
Limestone and thin platy tan shale	. 1
Bentonite	. 1–. 2
Limestone, greenish-buff, nodular, argillaceous, and light-brown interbedded shale	. 3
Total, Spechts Ferry	3. 0
Total, Decorah	32. 6+
Platteville formation:	
Quimbys Mill member ("glass rock"):	
Limestone, light-brown to brown, thin- to medium-bedded, very fine grained and dense, conchoidal fracture; dolomitic shaly zone at base	8. 0

Westward from the mining district the Decorah becomes rather uniformly greenish shale with limestone nodules, as is seen at Decorah, Iowa (fig. 35).

Calvin's (1906, p. 85) "typical exposure of the shale at the foot of the bluff on the left of the 'Dugway' " today shows only the upper 15 feet of what corresponds to the Ion dolomite member, of the Decorah formation. Calvin stated further that "the shales overlie the limestones in the west quarry of Mr. Halloran, east of the Ice Cave bridge." In this quarry only the lower 5 feet or so of the Decorah, which corresponds in position to the Spechts Ferry shale member, is visible above 3 feet of limestone, here assigned to the unnamed member at the base of the Decorah.

A section that exposes the full thickness of the Decorah formation was noted by Kay (1929, p. 651), and because it is only 8 miles from the city of Decorah it may be considered typical (see section 4, p. 306).

The Decorah formation changes in lithology across the mining district so that at the east border of the district the formation consists wholly of dolomite. In like manner the thickness decreases easterly, the unnamed member is absent east of Platteville, Wis., and the Spechts Ferry is absent in the eastermost part of the mining district. A typical section of the Decorah formation in this eastern facies is given in section 5, page 306.

In the western part of the mining district the lithology of the Decorah is limestone and shale, and the formation is approximately 44 feet thick. In the central part of the zinc-lead district the Spechts Ferry has about the same lithology as to the west; the Guttenberg and Ion members, however, contain less shale, and regional dolomitization has affected the upper part of the Ion member (Agnew, 1950). The thickness of the Decorah formation in the central area is approximately 41 feet, owing principally to a decrease in thickness of the Spechts Ferry shale member. Farther east, at Darlington (fig. 35, loc. 13) the Spechts Ferry is almost absent, and the Guttenberg and Ion are both dolomite because of regional dolomitization; the Decorah in this area is only about 30 feet thick.

Good exposures of the Decorah formation can be seen as follows: western area, roadcut along U. S. Highway 52 at north edge of Guttenberg, Clayton County, Iowa (fig. 35, loc. 33); central area, east bank of Galena River, Jo Daviess County, Ill. (loc. 34); eastern area, quarry in south part of Darlington, Lafayette County, Wis. (loc. 13).

FIGURE 47.—Type section of Spechts Ferry shale member (*Ods*) of Decorah formation, overlain by Guttenberg limestone member (*Odg* overhang); underlain by McGregor limestone member (*Opm*) of Platteville formation, in quarry 200 yards southeast of Spechts Ferry station, Dubuque County, Iowa (fig. 35, loc. 10).

SPECHTS FERRY SHALE MEMBER

LITHOLOGIC DESCRIPTION AND STRATIGRAPHIC RELATIONS

Kay (1928) noted that in the "ravine southwest of the C. M. & St. P. railroad station at Spechts Ferry," Dubuque County, Iowa (loc. 10, fig. 35), the Spechts Ferry consists of

> * * * the eight and one half feet of shales and interbedded limestones [which] form a lithologic unit lying above the "Platteville" limestone; the "Platteville" of Iowa does not include the uppermost beds of the typical Platteville of southwestern Wisconsin. The Spechts Ferry member includes the "glass rock" and overlying shales at the top of the typical Platteville.

Later, Kay (1929, p. 645) stated that in the type outcrop of the Spechts Ferry

> * * * true "glass rock" beds are not present in the base of the Spechts Ferry member, though there are conspicuous limestones.

Further:

> * * * there is no evidence to prove that these limestones are the same, and it is possible that they are younger than the "glass rock" and that those beds are absent at Spechts Ferry.

Although the "glass rock" unit (Quimbys Mill member) is virtually absent at this locality, its presence is indicated by a thin dark-brown green-mottled fissile shale. The quarry 200 yeards east of the ravine shows the following section (see fig. 47; section 8, p. 307). This description is a slight revision of Kay's (1929, p. 646, table III) description because he included the dark brown shale—herein called Quimbys Mill member—in the Spechts Ferry shale member. This shale represents the western edge of the "glass rock" unit.

The Spechts Ferry is green or slightly bluish-green shale with subordinate thin beds of light-greenish-buff fine-grained sugary fossiliferous dense limestone.

The thickness of the Spechts Ferry at the type locality is 8.8 feet, but this decreases to the east so that a short distance west of Shullsburg, Wis. only 3 feet of Spechts Ferry remain (section 9, p. 307). The green shale pinches out farther east, as noted previously; an interesting section in this respect is that in the quarry at Calamine, Lafayette County, Wis., section 10, page 308 (fig. 35, loc. 42; fig. 48).

FIGURE 48.—Quimbys Mill member (*Opq*) of Platteville formation overlain by Guttenberg limestone member (*Odg*) of Decorah formation, in quarry at Calamine, Lafayette County, Wis. (fig. 35, loc. 42).

The Spechts Ferry shale member, referred to in the mining district as the "clay bed," ranges from 1 to 5 feet thick there. Of this thickness perhaps half is limestone which, in zones of mineralization, has been almost wholly leached away, there being left only the argillaceous residues and the original shale beds. The shale is blocky in the outcrop but becomes quite plastic and claylike in the presence of water, as in the mines.

The commonly recognized bentonite layer of the mining district occurs in this member 0.3–0.4 feet above the base. This bentonite is the yellowish "pipe clay" of the miners.

In the following section the bentonite layer is present; in addition, effects of the mineralization on the Guttenberg and Quimbys Mill strata are a striking feature of this quarry at Mifflin, Iowa County, Wis., (2 miles northeast of loc. 18, fig. 35).

Quarry along road ¼-mile south of Mifflin in SW¼NE¼ sec. 34, T. 5 N., R. 1 E., Iowa County, Wis.

[Described by A. F. Agnew and A. V. Heyl, April 21, 1943]

	Thickness (feet)
Decorah formation:	
Guttenberg limestone member (oil rock):	
Limestone, brownish-gray, mottled brown, sugary, dolomitized	4. 0–6. 0
Gougelike material; brown to chocolate-colored shaly clay	1. 0–3. 0
Spechts Ferry shale member (clay bed):	
Shale, greenish-brown; a 0.3-ft limestone at base	. 9
Shale, grayish-green, blocky	. 4
Bentonite, cream-colored; weathers yellow	. 4
Shale, green, blocky	. 4
Total, Spechts Ferry	2. 1
Platteville formation: Quimbys Mill member ("glass rock"): Dolomite, light-buff, fine-grained, granular; contains chert nodules of secondary origin	3+

The bentonite layer has been noted in many other outcrops; some of the better ones are the following:

Quarry, north end of Ice Cave Bridge, in NE¼NW¼ sec. 15, T. 98 N., R. 8 W., Winneshiek County, Iowa. This is one of Calvin's type sections of the Decorah (fig. 35).

Ravine along side road, Allamakee County, Iowa. This is the Ion type locality (loc. 36).

Ravine from south, Clayton County, Iowa. This is the McGregor type locality (loc. 25).

Roadcut, west side U. S. Highway 52, Clayton County, Iowa. This is the Guttenberg type locality (loc. 33).

Ravine from west, SE¼ sec. 30, T. 4 N., R. 4 W., Grant County, Wis. (8 miles southeast of loc. 17).

Roadcut, County trunk A, north side of road, Grant County, Wis. (loc. 28).

Ravine from west, in SW¼ sec. 4, T. 2 N., R. 3 W., Grant County, Wis. (5 miles west of loc. 12).

Roadcut, south side County Trunk O, in NW¼NE¼ sec. 35, T. 3 N., R. 2 W., Grant County, Wis. (2 miles north of loc. 6).

Roadcut, northeast side U. S. Highway 61, Grant County, Wis. (loc. 12).

Roadcut, west side U. S. Highway 151, Grant County, Wis. (loc. 6).

Ravine from east, in NW¼ sec. 20, T. 3 N., R. 1 W., Grant County, Wis. (1 mile west of Platteville).

Roadcut, County Trunk E, just east of center sec. 18, T. 5 N., R. 1 W., Grant County, Wis. (3 miles northwest of loc. 4).

Outcrop, west bank Fever River, in SW¼SW¼ sec. 14, T. 2 N., R. 1 E., Lafayette County, Wis. (2 miles northeast of loc. 7.)

Montfort quarry, north side of road, Iowa County, Wis. (loc. 43).

The heavy mineral suite of the Spechts Ferry is characterized by zircon (Bays, see footnote p. 278). Insoluble residues from limestones of the Spechts Ferry show brownish silt that differs from the honey-colored resinous silt of the overlying Guttenberg limestone member. Quimbys Mill strata show almost no residue (Aberdeen, see footnote p. 283), and its heavy minerals are characterized by garnet.

Near the top of the Spechts Ferry member are minute phosphatic pebbles, nodules, and fossils. Aberdeen attempted to estimate their stratigraphic value, both laterally and vertically. She stated that in the vicinity of Platteville on the basis of fossils two breaks of diastem proportions were recognizable, one at the base of a blue shale bed and another at its top; this bed she referred to the uppermost Spechts Ferry. She found phosphatic nodules in the limestone bed immediately overlying this blue shale bed and the presence of these nodules seemed to justify drawing the line between the Spechts Ferry and Guttenberg at the base of this limestone. Kay and Atwater (1935, p. 101) noted the presence of the phosphatic nodules in this limestone but assigned the limestone to the Spechts Ferry, as Kay had done in his description of the type section in 1929.

The field work associated with the present study has shown that the phosphatic nodules are not restricted to this limestone bed, which in the Platteville area is referred by the writers to the basal Guttenberg. In places (as at the Spechts Ferry type locality) phosphatic nodules are found in one or two limestone beds of the Spechts Ferry member below the upper bed, but separated from it by an interval of shale. Thus it can be said only that the phosphatic nodules occur in a zone near the contact of the two members.

The phosphatic pebbles are significant not because they depict a sedimentational break at their horizon, but because they are second only to glauconite in abundance at horizons "within a few feet above stratigraphic breaks" (Goldman, 1921, p. 4); the Platteville-Decorah disconformity occurs 5–10 feet below the phosphatic zone being discussed, and the less obvious Glenwood–St. Peter unconformity occurs 1–8 feet below a similar phosphatic zone with glauconite, at the contact of the Glenwood and Pecatonica.

Trowbridge and Shaw (1916, p. 39) found in the Spechts Ferry shale member "*Dalmanella subaequata* which show evidences of having been rolled or worn" and concluded that, as this species occurs abundantly in the upper part of the Platteville, an unconformity at the contact of the Galena and Platteville (marked by the clay bed) is suggested. Broken fossil shells are common in the coquina lenses of the Spechts Ferry, but are here interpreted as being one of the results of fairly shallow-water environment rather than being reworked from earlier deposits.

The Spechts Ferry member west of the mining district lies conformably on the unnamed limestone member of the Decorah. In the central and eastern parts of the mining district it rests disconformably on the corrosion surface at the top of the Quimbys Mill member of he Platteville formation. Farther east the Spechts Ferry is absent, and Guttenberg strata rest disconformably on Quimbys Mill.

Bays (1938) stated that the Spechts Ferry and Quimbys Mill are facies. Evidence bearing on this problem is as follows:

(1) The bentonite layer near the base of the Spechts Ferry is consistently present, despite the inverse convergences of the Spechts Ferry and the underlying Quimbys Mill strata. This feature was also noted by Kay and Atwater (1935, p. 101), who stated, "it has been believed that the thinning of the member is due to convergence rather than to disconformity [at the top]."

(2) The Spechts Ferry and Guttenberg thin to the east; on the other hand, to the east and southeast the Quimbys Mill increases in thickness.

(3) In all cases where the two units are exposed together, the Spechts Ferry overlies the Quimbys Mill.

(4) There is no known interbedding or interfingering of the two types of lithology typified by the green shale and limestone of the Spechts Ferry, and the purplish-brown limestone and brown shale of the Quimbys Mill.

(5) In the pitted upper surface of the Quimbys Mill the irregularities contain phosphatic pebbles and fillings of greenish argillaceous dolomite similar to that of the Spechts Ferry.

However, features that might be interpreted as arguing for contemporaneity and thus lateral facies are:

(1) Faunal contrasts between strata of the Quimbys Mill and the Spechts Ferry may be due solely to different environments and not to different ages.

(2) Bays' (footnote, p. 278) facies changes of the Spechts Ferry from green shale in the west to brown limestone (Quimbys Mill) to buff dolomite (Quimbys Mill) in the east have their parallel in the facies changes of the Guttenberg from green shale in the west to light-brown limestone to buff dolomite in the east, and in those of the Ion from green shales in the west to light-greenish-gray limestones and shales, to greenish buff dolomite in the east. Nevertheless, the zone of phosphatic nodules at the contact of the Spechts Ferry and Guttenberg carries across these changes in facies.

The bentonite layer is therefore of the utmost importance because other evidence might be termed not entirely conclusive. This bed of plastic clay was discussed as follows by C. S. Ross (written communication, June 14, 1945):

> Victor Allen * * * has examined the material and says that it resembles bentonite of that age [Middle Ordovician] which he has studied. Preservation of ash structures is very rare in both the eastern and the Mississippi Valley regions and so their absence in your material is not surprising. I * * * find abundant orthoclase which strongly suggests bentonite * * * also zircon, which Allen says is very characteristic. Therefore, it seems very probable that this material is bentonite.

This bentonite, originally correlated with the Hounsfield (Kay, 1931) and later shown (Kay, 1935b, p. 229) to be younger in age, has been reported from the Ordovician of New York; Ontario; from the Minnesota, Iowa, and Wisconsin region; and from Missouri. Allen's (1932) study of the bentonites in the Mississippi Valley provided several conclusive arguments for the truly bentonitic nature of the bed under discussion. Allen found crescent-shaped shards and sanidine feldspar as well as euhedral apatite and zircon grains. The occasional rounded grains of minerals such as garnet, which are foreign to volcanic deposits, he explained as having been "added by wave action during or shortly following the deposition of the volcanic material." This and other evidences suggested to him "active agitation and some reworking of the volcanic material before ordinary Decorah sedimentation was resumed."

Within the mining district, the contact of the Spechts Ferry and Guttenberg members is easily discernible, as it shows greenish shale and limestone overlain by brownish limestone and shale. To the east the Spechts Ferry is absent; to the northwest, however, as near Decorah, Iowa, and farther northwest, the basal green shale (Spechts Ferry) member of the Decorah thickens at the expense of the overlying limestone (Guttenberg) member.

DISTRIBUTION

Because of their shaly character the Spechts Ferry strata are commonly not well exposed. The good exposures are usually in quarries or roadcuts that include the limestone or dolomite beds above and below (p. 287).

FAUNA AND CORRELATION

Microfossils and megafossils are abundant. Kay (1929, p. 658) listed lower and upper Spechts Ferry faunas. His lower fauna came from

> * * * gray fine-textured, soft, vertically-jointed limestone beds from 1 to 4 feet from the bottom of the member. It has been recognized in Winneshiek County [Iowa] and as far to the southeast as Patch Grove township, Grant County, Wis. [fig. 35, loc. 37].

This collection is apparently from the unnamed limestone member, previously described (p. 264). His upper fauna came from the upper foot of "dark blue hard, pyritic shale."

Spechts Ferry strata have been correlated with the *Stictoporella* bed (fig. 37) of Minnesota (Bays and Raasch, 1935, p. 300; Kay 1940, p. 235), although earlier Kay (1935a, p. 287) had believed the Spechts Ferry to be the equivalent of the *Rhinidictya* bed above.

Kay (1929, p. 666) thought that strata of the Spechts Ferry (together with the lower Guttenberg strata) could be correlated with the Glenburnie member of the Chaumont (upper Black River) of New York (fig. 44) because of the bryozoa. Furthermore, he (1934, p. 330) believed that the bentonite near the base of the Spechts Ferry is "identical with the Hounsfield bentonite in the Glenburnie."

Bays and Raasch (1935, p. 301) correlated the Spechts Ferry faunas with both the Tyrone of Tennessee and the Leray of Ontario (see also Twenhofel, and others, 1954).

Kay (1935a, p. 288) noted that the "so-called 'Decorah shale' of * * * Missouri is synchronous with the Spechts Ferry member," and Bays and Raasch agreed.

ECONOMIC PRODUCTS

Disseminated zinc and lead minerals are common in the Spechts Ferry shale member, especially in places where ore minerals occur in the overlying beds. Because the unit is thin, however, and because it is difficult to mine and mill for the zinc and lead content, the Spechts Ferry is not normally considered an ore zone. Disseminated pyrite crystals are even more widespread than zinc and lead minerals. The Spechts Ferry in former years was almost without exception the lowest zone penetrated in prospecting and mining, as the miners believed that such a body of shale (which they called the clay bed) was impervious to the descending (according to views then current) solutions that deposited the zinc and lead minerals; furthermore, as the underlying Quimbys Mill is an aquifer, the miners were apprehensive about tapping this source of additional water because it might pose new problems of mine drainage.

The bentonite in the Spechts Ferry is said to have been used in a few places in the middle 1800's as a pipe clay.

GUTTENBERG LIMESTONE MEMBER

Kay's (1928) original description stated that the Guttenberg "consists of about fifteen and one half feet of brownish fine-textured limestone," and he (1929, p. 648) subsequently published the type section as seen in a "ravine a mile north of Guttenberg, Iowa." This ravine is now obscured by U. S. Highway 52; the roadcut, however, may be said to preserve the type section. (See section 11, p. 308; fig. 49.)

LITHOLOGIC DESCRIPTION AND STRATIGRAPHIC RELATIONS

A typical section of the Guttenberg in the mining distr'ct is that along the west bank of the Galena River, in sec. 4, T. 1 N., R. 1 E., Lafayette County, Wis., given on page 285.

Throughout most of the district the thickness of the unaltered Guttenberg is 12–14 feet. On the other hand, east of Mineral Point and Shullsburg the unit

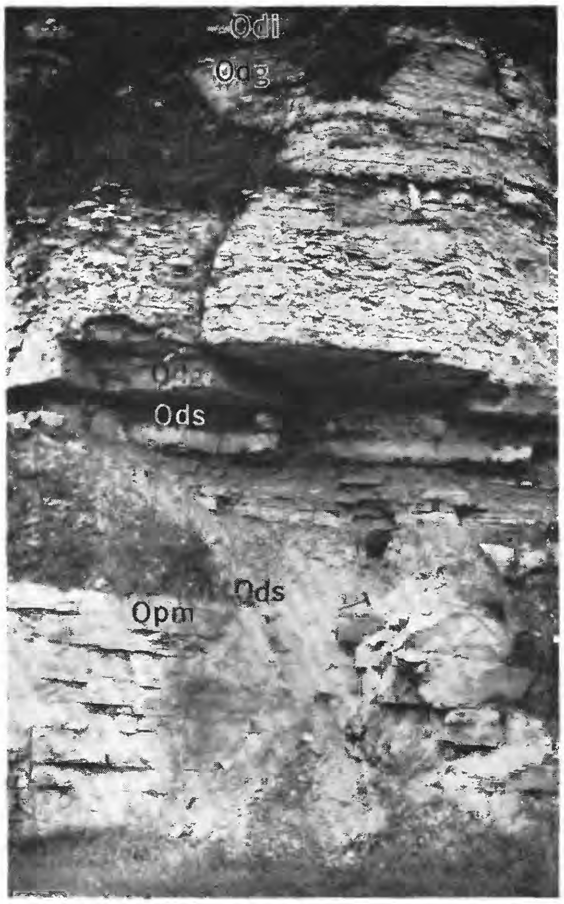


FIGURE 49.—Type section of Guttenberg limestone member (*Odg*) of Decorah formation; overlain by Ion dolomite member (*Odi*), underlain by Spechts Ferry shale member (*Ods*), in roadcut, U. S. Highway 52, 1 mile north of Guttenberg, Clayton County, Iowa (fig. 35, loc. 33).

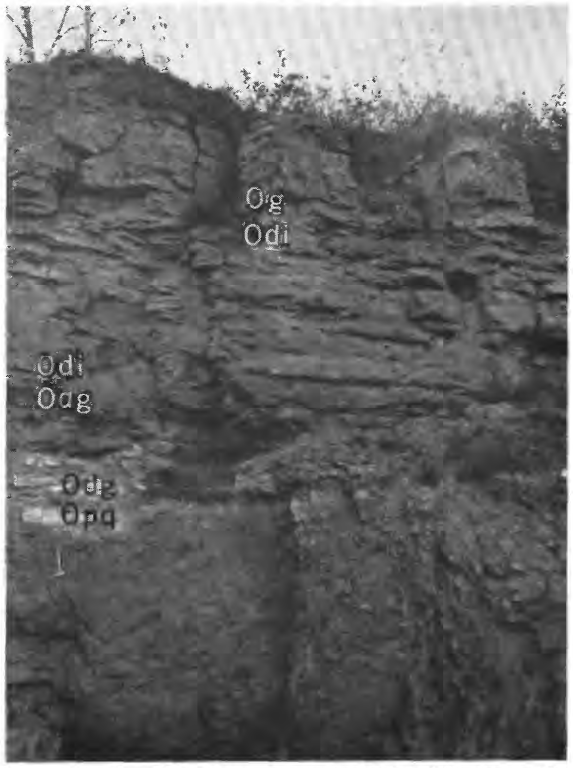


FIGURE 50.—Decorah formation, consisting of Ion dolomite member (*Odi*) and Guttenberg limestone member (*Odg*), overlain by Galena dolomite (*Og*), underlain by Quimbys Mill member (*Opq*) of Platteville formation, in quarry at York Church, Green County, Wis. (fig. 35, loc. 44).

begins to thin and at Blanchardville (fig. 35, loc. 29) it is only 6.5 feet thick. Slightly less than 2 feet remain near Rockford, Ill.

The Guttenberg becomes dolomitic east of Shullsburg and Mineral Point (see section 12, p. 308; fig. 35, loc. 44; fig. 50).

Herbert[9] found in some exposures a thin bentonite layer along a shale seam 2–3 feet above the base of the Guttenberg. The limestone below the bentonite layer is grayish brown, that above is tan or light brown. This bentonite layer was found at Spechts Ferry, Dubuque County, Iowa (fig. 35, loc. 10), northeast of Galena, Ill. (loc. 34), and midway between these two localities, in U. S. Bureau of Mines diamond-drill holes at Fairplay, Grant County, Wis. (secs. 25, 26, T. 1 N., R. 2 W.).

Insoluble residues of the Guttenberg show (Dake, footnote p. 278) an increase in quantity over those from the Quimbys Mill; the residue is mainly brownish chert with some quartz sand. Herbert related that the lower 2 to 3 feet of the Guttenberg has grayish argillaceous residues, whereas the rest of the member has tan argillaceous material with red and orange specks. The Guttenberg contains silicified fossils and quartz silt.

The Guttenberg unit contains carbonaceous shale partings (fig. 51). Locally the mineralizing solutions leached the limestone from this member as well as from the Spechts Ferry and Quimbys Mill members below, leaving a reduced thickness of beds that consist mostly of shale and argillaceous residuum. The chocolate-colored shaly residues of the Guttenberg found in mineralized areas are known as the oil rock. The following section illustrates markedly this feature, for it shows less than 5½ feet of Guttenberg (fig. 35, loc. 11):

Eagle Point Quarry, U. S. Highway 151, near southeast corner sec. 7, T. 89 N., R. 3 E., Dubuque County, Iowa

[Described by A. F. Agnew, spring, 1943]

	Thickness (feet)
Decorah formation:	
Ion dolomite member (blue beds): Limestone, blue, coarsely crystalline, recrystallized	4. 0
Guttenberg limestone member ("oil rock"):	
Limestone, pink, crystalline, mottled; dark-brown shale laminae	1. 2
Shale, dark-brown, with thin lenses of pink limestone; nodules of chertified limestone in lower 0.2 ft	. 9
Limestone, light-brownish-pink, nodular, chertified; chocolate shale seams	3. 0

[9] Herbert, Paul, Jr., 1949, Stratigraphy of the Decorah formation in western Illinois: unpublished Ph. D. thesis, Chicago Univ., Chicago, Ill.

Eagle Point Quarry, U. S. Highway 151, etc.—Con.

	Thickness (feet)
Decorah formation—Continued	
Guttenberg and Spechts Ferry members undifferentiated: Shale, chocolate-covered above, grading downward into greenish and yellowish-brown; phosphate nodules in lower 0.2 ft	0. 3–0. 5
Spechts Ferry shale member (clay bed):	
Shale, gray-green	. 9
Shale, bluish-green	. 9

Locally the oil rock is termed "rich" in the zones of mineralization because there its shaly residue phase is most abundant and the calcareous elements have been leached away, thus making the hydrocarbon content more conspicuous. Fairly well leached Guttenberg is called "medium oil rock" by the miners, and that which has been only slightly leached is designated "poor oil rock." Where no leaching has taken place and the original limestone and shale relations have been preserved, the rock is called "bastard oil rock" or "limy oil rock." (Fig. 52).

The above discussion suggests how an incorrect interpretation of the structure and of the relations between thickness of oil rock and localization of ore deposition came to be the accepted one. Geologists had found that the hydrocarbon-rich facies of the oil rock was thicker in the basins and near ore bodies, and thus they postulated irregularities in deposition to account for this feature; such views were held as late as 1934, when Scott[10] said that lateral variations such as 6 inches of oil shale terminating against limestone are due to sedimentary environment.

Actually, the stratigraphic unit as a whole had thinned greatly in such places because more of the

[10] Scott, E. R., 1934, Structural control of ore deposition: Unpublished M. S. thesis, Northwestern Univ., Evanston, Ill.

FIGURE 51.—Carbonaceous shale partings between wavy dolomite beds of Guttenberg limestone member (*Odg*) of Decorah formation, which rests on Quimbys Mill member (*Opq*) of Platteville formation, in quarry on Honey Creek, Green County, Wis. (fig. 35, loc. 45).

FIGURE 52.—Effect of mineralizing solutions on Guttenberg limestone member of Decorah formation. Dark material is brown oil rock—argillaceous and shaly residuum derived mainly from leaching of material similar to the adjoining calcareous rock. Liberty mine NE¼NE¼ sec. 16, T. 2 N., R. 1 E., Lafayette County, Wis. (1 mile north of loc. 7, fig. 35).

calcareous beds had been removed. The thinning caused by such leaching not uncommonly reduced the Guttenberg locally to 6–8 feet in thickness; indeed, in an extreme case in the Ginte Mine in Illinois (fig. 35, loc. 46), a reduction in thickness was found from the normal 13 feet to a minimum of 2 feet; the 2 feet consisted wholly of oil-rock shale. As another example, two adjacent drill holes (U. S. Bureau of Mines 58 and 59) in the Bautsch ore body (loc. 30) gave thicknesses of 13 feet and 7 feet, respectively.

The oil rock was called the "chocolate brown rock" and "brown rock" in the early reports (Strong, 1877, p. 695), and these names are still used by older miners near Montfort, Highland, and Dodgeville, in the northern part of the district. The unit was first described in detail as oil rock by Grant (1903, p. 34), as follows:

"[It] is a compact, very finely laminated, soft shale which varies in color from a very light-yellowish gray to a dark chocolate brown color, and even becomes perfectly black in places * * * It contains considerable percentage of carbonaceous matter * * * [and] when dry, particles of this rock will usually burn with a thick smoky flame."

Later Grant (1906, p. 40) stated that "when burning it gives off the peculiar petroleum odor and consequently has received the name 'oil rock.' "

Partial analyses of three samples of oil rock were reported by Strong (1877, p. 680). A sample taken from the Oakland level, in SW¼ sec. 5, T. 1 N., R. 2 E. (2 miles northwest of Shullsburg, Lafayette County, Wis.), gave 40.60 percent of "carbonaceous" matter; two samples from the Silverthorn mine, in NE¼ sec. 31, T. 2 N., R. 2 E. (2 miles farther northwest), showed 18.31 percent and 15.76 percent. Tests made by F. F. Grout on samples from the Dugdale prospect west of Platteville (Bain, 1906, p. 25) showed 20.85 percent of volatile matter and 7.96 percent of

true carbonaceous material in thoroughly air-dried shale. Leaching the shale with ether gave a thick, heavy oil * * * [containing] an appreciable amount of sulfur.

The more detailed analysis by R. T. Chamberlin (Bain, 1906, p. 26) gave 39.98 percent hydrocarbon, largely methane, and 6.79 percent hydrogen sulfide. One volume of the rock gave 57.46 volumes of gas.

David White (Bain, 1906, p. 26) made a microscopic examination of slides of the same material, concluding that there were present bodies

* * * corresponding to the contours of collapsed and flattened unicellular plants, * * * interpreted as the fossil remains of microscopic, unicellular, gelosic algae * * *

The soft brown shales of the oil rock, commonly convoluted with the yellowish bentonite of the underlying "clay bed" (Spechts Ferry), were locally termed "bull dum" by the miners.

In part of the district (T. 1 N., R. 1–2 E., southwestern Lafayette County, Wis.) the Guttenberg contains a bed of discrete chert nodules, 1.5–2 feet below its top.

Dolomitization accompanying the zinc-lead mineralizing solutions has caused confusion in the correct identification of the Guttenberg. In some places this dolomitization resulted in bleaching, as in the Trego mine (NE¼ sec. 10, T. 3 N., R. 1 W., at north edge of Platteville, Wis.), where the otherwise brownish rock is a light-cream color. In most dolomitized areas, however, the Guttenberg retained its original color, but became granular and sugary upon dolomitization, as in the Hoskins mine, Lafayette County, Wis. (SW¼ sec. 18, T. 1 N., R. 2 E., 2 miles southeast of loc. 27, fig. 35).

Silicification likewise was caused by the mineralizing solutions and notably affected the Guttenberg, where the replacement preserved the characteristics of the limestone and shales so faithfully that until the hardness is tested the rock appears normal; it is this rock that was named "bastard oil rock" originally, although more recently that term has been applied also to the hard unleached limestone phase of the Guttenberg. In many places the silicification progressed far enough that brown chert nodules were formed from limestone nodules, or grew between the shale laminae, seeming to force them apart.

As previously mentioned (p. 288, 289), the contact between Guttenberg and Spechts Ferry members is well-marked in the mining district.

To the southeast the Spechts Ferry is absent and the Guttenberg lies with apparently slight regional disconformity on the pitted surface of the uppermost bed of the Quimbys Mill below, whereas northwest of the district the Guttenberg passes into a greenish shale and argillaceous limestone facies, and in Allamakee and Winneshiek Counties, Iowa, is poorly distinguished, or indistinguishable from the overlying Ion.

In the mining district the upper boundary of the Guttenberg is almost as distinct as the lower; light-brown dense limestone and less-abundant chocolate-brown shale beds are overlain by gray-blue more coarsely crystalline limestone and greenish-gray fossiliferous shale. This change in lithology is even more striking in the areas of zinc-lead mineralization, where an abrupt change from chocolate-brown shale upward into bluish-green shale is seen.

Southeast of the mining district the light-gray dolomite of the Ion conformably overlies the light-brown dolomite of the Guttenberg, and the contact is distinct.

DISTRIBUTION

Despite the thin-bedded and nodular character of the Guttenberg, it usually is exposed as ledges and small cutbanks in streams and also in quarries where the lower or higher beds have been taken as quarry stone. Some good exposures are listed on page 287.

FAUNA AND CORRELATION

Kay (1929, p. 659) listed species of brachiopods, mollusks, and trilobites from Guttenberg strata along the Galena River 2 miles north of Galena, Ill. The fauna gains a bryozoan element in the shaly facies to the northwest, as shown by Kay's list of bryozoa from an exposure south of Waukon, Iowa. Kay (1935a, p. 290) stated that many of the species are common to the Rockland limestone (lowest Trenton) of Ontario (fig. 44).

In a later publication Kay (1940, p. 235) stated that the "Guttenberg member is believed to be represented in the *Rhinidictya* and *Ctenodonta* zones of Minnesota" (fig. 37), and he repeated his 1934 correlation of the Guttenberg with the Rockland (lower Trenton) of Ontario (see also Twenhofel, and others, 1954).

ECONOMIC PRODUCTS

The Guttenberg or oil rock contains zinc and lead ore in many places. In areas of rich oil rock the minerals are normally disseminated, as they are also in the underlying Spechts Ferry. However, in contrast to the Spechts Ferry (p. 289), mining and milling problems in the Guttenberg are not a deterrent. Furthermore, zinc-lead veins are present in many places and are mineable particularly where the overlying strata are mineralized.

ION DOLOMITE MEMBER

Kay (1929, p. 650) described the type section of the Ion, but field work by Paul Herbert, Jr., in 1944 made it appear advisable to redescribe the type section. The following section (fig. 35, loc. 36), is presented as a result of this study of outcrops and of a field conference, held August 18, 1945, in which the participants were Paul Herbert, Jr., H. B. Willman, and L. E. Workman of the Illinois State Geological Survey; A. F. Agnew, C. H. Behre, Jr., and A. V. Heyl, Jr. of the U. S. Geological Survey.

Outcrop in ravine along road in NW¼ sec. 35, T. 96 N., R. 4 W., Allamakee County, Iowa

[Described by Paul Herbert, Jr., November 8, 1944]

	Thickness (feet)
Galena dolomite:	
Cherty unit (zone D):	
Limestone, light-grayish-buff, slightly mottled grayish in lower part, finely to medium-crystalline, dense, fossiliferous	6+

Outcrop in ravine along road in NW¼ sec. 35, etc.—Continued

	Thickness (feet)
Decorah formation:	
Ion dolomite member:	
Shale, olive-brown	.3
Limestone, grayish, coarsely crystalline, fossiliferous, numerous *Prasopora*	1.0
Shale, green, *Prasopora*	.5
Shale, greenish, calcareous, and thin grayish-green shaly limestone beds; the ledges 2–3 ft above base contain *Glyptorthis* and *Dinorthis* in abundance	15.5
Limestone, thin-bedded, argillaceous; interbedded greenish shaly partings; ledge containing *Glyptorthis* 0.5 ft below top	3.2
Limestone, gray or greenish-gray, gray-mottled, thin-bedded; weathers buff to brown, wavy-bedded, fossiliferous	1.3
Total, Ion	22
Guttenberg limestone member: Limestone, light-brownish-buff, finely crystalline, dense, fossiliferous; partings of brown to chocolate-colored shale	8.3

Rocks of the Spechts Ferry and the McGregor are also exposed at the type section of the Ion. The section crops out in a shallow ravine and is accurately measured only with difficulty. The dips of the beds and the low gradient of the stream make the thickness measurements, especially of the Ion, not very precise. The differences between this described section and the description of Kay is that the upper 4.5 feet of Guttenberg (as described by Kay 1929) are here placed in the Ion. This interpretation is favored because this 4.5-foot zone is more similar lithologically to the local Ion, as well as to the Ion in the mining district to the southeast.

LITHOLOGIC DESCRIPTION AND STRATIGRAPHIC RELATIONS

Sections (see sections 11, 13, p. 308) showing Ion very similar to that at its type locality are exposed at Guttenberg, Iowa, and a short distance northwest of Potosi, Grant County, Wis. (fig. 35, loc. 47).

In contrast, about 10 miles southeast of the above locality the Ion is dolomitic, and this lithology is characteristic of the central and eastern part of the mining district, as follows: (fig. 35, loc. 12).

Roadcut, U. S. Highway 61, in NW¼ sec. 7, T. 2 N., R. 2 W., Grant County, Wis.

[Described by A. F. Agnew, Apr. 22, 1945]

	Thickness (feet)
Galena dolomite:	
Cherty unit (zone D):	
Dolomite, buff with slight greenish mottling, medium-crystalline to coarsely granular; thick-bedded	9.5
Decorah formation:	
Ion dolomite member (gray beds):	
Shale, dolomitic, olive-green; with casts of *Prasopora*(?)	.1

Roadcut, U. S. Highway 61, etc.—Continued

	Thickness (feet)
Decorah formation—Continued	
Ion dolomite member—Continued	
Dolomite, olive-gray, mottled, medium- to thick-bedded; grayish-green shale stringers and partings	14. 0
Total, gray beds	14. 1
Ion dolomite member (blue beds):	
Shale, dolomitic, olive-gray, somewhat fossiliferous	. 3
Shale, olive-gray; lenses of coquinalike limestone	1. 0
Limestone, olive-gray, medium-crystalline, medium-bedded; in wavy beds with olive shale partings	3+

In the eastern part of the mining district the Ion, still a dolomite, has lost the distinctive characteristics of its upper part so that it is inseparable from the basal strata of the overlying Galena formation (see section 14, p. 309, fig. 35, loc. 13).

The lithology of the Ion as seen from these sections consists of two facies: western facies of light- to dark-bluish-gray finely to coarsely crystalline fossiliferous limestone beds, with abundant greenish-gray shale beds; and eastern facies of light- to medium-grayish-blue, crystalline to granular, vuggy medium- to massive-bedded less fossiliferous dolomites, with subordinate amounts of olive-gray argillaceous patches and dolomitic shale beds.

The thickness of the Ion is consistently 20–22 feet in outcrops and in many drill holes.

In places minute phosphatic nodules (smaller and more sparse than those in the upper part of the Spechts Ferry) are present near the base of the Ion. The Ion contains scattered rounded grains of clear quartz sand that are relatively abundant near the base; such grains are likewise present, but are less common, in the Guttenberg below, and in the overlying beds of the cherty unit of the Galena formation.

The divisions of the Ion, which are known in the miners' terminology as the blue and the overlying gray, can be differentiated in most parts of the district. The blue beds consist of about 7 feet of gray dolomitic limestone whereas the gray beds contain approximately 14 feet of lighter gray dolomitic limestone. The blue beds have relatively more of the clear rounded grains of quartz sand, are more mottled, and in most places are more argillaceous and shaly than the gray beds. Minute phosphate granules are common near the base of the blue. Outside the district these separate units are not distinct, and in different parts of the district they show some variation. It is therefore best, as with the Mifflin (of Bays, 1938) and Magnolia (of Bays and Raasch 1935) subdivisions of the McGregor member, to use these terms only locally. In the northern part of the mining district the lower, or blue beds of the Ion are referred to as green rock (Strong, 1877, p. 695).

Herbert reported the insoluble residues from the Ion to be greenish clay. He also noted at the top of the blue beds, southward from the mining district, an erosion surface that was not seen by the writers.

A bentonite bed was observed at the base of the Ion at a quarry in SE¼ sec. 27, T. 3 N., R. 3 E., Lafayette County, Wis. (2 miles north of loc. 13, fig. 35), where it is the basal 0.2 foot of the Ion and rests on dolomite of the Guttenberg that is 8 feet thick.

As was already mentioned (p. 292), the contact of the Guttenberg and Ion is conformable and, although in most of the mining district the differentiation of the beds is relatively simple, to the northwest where the green shale and limestone facies of the Guttenberg occurs it is not so obvious. Likewise, southeast of the district where both the Guttenberg and the Ion are dolomite the boundary between these two units is drawn with some difficulty.

The upper contact of the Ion is conformable with the base of the Galena. In most places the contact is easily distinguishable although locally it is indistinct, especially in the eastern area of the outcrop, where strata near the contact are a grayish dolomite mottled with green areas that are argillaceous in part, but include no definite shale beds (see section 14, p. 309).

Studies of many outcrops in the region from Rockford, Ill., on the southeast to Decorah, Iowa, on the northwest, amply supplemented with the examination of cuttings from wells have shown the contact between the Decorah and Galena to be a conformable one regionally; and detailed, studies of closely spaced outcrops in certain areas of the mining district indicate that these relations remain constant. Thus the writers do not agree with Kay (1932) and Atwater (Kay and Atwater, 1935, p. 109–110), that

> * * * in the Upper Mississippi Valley Lead and Zinc District, there is a distinct disconformity at base of the Galena dolomite, bringing that formation in contact with beds of the Ion and of the Guttenberg ("Oil rock member") members of the Decorah formation.

The same authors continued that

> * * * this is in contrast to the stratigraphic relations in sections northwest of the district, where the Prosser limestone of the Galena group lies conformably on the Ion; this conformity continues into Minnesota.

Kay later (1939, p. 27) repeated the former statement even more emphatically.

It is the considered opinion of the writers that the sections of Kay and Atwater were incorrectly described and that the "clastic beds" which are said to mark this disconformity are actually altered strata in mineralized outcrops or weathered exposures heavily covered with loess and other surficial material.

For example, the two cases cited by Kay and Atwater (1935, table I, p. 103 and table II, p. 104) one-eighth of a mile apart at Spechts Ferry, Iowa, which they give as a major illustration of the so-called disconformity, are actually not at all dissimilar. They state (1935, p. 104) correctly that in the quarry the "Ion limestone has been so metasomatized as to become a dolomite." The effects of this "metasomatism" have been not only to alter the lithology of the affected strata in both exposures, but in addition it reduced materially their thicknesses, as is illustrated by similar changes in limestones of the Quimbys Mill and Guttenberg, described previously (p. 283, 292). The table below lists the observed thicknesses of the various units at the two Spechts Ferry localities, together with the normal thicknesses:

Effects of alteration on thickness at two exposures only 600 feet apart at Spechts Ferry, Dubuque County, Iowa

Rock units	Thickness, in feet		
	Quarry	Ravine	Normal
Galena: Cherty unit (zone *D*)	6.0	5.8	10
Decorah:			
Ion dolomite member	16.3	13.0	21
Guttenberg limestone member	14.8	13.6	15
Spechts Ferry shale member	8.1	8.0	8–8.1
Platteville: Quimbys Mill member	.3	.2	0.2–0.3

This alteration of lithology and thickness is a common feature in the mines to the east, and has been noted as far west as the vicinity of Beetown, Wis., (10 miles northwest of the Spechts Ferry localities), where it was accompanied by significant zinc ore mineralization.

Kay and Atwater described another exposure (1935, table IV, p. 105), which shows ocher-yellow silty clay with a "poorly defined" 3-inch bed of dolomite. This is nothing more than a weathered exposure in a stream bank. A similar condition is presented in their figure 4; the left part of the figure evidently shows a weathered and rubbly upper part of an outcrop. A detailed study of the outcrop by the present writers clearly established this conclusion.

It is thought that the facies changes of the Ion have helped cause this misinterpretation, as the Ion strata are irregularly dolomitic in the area where Kay and Atwater noted the so-called disconformable relations. The misinterpretation was aided by the secondary effect of the alteration by mineralization as previously described.

The Ion grades upward into the basal Galena. The rocks in the basal part of the Galena, however, contain slightly less greenish argillaceous material than the Ion does in its dolomite facies in the mining district and to the southeast. Similarly, the basal Galena strata in the limestone facies northwest of the mining district contain less green fossiliferous shales than the Ion beds do in that area.

DISTRIBUTION

Similar to the Guttenberg member, the Ion is exposed mainly as ledges in streams and in quarries (see p. 287).

FAUNA AND CORRELATION

At the top of the Ion is a zone of *Prasopora insularis* Ulrich. These bryozoa are abundant in the northwestern part of the area of outcrop, but become less common to the southeast so that only along the western edge of the mining district specimens of *Prasopora* are observed. This fossil is usually found in the upper foot and a half of the Ion. A zone containing abundant *Clyptorthis bellarugosa* (Conrad) occurs in the Ion 2–6 feet above its base.

Kay (1935a, p. 290) stated that the Ion contains typical Trenton forms (see Twenhofel, and others 1954) and the ostracodes, Kay (1934, p. 331) found, have a "striking similarity" to those of the lower Hull (of Raymond 1914) of Ontario (fig. 44); (Kay, 1940, p. 235) correlated the Ion with the *Phylloporina* (*Chasmatopora*) and Fucoid zones of Minnesota (fig. 37).

ECONOMIC PRODUCTS

The Ion beds are ore-bearing and, together with the overlying Galena dolomite, comprise the host rock of most of the zinc-lead vein ("pitch and flat") and breccia deposits of the mining district. The "pitch" of local miners refers to an inclined ore-filled fracture, and the "flat" is a vein along bedding; the two types of fracture are closely associated structurally, as the "flats" terminate against the "pitches."

DISTRIBUTION OF FACIES OF THE DECORAH AND CONDITIONS OF DEPOSITION

The Decorah strata are mainly shale with thin limestone bands and nodules west of the mining district; at Decorah, except for the lower, unnamed limestone member, it is difficult to distinguish subdivisions. In the mining district, however, the main part of the Decorah is limestone with relatively little shale, and only the Spechts Ferry shale member contains more shale than limestone. East of the mining district shale in the Decorah is very rare; the rocks are dolomite.

Not only is there a change in facies from dominantly shale in the west to dominantly carbonate rock in the east, but in addition the lower, unnamed limestone member and the Spechts Ferry shale member pinch out toward the east—the former in the western part of the mining district, the latter in the eastern part; furthermore, the Guttenberg member thins to the east of the district. This is generally in contrast with Platteville strata, as the Quimbys Mill and upper McGregor strata thin toward the west. Coupled with the evidence for a biatus between the Platteville and Decorah afforded by the bentonite layers in the lower Decorah strata, this indicates an incursion of the Decorah sea from the west over the corroded surface of the uppermost Platteville beds, in contrast to the eastward retreat of the sea at the end of the Platteville.

The shale and exceedingly shaly limestone beds of the Decorah were deposited under generally shallow-water conditions of a platform environment (Sloss, 1947). The shale beds are unfossiliferous; however, fossils are found as floods in coquinalike layers, commonly broken and washed, and are found in extremely fossiliferous fine-grained limestone beds. Thus, although the environment of the shale was generally hostile to life, the shells were contributed during the deposition of clay at times stormy conditions, and the 1- to 2-inch coquinoid layers therefore represent only instants in geologic time (see also Bucher, 1919).

The limestone beds and interbedded shale partings of the Decorah in the mining district were deposited under conditions generally similar to those prevailing when McGregor and Quimbys Mill strata were accumulating—that is, generally shallow-water environment.

The more coarse-grained dolomitic rock east of the mining district is due to subsequent dolomitization apparently related to the Wisconsin arch (see p. 284).

The bentonite beds, the result of volcanic activity probably in the southern Appalachian area (Nelson, 1922), may have caused disruption of animal and plant life development, although not so great as Sardeson (1926b) believed.

GALENA DOLOMITE

The beds called the upper magnesian limestone or cliff limestone by Owen (1840, p. 19, 24) were designated "Galena" by Hall (1851, p. 146) from their exposures in the vicinity of the town of Galena, Jo Daviess County Ill., (fig. 35). The strata making up the Galena in its type area were described by Hall as "gray, or drab-colored limestone, and very friable." As exposed in the vicinity of Galena, Ill., they consist of light-grayish or drab to light-brownish or buff medium- to thick-bedded medium crystalline to coarse-grained, "sugary," extremely vuggy dolomite. Many chert bands are present in the lower half of the formation, and the beds normally show a honeycomb type of weathering.

GENERAL FEATURES

Regionally it has been found useful to divide the Galena into two lithologic units, a cherty, and a noncherty one (Agnew, 1950).

The total thickness of the Galena in the mining district generally ranges between 215 and 230 feet. The following table shows the thickness of the Decorah formation, and the Galena dolomite and its subdivisions in wells irregularly distributed in and near the mining district:

Thickness of the Decorah formation, Galena dolomite, and its subdivisions in wells irregularly distributed in and near the mining district

[Localities shown on fig. 35]

	Decorah	Galena		
		Cherty	Noncherty	Total
County Home well, Clayton County, Iowa (loc. 16)	47	125	87	212
Colesburg city well 1, Delaware County, Iowa (loc. 21)	46	107	113	220
Wiest Brothers farm well, sec. 12, T. 3 N., R. 5 W., Grant County, Wis. (2 miles south of loc. 9)	39+	119	102+	221+
USBM Pikes Peak DD 7, sec. 33, T. 89 N., R. 2 E., Dubuque County, Iowa (5 miles west of loc. 22)	49	113	118+	231+
Swanson farm, sec. 26, T. 1 N., R. 2 E., Lafayette County, Wis. (2 miles south of Shullsburg)	25	103	113	216

CHERTY UNIT

Workable subdivisions of the cherty unit, arranged (Paul Herbert, Jr., Illinois Geological Survey, oral communications, 1944) in subsurface studies at the Bautsch mine, Illinois (fig. 35, loc. 30), were modified and applied to outcrops both locally and regionally in the course of the studies for the present report. Because these units are not stratigraphic entities large enough or definite enough regionally to require formal names, letter designations similar to those applied by Fowler and Lyden (1932) in the Tri-State zinc district are used.

The following points regarding the above classification are significant:

(1) Zone *D* is lithologically transitional between the Ion beneath and zone *C*.

(2) Zone *C* contains the lowest widespread chert of the Galena formation; this chert is abundant both as beds and nodular bands, and as separate nodules.

(3) Zone *B* is the lower *Receptaculites* zone; it contains *Receptaculites oweni* Hall abundantly, although not uniformly; chert bands and nodules are not nearly so common as in zone *C*, below.

(4) In exposures in the area bounded by the towns of Galena, Platteville, Guttenberg, and Dubuque, zone *A* (see p. 267) can be divided generally as follows, in descending order:

Subdivisions of zone A of cherty unit of Galena dolomite

	Thickness (feet)
Unit 1. Dolomite, light-buff, massive above to thin-bedded below; many chert bands; thin shale or shaly zone, locally with bentonite, at base	32
Unit 2. Dolomite, thin-bedded, as above; chert rare, *Receptaculites* and *Ischadites* sparse	6
Unit 3. Dolomite as above, chert common	6
Unit 4. Dolomite, light-gray to drab, thick-bedded, sparsely cherty near top but chert common near base; *Receptaculites* and *Ischadites* present sparsely in a thin zone near middle	26
Total, zone *A*	70

From subsequent field work in the correlation of these subdivisions of the cherty unit, several facts are evident, namely:

The shale parting at the base of zone *A*, unit 1 is in places more or less obscure; in some localities it is only a wafer-thin parting of dolomitic shale, whereas in others it is bentonite and shale;

The less-cherty zones differ somewhat in the abundance of chert present; the value of this feature is complicated in well cuttings by caving from overlying cherty beds;

The occurrence of *Receptaculites* and *Ischadites* in units 1 and 3 is helpful in outcrop studies, and the gray to drab color of unit 4, while not uniformly noteworthy in the outcrops, is nevertheless of value in the subsurface studies;

Strata in all the above units are commonly marked by extremely honeycomblike weathering (fig. 53); yet in some areas the same beds present a fairly massive appearance. Fucoidal surfaces are generally present and are especially characteristic of zone *A*, unit 4 and zone *B*.

The four major zones (*A*–*D*) described above can be distinguished in outcrops, diamond-drill cores, and churn-drill samples mainly on the basis of the relative abundance of chert, because in churn drill cuttings *Receptaculites* can not be recognized. As all four of the zones generally have only one type of weathering—and thus the color and texture of the weathered rock are not useful—the relative amount of chert present and subtle differences in bedding are the distinctive features in exposures.

In the western part of the district bentonite has been noted at a horizon normally represented by a shale parting near the base of unit 1, zone *A*. Localities showing this bentonite include the roadcut along U. S. Highway 61 in SE¼NE¼ sec. 26, T. 3 N., R. 3 W., Grant County, Wis. (3 miles northwest of loc. 12, fig. 35), and the roadcut along U. S. Highway 52, at the north edge of Guttenberg, Clayton County, Iowa (fig. 35, loc. 33).

FIGURE 53.—Honeycomblike weathering of zone *P* of noncherty unit, and zone A of cherty unit of Galena dolomite in roadcut, State Route 11, Grant County, Wis. (fig. 35, loc. 35).

The thickness of the cherty unit remains fairly constant at 100–105 feet, although in the western part of the mining district isolated chert nodules and a thin band of nodular chert are found as much as 8 feet above the top of the very cherty sequence that marks the top of zone *A* of that unit. The cherty unit is dolomite in the mining district and to the southeast. Some distance northwest of the district, however, beyond the mouth of the Wisconsin River the facies consists almost wholly of limestone, and in the same area green shale is also present in the lower three zones. The cherty unit includes units 2 through 8 of Stauffer and Thiel's section west of Wykoff, Minn. (p. 266).

NONCHERTY UNIT

The noncherty unit includes the upper, noncherty part of the Prosser cherty member, the Stewartville massive member, and the Dubuque shaly member. The first two of these three are similar in lithology and are thus difficult to differentiate, although the base of the Stewartville is supposedly marked by the base of the upper *Receptaculites* zone. Unfortunately, *Receptaculites* individuals are found sporadically at least 25 feet below the base of the zone; in poorly exposed strata their proper stratigraphic assignment is therefore exceedingly difficult. Furthermore, in drill cuttings the *Receptaculites* fossils have been destroyed, so the criterion is nonexistent.

On the other hand, in areas of excellent exposures a bedding plane at the base of a zone of abundant *Receptaculites* can be taken as a datum for mapping geologic structure locally. This is the boundary selected between the Stewartville and zone *P* of the noncherty unit.

The lower two subdivisions of the noncherty unit are light-yellowish-buff medium- to coarse-grained crystalline to granular dolomite in medium to thick beds; the strata weather brownish, and with honeycomblike surfaces that mask the bedding, making the rock appear massive. Minute yellowish to cinnamon-colored specks are characteristic of parts of the Stewartville.

Bentonite is found locally along a bedding plane that normally contains only shale, about 18 feet above the base of the noncherty unit, as in the roadcut along U. S. Highway 20 at the east edge of Galena, Ill. (sec. 20, T. 28 N., R. 1 E.).

Zone *P* is 35–40 feet thick, and the rocks of the overlying Stewartville total 37–47 feet.

The Dubuque member in the mining district is a light-gray to buff fine grained sugary and silty dolomitic limestone that weathers to a yellowish-buff color. This rock is medium- to thin-bedded and contains thin interbeds of platy dolomitic shale; as a result, it was called "shingle rock" by the early miners (Phillips, 1854, p. 129). The dolomitic limestone beds become thinner and more calcareous and shale is more abundant, in the upper part of the member. The contact of the Stewartville and Dubuque is gradational from massive honeycombed dolomite below to medium-bedded dolomite and interbedded dolomitic shale above. The Dubuque as a whole is more calcareous than the underlying Stewartville. The brachiopod *Lingula* (*Pseudolingula*) *iowensis* Owen is common, the shell standing vertically in the dolomite. The contact between the Dubuque and the overlying Maquoketa is regionally disconformable (DuBois, 1945, p. 15), and locally a corrosion zone shows pits in the Galena dolomite that are filled with the rocks of basal Maquoketa.[11]

The thickness of the Dubuque is fairly constant, ranging from 35 to 45 feet in the outcrop.

The noncherty unit is dolomite in the mining district and to the east. Toward the west, however, the lower one-third and upper one-third become limestone, as is seen in Stauffer and Thiel's section west of Wykoff, Minn.

DISTRIBUTION

The Galena strata generally form bluffs; the rock is commonly quarried for road material and agricultural limestone. The location and thicknesses in good exposures of parts of the Galena and adjacent strata are shown in the following table.

Because of its more thinly bedded and shaly character, the Dubuque does not form bluffs as does the more massive rock below. Nevertheless the unit is resistant enough to stand fairly well, and it is locally

[11] Rall, R. W., 1951, Ostracods from the depauperate zone of the Maquoketa shale: unpublished M. S. thesis, Ill. Univ., Urbana, Ill.

Location and thicknesses (in feet) in good exposures of parts of the Galena and adjacent strata

[Localities shown on fig. 35]

Location	Decorah	Galena					
		Cherty unit				Noncherty unit	
	Ion	Zone D	Zone C	Zone B	Zone A	Zone P	Stewartville
Quarry and roadcut, U. S. Highway 151, Iowa County, Wis. (loc. 49)	13+	10	10	15	25+	-----	-----
Quarry, south side of road NW¼SE¼ sec. 20, T. 3 N., R. 1 W., 2 miles southwest of Platteville, Wis.	-----	-----	-----	7+	25+	-----	-----
Roadcut, U. S. Highway 61, SW¼SE¼NE¼ sec. 26, T. 3 N., R. 3 W., Grant County, Wis. (3 miles northwest of loc. 12)	-----	-----	-----	-----	36+	-----	-----
Quarry, 500 feet south of County Trunk U, Grant County, Wis. (loc. 47)	21.5	8.5	13	15+	-----	-----	-----
Roadcut, U. S. Highway 151, Grant County, Wis. (loc. 6)	10.5+	10.5	24.1		10+	-----	-----
Roadcuts, U. S. Highway 61, Grant County, Wis. (loc. 12)	18.5+	9.5	16	16	4+	-----	-----
East portal, old R. R. tunnel, Lafayette County, Wis. (loc. 50)	19+	9.5	11	12+	-----	-----	-----
Roadcut, near center east line NW¼NE¼ sec. 24, T. 1 N., R. 1 E., Lafayette County, Wis. (3 miles east of loc. 50)	-----	-----	3.5+	17	40+	-----	-----
Roadcut, State Route 11, Grant County, Wis. (loc. 48)	-----	-----	-----	5+	69.5	38	8+
West portal Illinois Central R. R. tunnel, Jo Daviess County, Ill. (loc. 22)	-----	-----	-----	11+	69	11+	-----
Eagle Point Quarry, west side U. S. Highway 151, Dubuque County, Iowa (loc. 11)	17.5	12	11	20	75.5±	37±	17+
Roadcut, U. S. Highway 52, Clayton County, Iowa (loc. 33)	19	10.5	29.5		73.5	21+	-----

well exposed in road cuts and quarries. Some of the better exposures of the Dubuque strata are listed below:

Roadcuts along new U. S. Highway 20, in sections 27 and 28, T. 89 N., R. 2 E., Dubuque County, Iowa (6 miles southwest of loc. 11, fig. 35).

Quarry at Loras College, in SE¼ sec. 23, T. 89 N., R. 2 E., Dubuque County, Iowa. This is the Dubuque type locality (3 miles southwest of loc. 11).

Ravine from east, in SW¼NE¼ sec. 33, T. 27 N., R. 1 E., Jo Daviess County, Ill. (4 miles south of loc. 30).

Roadcuts along State Route 11, in sec. 30, T. 1 N., R. 1 W., and in sec. 33, T. 1 N., R. 2 W., Grant County, Wis. (3 miles east, and 1 mile west, respectively, of loc. 48).

Roadcut along U. S. Highway 151 at Chicago and Northwestern Ry. underpass, near center of east line sec. 18, T. 3 N., R. 1 E., 3½ miles east of Platteville, Wis.

Wells that intersected representative thicknesses of the Galena are:

Locality (See fig. 35)	Cherty unit	Noncherty unit		
	Zone *A* (feet)	Zone *P* (feet)	Stewartville (feet)	Dubuque (feet)
Well, Swanson farm, SE¼SW¼ sec. 26, T. 1 N., R. 2 E., Lafayette County, Wis. (2 miles south of Shullsburg)	65+	45	35	33
U. S. Bureau of Mines D. D. holes 15–24, 29, Bautsch lease Jo Daviess County, Ill. (loc. 30)	66–71	71–77.5		42–46
Roadcut, State Route 11, Grant County, Wis. (loc. 48)	69.5	38	8+	---------
U. S. Bureau of Mines D. D. hole 6, Pikes Peak lease, SE¼ sec. 33, T. 89 N., R. 2 E., Dubuque County, Iowa (5 miles west of loc. 22)	67	34	49	14+
Woodward farm well, near southeast corner NW¼ sec. 35, T. 89 N., R. 1 E., Dubuque County, Iowa (9 miles west of loc. 22)	12+	43	32	33
U. S. Bureau of Mines churn drill holes 1, 5, Piquette lease, SE¼NE¼ sec. 35, T. 3 N., R. 3 W., Grant County, Wis. (2 miles northwest of loc. 12)	75±	36	19+	---------
Well, Wiest Brothers farm, SE¼SW¼ sec. 12, T. 3 N., R. 5 W., Grant County, Wis. (2 miles south of loc. 9)	73±	80		22+
Colesburg city well 1, Delaware County, Iowa (loc. 21)	62±	43	35	35
Well, County Home, Clayton County, Iowa (loc. 16)	85±	70		17

DISTRIBUTION OF FACIES OF THE GALENA AND CONDITIONS OF DEPOSITION

The Galena in the mining district is mainly dolomite, with bands of chert nodules in the lower half. The upper part contains interbedded dolomitic shale.

The dolomite (see p. 284) and possibly the chert were formed subsequent to the deposition of the strata and are related to the Wisconsin arch, although in a more general manner than the chert of the Platteville formation. The contact of the dolomite and limestone generally ascends in the cherty unit toward the west so that along the western fringe of the district the lower part of the cherty unit is limestone (see also Calvin and Bain, 1900, p. 406–411); limestone islands, such as the limestone lithology of zones *C* and *D* in the center of the mining district (near loc. 32, fig. 35) are present, however. Beds of the Dubuque are limestone northwest of Elkader, Clayton County, Iowa (loc. 16), according to Kay (1935c, fig. 8).

The Galena strata were deposited as platform limestone (Sloss, 1947) in a fossiliferous environment of relatively shallow water. The limestone and shale sediments of the upper subdivision of the noncherty unit, and west of the mining district the lower strata of the noncherty unit were deposited under somewhat deeper water conditions, and Sloss would assign this facies also to the platform type of deposit.

The two discontinuous bentonitic seams near the contact of the cherty and the noncherty units denote volcanic activity similar to that which supplied the bentonitic material of the Decorah (see p. 296).

FAUNA AND CORRELATION

In Minnesota the Prosser member has been divided into the following three zones in ascending order (Ulrich, 1911b, p. 488): *Vellamo* (*Clitambonites*) zone, *Nematopora* zone, and *Fusispira* zone (fig. 37).

Kay (1935a, p. 291) stated that the *Vellamo* zone is equivalent to the upper Hull (of Raymond 1914) (basal Trenton) in New York, and that the overlying *Nematopora* zone has bryozoa that are common in the overlying Sherman Fall formation in New York (see also Twenhofel, and others, 1954), although Sardeson (1897b, p. 190) had warned that these are facies faunas.

Kay (1935a, p. 291) continued,

> The Lower *Receptaculites* zone, in which *Receptaculites oweni* Hall is abundant, persists southward [from Minnesota] at about the horizon of the *Nematopora* zone.

This is true only for southeastern Minnesota and northeastern Iowa; there it represents zone *C* as well as *B* of the cherty unit. To the south the base of the lower *Receptaculites* zone migrates upward stratigraphically; as a consequence, in the mining district zone *C* contains no *Receptaculites* individuals, whereas zone *B* above bears that fossil in abundance and is the lower *Receptaculites* zone there. Toward the north, as is well shown near Guttenberg, Iowa (fig. 35, loc. 33), the fossils are present four feet above the base of zone *C* and upward through all of zone *B*.

Zone *A* can probably be correlated with the Sherman Fall (fig. 44) of northern Michigan (Kay, 1935a, p. 292). The Kimmswick limestone of Missouri is said to be the equivalent of the Prosser.

The Stewartville has been correlated with the upper Cobourg (of Raymond, 1921) because of fauna, and with the McCune limestone (of Keyes, 1898) of eastern Missouri (Kay, 1935a, p. 292; Twenhofel, and others, 1954).

Sardeson (1907, p. 193) correlated the Dubuque with the Oxoplecia (Triplecia) beds of Minnesota which, however, he placed in the Maquoketa shale. Kay

(1935c, p. 583) correlated the Dubuque with the Collingwood formation of northern Michigan both by fauna and because of stratigraphic position (see also Twenhofel, and others, 1954), and Stauffer and Thiel (1941, p. 90) hold that the Dubuque fauna of Minnesota "seems to lack most of the diagnostic Galena fossils." This is undoubtedly a facies fauna from the shale and limestone facies of the Dubuque, and thus difficulty may be expected in attempts to correlate it with the dolomite-limestone facies.

It has been mentioned by several other stratigraphers that the Dubuque member is Utica or even Richmond in age. On the other hand, Kay (1935c, p. 579; also oral communication, December 27, 1945) has stated that he now considers both the Stewartville and the Dubuque to be of Trenton age, as does Fettke (1948, fig. 2).

The existence of a hiatus between the Stewartville and the Dubuque, postulated by Kay and others apparently because of the dissimilarity between the Stewartville and Dubuque faunas, is doubted by the present writers, as no physical evidence of this feature can be found. Furthermore, the writers believe that this dissimilarity is due to facies.

As the Dubuque fauna has not been carefully studied throughout all of its facies, the evidence is inconclusive (see Twenhofel, and others, 1954, p. 270 and chart; Lattman, 1954).

ECONOMIC PRODUCTS

The Galena, called by the miners the yellow sandy (noncherty unit) and the drab (cherty unit), is the principal host rock for zinc and lead minerals. In the northern part of the district (15 miles northwest of Mineral Point) miners call the upper part of the Ion and the lower part of the cherty unit the wool rock. The main vein (pitch and flat) and breccia deposits are in the lower part of the Galena (zones *B*, *C*, and *D* of the cherty unit. In the upper part of the Galena dolomite (noncherty unit and zone *A* of the cherty unit are the "openings" along vertical joints ("crevices") from which lead and zinc minerals were mined in the early days. An "opening" (Whitney, 1858, p. 439–440) is a zone of weathered sandy dolomite at a favorable stratigraphic horizon, and was the locus for lead mineralization. Several openings commonly are superimposed along a crevice. An opening normally varies between 5 or 6 feet wide and a fraction of an inch. Above the water table galena is the principal mineral of economic importance, and below it sphalerite is in most places predominant; in the zone near the water table smithsonite and galena are most common.

The Galena dolomite is the principal source of water for most of the farms in the mining district.

POST-GALENA ROCKS

Because this report deals primarily with rocks related to the ore deposits, post-Galena rocks will be discussed only briefly.

Information regarding these strata is derived mainly from studies by Agnew before 1947. More detailed discussions of the Maquoketa will be forthcoming in the publication dealing with the state of Iowa (Agnew, 1955), further work is contemplated for the Silurian rocks, and additional study of the post-Silurian deposits is currently under way.

ORDOVICIAN ROCKS—MAQUOKETA SHALE

The name Maquoketa was applied by White (1870, p. 181) to the shales exposed along the Little Maquoketa River about 12 miles west of Dubuque, Iowa (fig. 31). In the mining district the Maquoketa occurs below and at the base of erosional remnants called "mounds;" in Wisconsin these are 4 and 7 miles east of Platteville, 16 miles south of Platteville, and 25 miles northeast of Mineral Point. Elsewhere in Wisconsin the Maquoketa shale is in the uplands south of Shullsburg and along the Grant-Lafayette County line south of Platteville, and in Illinois and Iowa it is exposed next to the escarpment of southward-dipping Silurian strata, which passes easterly and northwesterly from Galena, Ill.

The Maquoketa is principally blue or gray dolomitic silty shale and some grayish-buff medium-grained sugary argillaceous thin-bedded dolomite; the lower 30–40 feet of the formation, however, is commonly brown in color. In the basal few feet phosphatic pebbles and minute fossils are present. This is the depauperate zone (Ladd, 1929, p. 371–375), a zone of "universal smallness" that contains forms which, because of the unfavorable environment, do not attain the size of other species of these genera; they are distinct from forms that are dwarfed, which under favorable environmental conditions attain larger size. Away from the mining district the Maquoketa varies greatly in lithology; to the west, south, and east dolomite is more abundant than shale. Furthermore, the thickness is not constant. A few miles south of Galena, Ill., in U. S. Bureau of Mines Mougin diamond-drill hole (fig. 35, loc. 30), the Maquoketa is only 108 feet thick; 8 miles south of Shullsburg, Wis., in the T. T. Redfern well (fig. 35, loc. 51), it is at least 170 feet thick; (data in files of Illinois Geological Survey, Urbana, Ill.) at Blue Mounds, Iowa County, Wis., NW¼ sec. 1, T. 6 N., R. 5 E. (3 miles east of loc. 49, fig. 35), it is 240 feet thick; (data in files of Wisconsin Geological and Natural History Survey, Madison, Wis.) and in Fayette County, Iowa, it is about 260 feet thick (Savage, 1905, p. 486).

At the top of the Maquoketa where it is thickest, a reddish hematitic clay and pebble zone has been reported (Agnew, 1955; Workman, 1950) outside the mining district. This zone (the Neda formation of Savage and Ross, 1916), probably represents a soil zone that marks the unconformity between the Maquoketa and the overlying Silurian.

A good exposure of the upper part of the Maquoketa can be seen along U. S. Highway 67 at the south edge of Bellevue, Jackson County, Iowa (fig. 35, loc. 8; fig. 54); the lowermost beds, including the depauperate zone, can be seen in the railroad cut just west of Scales Mound, Jo Daviess County, Ill., SW¼ sec. 26, T. 29 N., R. 2 E. (1 mile northeast of loc. 51, fig. 35).

The Maquoketa strata are a poor host rock for zinc and lead minerals. In the Glanville prospect at Scales Mound, Jo Daviess County, Ill., NW¼ sec. 24, T. 29 N., R. 2 E. (3 miles northeast of loc. 51, fig. 35), a short drift was driven for sphalerite and barite in dolomite at about the middle of the Maquoketa; the minerals did not occur in paying quantity. In some of the more dolomitic beds pyrite is not uncommon, and in many places it is abundant in the phosphatic depauperate zone.

FIGURE 54.—Maquoketa shale (*Om*) overlain by dolomite of early Silurian age (*Sd*), in roadcut and quarry, U. S. Highway 67, half a mile south of Bellevue, Jackson County, Iowa, (fig. 35, loc. 8).

The basal part of the Maquoketa contains abundant organic material and in many places gives an oily scum to the water bailed during the drilling of wells and prospect holes.

SILURIAN ROCKS

Silurian rocks, locally referred to as Niagaran although they are older than Niagaran, are found only in the "mounds" and at the southern edge of the mining district, where erosion of the southward dipping beds has created an escarpment (p. 300). Excellent exposures of the upper beds are seen in quarries at Platte Mound, locality 52, Lafayette County, Wis. (fig. 35) and Belmont Mound, Lafayette County, Wis., NW corner, sec. 2, T. 3 N., R. 1 E. (3 miles east of loc. 52); the lower beds are well exposed at Bellevue, Jackson County, Iowa (loc. 8).

The Silurian rocks in the zinc-lead district are mainly yellowish-buff medium- to coarse-grained "sugary" dolomite, in part vuggy. Near Galena, Ill., the thickness totals as much as 200 feet (Willman and Reynolds, 1947, p. 7). Near Galena the uppermost 90 feet of rock contains chert and is marked at the top by *Pentamerus;* next below occurs approximately 20 feet of noncherty strata; below that lies about 65 feet of cherty beds. The basal 20 feet of strata is argillaceous dolomite. In general the Silurian rocks differ from the Galena dolomite in being less vuggy and more yellowish; furthermore, the Galena dolomite of the mining district possesses no beds comparable to the laminated silty and argillaceous dolomite of the lower part of the Silurian.

Rocks of Silurian age overlie the Maquoketa unconformably; the basal argillaceous silty zone appears to thicken and thin inversely with the thickness of the underlying Maquoketa.

An interesting effect of rock alteration is seen at the Blue Mounds (3 miles east of loc. 49, fig. 35), where the complete sequence of dolomite of Silurian age has been silicified (Whitney, 1862, p. 190. See also well for radio station WIBA–FM transmitter, NW¼ sec. 1, T. 6 N., R. 5 E., Iowa County, Wis.; data in files of Wisconsin Geological and Natural History Survey, Madison, Wis.). This is thought to be due to leaching and weathering of a limestone that contained siliceous fossil shells (Hubbard, 1900).

The dolomite of the Silurian, because of its similarity to that of the Galena, should be a potential host rock for zinc and lead minerals. However, because it is present mainly along the southern margin of the mining district and to the south, away from the center of mining activity, and as it is covered throughout most of its extent near the district by glacial deposits, its ore-bearing possibilities have not been appraised. Isolated crystals of sphalerite and galena have been found in many places, and mining attempts have followed the discoveries of small amounts of galena at Sherrill Mound, 10 miles northwest of Dubuque, and near Clinton and Anamosa (Calvin, 1896, p. 110), Iowa, which are 30–40 miles southeast and southwest of Dubuque, respectively (fig. 31).

South and west of the mining district the dolomite of Silurian age is an adequate source of water for farm wells.

POST-SILURIAN DEPOSITS

Several types of deposits of post-Silurian age have been found locally in the mining district. These include:

1. Boulders of quartz sandstone in anomalous stratigraphic positions, mostly in the Galena and Decorah. These may be related to sandstone "dikes" injected into joints from below, or as sedimentary filling from above. They occur at many localities in the central part of the mining district.
2. Boulders of hematite—near heads of ravines southeast of Hazel Green, Wis. (southwest corner of Lafayette County).
3. Boulders of quartzite and greenstone—near head of ravine in Wisconsin, 7 miles northwest of Spechts Ferry, Iowa (fig. 35, loc. 10).
4. Conglomerate at McCartney—poorly cemented aggregate of local and exotic pebbles, at crest of ridge, near No. 3, above.

These four types of deposits may have been laid down at one or more times since the end of the Silurian period. During Pennsylvanian time sandstone may have been deposited in what is now the mining district; the present northernmost exposure of sandstone of Pennsylvanian age in this general area is only 35 miles south of Dubuque. During Cretaceous time iron-cemented gravels or conglomerates were emplaced in this general region; the nearest such deposit is at Waukon, Iowa (fig. 35). During Pleistocene time it is possible that some of these deposits were laid down by any of several processes, including ice rafting. Further study of these interesting stratigraphic features is under way.

LITERATURE CITED

Agnew, A. F., 1950, Detailed stratigraphy of Galena-Decorah-Platteville sequence in Upper Mississippi Valley [abs.]: Geol. Soc. America Bull., v. 61, no. 12, pt. 2, p. 1439.

——— 1955, Facies of Middle and Upper Ordovician strata in Iowa: Am. Assoc. Petroleum Geologists Bull. v. 39, no. 9, p. 1703–1752.

Agnew, A. F., Flint, A. E., and Allingham, J. W., 1953, Exploratory drilling program of U. S. Geological Survey for evidences of zinc-lead mineralization in Iowa and Wisconsin, 1950–1951: U. S. Geol. Survey Circ. 231.

Agnew, A. F., Flint, A. E., and Crumpton, R. P., 1954, Geology and zinc-lead-barite deposits of area east of Cuba City, Wis.: U. S. Geol. Survey Mineral Inv. Ser. Field Studies Map MF 15.

Agnew, A. F., and Heyl, A. V., Jr., 1946, Quimbys Mill, new member of Platteville formation, Upper Mississippi Valley: Am. Assoc. Petroleum Geologists Bull., v. 30, p. 1585–1587.

Agnew, A. F., and Heyl, A. V., Jr., 1947, Recent developments in the Wisconsin-Illinois-Iowa lead-zinc district: Iowa Acad. Sci. Proc., v. 57, p. 225–231 [1946].

Allan, R. S., 1948, Geological correlation and paleontology: Geol. Soc. America Bull., v. 59, no. 1, p. 1–10.

Allen, V. T., 1932, Ordovician altered volcanic material in Iowa, Wisconsin, and Missouri: Jour. Geology, v. 40, p. 259–269.

Bain, H. F., 1905, Zinc and lead deposits of northwestern Illinois: U. S. Geol. Survey Bull. 246.

——— 1906, Zinc and lead deposits of the upper Mississippi Valley: U. S. Geol. Survey Bull. 294.

Bays, C. A., 1938, Stratigraphy of the Platteville formation [abs.]: Geol. Soc. America Proc. 1937, p. 269.

Bays, C. A., and Raasch, G. O., 1935, Mohawkian relations in Wisconsin: Kans. Geol. Soc. Guidebook, 9th Ann. Field Conf., p. 296–301.

Bell, W. C., 1950, Stratigraphy: a factor in paleontologic taxonomy: Jour. Paleontology, v. 24, no. 4, p. 492–496.

Bell, W. C., Feniak, O. W., and Kurtz, V. E., 1952, Trilobites of the Franconia formation, southeast Minnesota: Jour. Paleontology, v. 26, no. 2, p. 175–198.

Berg, R. R., 1953, Franconian trilobites from Minnesota and Wisconsin: Jour. Paleontology, v. 27, no. 4, p. 553–568.

——— 1954, Franconia formation of Minnesota and Wisconsin: Geol. Soc. America Bull., v. 65, p. 857–882.

Bevan, Arthur, 1926, The Glenwood beds as a horizon marker at the base of the Platteville formation: Ill. Geol. Survey, Rept. Inv. 9.

Boericke, W. F., and Garnett, T. H., 1919, The Wisconsin zinc district: Am. Inst. Min. Engineers Bull. 152, p. 1213–1235; Trans., v. 63, p. 213–243, 1920.

Bucher, W. H., 1919, On ripples and related sedimentary surface forms and their paleogeographic interpretation: Am. Jour. Sci., 4th ser., v. 47, p. 149–210, 241–269.

——— 1953, Fossils in metamorphic rocks: A review: Geol. Soc. America Bull., v. 64, p. 275–300.

Calvin, Samuel, 1896, The geology of Jones County, Iowa: Iowa Geol. Survey, v. 5, p. 33–112.

——— 1906, Geology of Winneshiek County, Iowa: Iowa Geol. Survey, v. 16, p. 37–146.

Calvin, Samuel, and Bain, H. F., 1900, Geology of Dubuque County: Iowa Geol. Survey, v. 10, p. 379–622.

Chamberlin, T. C., 1877, Geology of eastern Wisconsin: Geology of Wisconsin, v. 2, p. 91–405.

———1882, Ore deposits of southwestern Wisconsin: Geology of Wisconsin, v. 4, p. 365–571.

Cohee, G. V., 1948, Cambrian and Ordovician rocks in Michigan basin and adjoining areas: Am. Assoc. Petroleum Geologists Bull, v. 32, no. 8, p. 1417–1448.

Cox, G. H., 1911, The origin of the lead and zinc ores of the upper Mississippi Valley district: Econ. Geology, v. 6, no. 5, p. 427–448, 582–603.

Davis, R. E., 1906, Mississippi Valley lead and zinc district: Mining World, v. 24, p. 548–549.

DuBois, E. P., 1945, Subsurface relations of the Maquoketa and "Trenton" formations in Illinois: Ill. Geol. Survey Rept. Inv. 105.

Elder, S. G., 1936, The contact between the Glenwood and Platteville formations: Ill. Acad. Sci. Trans., v. 29, no. 2, p. 164–166.

Ellis, E. E., 1905, Zinc and lead mines near Dodgeville, Wis.: U. S. Geol. Survey Bull. 260, p. 311–315.

Fettke, C. R., 1948, Subsurface Trenton and sub-Trenton rocks in Ohio, New York, Pennsylvania, and West Virginia: Am. Assoc. Petroleum Geologists Bull., v. 32, p. 1457–1492.

Flint, A. E., and Brown, C. E. 1955, Geology and zinc-lead deposits in the Durango area, Dubuque County, Iowa: U. S. Geol. Survey, Min. Inv. Ser. Field Studies Map MF 33.

Fowler, G. M., and Lyden, J. P., 1932, The ore deposits of the Tri-State district: Am. Inst. Min. Engineers Tech. Pub. 446; Trans., v. 102, p. 206–251.

Goldman, M. I., 1921, Lithologic subsurface correlation in the "Bend Series" of north-central Texas: U. S. Geol. Survey Prof. Paper 129–A.

Grant, U. S., 1903, Preliminary report on the lead and zinc deposits of southwestern Wisconsin: Wis. Geol. and Nat. History Survey, Bull. 9.

——— 1906, Report on the lead and zinc deposits of Wisconsin: Wis. Geol. and Nat. History Survey, Bull. 14.

Grant, U. S., and Burchard, E. F., 1907, Description of the Lancaster and Mineral Point quadrangles: U. S. Geol. Survey Geol. Atlas, folio 145.

Grogan, R. M., 1949, Present state of knowlege regarding the pre-Cambrian crystallines of Illinois: Ill. Acad. Sci. Trans., v. 42, p. 97–102.

Grohskopf, J. G., 1948, Zones of Plattin-Joachim of eastern Missouri: Bull. Am. Assoc. Petroleum Geologists, v. 32, p. 351–365.

Hall, C. W., and Sardeson, F. W., 1892, Paleozoic formations of southeastern Minnesota: Geol. Soc. America Bull., v. 3, p. 331–368.

Hall, James, 1851, Lower Silurian system, *in* Foster, J. W., and others, Geology of Lake Superior land district: Congressional Documents, 32d Cong., Special sess., S. Ex. Doc. 4, p. 140–166; Am. Jour. Science, ser. 2, v. 17, p. 181–194, 1854.

Hall, James, 1862, Physical geography and general geology [of Wisconsin] *in* Hall, James, and Whitney, J. D., Report of the geological survey of the State of Wisconsin, v. 1, p. 1–72.

Herbert, Paul, Jr., 1946, Distribution of the limestone and dolomite phases of the Oil rock and Glass rock, *in* Willman, H. B., Reynolds, R. R., and Herbert, Paul, Jr., Geological aspects of prospecting and areas for prospecting in the zinc-lead district of northwestern Illinois: Ill. Geol. Survey Rept. Inv. 116.

Hershey, O. H., 1894, The Elk Horn Creek area of St. Peter sandstone in northwestern Illinois: Am. Geologist, v. 14, p. 169–179.

——— 1897, The term Pecatonica limestone: Am. Geologist, v. 20, p. 66–67.

Heyl, A. V., Jr., Agnew, A. F., Lyons, E. J., Behre, C. H., Jr. (in preparation), The geology of the upper Mississippi Valley zinc-lead district: U. S. Geol. Survey Prof. Paper.

Heyl, A. V., Jr., Lyons, E. J., and Agnew, A. F., 1951, Exploratory drilling in the Prairie du Chien group of the Wisconsin zinc-lead district by the U. S. Geological Survey in 1949–1950: U. S. Geol. Survey Circ. 131.

Heyl, A. V., [Jr.], Lyons, E. J., Agnew, A. F., Behre, C. H., Jr., 1955, Zinc-lead-copper resources and general geology of the Upper Mississippi Valley district: U. S. Geol. Survey Bull. 1015–G, p. 227–245.

Heyl, A. V., Jr., Lyons, E. J., and Theiler, J. L., 1952, Geologic structure of the Beetown lead-zinc area, Grant County, Wis.: U. S. Geol. Survey Min. Inv. Ser., Field Studies Map MF 3.

Howell, B. F., and others, 1944, Correlation of the Cambrian formations of North America: Geol. Soc. America, Bull., v. 55, p. 993–1003, chart.

Hubbard, G. D., 1900, The Blue Mound quartzite: Am. Geologist, v. 25, p. 163–168.

Ireland, H. A., and others, 1947, Terminology for insoluble residues: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 1479–1490.

Kay, G. M., 1928, Divisions of the Decorah formation: Science, new ser., v. 67, pt. 1, p. 16.

——— 1929, Stratigraphy of the Decorah formation: Jour. Geology, v. 37, no. 7, p. 639–671.

——— 1930, Formations subjacent to the Black River-Trenton line [abs.]: Geol. Soc. America Bull., v. 41, p. 201–202.

——— 1931, Stratigraphy of the Ordovician Hounsfield metabentonite: Jour. Geology, v. 39, p. 361–376.

——— 1932, Base of Ordovician Galena formation [abs.]: Geol. Soc. America Bull., v. 43, p. 268.

——— 1934, Mohawkian Ostracoda, species common to Trenton faunules from the Hull and Decorah formations: Jour. Paleontology, v. 8, p. 328–343.

——— 1935a, Ordovician system in the upper Mississippi Valley: Kans. Geol. Soc. Guidebook 9th Ann. Field Conf., p. 281–295.

——— 1935b, Distribution of Ordovician altered volcanic materials and related clays: Geol. Soc. America Bull., v. 46, p. 225–244.

——— 1935c, Ordovician Stewartville-Dubuque problems: Jour. Geology, v. 43, p. 561–590.

——— 1939, Stratigraphic setting, Wisconsin-Illinois district, *in* Bastin, E. S., and others, Contributions to a knowledge of the lead-zinc deposits of the Mississippi Valley region: Geol. Soc. America Special Paper 24, p. 25–28.

——— 1940, Ordovician Mohawkian Ostracoda: Lower Trenton Decorah fauna: Jour. Paleontology, v. 14, p. 234–269.

Kay, G. M., and Atwater, G. I., 1935, Basal relations of the Galena dolomite in the upper Mississippi Valley lead and zinc district: Am. Jour. Science, 5th ser., v. 29, no. 170, p. 98–111.

Kay, Marshall, 1948, Summary of Middle Ordovician bordering Allegheny synclinorium: Am. Assoc. Petroleum Geologists Bull., v. 32, no. 8, p. 1397–1416.

Keyes, C. R., 1898, Some geological formations of the Cap-au-Gres uplift [Ill.]: Iowa Acad. Sci. Proc., v. 5, p. 58–63.

Krumbein, W. C., 1947, Shales and their environmental significance: Jour. Sed. Petrology, v. 17, no. 3, p. 101–108.

Ladd, H. S., 1929, The stratigraphy and paleontology of the Maquoketa shale of Iowa: Iowa Geol. Survey, v. 34, p. 305–448.

Lattman, L. H., 1954, The sub-Eden beds of the Ohio Valley around Cincinnati: Am. Jour. Sci., vol. 252, no. 5, p. 257–276.

Lincoln, F. C., 1947, Last Chance zinc mine, Grant County, Wis.: U. S. Bur. Mines Rept. Inv. 4028.

McFarlan, A. C., and White, W. H., 1948, Trenton and pre-Trenton of Kentucky: Am. Assoc. Petroleum Geologist Bull., v. 32, no. 8, p. 1627–1646.

Nelson, W. A., 1922, Volcanic ash bed in the Ordovician of Tennessee, Kentucky, and Alabama: Geol. Soc. America Bull., v. 33, p. 605–615.

Owen, D. D., 1840, Report of a geological exploration of part of Iowa, Wisconsin, and Illinois, 1839: Congressional Documents, 26th Cong., 1st sess., H. Ex. Doc. 239.

Percival, J. G., 1855, Annual report on the geological survey of the State of Wisconsin (1854), Madison.

——— 1856, Annual report of the geological survey of the State of Wisconsin (1855), Madison.

Pettijohn, F. J., 1926, Intraformational phosphate pebbles of the Twin City Ordovician: Jour. Geology, v. 34, p. 361–374.

Phillips, J. V., 1854, The geology of the Upper Mississippi Lead region: Mining Mag., v. 2, p. 129–138.

Powers, E. H., 1935, Stratigraphy of the Prairie du Chien (upper Mississippi Valley): Kans. Geol. Soc. Guidebook 9th Ann. Field Conf., p. 350 (fig. 224), 390–394.

Raasch, G. O., 1935, Stratigraphy of the Cambrian system of the upper Mississippi Valley: Kans. Geol. Soc. Guidebook 9th Ann. Field Conf., p. 302–315.

——— 1951, Revision of Croixian Dikellocephalids: Ill. Acad. Sci., Trans. v. 44, p. 137–151.

———, 1952, Oneota formation, Stoddard quadrangle, Wisconsin: Ill. Acad. Sci. Trans., v. 45, p. 85–95.

Raymond, P. E., 1914, The Trenton group in Ontario and Quebec: Canada Geol. Survey Summary Rept. 1912, p. 342–350.

———, 1921, A contribution to the description of the fauna of the Trenton group: Canada Geol. Survey Mus. Bull. 31.

Rich, J. L., 1951, Three critical environments of deposition, and criteria for recognition of rocks deposited in each of them: Geol. Soc. America Bull., v. 62, no. 1, p. 1–20.

Sardeson, F. W., 1896a, The St. Peter sandstone: Minn. Acad. Nat. Sci. Bull., v. 4, p. 64–88.

——— 1896b, The Galena and Maquoketa series, Pt. I.: Am. Geologist, v. 18, pt. 2, p. 356–368.

——— 1897a, The Galena and Maquoketa series, Pt. II: Am. Geologist, v. 19, pt. 1, p. 21–35.

——— 1897b, The Galena and Maquoketa series, Pt. IV: Am. Geologist, v. 19, p. 180–190.

——— 1897c, Nomenclature of the Galena and Maquoketa series: Am. Geologist, v. 19, p. 330–336.

——— 1898, Intraformational conglomerates in the Galena series: Am. Geologist, v. 22, p. 315–323.

——— 1907, Galena series: Geol. Soc. America Bull., v. 18, p. 179–194.

——— 1926a, Beloit formation and bentonite (1): Pan Am. Geologist, v. 45, p. 383–392.

——— 1926b, Pioneer re-population of devastated sea bottoms: Pan Am. Geologist, v. 46, p. 273–288.

——— 1933, Stratigraphic affinities of Glenwood shales: Pan Am. Geologist, v. 60, p. 81–90.

Savage, T. E., 1905, Geology of Fayette County: Iowa Geol. Survey, v. 15, p. 433–546.

Savage, T. E., and Ross, C. S., 1916, The age of the iron ore in eastern Wisconsin: Am. Jour. Science, 4th ser., v. 41, p. 187–193.

Schuldt, W. C., 1943, Cambrian strata of northeastern Iowa: Iowa Geol. Survey, v. 38, p. 379–422.

Scott, E. R., and Behre, C. H., Jr., 1935, Structural control of ore deposition in the Wisconsin-Illinois lead-zinc district [abs.]: Ill. State Acad. Sci. Trans., v. 27, p. 117.

Shaw, E. S., and Trowbridge, A. C., 1916, Galena Elizabeth quadrangles: U. S. Geol. Survey Geol. Atlas, folio 200.

Sloss, L. L., 1947, Environments of limestone deposition: Jour. Sed. Petrology, v. 17, no. 3, p. 109–113.

Stauffer, C. R., 1925, Mineralization of the Platteville-Decorah contact zone in the Twin City region: Geol. Soc. America Bull., v. 36, p. 615–622.

———, 1935, Conodonts of the Glenwood beds: Geol. Soc. America Bull., v. 46, p. 125–168.

Stauffer, C. R., and Thiel, G. A., 1941, The Paleozoic and related rocks of southeastern Minnesota: Minn. Geol. Survey Bull. 29.

Strong, Moses, 1877, Geology and topography of the lead region: Geology of Wisconsin [Wisconsin Geol. Survey], v. 2, pt. 4, p. 643–752.

Templeton, J. S., 1948, Members of the Glenwood formation in northern Illinois and southern Wisconsin [abs.]: Geol. Soc. America Bull., v. 59, no. 12, pt. 2, p. 1357.

———, 1950, The Mt. Simon sandstone in northern Illinois: Ill. Acad. Sci. Trans., v. 43, p. 151–159.

Templeton, J. S., and Willman, H. B., 1952, Guidebook 16th Ann. Field Conf. Tri-State Geol. Soc. (central-northern Illinois): Ill. Geol. Survey.

Thiel, G. A., 1937, Petrographic analysis of the Glenwood beds of southeastern Minnesota: Geol. Soc. America Bull., v. 48, no. 1, p. 113–122.

Thwaites, F. T., 1923, The Paleozoic rocks found in deep wells in Wisconsin and northern Illinois: Jour. Geology, v. 31, no. 7, p. 529–555.

———, 1931, Buried pre-Cambrian of Wisconsin: Geol. Soc. America Bull., v. 42, no. 3, p. 719–750.

Trowbridge, A. C., and Atwater, G. I., 1934, Stratigraphic problems in the upper Mississippi Valley: Geol. Soc. America Bull., v. 45, no. 1, p. 21–80.

Trowbridge, A. C., and Shaw, E. W., 1916, Geology and geography of the Galena and Elizabeth quadrangles: Ill. Geol. Survey, Bull. 26.

Twenhofel, W. H., and others, 1954, Correlation of the Ordovician formations of North America: Geol. Soc. America Bull., v. 65, p. 247–298, chart.

Twenhofel, W. H., Raasch, G. O., and Thwaites, F. T., 1935, Cambrian strata of Wisconsin: Geol. Soc. America Bull., v. 46, no. 11, p. 1687–1744.

Ulrich, E. O., 1911a, Bearing of the Paleozoic Bryozoa on paleogeography: Geol. Soc. America Bull., v. 22, p. 252–257.

———, 1911b, Revision of the Paleozoic systems: Geol. Soc. America Bull., v. 22, p. 281–680.

———, 1924, Notes on new names in table of formations and on physical evidence of breaks between Paleozoic systems in Wisconsin: Wis. Acad. Sci., Arts, Letters Trans., v. 21, p. 71–107.

Ulrich, E. O., Foerste, A. F., and Bridge, Josiah, 1930, systematic paleontology [of late Cambrian and early Ordovician formations of Ozark region, Missouri]: Mo. Bur. Geology and Mines, 2d ser., v. 24, p. 188–212.

White, C. A., 1870, Report on the geological survey of the State of Iowa: Iowa Geol. Survey, v. 1.

Whitney, J. D., 1858, Chemistry and economical geology [of Iowa] *in* Hall, James and Whitney, J. D., Report on the geological survey of the State of Iowa, v. 1, p. 324–472.

———, 1862, Stratigraphical geology, *in* Hall, James and Whitney, J. D., Report of the geological survey of the State of Wisconsin, v. 1, p. 140–193.

Williams, James Steele, 1952, Discussion *in* Symposium of evolutionary explosions in geologic time: Jour. Paleontology, v. 26, no. 3, p. 387–388.

Willman, H. B., and Payne, J. N., 1942, Geology and mineral resources of the Marseilles, Ottawa and Streator quadrangles: Ill. Geol. Survey Bull. 66.

Willman, H. B., and Reynolds, R. R., 1947, Geological structure of the zinc-lead district of northwestern Illinois: Ill. Geol. Survey Rept. Inv. 124.

Wilmarth, M. G., 1938, Lexicon of geologic names of the United States: U. S. Geol. Survey, Bull. 896, pts. 1, 2.

Winchell, N. H., and Ulrich, E. O., 1897, The Lower Silurian deposits of the upper Mississippi province: Minn. Geol. Survey, v. 3, pt. 2, p. lxxxiii–cxxviii.

Workman, L. E., 1950, The Neda formation in northeastern Illinois: Ill. Acad. Sci. Trans., v. 43, p. 176–182.

STRATIGRAPHIC SECTIONS

Section 1.—*Type section of McGregor limestone member. Ravine from south, one mile west of McGregor, Clayton County, Iowa, NE¼ sec. 28, T. 95 N., R. 3 W. (fig. 35, loc. 25)*

[Described by Paul Herbert, Jr., and A. F. Agnew, Nov. 7, 1944; revised by Agnew, Aug. 18, 1945]

	Thickness (feet)
Decorah formation:	
Spechts Ferry shale member:	
Shale, bluish-green, very fossiliferous; many lenses of greenish-buff fine-grained earthy limestone (partly covered)	6. 0
Shale, gray	1. 6
Bentonite, with platy chocolate shale on top	. 1
Shale, brown and green, mottled	. 3
Total, Spechts Ferry	8. 0
Unnamed member:	
Limestone, dark-brownish-gray, medium crystalline	. 7
Shale, dark-brown, platy, and light-gray, orange-weathering bentonite; bentonite grades laterally into orange siltstone	. 4
Total, unnamed member	1. 1
Platteville formation:	
McGregor limestone member:	
Limestone, light-grayish-buff with buff mottled areas, fine-grained, somewhat fossiliferous	4. 8
Limestone, light-grayish-pink, very fine grained, very dense, in thin nodular beds, very fossiliferous (mainly brachiopods and bryozoans); many grayish-brown thin wavy shale partings	18. 0
Total, McGregor	22. 8
Pecatonica dolomite member:	
Limestone, somewhat dolomitic and silty, light-brown, fine- to medium-grained, sugary, in medium to thick beds; basal bed contains phosphatic nodules	18. 3

Section 2.—*Roadcut, County Trunk A, center E½ sec. 1, T. 4 N., R. 3 W., Grant County, Wis. (fig. 35, loc. 28)*

[Described by A. F. Agnew, spring 1943; revised Aug. 11, 1953]

	Thicknes (feet)
Decorah formation:	
Spechts Ferry shale member:	
Shale, green to olive, blocky; thin lenses of coquina	4. 5
Limestone, coarsely crystalline, coquinoid, wavy base; argillaceous coquina lens plastered against base	0. 3–0. 5
Limestone, light-gray, fine-grained, dense	0. 5–0. 7
Total, Spechts Ferry	5. 5
Unnamed member:	
Limestone, dark-pink, coarsely crystalline	0. 1
Shale, brownish-green, mottled	. 2
Limestone, buff, fine-grained, dense	. 5
Siltstone, dolomitic, brownish-yellow; brown soft bentonite at base, 0.1 ft thick	. 7
Total, unnamed member	1. 5
Platteville formation:	
Quimbys Mill member:	
Limestone, purplish-brown, fine- to medium-grained, dense; hard dark-brown shale at top	. 3
Total, Quimbys Mill	0. 3
McGregor limestone member (Magnolia of Bays and Raasch 1935):	
Limestone, light-gray, fine-grained, dense, conchoidal fracture	2. 0
Limestone as above, thin- to medium-bedded, fracture not conchoidal	7. 0+

Section 3.—*Quarry just west of Blanchardville, near center sec. 23, T. 4 N., R. 5 E. Lafayette County, Wis., (fig. 35, loc. 29).*

[Described by A. F. Agnew, spring, 1945]

	Thickness (feet)
Decorah formation:	
Guttenberg limestone member:	
Dolomite, buff to light-brown, thin-bedded, medium- to coarse-grained, fossiliferous; some reddish-brown shale; a 0.2 ft bed of light gray, fine, dense dolomite at base	6. 5
Platteville formation:	
Quimbys Mill member:	
Dolomite, buff, fine-grained, sugary; conchoidal fracture; very fossiliferous, especially in upper 3.5 ft; band of chert nodules 0.5 ft below top; thin limonitic fossiliferous parting at base	13. 0
McGregor limestone member (Magnolia of Bays and Raasch 1935):	
Dolomite, slightly grayish-buff, medium- to thick-bedded	12+

Section 4.—*Coon Creek section, the second ravine north of road along south line SW¼ sec. 13, T. 98 N., R. 7 W., Winneshiek County, Iowa, (6 miles east of loc. 14, fig. 35).*

[Described by A. F. Agnew, Paul Herbert, Jr., H. B. Willman, October 1, 1944; revised by Herbert, November 7, 1944]

	Thickness (feet)
Galena dolomite:	
Cherty unit (zone D):	
Limestone, buff to light-brownish, fine-grained, thin-bedded, fossiliferous; local greenish argillaceous areas and paper-thin green shale partings	15. 0±
Decorah formation:	
Ion dolomite member:	
Shale, greenish, calcareous, fossiliferous; *Prasopora*	. 4
Limestone, grayish-brown and gray, mottled, coarsely crystalline, dense, fossiliferous; local green shale partings	2. 1
Shale, essentially green to gray-green; thin lenses of nodular limestone; *Prasopora* at top	10. 9
Limestone, brownish-gray, coarsely crystalline, dense, fossiliferous; some greenish argillaceous areas; interbedded green shale	1. 4
Shales, green to gray-green	7. 9
Total, Ion	22. 7
Guttenberg limestone member:	
Limestone, gray, with dark-gray spots, medium-crystalline, fairly argillaceous	1. 0
Limestone, greenish-buff, dense, nodular, fossiliferous; green and partly brown shale; brown shale at base	4. 0
Limestone, greenish-gray with dark-gray mottlings, dense, nearly lithographic, fossiliferous; some green calcareous shale	1. 5
Total, Guttenberg	6. 5
Spechts Ferry shale member:	
Shale, green to blue-green, with interbedded lenses of greenish fossiliferous coquina-like limestone; thin orange-weathering bentonite 2.4 ft above base	14. 5
Total, Spechts Ferry	14. 5
Unnamed member:	
Limestone, dark-gray, dense, glassy; thin brownish shale at top and base	. 7
Limestone, light-brown, mottled gray, dense	1. 1
Bentonite, orange-weathering	. 2
Shale, dark-brown	. 1
Total, unnamed member	2. 1
Total, Decorah	45. 8
Platteville formation: McGregor limestone member:	
Limestone, medium-gray, mottled, glassy, thin-bedded	1. 5

Section 5. *Quarry, 1 mile north of Darlington, in SW¼SE¼ sec. 27, T. 3 N., R. 3 E. Lafayette County, Wis. (2 miles north of loc. 13, fig. 35)*

[Described by A. F. Agnew, August 11, 1945; revised April 7, 1946]

	Thickness (feet)
Decorah formation:	
Ion dolomite member:	
Dolomite, light-grayish-blue, coarsely crystalline, sugary, thin-bedded; very fossiliferous near base	9+
Shale, white to light-brown; weathers yellowish-orange like bentonite but is hard and gritty because of dolomite grains	. 2
Guttenberg limestone member:	
Dolomite, light-brownish-buff, otherwise like Ion above; in thin nodular beds, but weathers massive; fossiliferous	3. 0
Dolomite as above, but weathers to thin beds	5. 0
Total, Guttenberg	8. 0
Spechts Ferry shale member:	
Limestone, like Quimbys Mill below, but greenish-gray; dolomitic shale parting at base	. 2
Total, Spechts Ferry	0. 2
Platteville formation:	
Quimbys Mill member:	
Limestone, buff, fine-grained, greenish-gray mottled dolomitic shale parting at top; fucoidal openings containing phosphatic pebbles and green shale fragments in upper 0.2 ft	. 5
Dolomite, light-grayish-buff, slightly pinkish, fine-grained, dense, medium-thick bedded, nodular; conchoidal fracture	13. 5

Section 6.—*Quarry Ice Cave Bridge, NE¼NW¼ sec. 15, T. 98 N., R. 8 W., Decorah, Winneshiek County, Iowa (fig. 35)*

[Described by Paul Herbert, Jr., Nov. 9, 1944; revised by Herbert and Agnew, Sept. 1, 1945]

	Thickness (feet)
Decorah formation:	
Spechts Ferry shale member:	
Rubble of green shale and limestone blocks; thin bentonite 0.3 ft above base	5 +
Shale, dark-green to olive, blocky; 0.2 ft grayish-buff argillaceous limestone beds at top and base	1. 3
Shale, green above, dark brownish-gray mottled green and olive at base	. 9
Thickness, Spechts Ferry	7. 2+
Unnamed member:	
Limestone, light-brown, fine-grained, very dense, medium-bedded; thin yellowish shale parting at top; undulatory lower surface	2. 4–2. 7
Shale and siltstone, buff to orange, bentonitic; grades laterally into bentonite; brown platy shale at base	0. 2–0. 5
Thickness, unnamed member	2. 9
Platteville formation:	
McGregor limestone member:	
Limestone, gray, weathers light-brown, mottled grayish	10 +

Section 7.—*Ravine, west of State Route 51, near center W½NE¼ sec. 32, T. 97 N., R. 5 W., Allamakee County, Iowa (fig. 35, loc. 35).*

[Described by A. F. Agnew, June 29, 1953]

	Thickness (feet)
Decorah formation:	
Guttenberg limestone member:	
Limestone, grayish-buff, fine-grained, dense, fossiliferous; buff platy interbedded shale	10. 0
Covered	10. 0
Unnamed member:	
Limestone, flesh-colored, fine-grained, dense, fossiliferous	. 8
Limestone in 2 beds, the upper like that above; the lower bluish to flesh-colored	. 5
Bentonite, orange, soft	0. 1–0. 2
Thickness, unnamed member	1. 4–1. 5+
Platteville formation:	
McGregor limestone member:	
Limestone, buff to flesh-colored, mottled brown, fine-grained, dense	. 5
Limestone, buff, thin-bedded	22. 0±

Section 8.—*Quarry at Spechts Ferry, Iowa, near center sec. 4, T. 90 N., R. 2 E., Dubuque County, Iowa (fig. 35, loc. 10)*

[Described by A. F. Agnew, November 1942; revised October 1945.]

	Thickness (feet)
Decorah formation:	
Guttenberg limestone member ("oil rock"):	
Limestone, tan to light-pinkish-brown, fine-grained, dense, conchoidal fracture, nodular; interbedded brown shaly partings	12. 4
Spechts Ferry shale member (clay bed):	
Limestone, light- to medium-brown, fine grained, crystalline, dense, nodular; phosphatic pebbles rare near top; olive-brown shale parting at top	. 7
Shale, greenish and brownish, weathers brown; blocky	. 3
Limestone, light-brown to buff, slightly mottled greenish, finely crystalline, dense, fossiliferous; phosphatic nodules rare at base; basal contact wavy	1. 0
Shales, greenish-blue and purplish-gray, blocky, thin-bedded; with thin coquinas and dark-brown weathered zones	1. 3
Limestone, light-greenish-gray, fine-grained, dense	0. 1–. 2
Shale, greenish-blue, blocky, very fossiliferous	. 3
Limestone as above, with coquina at top	. 2
Shale, greenish-blue, blocky	. 8
Coquina	. 1
Limestone as above	. 3
Shale, greenish-blue, blocky	. 2
Limestone as above	. 3
Shale, yellowish-olive, soft, clayey	. 1
Shale, purplish-gray, thin-bedded, calcareous, fossiliferous	. 4
Shale, soft, olive, weathers orange (fossil remains?)	. 0–. 1
Shale, dark-grayish-green, blocky	. 9
Limestone, dark-greenish-gray, fine-grained, dense, conchoidal fracture	. 3

Section 8.—*Quarry at Spechts Ferry, Iowa, etc.*—Continued

	Thickness (feet)
Decorah formation—Continued	
Guttenberg limestone member—Continued	
Shale, dark-grayish-olive, hard, calcareous, fossiliferous	. 1
Limestone, as next above	. 5
Shale, dark-brownish-gray	. 1
Bentonite, weathering yellowish-orange	. 1
Shale, dark-brownish-gray, blocky	. 3
Limestone, as next above; brownish in lower 0.1 ft	. 3
Total, Spechts Ferry	8. 8
Platteville formation:	
Quimbys Mill member ("glass rock"):	
Shale, dark-brown, mottled with greenish areas, hard, thin-bedded	0. 1
Shale, dark-brown, platy, and brown dense limestone	. 2
Total, Quimbys Mill	0. 3
McGregor limestone member (Magnolia [of Bays and Raasch 1935] Trenton):	
Limestone, light-grayish-buff near top, merging into light-greenish-gray below, finely crystalline, dense, fossiliferous, conchoidal fracture	3. 1

Section 9.—*Bluff, southeast bank Galena River, in NW¼NE¼ sec. 15 T. 1 N., R. 1 E., Lafayette County, Wis. (one mile south of loc. 27, fig. 35)*

[Described by A. F. Agnew, September 18, 1944]

	Thickness (feet)
Decorah formation:	
Guttenberg limestone member ("oil rock"):	
Limestone, light pinkish-buff, fine-grained, dense, conchoidal fracture, nodular, fossiliferous; light-brown, chocolate-colored shale	13±
Spechts Ferry shale member (clay bed):	
Shale, brown and greenish-olive, blocky	. 3
Limestone, light-gray, very thin bedded, nodular, fine-grained, dense, fossiliferous	. 9
Limestone, mottled pink and greenish, fine-grained, dense, fossiliferous; phosphatic nodules abundant	. 4
Shales, greenish and brownish, calcareous; limestone nodules; greenish and pink coarsely crystalline coquina	0. 1–. 2
Limestone, light-greenish-gray, very fine grained, very dense, sublithographic, nodular	1. 0
Bentonite, white; weathers orange-brown	0. 1–. 2
Limestone, nodular, as above but unfossiliferous	0. 1–. 2
Total, Spechts Ferry	3. 0–3. 1
Platteville formation:	
Quimbys Mill member ("glass rock"):	
Limestone, dark-pink, more coarsely crystalline than above, nodular, fossiliferous	0. 1
Limestone, purplish, medium-grained, dense, conchoidal fracture	6+

Section 10.—*Quarry half a mile east of Calamine, Wis., just north of the bend in the road, near the southwest corner sec. 9, T. 3 N., R. 3 E., Lafayette County, Wis. (fig. 35, loc. 42)*

[Described by A. F. Agnew, August 11, 1945]

	Thickness (feet)
Decorah formation:	
Guttenberg limestone member:	
Dolomite, light-brown to buff, weathers light-yellow-buff; fine- to medium-grained; fossiliferous; in thin, wavy beds with light-brown argillaceous and thin platy shale partings; very shaly and fossiliferous in lower 0.5 ft	5+
Dolomite, light-brown to buff, fine-grained, fossiliferous; very sandy with dolomite granules	2
Dolomite, light-grayish-buff, finely granular, dense	.1
Spechts Ferry shale member:	
Dolomite, greenish and buff-spotted, argillaceous, containing phosphatic nodules; otherwise not fossiliferous	0.0–.1
Platteville formation:	
Quimbys Mill member:	
Dolomite, light-grayish-buff, slightly pinkish, fine-grained, medium-bedded, nodular; light-brownish-buff argillaceous and platy shale partings rare, fossiliferous; zone of involutions at top contains phosphatic pebbles and green argillaceous dolomite inclusions	11.5

Section 11.—*Roadcut, U. S. Highway 52, about 1 mile north of Guttenberg, Iowa, in SW¼ sec. 5, T. 92 N., R. 2 W., Clayton County, Iowa (fig. 35, loc. 33)*

[Described by A. F. Agnew, Paul Herbert, Jr., H. B. Willman, October 1, 1944; revised by Herbert and Agnew, September 3, 1945]

	Thickness (feet)
Decorah formation:	
Ion dolomite member:	
Limestone, dark-gray to pinkish, crystalline, dense, thinly bedded	2.7
Shale, gray-green, platy, calcareous	.3
Limestone, as above, but more bluish and fossiliferous	.8
Shale, as above	.8
Guttenberg limestone member:	
Limestone, slightly more pink than above, becoming darker pinkish brown downward, nodular; reddish-brown shale common	6.9
Shale, brown, wavy-bedded, some reddish cast	.3
Limestone as above	7.6
Shale, light-brown	.1
Limestone as above, but very dense, glassy, with conchoidal fracture	.6
Total, Guttenberg	15.5
Spechts Ferry shale member:	
Shale, greenish-olive, weathering brownish, platy, fossiliferous	.4
Limestone, light-grayish-brown to grayish-green; argillaceous phosphatic nodules common	.7
Shale, green, blocky; thin coquina beds	1.5
Limestone, blue-green; in thin beds, very fossiliferous	1.1

Section 12.—*Quarry ¼-mile north of York Church, Wis., near center sec. 5, T. 4 N., R. 6 E., Green County, Wis. (fig 35, loc. 44)*

[Described by A. F. Agnew, spring, 1943]

	Thickness (feet)
Decorah formation:	
Ion dolomite member:	
Shale, gray-green, gritty, somewhat fossiliferous, thin-bedded argillaceous greenish-gray dolomite	4.0
Dolomite, in thicker beds but otherwise similar to that above	5.5
Guttenberg limestone member:	
Dolomite, light-gray to buff, pinkish, medium- to fine-grained, somewhat vuggy, thin- to medium-bedded, nodular; a few very thin stringers of reddish-brown platy shale; at base a 0.1-ft zone of red shale and pinkish dolomite	6.5
Platteville formation:	
Quimbys Mill member:	
Dolomite, light-cream to buff, fine-grained, very dense, semiconchoidal fracture; layer of chert 1.5 ft below top; at base a thin reddish-brown indistinct shale parting	13.0

Section 13.—*Quarry, 500 feet south of County Trunk U, near center of SE¼ sec. 18, T. 3 N., R. 3 W., Grant County, Wis. (fig. 35, loc. 47)*

[Described by A. F. Agnew, July 1, 1945]

	Thickness (feet)
Galena dolomite:	
Cherty unit (zone *D*):	
Dolomite, buff, vuggy, coarse-grained	8.5
Decorah formation:	
Ion dolomite member (gray beds):	
Shale parting, olive-gray, dolomitic	.1
Limestone, dolomitic, buff to gray, coarsely crystalline, vuggy	1.4
Shale, greenish-gray, argillaceous; greenish-gray shaly dolomite	.7
Limestone as above	9.3
Limestone, light-gray, coarsely crystalline	2.5
Total, gray beds	14.0
Ion dolomite member (blue beds):	
Shale, olive-gray, very fossiliferous; thin coquina beds	1.6
Limestone, dark-gray, medium-crystalline, dense	.5
Shale, greenish-gray	.1
Limestone as above	.9
Shale as above	.3
Limestone as above	1.6
Shale as above	.2
Limestone, grayish-green, coarsely crystalline; rounded medium-sized quartz sand grains	.7
Shale parting, greenish-gray	.1
Limestone, light-gray to buff, coarsely crystalline, transitional with Guttenberg limestone below	1.5
Total, blue beds	7.5
Total, Ion	21.5
Guttenberg limestone member ("oil rock"):	
Limestone, light brownish-pink, medium-crystalline, dense, fossiliferous; brownish wavy thin shale beds	5+

Section 14.—*Quarry, southwest edge of Darlington, Wis., in SE¼ sec. 3, T. 2 N., R. 3 E., Lafayette County, Wis. (fig. 35, loc. 13)*

[Described by A. F. Agnew, summer 1943]

	Thickness (feet)
Galena dolomite:	
Cherty unit (zone *C*):	
Dolomite, grayish-buff, coarse-grained, mottled; bands of chert nodules common	2. 0
Galena and Decorah formations:	
Cherty unit (zone *D*)—Ion member (gray beds):	
Dolomite, light creamy-gray to light-olive, coarsely granular, mottled	15. 0
Decorah formation:	
Ion dolomite member (gray beds):	
Dolomite, lighter colored than above; a very few olive-buff shale beds, including a 0.1-foot shale 2 feet from top, and a 0.2-ft shaly zone 2.5 ft above base	10. 5
Ion dolomite member (blue beds):	
Dolomite, dark-bluish-gray to light-blue, fine- to medium-grained, with much interbedded shale—the upper 0.5 ft is very shaly, fossiliferous	6. 0
Guttenberg limestone member ("oil rock"):	
Dolomite, reddish, very coarse-grained, vuggy	3+

INDEX