Information Circular
Number 11

UNIVERSITY EXTENSION

The University of Wisconsin
Geological and Natural History Survey
George F. Hanson, State Geologist & Director

FIELD TRIP GUIDE BOOK FOR

Cambrian-Ordovician Geology of Western Wisconsin

Special Papers

Lithologic Cycles in Lower Paleozoic Rocks of Western Wisconsin
Meredith E. Ostrom

Lithostratigraphy of the Prairie du Chien Group
Richard A. Davis, Jr.

FIELD TRIP COMMITTEE

Meredith E. Ostrom
Richard A. Davis, Jr.
Lewis M. Cline

Prepared for the Annual Meeting of

THE GEOLOGICAL SOCIETY OF AMERICA
and
ASSOCIATED SOCIETIES

Milwaukee, Wisconsin, 1970

Available from the Geological and Natural History Survey, the University of Wisconsin, 1815 University Ave., Madison, Wis., 53706. Price $2.50.

WISCONSIN GEOLOGICAL & NATURAL HISTORY SURVEY

Information Circular ~~12~~ 11

Errata

Page 4, Figure 4. Contact of Stockton Hill and Hager City members should coincide with contact of Hickory Ridge with the Mound Ridge.

Page 35, Title. Lithostratigraphy of the Prairie du Chien Group.

Page 40, first line. U. S. Highway 63.....

Page 43, B. Close parentheses after Oneota Formation.

Page 47, Symbol Key omits. [◇] Calcite spar.

Page 50, diagram of Stop 2. Chippewa River, not Wisconsin River.

Page 76, Figure 25 ...... the Oneota Formation at .....

Page 78, Figure 27 ...... with Oneota Formation in ....

Page 83 and 84, mileages 212.9, 215.1, 216.7, 217.3, 220.3. Prairie du Chien dolomite.

TABLE OF CONTENTS

TABLES

PLATE

STOPS

INTRODUCTION

The geologic history and correlation of Upper Cambrian and Lower and Middle Ordovician rocks in the Upper Mississippi Valley area have long been the subject of study and controversy. As with all things the development of new information and new ideas provides a basis for review and for change or retirement of traditional concepts. This field trip is intended to acquaint visitors to the Upper Mississippi Valley area with the Lower Paleozoic rocks of the area and to review some of the more pertinent changes in interpretation and correlation that have taken place over the past 20 years. Due to the limitations imposed by time and distance only selected outcrops can be visited. Many other exposures that demonstrate the principles described here, often to much better advantage, occur outside the route area.

The ideas and concepts formulated prior to 1935 and which were integrated in the guidebook to field trips for the Ninth Annual Field Conference of the Kansas Geological Society (1935) and in a paper by Twenhofel et al (1935) prevailed up to about 1950. Since 1950, and especially since about 1960, there has been a resurgence of interest in the Cambrian and Ordovician rocks of the area.

These rocks were the subject of several articles of Field Trip Number 2 for the Geological Society of America in 1956 (Sloan) when it was held in Minneapolis, Minnesota. New information and ideas provided by studies that have been completed since that time but especially in the past 20 years serve as a basis for reevaluation of former concepts. A partial listing of these studies includes Starke (1949), Boebel (1950), Raasch (1951, 1952), Raasch and Unfer (1964), Templeton (1951), Ericson (1951), Ahlen (1952), Boardman (1952), Berg (1954), Andrews (1955), Dapples (1955), Nelson (1956), Bell et al (1956), Heller (1956), Kraft (1956), Farkas (1958), Driscoll (1959), Shea (1960), Buschbach (1960), Emrich (1962), Templeton and Willman (1963), Ostrom (1964a, 1964b, 1965, 1966, 1969), Ostrom and Slaughter (1969), Davis (1966a, 1966b, 1969), Melby (1967), Morrison (1968), and Asthana (1969).

This conference provides the opportunity to examine and judge first hand some of the field data pertinent to revisions in interpretation and correlation of the Lower Paleozoic rocks of the area. In addition there are included two papers that summarize some of these changes. The subject matter of these papers deals with historical interpretation and with classification and correlation. Subjects covered are cyclical sedimentation (Ostrom), and classification and correlation of the Prairie du Chien Group (Davis). For detailed discussions the reader is referred to the original works.

Geologic and geographic orientation for the field trip is provided by the geologic map (Figure 1), the glacial deposits map (Figure 2), the map of the buried Precambrian surface (Figure 3), the stratigraphic column (Figure 4), and by highway maps (Figures 5 and 6).

The Committee gratefully acknowledges the comments and suggestions of George F. Hanson, Chairman of field trips for the annual meeting of the Geological Society of America, 1970. The patience and resourcefulness of Roger Peters who drafted the outcrop diagrams and assisted with other drafting chores and the capable secretarial services of Mrs. Adeline Colvin and her assistants Mrs. Beth Czerwonka and Miss Marilyn Gabel are also acknowledged.

M.E.O.

Figure 1

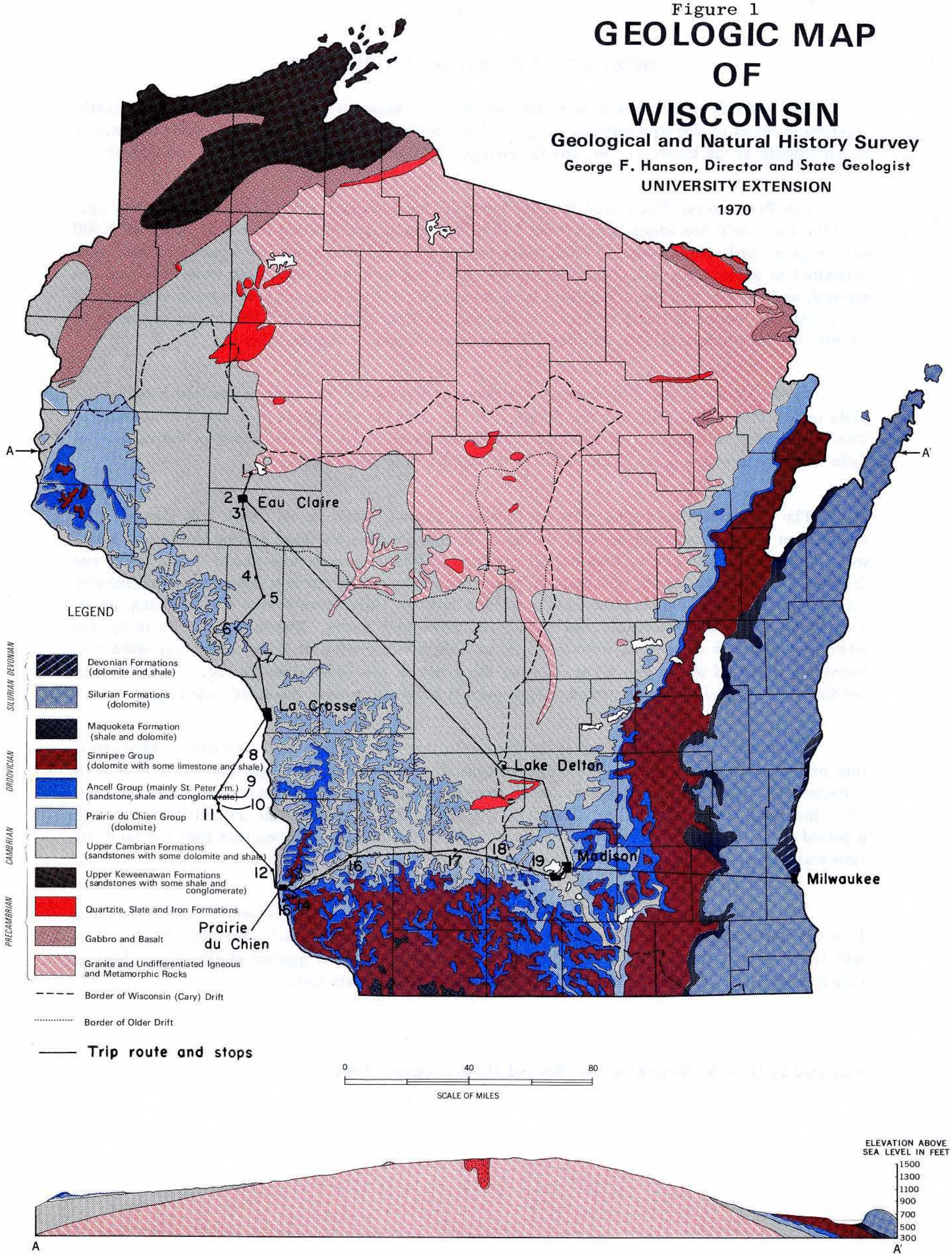
GEOLOGIC MAP OF WISCONSIN

Geological and Natural History Survey

George F. Hanson, Director and State Geologist

UNIVERSITY EXTENSION

1970



SHORT GEOLOGIC HISTORY OF WISCONSIN

The bedrock of Wisconsin is separated into two major divisions: (1) older, predominantly crystalline rocks of the Precambrian Era, which were extensively deformed after their deposition by movements of the Earth's crust; and (2) younger flat-lying sedimentary rocks of the Paleozoic.

The Precambrian Era lasted from the time the earth cooled, over 4,000 million years ago, until the Paleozoic Era which began about 500 million years ago. During this vast period of 3,500 million years sediments, some of which were rich in iron and which now form our iron ores, were deposited in ancient oceans, volcanoes spewed forth ash and lava, mountains were built and destroyed, and the rocks of the upper crust were invaded by molten rocks of deep-seated origin. Only a fragmentary record of these events remains but, as tree stumps attest the former presence of forests, the rocky roots tell the geologist of the former presence of mountains.

At the close of the Precambrian Era most of Wisconsin had been eroded to a rather flat plain upon which stood hills of more resistant rocks as those now exposed in the Baraboo bluffs. There were still outpourings of basaltic lava in the north and a trough formed in the vicinity of Lake Superior in which great thicknesses of sandstone were deposited.

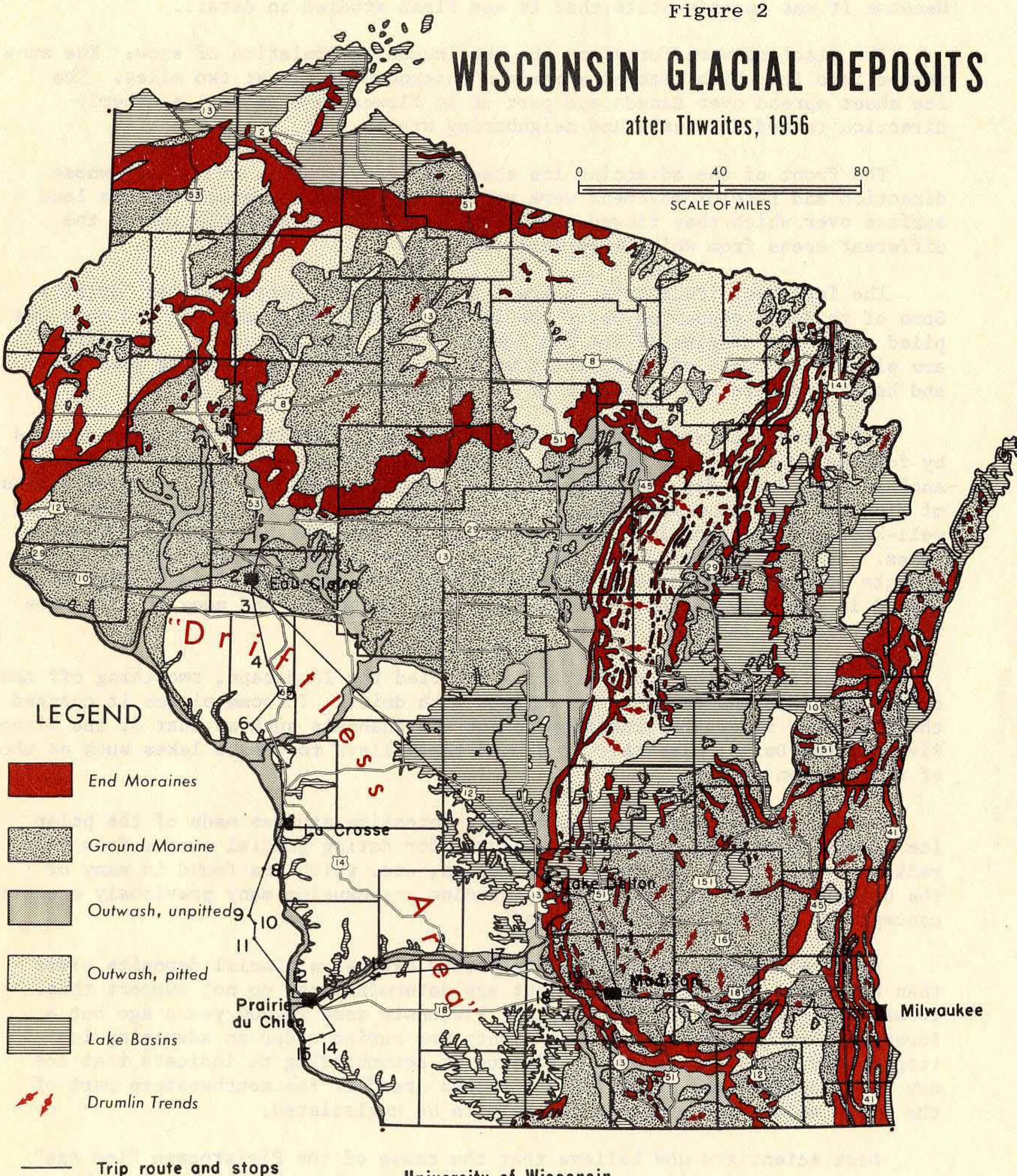
The Paleozoic Era began with the Cambrian Period, the rocks of which indicate that Wisconsin was twice submerged beneath the sea. Rivers draining the land carried sediments which were deposited in the sea to form sandstones and shales. Animals and plants living in the sea deposited calcium carbonate and built reefs to form rocks which are now dolomite—a magnesium-rich limestone. These same processes continued into the Ordovician Period during which, as indicated by the rocks, Wisconsin was submerged three more times. Deposits built up in the sea when the land was submerged were partially or completely eroded at times when they were subsequently elevated above sea level. During the close of the Ordovician Period, and in the succeeding Silurian and Devonian periods, Wisconsin is believed to have remained submerged.

There are no rocks outcropping in Wisconsin that are younger than Devonian. Absence of this part of the rock record makes interpretation of post-Devonian geologic history in Wisconsin a matter of conjecture. Available evidence from neighboring areas, where younger rocks are present, indicates that towards the close of the Paleozoic Era, perhaps some 250 million years ago, a period of gentle uplift began which has continued to the present. During this time the land surface was carved by rain, wind and running water.

The final scene took place during the last million years when glaciers invaded Wisconsin from the north and sculptured the land surface. They smoothed the hill tops, filled the valleys and left a deposit of glacial debris over all except the southwest quarter of the State where we may now still see the land as it might have looked a million years ago.

Prepared by U. of W. Geological and Natural History Survey, 1963.

Figure 2



University of Wisconsin

Wisconsin Geological and Natural History Survey

George F. Hanson, Director and State Geologist

SHORT HISTORY OF THE ICE AGE IN WISCONSIN

The Pleistocene Epoch or "Ice Age" began about 1,000,000 years ago which, in terms of geologic time, is a very short time ago. There were four separate glacial advances in the Pleistocene each followed by an inter-glacial period when the ice receded. The fourth glacial stage is called the Wisconsin Stage because it was in this State that it was first studied in detail.

The glaciers were formed by the continuous accumulation of snow. The snow turned into ice which reached a maximum thickness of almost two miles. The ice sheet spread over Canada and part of it flowed in a general southerly direction toward Wisconsin and neighboring states.

The front of the advancing ice sheet had many tongues or "lobes" whose direction and rate of movement were controlled by the topography of the land surface over which they flowed and by the rates of ice accumulation in the different areas from which they were fed.

The ice sheet transported a great amount of rock debris called "drift". Some of this was deposited under the ice to form "ground moraine" and some was piled up at the margins of the ice lobes to form "end moraines". "Drumlins" are elongated mounds of drift which were molded by the ice passing over them and hence indicate the direction of ice movement.

The pattern of end moraines, in red, shows the position that was occupied by four major ice lobes. One lobe advanced down the basin of Lake Michigan, another down Green Bay, a third down Lake Superior and over the northern peninsula of Michigan and yet a fourth entered the state from the northwest corner. The well-known "Kettle Moraine" was formed between the Lake Michigan and Green Bay lobes. As the ice melted the drift was reworked by the running water. Large amounts of sand and gravel were deposited to form "outwash plains"; pits were formed in the outwash where buried blocks of ice melted and many of these are now occupied by lakes.

The action of the ice profoundly modified the landscape, smoothing off the crests of hills and filling the valleys with drift. In some places it changed the course of rivers forcing them to cut new channels such as that of the Wisconsin River at the Dells; elsewhere it dammed the valleys to create lakes such as those of the Madison area.

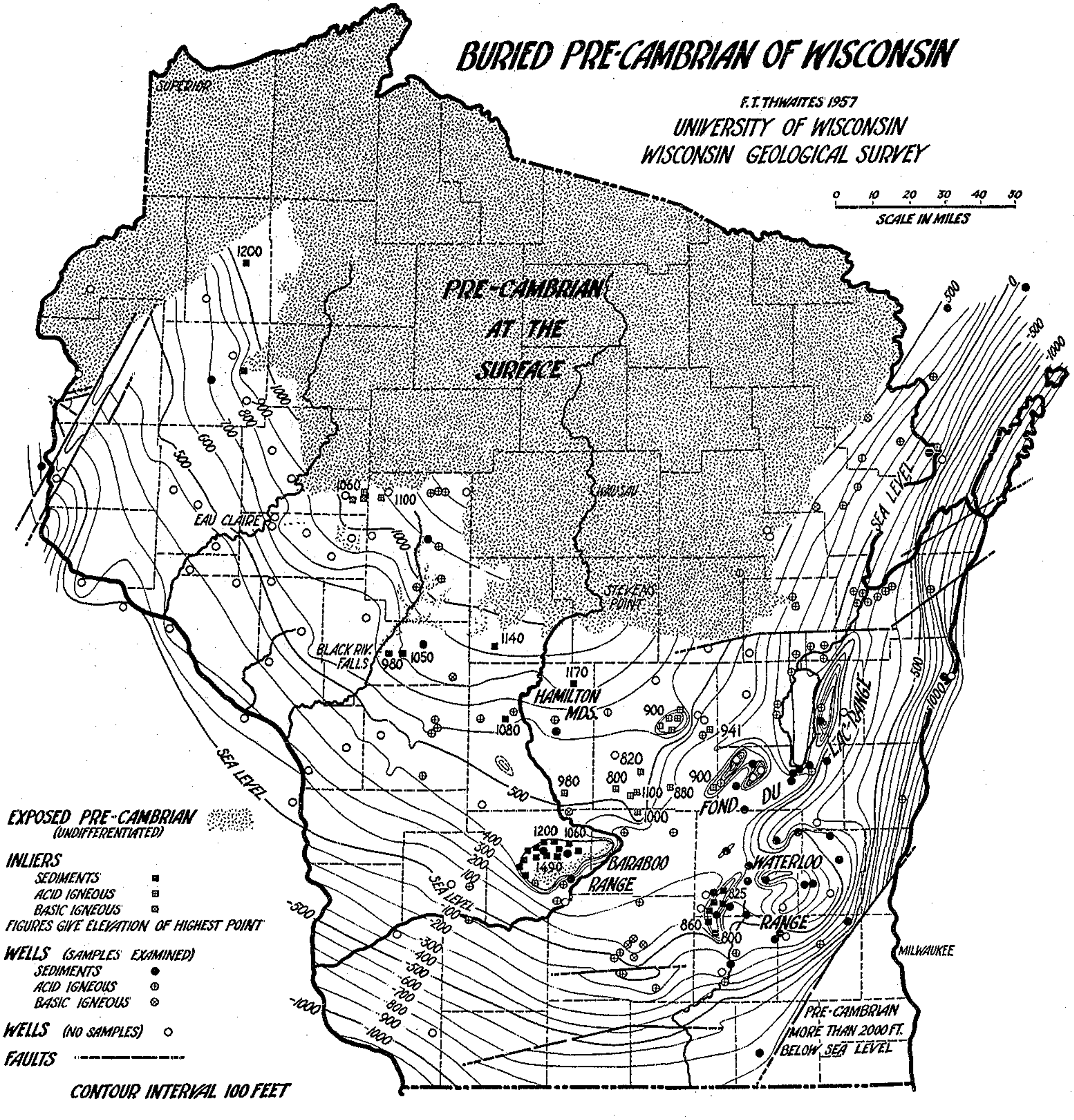
During recent years there have been intensive studies made of the polar ice caps, and methods have been developed for dating glacial events from the radioactivity of the carbon in wood, bones, etc. which are found in many of the deposits. The results of these studies are causing many previously accepted concepts to be changed or challenged.

We once thought that there were rather extensive glacial deposits older than Wisconsin age in the State, but age determinations do not support this. It was also thought that the ice left Wisconsin some 20,000 years ago but a forest at Two Creeks in Manitowoc County was buried under an advancing ice tongue only 11,000 years ago. Evidence is accumulating to indicate that ice may have occupied the so-called "Driftless Area" of the southwestern part of the State which hitherto has been held to be unglaciated.

Most scientists now believe that the cause of the Pleistocene "Ice Age" was due to variations in the solar energy reaching the earth, but how these may have occurred is still a matter of conjecture. We are still in the Ice Age and it is anybody's guess whether future millenia will see the melting of the ice caps and the slow drowning of our coastal cities, or the regrowth and once more the inexorable advance of the glaciers.

Prepared by the University of Wisconsin Geological & Natural History Survey, August 1964

Figure 3


BURIED PRE-CAMBRIAN OF WISCONSIN
F.T. THWAITES 1957
UNIVERSITY OF WISCONSIN
WISCONSIN GEOLOGICAL SURVEY
0 10 20 30 40 50
SCALE IN MILES
PRE-CAMBRIAN AT THE SURFACE
SUPERIOR
EAU CLAIRE
WAUSAU
STEVENS POINT
BLACK RIV. FALLS
HAMILTON MDS.
FOND DU LAC RANGE
BARABOO RANGE
WATERLOO RANGE
MILWAUKEE
SEA LEVEL
PRE-CAMBRIAN MORE THAN 2000 FT. BELOW SEA LEVEL
EXPOSED PRE-CAMBRIAN (UNDIFFERENTIATED)
INLIERS
SEDIMENTS
ACID IGNEOUS
BASIC IGNEOUS
FIGURES GIVE ELEVATION OF HIGHEST POINT
WELLS (SAMPLES EXAMINED)
SEDIMENTS
ACID IGNEOUS
BASIC IGNEOUS
WELLS (NO SAMPLES)
FAULTS
CONTOUR INTERVAL 100 FEET

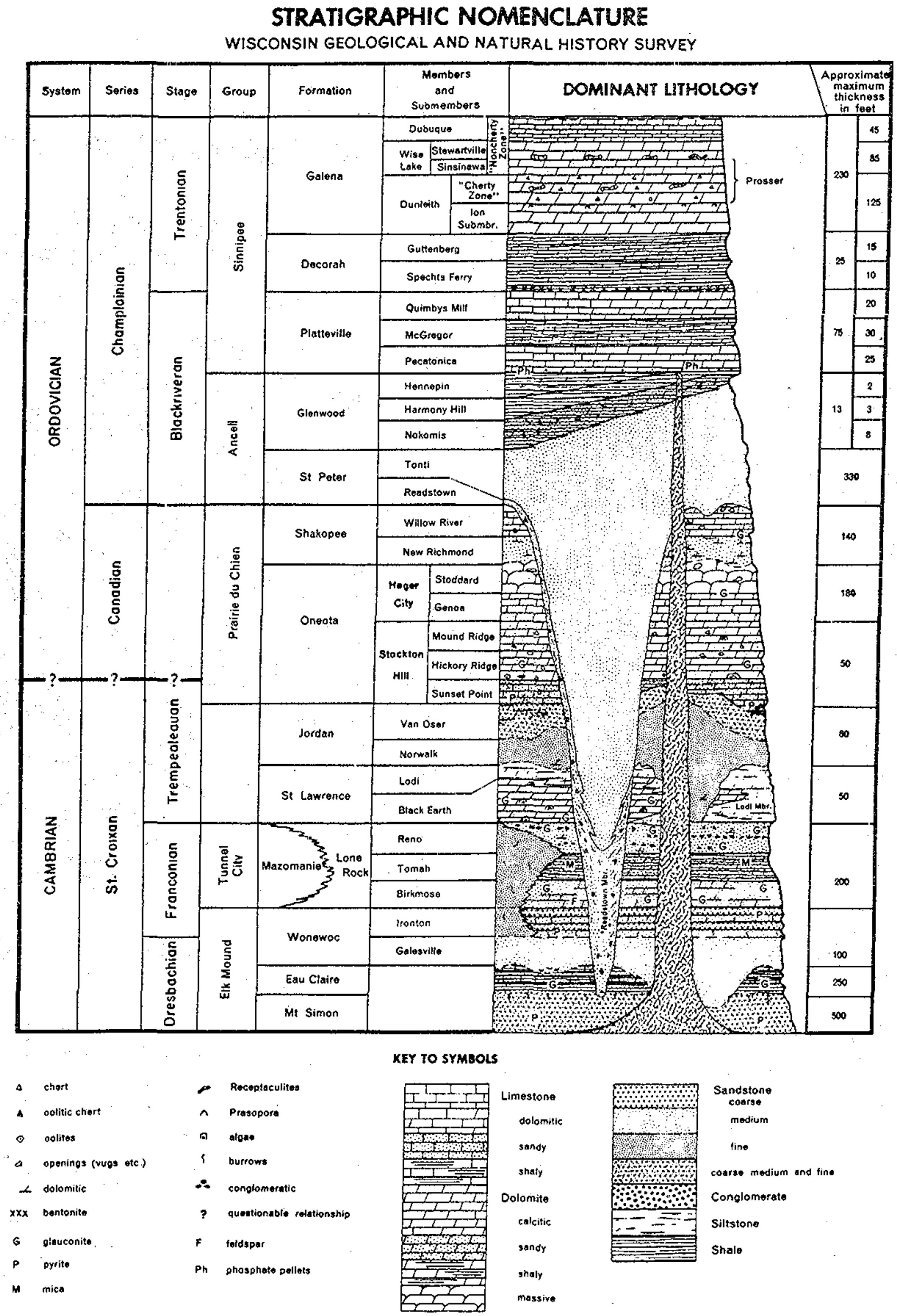
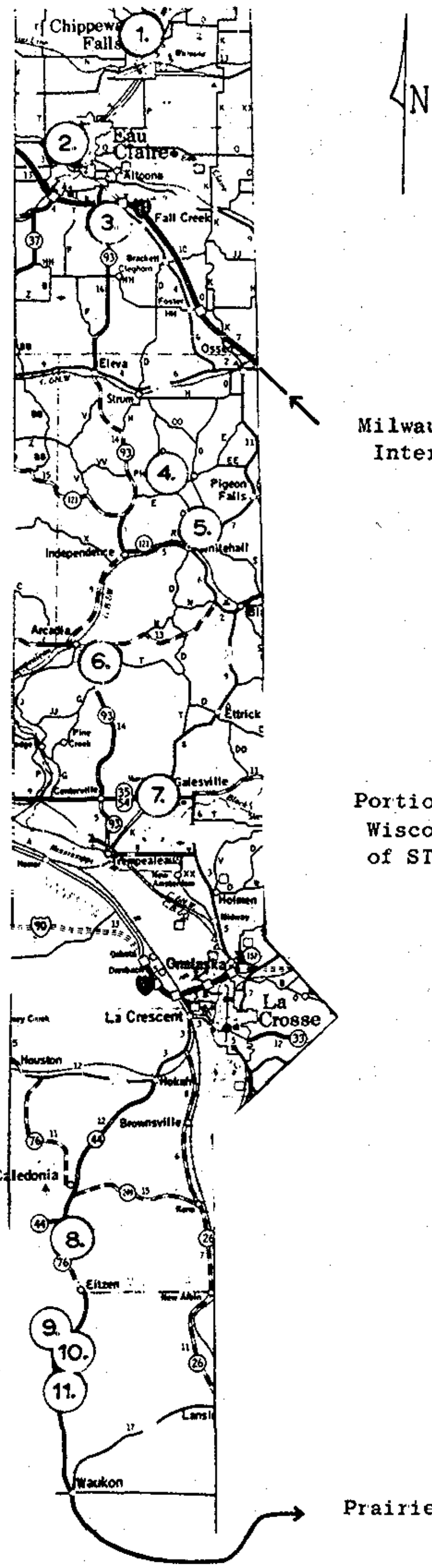


Figure 4. Stratigraphic column of Upper Cambrian and Lower and Middle Ordovician rocks of Wisconsin (modified from Ostrom, 1967).



Milwaukee 224 miles via
Interstate Highway 94

Figure 5

Portion of official roadmap of Wisconsin showing locations of STOPS 1 through 11.

Prairie du Chien 28 miles

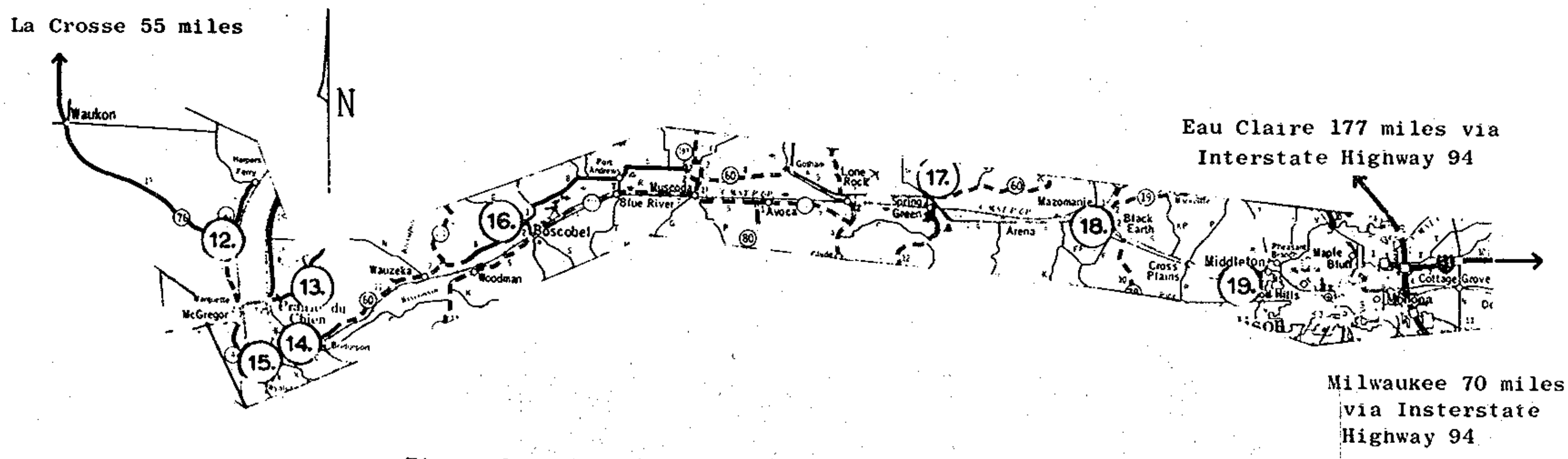


Figure 6

Portion of official roadmap of Wisconsin showing locations of STOPS 12 through 19

SEDIMENTATION CYCLES IN THE LOWER PALEOZOIC ROCKS OF WESTERN WISCONSIN

by
Meredith E. Ostrom*

INTRODUCTION

Lower Paleozoic rocks of the Upper Mississippi Valley area have long been recognized as cyclic. In 1964 the author discussed previous work and presented his own conclusions on the basis of a re-study of the area. The following discussion is based primarily on the former presentation but does include more recent observations. It has been prepared for the Cambro-Ordovician field trip of the 1970 Geological Society of America annual meeting.

Four major lithotopes are present in the Lower Paleozoic rocks of the Upper Mississippi Valley. These are: (1) thick-bedded, medium to coarse-grained, well-sorted, and cross-bedded quartzarenite; (2) medium to thin-bedded, reworked quartzarenite characterized by alternating poorly-sorted sandstone which is commonly burrowed, calcareous, slightly glauconitic and shaly and of well-sorted, medium to coarse-grained sandstone; (3) shale or argillaceous thin-bedded sandstone that is fine-grained, glauconitic, and shaly with minor carbonate; and (4) carbonate or sandy or silty carbonate or calcareous siltstone. Each lithotope is interpreted as the manifestation of a different and distinct marine shelf sediment zone which has its analogue in recent sediments such as those of the Northwest Gulf of Mexico (Van Andel and Curray, 1960).

Previous investigators recognized the broad cyclic pattern in the Lower Paleozoic rocks of this area and described them as an alternating sequence of carbonates and sandstones but relationships of beds and the implications of these relationships were only poorly known and described. Berg, Nelson, and Bell (1956) recognized four principal lithotopes which occur repeatedly in the Upper Cambrian rocks of Southeastern Minnesota and which coincide approximately with those described in this paper. The major differences between their work and this paper is in interpretation and in expansion to include the Lower and Middle Ordovician rocks of the area.

Berg et al (op. cit.) interpreted the Mt. Simon through Galesville formations as a record of a "...relatively simple transgressive-regressive cycle of marine sedimentation across an area of moderately low relief." The nearshore deposits of the transgressive and regressive phases of their cycle consist of medium to coarse-grained quartzose sandstones which are, respectively, the Mt. Simon Formation and the Galesville Member of the Wonewoc Formation. In their opinion the Galesville is topped by a disconformity which they attribute to pre-Franconia erosion and which they, at least in part, believe is responsible for regional thinning of the underlying rocks.

In the present study no evidence for disconformity of the Galesville and overlying Ironton Sandstone was found: their contact is transitional. However, the basal contact of the Galesville is clearly one of disconformity which resulted from pre-Galesville erosion. Thus, it is apparent that both the Mt. Simon and Galesville sandstones are nearshore deposits of transgressive phases of two separate cycles.

---

*Associate State Geologist, Wisconsin Geological and Natural History Survey, University Extension.

In the overlying rock section the quartzarenite lithology is repeated three more times as the Jordan Sandstone, New Richmond Sandstone, and St. Peter Sandstone. There is a major widely recognized unconformity at the base of the St. Peter (Dapples, 1955) and a minor unconformity at the base of the New Richmond (Ulrich, 1924; Andrews, 1955; Davis, this publication). The contact at the base of the Jordan Sandstone has not been positively identified from outcrops as disconformable although it commonly is sharp and is marked by a distinct lithologic change from sandy and/or silty carbonate below to quartzarenite above. Studies of well cuttings suggest that in the subsurface (Figure 17) this contact is unconformable.

These data and the regular and repetitive occurrence of other lithotopes suggested that there might be a broad and predictable cyclical pattern of rock-type occurrence and contact relationships which would reflect a cyclical pattern of sedimentation different than that described by Berg et al (1956). Subsequent examination revealed this to be true (Ostrom, 1964) as shown by the fact that each of the five quartzarenites which occur in the Lower Paleozoic section of this area is commonly unconformable with underlying rocks and the contacts are commonly marked by an erosion surface mantled by quartzose sandstone. Furthermore, each of the sandstones is separated by a similar sequence of rock units. The close similarity of cycles with regard to contact relationships and arrangement of lithotopes led to the interpretation that they reflect a tectonic and depositional history characterized by repetition of similar tectonic and depositional events. The tectonic events are believed to have been, in the simplest context, periodic uplifts and downdrops of the Wisconsin Dome which caused periodic fluctuations in sea level, each one recording the tectonic activity by cyclic deposition of the various lithotopes as the sediment zones migrated over the shelf.

THE LITHOLOGIC CYCLE AND LITHOTOPES

Lithologic Cycle

A lithologic cycle is a recurring sequence of strata consisting of several lithotopes arranged in the same order. Lithologic cycles record a definite series of physical conditions and geologic events which recurred in the same order with only minor variations. In the Cambrian and Ordovician rocks of the Upper Mississippi Valley area the cycles are asymmetrical because the succession of lithotopes in the transgressive order does not match that of the regressive order. Asymmetry here is attributed mainly to post-depositional erosion or variations in the source area and sediment supply or the distribution pattern of reworking and dispersing agents.

Four major lithotopes which recur in the same sequence in five lithologic cycles, as shown in Table I, are recognized in the Upper Cambrian and Lower and Middle Ordovician rocks of the Upper Mississippi Valley area. The four lithotopes are: (1) quartzarenite, (2) reworked quartzarenite, (3) argillaceous sandstone or shale, and (4) carbonate. The lithotopes are believed to have formed in different sediment zones located on a marine shelf and oriented approximately parallel with the shoreline. The sediment zones are roughly analogous to the zones described by Curray (1960) and Van Andel (1960) for Recent sediments in the Northwest Gulf of Mexico which, in a seaward direction, are the high energy <u>littoral zone</u> of sands, the slow or <u>nondepositional zone</u> of reworked

Table 1. *Correlation of lithologic cycles with lithotopes, shelf sediment zones, and lithostratigraphic units.*

CYCLES	LITHOTOPES	SHELF SEDIMENT ZONES	LITHOSTRATIGRAPHIC UNIT		
V	Carbonate	Biogenic	Sinnipee Gp.		
	Argillaceous Sandstone and/or Shale	Depositional Shelf	Glenwood Fm.	Harmony Hill Mbr.	
	Reworked Quartzarenite	Nondepositional Shelf		Nokomis Mbr.	
	Quartzarenite	Littoral	St. Peter Fm.		
IV	Carbonate	Biogenic	Shakopee Fm.	Willow River Mbr.	
	Argillaceous Sandstone and/or Shale	Depositional Shelf		New Richmond Mbr.	
	Reworked Quartzarenite	Nondepositional Shelf			
	Quartzarenite	Littoral			
III	Carbonate	Biogenic	Oneota Fm.	Hager City Mbr.	Stoddard Subm.
					Genoa Subm.
				Stockton Hill Mbr.	Mound Ridge Subm.
					Hickory Ridge Subm.
	Argillaceous Sandstone and/or Shale	Depositional Shelf			Sunset Point Subm.
	Reworked Quartzarenite	Nondepositional Shelf			
	Quartzarenite	Littoral	Jordan Fm.		
II	Carbonate	Biogenic	St. Lawrence Fm.	Black Earth Mbr.	Lodi Mbr.
	Argillaceous Sandstone and/or Shale	Depositional Shelf	Tunnel City Gp.	Lone Rock Fm.	Mazomanie Fm.
	Reworked Quartzarenite	Nondepositional Shelf	Wonewoc Fm.	Ironton Mbr.	
	Quartzarenite	Littoral		Galesville Mbr.	
I	Carbonate	Biogenic	Bonneterre Fm.		
	Argillaceous Sandstone and/or Shale	Depositional Shelf	Eau Claire Fm.		
	Reworked Quartzarenite	Nondepositional Shelf	Mt. Simon Fm.		
	Quartzarenite	Littoral			

alternating sands and muds, the shelf depositional zone of fine-grained clastics and the biogenic zone of calcareous "reefs".

The extent to which a deposit in a given sediment zone can develop depends upon the coincidence of many factors, chief among which are sediment source, sediment supply, energy, suitability of receiving area, and sediment distribution pattern. Variations in these factors are reflected in the relationships of the resultant lithotopes.

The littoral sediment zone exhibits the greatest stability in terms of energy and location chiefly because current and energy conditions in this zone are consistent and high and because its landward boundary is relatively stable. Distribution and size of the other zones which have lower energy levels is subject to the vagaries of available energy and distribution pattern of reworking and dispersing agents. Where these conditions are stable there is minor shifting of zones, thus little mixing of sediment type. Under fluctuating conditions deposits of different zones will be intermingled.

Quartzarenite Lithotope

The quartzarenite lithotope which is the basal unit of each cycle is represented by the Mt. Simon, Galesville, Jordan, New Richmond, and St. Peter sandstone formations. This lithotope is characterized by thick bedding, uniform lithology and mineralogy, and cross bedding. Lithologically, the lithotope consists mainly of well-sorted, clean, friable, medium and fine-grained sandstone. The basal few feet may locally contain coarse and very coarse sand, granules, pebbles and cobbles. In the base of the Mt. Simon and St. Peter sandstones coarse materials may locally be more abundant than in the other quartzarenites.

Mineralogically, the quartzarenite lithotope consists chiefly of quartz sand grains with an exception shown by a recent study done by Virendra Asthana (1968) supported by the Wisconsin Geological Survey which indicates the Mt. Simon Sandstone of the initial cycle contains up to 40 percent feldspar grains with an average of 18 percent. Previous studies (Tyler et al, 1940; Stauffer and Thiel, 1941; Potter and Pryor, 1961) indicate lower feldspar values with a maximum reported value of 22.5 percent (Potter and Pryor, 1961) and an average of about 3 percent. Heavy minerals common to this lithotope are magnetite, ilmenite, leucoxene, zircon, tourmaline, and garnet. The amount of garnet is generally less than 5 percent of the total heavy mineral content.

Fossils are rare or absent in the quartzarenite lithotope. Where present they tend to occur either in the basal few feet or near the top.

The quartzarenites occur as blankets of sand which grade into fine-grained shaly sands and carbonates laterally to the south and east across the craton in the direction of the Appalachian Geosyncline as is illustrated in Figure 7. Directional indicators show that current direction at the time and place of deposition of the quartzarenites was predominantly to the southwest and south (Figure 8). Locally quartzarenites tend to thicken in basins such as the Illinois Basin and to thin over highs such as the Wisconsin Dome.

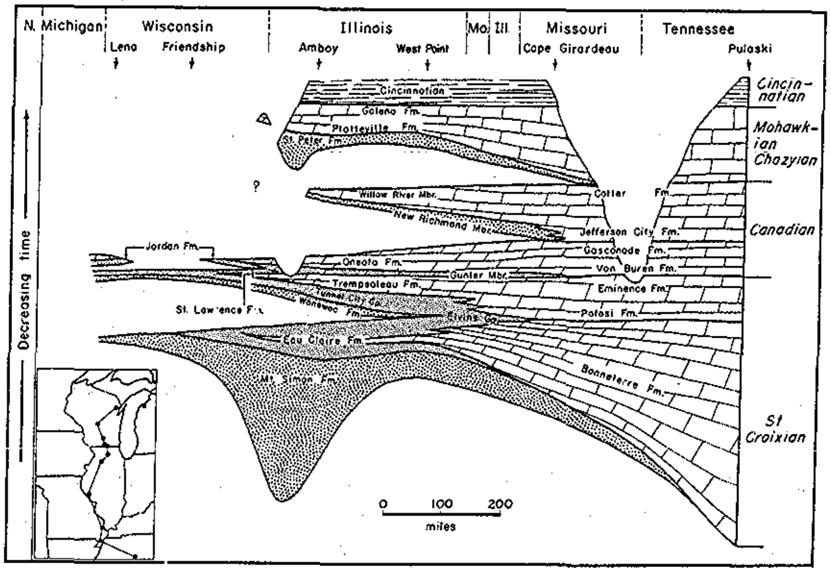


Figure 7. North-south generalized cross section showing relationships of pre-Cincinnatian Paleozoic strata from Lena, Wisconsin to Pulaski, Tenn. Vertical scale is much exaggerated and is intended to show relative thickness, inferring a general time relationship. Section is approximately 1200 miles long. Prepared from sample studies of Wisconsin wells and from published logs from Illinois (Workman and Bell, 1948), Missouri (Grohskopf, 1955), and Tennessee (by Freeman, in Dott and Murray, 1954).

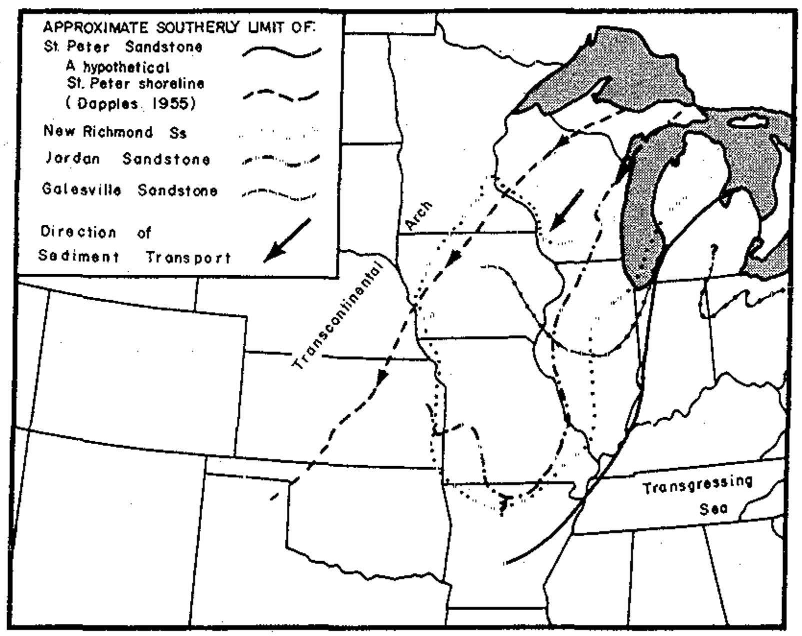


Figure 8. Map indicating approximately southerly limit of occurrence of quartzarenites. Limit is interpreted to indicate approximately shoreline configuration at time of deposition of sands which formed earliest deposits of these formations. Dominant transport directions, as determined from current lineation and cross-bedding measurements, are indicated by arrows. Limits of Galesville, New Richmond, and St. Peter sandstones modified from Workman and Bell (1948), Emrich (1962), Powers (1935), and Dapples (1955).

The basal contact is commonly sharp and may be marked by lithologic change. The relationship of the quartzarenites with underlying beds is commonly unconformable and may be angular which is interpreted to indicate erosion prior to their deposition.

The contact with the overlying lithotope is commonly transitional but may locally be sharp and distinct. The upper contact is placed approximately where there is a distinct change from thick bedding to thinner and uniform bedding and/or where there is evidence of reworking of bottom materials. The succeeding lithotope may locally be well-cemented with carbonate in which case it is markedly more resistant to weathering than is the underlying massive sandstone and tends to form a prominent ledge.

The quartzarenite lithotope is believed to have developed in the littoral sediment zone which is defined to include the sediments of the beaches, barriers, spits and nearshore zone along a coast. A modern analogue to this lithotope is forming in the littoral sediment zone of the Northwest Gulf of Mexico (Van Andel and Curray, 1960).

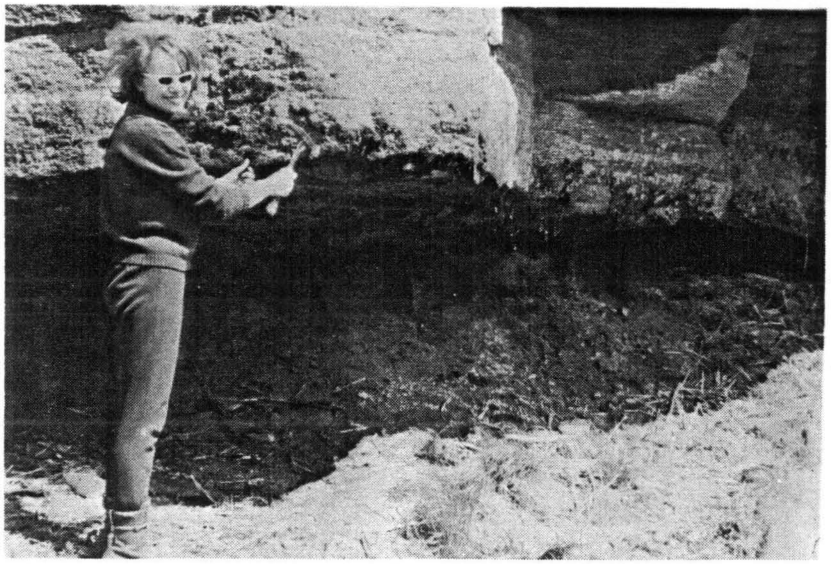
Formation of these blanket-type deposits of sand is attributed to the coalescing of a continuous series of littoral sands which migrated over a shallow marine shelf during progressive subsidence (Curray, 1960; DuBois, 1945; Dapples, 1955; Freeman, 1949; Calvert, 1962; Ostrom, 1964). Sediment delivered to the sea by rivers, together with sediment eroded from the shore by the transgressing sea, is winnowed and redistributed by waves and currents. The coarser fraction, consisting of sand, is distributed in the littoral zone by waves and longshore currents similar to those of the Northwest Gulf of Mexico which parallel the shoreline. The finer fraction is carried farther out on the shelf and is deposited according to the distributing pattern of marine dispersing agents.

The width of the littoral zone, in a seaward direction, in the present-day Northwest Gulf of Mexico is shown at a maximum of about 10 miles by Van Andel (1960) and includes the high energy surf zone and turbulent zone down to a depth of 6 fathoms off the Texas coast. Movement of sand parallel to the shoreline in the littoral drift system is reported out to depths of 60 to 80 feet (Johnson, 1956).

The seaward limit of deposits of the littoral sediment zone at the time of maximum regression can be mapped and is interpreted to indicate approximately the configuration of the ancient shoreline at that time as is shown in Figure 8.

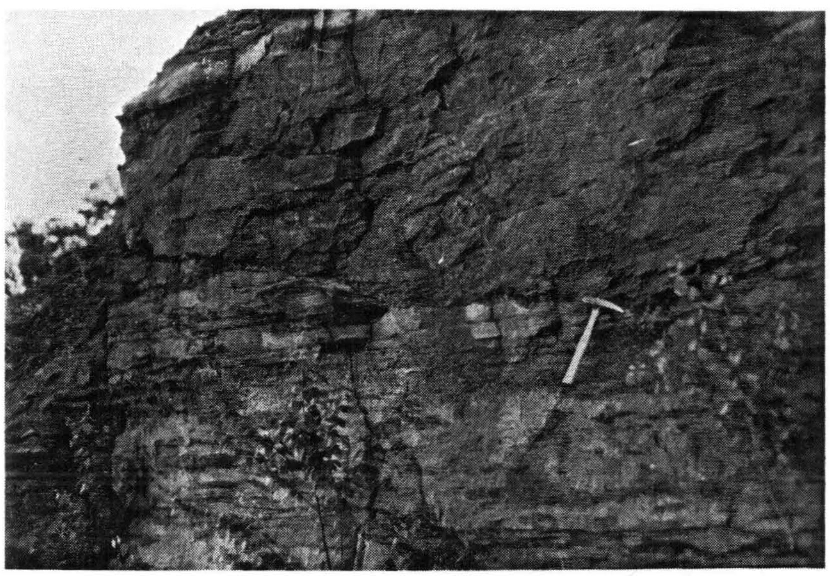
Reworked Quartzarenite Lithotope

The reworked quartzarenite lithotope overlies the quartzarenite lithotope and is represented in the sequence by the upper 20 to 40 feet of Mt. Simon Sandstone, the Ironton, the lower part of the Stockton Hill Member (Sunset Point), and the lower part of the Glenwood Formation (Nokomis Member). Each is distinct and well-developed except the upper part of the New Richmond Sandstone. This may be explained by the fact that at many places the entire New Richmond is lithologically similar to the reworked quartzarenite lithotope of other cycles which suggests that this lithotope does in fact exist but that it



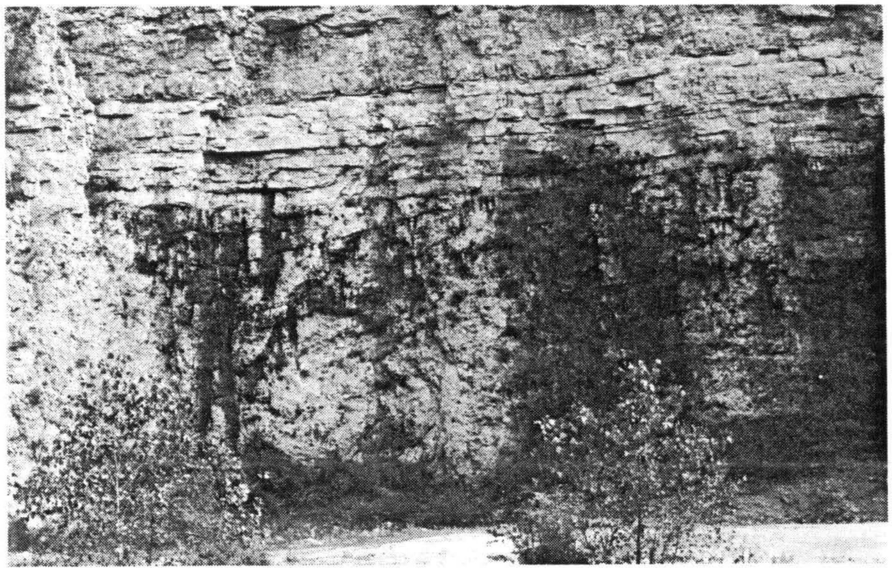
Mt. Simon Ss.
Precambrian

Figure 9. Unconformable contact of Mt. Simon Sandstone with weathered Precambrian rock in a cutbank at the east side of Duncan Creek in Irvine Park, Chippewa Falls (Stop 1).



Galesville Ss.
Eau Claire Ss.

Figure 10. Unconformable contact of Galesville Sandstone with Eau Claire Sandstone in quarry located in an abandoned quarry at east side of County Trunk Highway D about 4.5 miles southeast of Strum (Stop 4).



Shakopee Fm.
Oneota Fm.

Figure 11. Unconformable contact of New Richmond Sandstone with Oneota Dolomite in south face of Chicago, Burlington, and Quincy Railroad Quarry at north edge of Wyalusing (Stop 15).

St. Peter Ss.
Shakopee Fm.

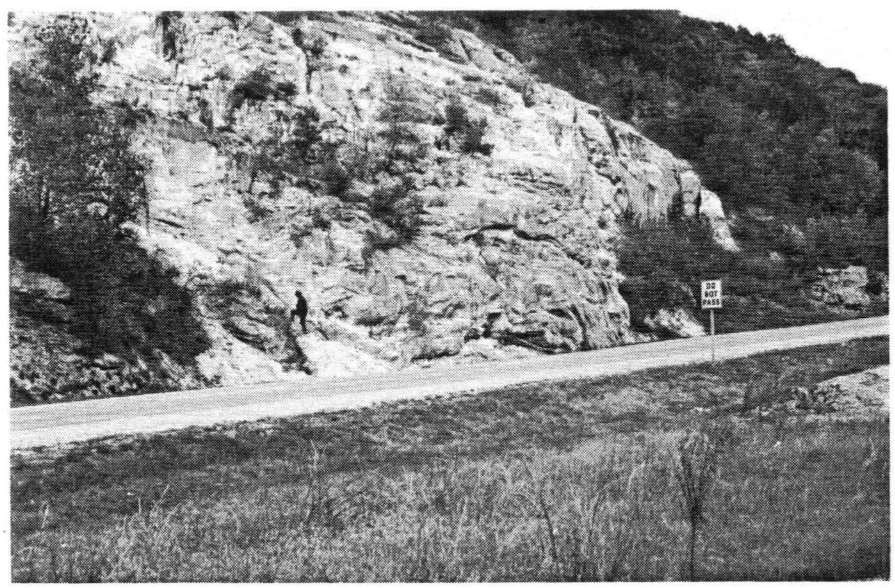


Figure 12. Unconformable contact of St. Peter Sandstone with Shakopee Formation in roadcut at north side of State Highway 27 about 1.5 miles east of Prairie du Chien (Stop 13). The Shakopee is visible at both sides of the picture above road level.

has not been distinguished from the quartzarenite lithotope with which it has been erroneously equated.

The reworked lithotope is compositionally and texturally transitional with both the overlying and underlying lithotopes, having some of the characteristics of each of them as well as possessing certain unique characteristics. Its contacts may be sharp and well defined or transitional and obscure.

The reworked lithotope consists of coarse-grained quartzarenites which are commonly interbedded with poorly-sorted strata composed of materials ranging in size from clay to granules or with arenaceous carbonate strata. The interbedding is expressed on weathered outcrops as ledges separated by reentrants and reflects differences in texture and cementing character of beds (Figure 13).

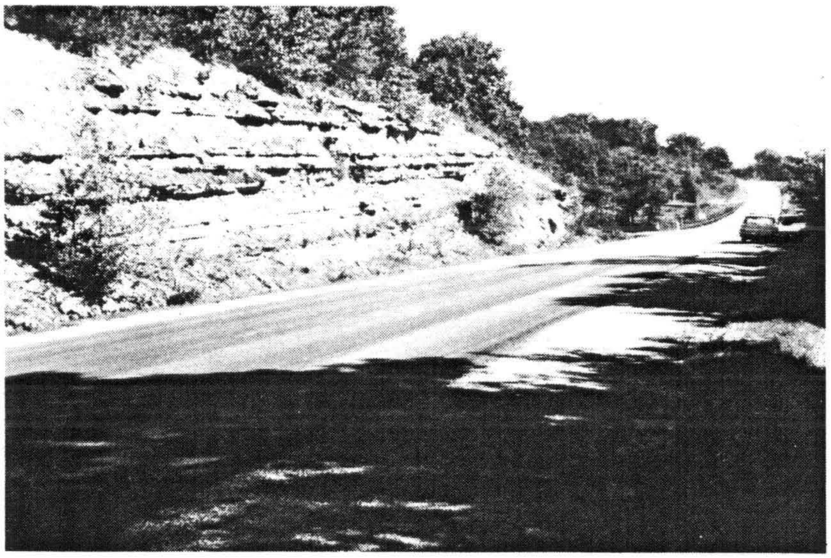


Figure 13. Outcrop expression common to the poorly-sorted reworked quartzarenite lithotope is shown by this exposure of the Ironton Sandstone near Tunnel City, Wisconsin.

The normally well-sorted coarse sandstone beds locally contain thin shale laminae and intraclasts. Heavy minerals are essentially the same as those which occur in the underlying quartzarenite, although the garnet content is commonly higher. The coarser grained beds are commonly cross-bedded. They may be, at least in part, lag concentrates formed by wave and current removal of fine-grained materials from bottom deposits similar to those of intervening beds which contain particles ranging in size from clay to granules.

The poorly-sorted silty beds are thick and may contain abundant burrows. The mixing, reworking, and burrowing of these beds is thought to have all been done by the same organisms. Ripple marks are most common in finer grained beds. Conglomerates are of limited lateral extent and are commonly composed of intraclasts.

Fossils are locally common, especially in the upper part and in finer grained and poorly-sorted beds. They consist of the burrows already mentioned and of trails, and less commonly of brachiopod shell fragments and of trilobites.

Contact with the underlying quartzarenite may be sharp or transitional. The contact is placed at the base of the lowest bed indicating reworking and is generally based on the change upward to coarser grained sandstone that is better sorted in individual beds but may contain materials ranging in size from clay to granules. These strata are generally silty and somewhat calcareous, and may contain ferruginous cement, fossils, glauconite, pyrite, and beds of shale, dolomite, and conglomerate.

The reworked lithotopes are commonly thinnest over positive features such as the Wisconsin Dome and Arch and tend to thicken into intracratonic basin areas. For example, the Ironton Formation shows an increase of from zero feet over the Wisconsin Arch in south-central Wisconsin to about 100 feet basinward in northeastern Illinois (Emrich, 1962; Buschbach, 1960) and 50 feet in western Wisconsin (Emrich, 1962); the lower portion of the Glenwood Formation (Nokomis) increases from zero feet over the Wisconsin Arch to about 8 feet in southwestern Wisconsin (Ostrom, 1969).

Detailed examination of particular units assigned to the reworked quartzarenite lithotope indicates that some beds can be traced over broad areas. Certain beds in the Ironton Formation are cited as being laterally persistent and as maintaining an essentially uniform thickness over distances of up to 100 miles in west-central Wisconsin (Emrich, 1962).

The reworked quartzarenite lithotope developed in a shelf zone that produced vertical variability between beds and lateral persistence of individual units. Vertical lithologic variability is interpreted to mean unstable and frequently changing environmental conditions. Such an area is the shelf zone of slow or no deposition characterized by reworked and alternating beds of sand and finer sediments analogous to that described for the Northwest Gulf of Mexico, by Curray (1960) and Van Andel (1960). In the Northwest Gulf of Mexico burrowing organisms and occasional hurricane waves rework bottom sediments and mix small quantities of newly added clay and biogenous carbonate with the underlying older sands. The result is sands interbedded and mottled with clay or clayey sands. Such mixing penetrates to a depth of up to about 5 feet and may produce a crude graded bedding.

Neighboring sediment zones may encroach into the slow or no deposition zone of reworking in response to a variety of conditions related to changes in sediment supply and available energy and produce an intermingling of deposits of both zones in an alternating pattern. The energy level in the zone of slow or no deposition is erratic and is subject to extremes of energy conditions. At times of low wave and current energy finer materials normally carried to more remote areas of the shelf may be deposited, bottom conditions stabilize, benthonic animals establish themselves, and neighboring environments of lower energy may encroach on the area. At times of high wave and current energy bottom sediment is churned up, finer materials are kept in suspension or removed, coarse materials are left behind, animals adapted to low-energy conditions are displaced or destroyed, and neighboring environments of lower energy are encroached upon.

The zone of slow or no deposition is, thus, seen to expand, contract, and shift position frequently in response to changing energy conditions causing intricate intermixing with deposits characteristic of neighboring environments which may encroach into and retreat from this zone.

Argillaceous Sandstone or Shale Lithotope

The argillaceous sandstone or shale lithotope overlies the reworked quartzarenite lithotope and locally, where the latter is missing, rests directly on the quartzarenite lithotope. Strata assigned to the argillaceous lithotope are the Eau Claire Sandstone, the Lone Rock Formation, the thin clayey sandstone or shale or calcareous shale in the lower part of the Stockton Hill Member and at the top of the "Sunset Point" (the Blue Earth Siltstone of Minnesota), a thin pale green clayey sandstone and calcareous shale at the top of the New Richmond Sandstone, and the Harmony Hill and Hennepin members of the Glenwood Formation.

The argillaceous lithotope is characterized by fine-grained sediments consisting of shale or silty or argillaceous sandstone. The sand grains are predominantly quartz and feldspar. Clay may occur as a green coating on sand grains or it may be present as thin shale partings or in shale beds up to 10 or 12 feet thick; it may also occur in the form of abundant glauconite pellets. Carbonate is common as cementing material or as thin beds. The heavy mineral suite is dominated by garnet (the Lone Rock heavy mineral suite contains up to 90 percent: Driscoll, 1959) with lesser amounts of ilmenite, leucoxene, tourmaline, and zircon.

This lithotope is essentially uniform in composition on a regional scale. Variations are due chiefly to differences in shale-to-sand ratio and locally in carbonate content.

Fossils commonly consist of fragmented brachiopods, trilobite molds and casts, and abundant burrows and trails.

The argillaceous lithotope is commonly thin bedded or shaly which distinguishes it from the underlying lithotopes in which bedding ranges from thick to thin and in which shale is rare. Cross-bedding is common and is well developed. Ripple marks and current lineation features are locally abundant. Beds of intraclasts are common and consist chiefly of sandstone clasts in a matrix of fine sand, silt, clay, and glauconite cemented with carbonate.

Regionally the argillaceous lithotopes are transitional laterally with carbonates and tend to thin southward and southeastward in the direction of the Appalachian Geosyncline. They tend to thicken into basin areas and to thin over highs such as the Wisconsin Arch.

The environment of deposition of the argillaceous lithotope is believed to have been the depositional zone of the shelf located generally seaward from the zone of slow or no deposition (Van Andel, 1960). The uniformity of texture, composition, and thickness of this lithotope over broad areas is interpreted to indicate a stable environment having an essentially constant energy level and a uniform rate of sediment accumulation. Variations in this uniformity are attributed to nearness to neighboring depositional zones or to minor shifts of environmental areas at times of major wave and current activity which would cause intermingling with neighboring depositional zones.

The sediments of the depositional zone consist of the fine clastics winnowed from the river sediments and beaches and deposited farther offshore in accordance with the distribution pattern of marine currents. The amount of sediment which accumulates is a function of sediment supply and of local shelf subsidence.

Present-day deposition of fine sediment on the shelf in the Northwest Gulf of Mexico is limited primarily to the area beyond the littoral zone and occurs mainly in the middle and outer shelf areas. The pattern of dispersion of these sediments appears to be independent of the coarser sand distribution (Van Andel, 1960).

Carbonate Lithotope

Formations assigned to the carbonate lithotope include the Bonneterre Dolomite, St. Lawrence Dolomite, upper part of the Stockton Hill Member (Hickory Ridge and Mound Ridge) plus the Hager City Member, Willow River Dolomite, and Sinnipee Group. What may be Bonne Terre Dolomite in this area is limited in distribution to the southern edge of the state near Beloit. It is a persistent carbonate unit which occurs in the upper part of the Eau Claire Formation in the area and which is considered to be the lithostratigraphic equivalent of the Bonne Terre Dolomite of Missouri.

The carbonate lithotope is the most readily recognized of all the lithotopes as it is characterized by carbonate rocks. In the lower part of each carbonate unit sand and minor amounts of shale and/or glauconite and silt are generally present. Higher in the section these constituents may be totally absent. In other cases, beds of shale and sand can be found throughout the unit. Bedding is commonly medium but varies from thin to thick.

In this lithotope fossils are more diversified and plentiful than in those of the other three lithotopes. Biohermal reefs are present in all carbonates except the Sinnipee Group.

The carbonate lithotope maintains a uniform thickness locally and shows a regional thickening into basin and geosynclinal areas. In the geosynclinal area (Figure 7) carbonate sections appear to be continuous and are uninterrupted by intervening beds of sandstone or shale. Exceptions to the local uniformity of thickness occur where erosional unconformity exists between a carbonate and the overlying lithotope or where an irregular reef surface is buried by sediment of a succeeding lithotope. Where the carbonate is succeeded by a deposit characteristic of a neighboring environment, as for example that of the depositional shelf area, the contact is commonly transitional and even. If the carbonate is succeeded by a deposit characteristic of a more remote environment of deposition, for example that of the littoral zone, then the contact is likely to be one of unconformity.

Contact of the carbonate lithotope with the underlying lithotope may be sharp or transitional and is most often even. Departure from this condition may occur locally due to variations in bottom topography and energy and to the distribution pattern of marine reworking and dispersing agents. Where the contact is transitional the carbonate lithotopes may initially contain beds of quartzarenite, shale, fine-grained dolomite, stromatolites, intraclasts, or discontinuous thin beds of oolitic white chert indicative of shallow agitated waters as are the upper surfaces of the dolomite beds which may be marked by ripple marks and dessication cracks. The vertical lithologic variability of the transitional beds in the base of certain of the carbonates, such as the Willow River Dolomite, is interpreted to indicate intermingling of deposits of the biogenic carbonate zone with those of neighboring depositional zones in response to changes in energy conditions and in the distribution pattern of marine reworking and dispersing agents.

Deposits having these characteristics are found in shallow-water lagoons and tidal areas behind algal headlands or reefs and differ considerably from those of the open shelf such as banks or platforms which consist almost entirely of carbonate material. Sediment deposited in lagoonal areas may come from four sources: the mainland, the algal headland, non-headland skeletal hard parts, and chemical precipitation. The gradation from algal headland into lagoonal sediments ranges from sharp to indefinite. In a shoreward direction the headland may merge, with indefinite or complex interfingering relations, into lime sands that surround small patch reefs and eventually into lagoon lime sands, evaporites, or clastic sediments (Cloud, 1952).

The amount of terrigenous and calcareous materials that accumulate in a lagoon varies with supply and nearness to the mainland or the reef. In the area of the Great Barrier Reef, terrigenous material commonly exceeds 90 percent near the mainland (Fairbridge, 1950). In the reef vicinity calcareous clastic materials and chemically precipitated lime muds may form 98 percent of the total.

The bulk of carbonate deposition today is taking place in biogenic environments similar to those which occur on the shelf off the east coast of Australia, off the southeast coast of Florida, or in the Northwest Gulf of Mexico (Fairbridge, 1950; Illing, 1954; Ludwick and Walton, 1957). Areas of active reef development in the Northwest Gulf of Mexico are located in water shallower than 30 fathoms (Parker and Curray, 1956; Stetson, 1953) in the zone of slow to no deposition and in areas of stable but unconsolidated bottom where all other requirements for their development exist. Ladd and Hoffmeister (1936) and Cloud (1952) maintain that reefs may develop upward from any stable, preexisting platform in areas where all other requirements for their development exist and that they will continue to develop so long as these requirements are not altered. Carbonate deposition and reef formation seldom if ever occur where bottom conditions are unstable or where there is abundant shifting sediment.

The carbonate lithotopes in Cambrian and Ordovician rocks of the Upper Mississippi Valley area are interpreted to represent a biogenic zone of carbonate deposition. The conclusion that these lithotopes probably developed in such a zone seems logically inescapable (Gilluly, Waters, and Woodford, 1951; Cloud, 1952). Studies of the Oneota Dolomite (Starke, 1949) and of the "Trenton" formations (Du Bois, 1945) in the Upper Mississippi Valley indicate that these carbonates were deposited during times of transgression by the sea and that they accumulated in biogenic zones of deposition as a series of coalescing deposits which were spread out as sheetlike bodies shoreward over the shelf as the sea transgressed.

PATTERN OF SEDIMENTATION

Depositional Setting

The area of deposition of Upper Cambrian and Lower and Middle Ordovician sediments in the Upper Mississippi Valley was a craton on which there were active intracratonic basins and scattered arches and domes. A study of dispersal centers of Paleozoic and later clastics of this and adjacent areas indicated to Potter and Pryor (1961) that the southward direction of sediment movement and slope of the craton have persisted through the Paleozoic to the present. They believe that (p. 1229-30):

> "Such uniformity over so long a time and over such a wide area can reflect only major tectonic control. The behavior of basement rocks of the craton provides that control. This underlying tectonic control is the immediate cause of persistent paleoslopes, of recycling, and of the location and orientation of major clastic deposits ultimately derived from distant tectonic lands."

In the Upper Mississippi Valley area direction of sediment transport, especially in the littoral zone, is interpreted to have been parallel to the shoreline, hence approximately parallel to the continental margin, which lay toward the Appalachian Geosyncline to the southeast and south, and perpendicular to the paleoslope, a relationship demonstrated for the St. Peter Sandstone by Dapples (1955).

During the Late Cambrian and Early and Middle Ordovician there existed high areas in the Upper Mississippi Valley referred to as the Wisconsin Dome, the North Huron Dome, a connecting link between these two domes called the Northern Michigan Highland, and the Canadian Shield (Figure 14). The major

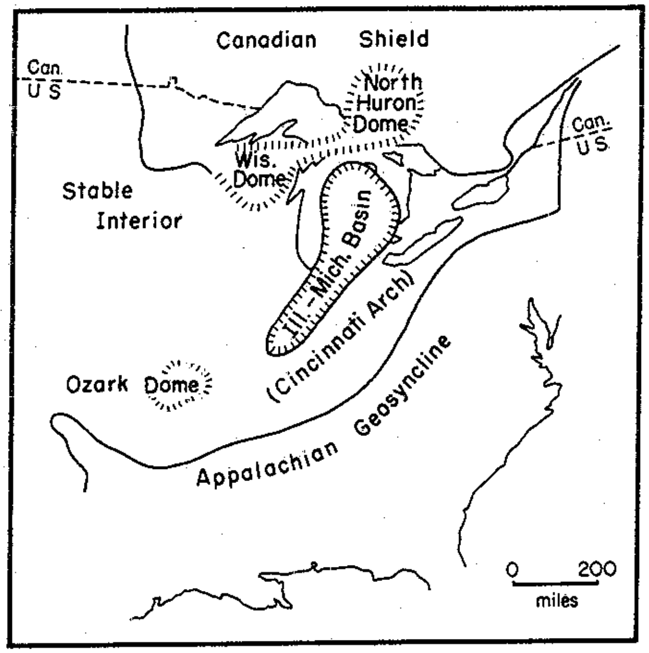


Figure 14. Map of eastern North America indicating areas of Pre-Cincinnatian Paleozoic orogenic activity (adapted in part from Eardley, 1951; King, 1959).

intracratonic basin of this time was the Illinois-Michigan Basin. The Ozark area is considered to have subsided during pre-St. Peter time and to have risen before the end of the Cincinnatian (Eardley, 1951; Lee, 1943). Deformation during this interval is believed to have resulted in the development of many arches and other structural features on the craton including the Kankakee Arch, which separated the Michigan Basin from the Illinois Basin (Ekblaw, 1938), and the Findlay and Waverly arches which bordered these basins along their southeastern margin (Woodward, 1961).

DEVELOPMENT OF CYCLES

Distribution of major depositional zones over present-day shelf surfaces is roughly parallel to the coastline. Changes in sea level cause each zone to migrate over the shelf. Lowering of sea level relative to the land causes zones to shift seaward; conversely, a relative rise in sea level results in a shoreward shift. Minor sea-level changes, over shallow shelves, may cause broad shifts of the strandline emerging or submerging vast areas and can account for many thin, but widespread, units. Major changes in sea level result in the development of complete cycles which should consist ideally of deposits of both transgressive and regressive phases.

In a somewhat irregular pattern seaward from, and roughly parallel with, the coast one can expect to encounter the high energy littoral zone of well-sorted sand, the slow or no deposition zone of reworked alternating sands and muds, the shelf depositional zone of fine-grained clastics, and the biogenic zone of calcareous "reefs" (Van Andel, 1960; Van Andel and Curray, 1960). Migration of each environment over the shelf results in their being deposited in sheetlike bodies over the shelf surface, one on top of the other.

Deposits of the emergent phase are not as well represented as those of the submergent phase. This is especially true of deposits developed in higher energy environments located in the littoral and inner shelf depositional zones. Regression of the sea exposes these zones and their characteristic deposits to subaerial erosion. Thus, during emergence, deposits of the littoral zone are continually reworked and removed to the retreating shoreline. For this reason they can be expected to be rare unless they are lowered, by local subsidence, beyond reach of erosion in which case they will be preserved.

A continuous sheet of coalescing nearshore beach sands will be deposited over the erosion surface as the sea readvances over the land in the subsequent submergent phase. Deposits of the submergent phase will be separated from those of the preceding emergent phase by a hiatus except in the area defined by the width and breadth of the littoral zone at the time of maximum emergence. The hiatus may be apparent if there is an obvious difference in lithology, an unevenness of the contact surface, or clasts occur in the base of the overlying unit. However, if, on the other hand, the lithologies are similar and the underlying unit is so soft that the erosion surface is not preserved and clasts do not form, then the hiatus may be obscured.

Cycles are likely to develop in nearshore areas because such areas are the most readily affected by minor sea level changes which cause environmental zones to shift widely back and forth. Where there is little change in environmental conditions, and where deposition is continuous from one cycle to the next as can occur in outer shelf areas in which local environmental conditions are unaffected by sea-level changes, there may be no discernible cycles.

VARIATIONS IN CYCLES

Lower Paleozoic sedimentary cycles may appear incomplete because of erosional lacunas. A lithotope representing a specific depositional zone will develop only if that zone is present in the area. Thus, deposits of the littoral zone will not occur seaward beyond the area of maximum regression of this environment nor will they occur shoreward beyond the area of maximum transgression of the environment.

Subaerial erosion may produce surfaces with high local relief, such as that at the base of the St. Peter Sandstone, which is the reason for abrupt lateral changes in thickness of the underlying lithotope and often its complete removal. On the other hand subaerial erosion may not cut deeply and only partially remove the underlying lithotope as in the case of erosion prior to deposition of the New Richmond Sandstone.

Regressive phases are identified in Cambrian cycles in the Upper Mississippi Valley area but are unknown in Ordovician cycles. Presence of a regressive phase in the Eau Claire Formation was described by Ostrom (1964) and a regressive phase for the upper part of the St. Lawrence Formation in western Wisconsin was described by Nelson (1956). It is suggested that active subsidence of the Illinois-Michigan Basin during shelf emergence, at the close of the Mt. Simon and Galesville cycles, caused regressive deposits to be lowered beyond the reach of subsequent erosion and resulted in their preservation. The Jordan and New Richmond cycles of the Lower Ordovician differ from older cycles in that their shale or argillaceous sandstone lithotopes, representing the depositional shelf environment, are poorly-developed. Regression prior to development of these cycles was probably less than during previous cycles and did not extend into basin areas; land areas were, thus, low and of low relief and provided only small amounts of clastics, and consequently less sediment accumulated in the depositional shelf environment.

GEOLOGIC HISTORY

As a result of this study, it is possible to formulate a working hypothesis regarding the geologic history and paleogeographic evolution of Lower Paleozoic rocks in the Upper Mississippi Valley.

Five sedimentary cycles, indicating five successive episodes of shelf submergence and emergence, occur in these rocks. Strata comprising each cycle and their relationships are indicated in Table I.

Lower Paleozoic sediments were deposited on an erosion surface cut in Precambrian rocks. The basal Paleozoic deposit in this area is the Mt. Simon Sandstone. The Mt. Simon is a quartzarenite which was deposited in the littoral zone by a transgressing sea as a sheet of prograding and coalescing sand bodies which filled in and mantled the erosion surface. The Mt. Simon does not occur southeast of a northeast-southwest trending line which crosses Tennessee approximately where shown in Figure 7 and which is believed to mark approximately the position of the shoreline before transgression began. Directional indicators in the Mt. Simon of the outcrop area of western Wisconsin show that sediment was transported to the south and southwest parallel to the shoreline.

Seaward from the littoral zone in which the Mt. Simon was deposited was the nondepositional shelf zone. The poorly-sorted reworked quartzarenite, which characterizes this zone, is not known to occur everywhere but may be seen at the type exposure of the Mt. Simon, at Eau Claire, Wisconsin. There, it is represented by a unit about 20 feet thick consisting of alternating layers of silty, poorly-sorted sandstone containing burrows, shale laminae, minor amounts of calcareous cement, and of layers of predominantly coarse-grained, well-sorted quartzarenite.

The shale and argillaceous fine-grained sandstones of the depositional shelf zone indicative of the next seaward depositional zone are represented by the Eau Claire Sandstone in which both transgressive and regressive phases are recognized. The two phases of this lithotope are separated by the expected carbonate unit developed in the carbonate zone. In Wisconsin this unit is known only from the subsurface and occurs in southern Wisconsin. Here it is a thin, previously undifferentiated bed less than 20 feet thick and thickens southward to form the Bonne Terre Dolomite of southern Illinois and Missouri (Workman and Bell, 1949; Buschbach, 1960).

The transgressive phase of the Eau Claire, below the Bonne Terre, is thin or absent in southeastern Missouri (Figure 7). Northward in Illinois the Eau Claire thickens, as does the underlying Mt. Simon. The increase in thickness may be due to the correspondence of the subsiding Illinois-Michigan Basin and the environments of deposition represented by these two lithotopes. That the Eau Claire was deposited during transgression is supported by paleontological evidence which suggested to Raasch and Unfer (1964) that the "...absence of .... earlier Cedarian fauna in the Mississippi Valley appears logically to have been a result of the later arrival of the Dresbachian marine transgression here."

Northward from the Illinois Basin, the Eau Claire thins until in eastern Wisconsin it is absent (Twenhofel, Raasch, and Thwaites, 1935). Traced into western Wisconsin and eastern Minnesota the Eau Claire reappears and thickens to from 60 to 100 feet. The reason for the thinning and local absence of the Eau Claire is believed to be due both to depositional wedging onto the Wisconsin Arch and in large measure to pre-Galesville erosion. An erosion surface is described at the top of the Eau Claire from cores taken near Troy Grove in north-central Illinois (Quick, 1959). In the Northern Peninsula of Michigan, the stratigraphic position of the Eau Claire is marked by an erosion surface mantled by a basal conglomerate of the succeeding cycle (Ostrom, 1967). In western Wisconsin the erosion surface is apparent at all exposures of this contact (Ostrom, 1965, 1967, and 1969; Morrison, 1968). In the Illinois Basin (Workman and Bell, 1948; Buschbach, 1964) and the Hollandale Embayment of the Forest City Basin (Austin, 1969) the contact is reported to be transitional from the Eau Claire into the overlying Galesville. Thus, the contact of the Eau Claire with the Galesville is marked by an erosion surface in positive areas and by a transitional relationship in negative areas. The erosion is believed to have occurred in land areas exposed during the same episode of emergence which produced the regressive phase of the Eau Claire. Preservation in the Illinois-Michigan Basin of the regressive phase of the Eau Claire is interpreted to indicate that basin subsidence, contemporaneous with shelf emergence, lowered these deposits beyond reach of erosion.

Raasch and Unfer (1964) ascribe the absence of the Aphelaspis faunal zone in the Upper Mississippi Valley area to post-Galesville erosion which they assign to the Dresbachian-Franconian hiatus. An alternative to this hypothesis is that in the Upper Mississippi Valley area the Dresbachian terminated with the withdrawal of seas and the Franconian commenced with the readvance of the sea and the first appearance of Franconian fossils. This alternative interpretation is supported by the well-developed erosion surface separating the Eau Claire from the Galesville, the absence of the uppermost Dresbachian faunal zone (Aphelaspis) from the Eau Claire in this area, absence of fossils from the Galesville, and the transitional relationship of the Galesville with Franconian rocks.

Maximum regression of the strandline is marked approximately by the southerly limit of littoral zone deposits formed during the subsequent cycle, namely the Galesville Sandstone. The Galesville is not known to occur south of a line which intersects the cross section of Figure 7 at about West Point, Hancock County, in west-central Illinois (Ostrom, 1964) and which extends eastward through central Illinois and then northeastward through north-central Indiana toward northeastern Indiana (Figure 8; Emrich, 1966). South of this area deposits of more seaward open shelf environments were laid down.

The Galesville Sandstone Member of the Wonewoc Formation is succeeded by the Ironton Member which is generally poorly-sorted and consists of coarse and medium-grained sand and poorly-sorted, silty and calcareous beds containing abundant burrows. It is typical of the lithotope developed in the nondepositional environment. In western Wisconsin successive alternating strata in the Ironton Member can be traced laterally over distances of up to 100 miles (Emrich, 1966). The first appearance of fossils of Franconian age in this area, namely <u>Camaraspis convexus</u> and <u>Elvinia roemeri</u>, is in the Ironton Member.

Seaward from this zone was the depositional shelf zone. Deposits of the argillaceous lithotope, which developed in this environment, are represented by the Tunnel City Group and in the northern part of the area by the Tunnel City and the overlying Lodi Siltstone, an argillaceous and calcareous member of the St. Lawrence Formation, in which both a transgressive and regressive phase are recognized (Nelson, 1956). The predominantly transgressive Tunnel City (Ostrom, 1966) is lithologically indistinguishable from the underlying regressive phase of the Eau Claire south of the area of Galesville occurrence and within the area of maximum regression of the depositional shelf environment (Figures 7 and 8) represented in Missouri by the Elvins Group. In Wisconsin the Tunnel City Group is composed of two formations, namely the Lone Rock and the Mazomanie. The Lone Rock consists of shaly and/or glauconitic fine-grained, thin and medium-bedded sandstone. It partially encloses the Mazomanie which is a tongue of sand which extends southward off the Wisconsin Dome and parallel to the Wisconsin Arch (Figures 15 and 16: Ostrom, 1966) and grades from fine-grained, non-shaly, slightly glauconitic, thin-bedded sandstone at its outer edges to medium and fine-grained, well-sorted sandstone, similar to the Galesville Sandstone, over the arch. The shape and lithology of the Mazomanie suggest that it formed during a minor regression which was imposed on the major transgressive phase of the cycle.

The transgressive and regressive phases of the Tunnel City plus the overlying Lodi are separated in southern Wisconsin by the Black Earth Dolomite Member of the St. Lawrence Formation, a northward pinching wedge representing the carbonate depositional zone. To the north this carbonate is absent. Southward it increases in thickness and is correlated with the Trempealeau Formation of Illinois and the Eminence and Potosi formations of Missouri.

The maximum northward transgression of the sea at this time is unknown. Subsequent emergence resulted in subaerial erosion in northerly areas and removal of these deposits (Nelson, 1956). This erosion surface is poorly known, but evidence for its development exists in eastern Wisconsin (Figure 17) and as far south as Rochelle, in north-central Illinois (Willman and Templeton, 1952).

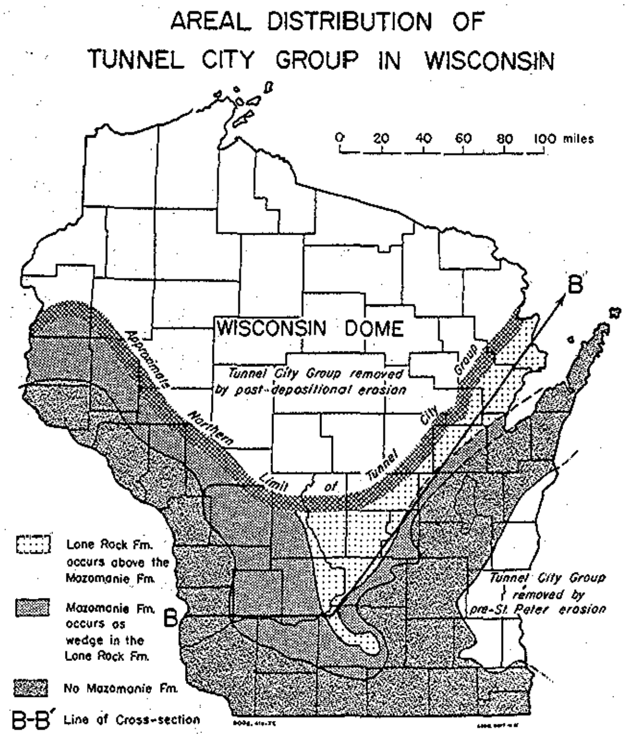


Figure 15. Areal distribution of the Tunnel City Group in Wisconsin (Ostrom, 1966).

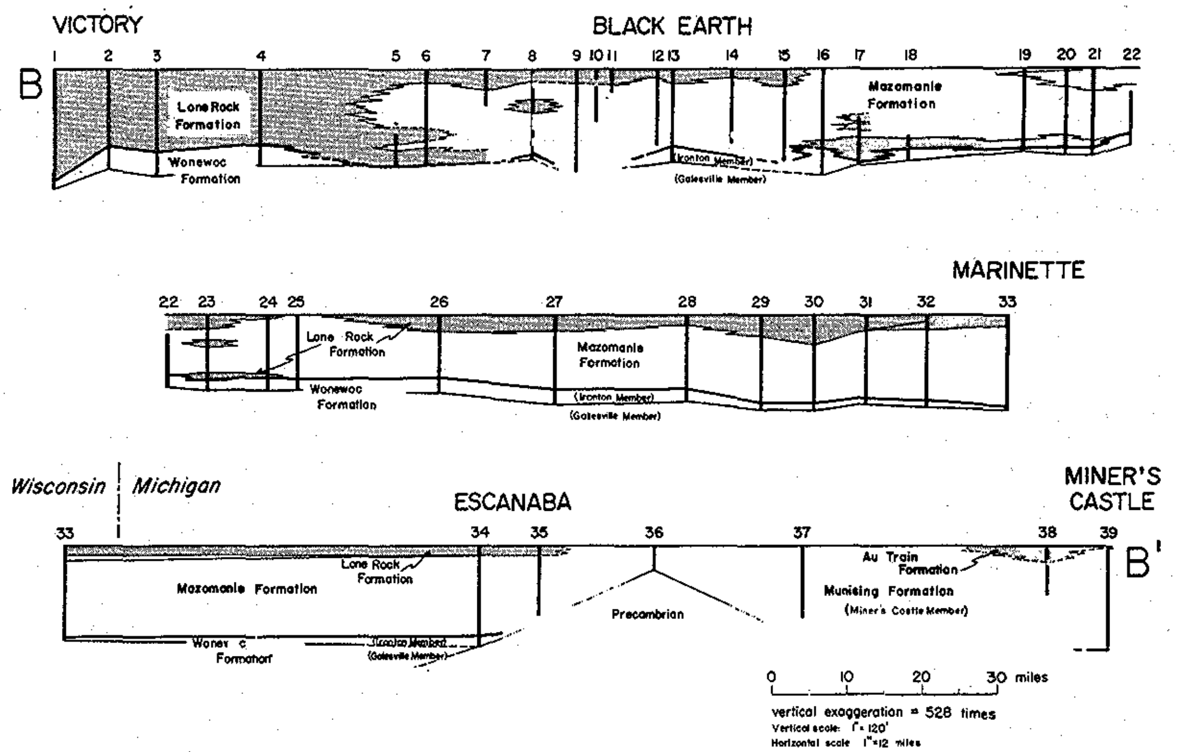


Figure 16. Cross section B - B' (refer to Figure 22) showing relationship between Lone Rock Formation and Mazomanie Formation (Ostrom, 1966).

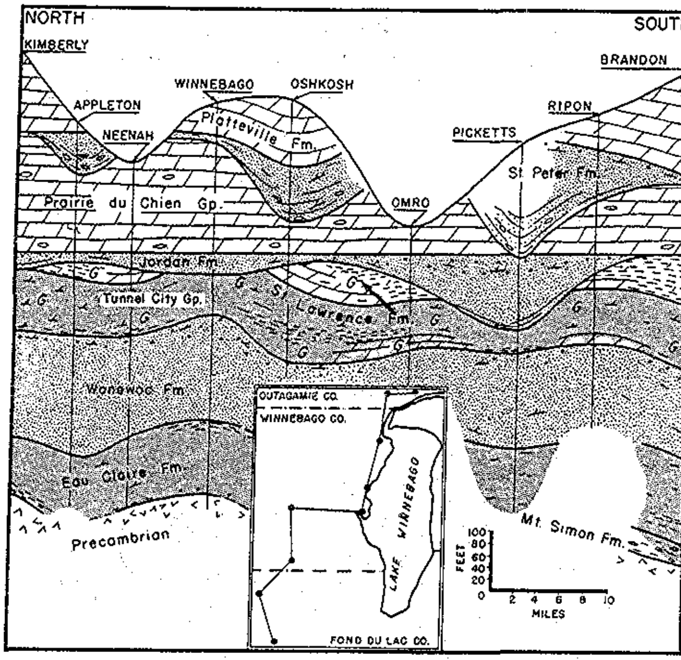


Figure 17. Northeast-southwest cross section of pre-Cincinnatian Paleozoic strata from Kimberly to Brandon in eastern Wisconsin showing variability in thickness and lithology of St. Peter and Jordan formations. Base of Prairie du Chien is used as datum plane. Section covers horizontal distance of approximately 40 miles.

Littoral deposits of the subsequent cycle, characterized by thick deposits of Jordan Sandstone, are not known to occur southeast of an indefinite line extending approximately along the eastern border of Wisconsin, then around the western border of Illinois to east-central Missouri, and finally westward where the boundary is lost (Figure 8).

The Jordan Sandstone is succeeded by deposits developed in the nondepositional shelf zone represented by the Kasota Sandstone of Minnesota and the Sunset Point of Wisconsin. The Sunset Point is poorly—sorted and consists mainly of alternating beds of sandstone, silty sandstone, sandy dolomite, and dolomite which occurs in the base of the Stockton Hill Member. Seaward from the nondepositional shelf zone was the depositional shelf zone. Deposits of the depositional shelf in the Jordan cycle are thin or obscure and poorly known. They are represented by a blue-green shale or calcareous, argillaceous and silty zone in Minnesota, the Blue Earth Siltstone Member (Stauffer and Thiel, 1941), and by a greenish argillaceous, silty and sandy zone in Wisconsin. This lithotope is not known to exceed 3 feet in thickness. The lack of an extensive shale deposit at this position is interpreted to mean that the depositional shelf environment did not regress southward far enough to coincide with the subsiding basin and that the exposed land area was smaller and lower than at previous times of emergence. Consequently only a small amount of clay was delivered to the sea.

Traditionally a major sequential break, the contact of the Cambrian with the Ordovician has been placed at the contact of the Sunset Point (Madison of older publications) with the overlying portion of the Stockton Hill Member (Hickory Ridge of Raasch, 1952). Ulrich (1924) described a "diastrophic" break between the Cambrian (Sunset Point) and the Ozarkian (Hickory Ridge). Twenhofel, Raasch and Thwaites (1935) followed Ulrich. Raasch (1939) believed the Jordan Sandstone marked the end of sand deposition due to marine retreat. The following marine transgression is marked by the Hickory Ridge. The Sunset Point developed between the Jordan and Hickory Ridge from supposed local reinvasions of irregular and shallow depressions on the Jordan surface.

Raasch and Unfer (1964) followed previous authors but recognized an additional break between the Jordan Sandstone and the Sunset Point based on their concept that:

> "...the Jordan strata beneath the Sunset Point are appreciably truncated in the region of the Wisconsin Arch, where the total Jordan succession is not only notably thinner, but the upper, or Van Oser Member, is missing. Hence a significant nonsequence within the Saukian Zone faunal succession coincides with physical contact between the Jordan and Sunset Point formations...the Jordan-Sunset Point break does not coincide with a major (genera-zone) faunal break."

Kraft (1956), Heller (1956), and Ostrom (1964; 1965) believed the Sunset Point to be transitional between the Van Oser and Hickory Ridge. Melby (1967) suggested that there is no major time gap between the Sunset Point and Hickory Ridge on the basis of his field study which revealed no evidence to support a significant time break. He makes no mention of an erosional surface contact relationship at either the top or bottom of the Sunset Point.

Melby (op. cit.) examined conodonts obtained from samples of the Van Oser, Sunset Point, and Hickory Ridge and reports that the "...results suggest that there is no sharp faunal break between the Van Oser and Sunset Point sandstones nor between the Sunset Point and the overlying ....(Hickory Ridge)... west of the Wisconsin arch... Comparison of the Sunset Point conodonts with those found by Furnish (1938) in the overlying Oneota Dolomite, tends to indicate that there is no obvious evolutionary break between the two units (D. L. Clark, 1967, Personal communication) ....The conclusion reached is that the Sunset Point sandstone in western Wisconsin may be Lower Ordovician and not Upper Cambrian as presently thought."

Seaward from the depositional shelf zone deposits of the carbonate zone developed and are manifest in the Oneota dolomite above the Sunset Point. In northerly areas the Oneota is lost to erosion (Figure 7), thus its northward extent must be inferred. The erosion surface which developed during subsequent emergence is only poorly known but has been described from exposures in the Upper Mississippi Valley area by Ulrich (1924; Canadian-Ozarkian break), and from exposures near Eastman, western Wisconsin (Andrews, 1955), near Minneapolis, Minnesota (Ulrich and Resser, 1930), in the Ozark area in Missouri (Lee, 1943) and by Ostrom (1964) and Davis (1966) from studies in the Upper Mississippi Valley area. Maximum retreat of the sea during the emergence which produced this erosion surface coincides approximately with the southern limit of deposits of quartzarenite lithotope (Figure 8). This limit of the New Richmond Sandstone is along a line trending southwestward from about Danville, in east-central Illinois, toward Cape Girardeau, Missouri (Workman and Bell, 1949).

The New Richmond developed in the littoral zone during the succeeding cycle. It is succeeded by poorly known or defined deposits of the nondepositional and depositional shelf zones similar to those of the preceding Jordan cycle, and is overlain by deposits of the carbonate zone, the Shakopee Dolomite, developed further seaward. In more seaward areas to the south the Shakopee Dolomite is continuous with the Oneota Dolomite of the preceding Jordan cycle and consists almost entirely of carbonate. Northward, as for example, near Utica in north-central Illinois, the Shakopee overlies the New Richmond and has a variable lithology which consists of dolomite containing layers of quartzarenite, shale, and discontinuous thin beds of oolitic chert. The dolomite beds range up to 10 feet in thickness, are seldom more than 3 feet thick, and are commonly very fine-grained, and their upper surfaces may be ripple marked and mudcracked. The sandstone beds may be cross-bedded and commonly contain pebbles and cobbles derived from the underlying dolomite bed in their lower part. Beds of shale reach a known maximum thickness of 6 inches. The variable lithologic character of the Shakopee in this area is interpreted to indicate frequent environmental changes and "...fluctuation of conditions of sedimentation characteristic of shallow water deposition" (Cady, 1919). It is postulated that the Shakopee Formation accumulated in a very shallow environment situated shoreward from an area of algal headlands. This zone is considered to have been a broad, flat, and shallow lagoon or shoaling area subjected to the influence of the land on one side and the algal headlands and reefs on the other, while at the same time being influenced by other factors affecting carbonate deposition.

The Shakopee Dolomite and older strata were eroded in northerly areas in Wisconsin during pre-St. Peter regression to an indefinite northeast-trending strandline through western Kentucky (Dapples, 1955). The geology of the eroded surface is shown in Figure 18. The surface is one of prominent relief

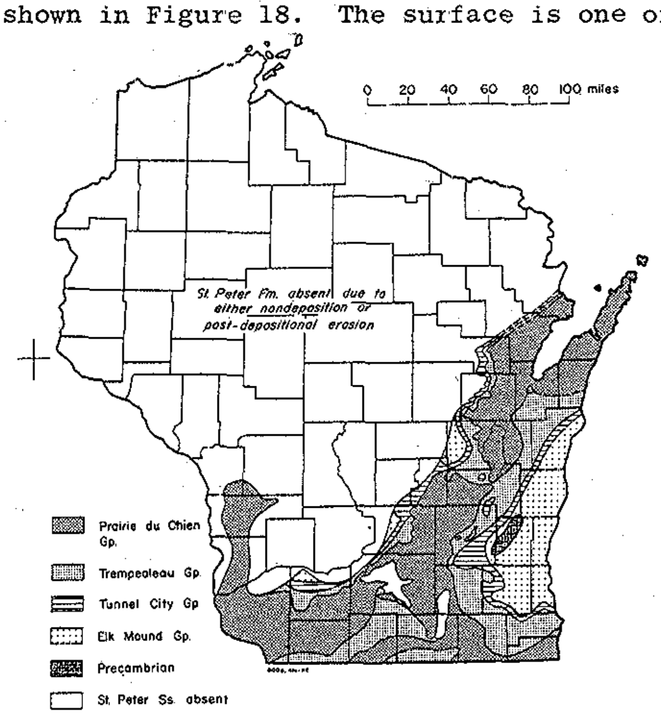


Figure 18. Paleogeology of the pre-St. Peter erosion surface in southern and eastern Wisconsin.

in Wisconsin and northern Illinois. This emergence coincided approximately with the development of many new intracratonic structural features as, for example, the Kankakee Arch (Ekblaw, 1938) and Ozark Dome (Lee, 1943; Dapples, 1955). A prominent pre-St. Peter positive feature is shown in the vicinity of Milwaukee in Figure 18. Development of this feature is believed to be related to the same tectonic activity that produced the Kankakee Arch.

The St. Peter Sandstone was deposited on this erosion surface during the transgressive phase of the subsequent cycle. It is representative of the littoral zone. Seaward from this zone deposits of the nondepositional shelf zone developed. The poorly sorted lithotope that characterizes this environment is manifest in the lower part of the Glenwood Formation (Nokomis Member) which consists of poorly-sorted, silty sandstone which may be interbedded with coarse-grained, orthoquartzitic sandstone or with shaly dolomite ranging from 0 to 100 feet in thickness. Deposits of the argillaceous lithotope which characterize the depositional shelf zone are represented by the upper part of the Glenwood (Harmony Hill plus Hennepin members) which consists predominantly of shale ranging from 0 to 30 feet in thickness. In more seaward areas carbonate was deposited in the carbonate zone and is represented by a sequence of overlapping carbonates which include, in ascending order beginning in southern Illinois, the Dutchtown, Joachim, Platteville, Decorah, and Galena formations referred to en masse as the "Trenton" formations (Du Bois, 1945), as the Ottawa Limestone Megagroup (Swann and Willman, 1961), and in Wisconsin, as the Sinnipee Group (Ostrom, 1969).

Deposition of Cincinnatian clays and carbonates marked the end of cyclic sedimentation characterized by the quartzarenite-carbonate association in the Upper Mississippi Valley. Although the alternating occurrence of clastics and carbonates continued, the clastics of succeeding cycles were derived in large measure from the newly emergent eugeosynclinal area of the Appalachian province (Woodward, 1961; Potter and Pryor, 1961).

SUMMARY AND CONCLUSIONS

Upper Cambrian and Lower and Middle Ordovician deposits of the Upper Mississippi Valley consist of four recurring lithotopes comprising five sedimentary cycles. The lithotopes and depositional zones are: (1) thick-bedded quartzarenites deposited in the littoral zone; (2) thin to medium-bedded, poorly-sorted, reworked quartzarenites, transitional with overlying and underlying lithotopes and formed in the non-depositional shelf zone; (3) shales or argillaceous sandstones formed in the depositional shelf zone; and (4) carbonates formed in the biogenic carbonate zone.

The depositional zone in which each lithotope developed occupied a position that was roughly parallel to the shoreline and that migrated over the shelf landward in response to submergence and seaward in response to emergence. Each cycle has in its base a quartzarenite which marks the environment of the littoral depositional zone. These are overlain, in turn, by deposits developed successively farther out to sea, namely those of the nondepositional shelf zone, depositional shelf zone, and carbonate zone. Deposition during emergence resulted in reversed order of occurrence.

Rock units which comprise the five cycles of sediments, in ascending order, are the: (1) Mt. Simon Sandstone, Eau Claire Sandstone, Bonneterre Dolomite; (2) Galesville Sandstone Member, Ironton Member, Tunnel City Group, St. Lawrence Formation; (3) Jordan Sandstone, Sunset Point Member or Kasota Sandstone and Blue Earth Siltstone, Oneota Dolomite (excluding the Sunset Point); (4) New Richmond Sandstone, Willow River Dolomite; and (5) St. Peter Sandstone, Glenwood Formation, and Sinnipee Group.

The relationships of factors affecting pre-Cincinnatian Paleozoic sedimentation in the Upper Mississippi Valley are summarized in Figure 19.

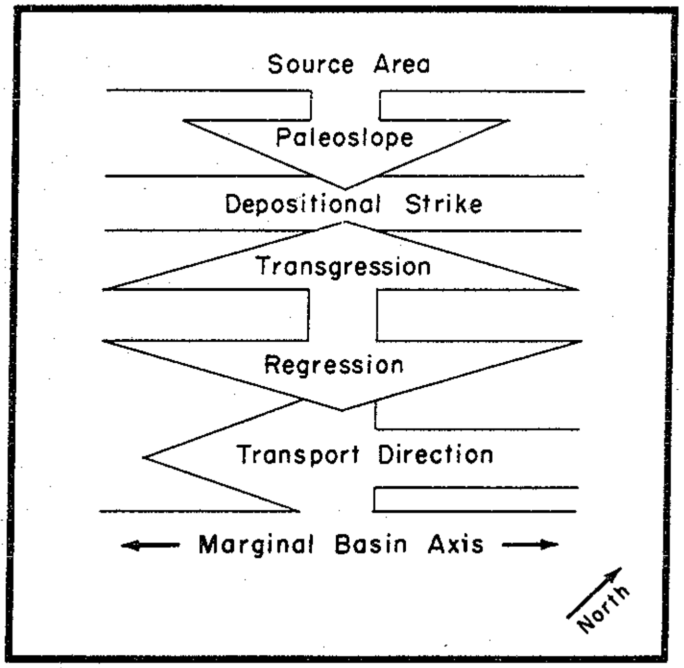


Figure 19. Model summarizing relationships of factors which affected pre-Cincinnatian Paleozoic sedimentation in the Upper Mississippi Valley area.

Deposition of Cambrian and Lower and Middle Ordovician sediments in this area was on the craton which was situated northwest of the Appalachian geosyncline, and on which were located more rapidly subsiding intracratonic basins and essentially stable arches and domes. It is believed that the lithic cycles are the product of repeated emergence, which was caused by rejuvenation of tectonically positive portions of the craton, and submergence, which resulted from subsidence of the geosyncline and of the neighboring shelf area of the craton.

The paleoslope of the area remained constant throughout the time of deposition of these sediments and had a dip to the southeast in the direction of the geosyncline. The dominant direction of sediment transport was to the south and southwest roughly parallel to ancient shorelines.

Regressive phases are identified in Cambrian cycles in the area but are unknown in Ordovician cycles. It is suggested that active subsidence of the Illinois-Michigan Basin during shelf emergence at the close of the Cambrian Mt. Simon and Galesville cycles allowed deposits developed during regression to be lowered beyond the reach of subsequent erosion.

The Jordan and New Richmond cycles of the Lower Ordovician differ from previous cycles, and from the succeeding St. Peter cycle, in that their shale or argillaceous sandstone lithotopes, representing the depositional shelf zone, are poorly developed. Development of this lithotope in the other cycles is thought to have been caused by coincidence of the depositional shelf zone with the actively subsiding basin area which received large amounts of clastic sediment from a land area of moderate relief during regression. Poor development of the argillaceous lithotope in the Jordan and New Richmond cycles is interpreted to mean that the depositional shelf zone did not regress as far south as the subsiding basin, that the land area exposed to erosion was lower and less extensive than at previous times of regression, and consequently, that less sediment was delivered to the shelf.

The results of this study are the basis of a working hypothesis being used by the Wisconsin Geological and Natural History Survey for interpreting problems of Cambrian and Ordovician stratigraphy and sedimentation. It is not meant to infer that conclusions drawn from this study are final. However, use of the cyclical hypothesis provides a rationale to explain stratigraphic relationships which have hitherto been poorly known on the local and regional scale, as well as to define geologic problems for additional investigation.

PRAIRIE DU CHIEN GROUP IN THE UPPER MISSISSIPPI VALLEY

by
Richard A. Davis, Jr.
Department of Geology
Western Michigan University

INTRODUCTION

The first description of rocks comprising the Prairie du Chien Group was made by D. D. Owen (1840, p. 17) who named these strata "Lower Magnesian Limestones" which included all rocks between the "lower sandstone" (Jordan Sandstone) and the "upper sandstone" (St. Peter Sandstone). Since then there has been considerable confusion and misinterpretation of the character and distribution of rock stratigraphic units in the Prairie du Chien Group resulting in a chaotic literature due to broad and hasty conclusions drawn from restricted investigations. A regional study of the entire Prairie du Chien Group in the Upper Mississippi Valley (Davis, in press) provides a logical and workable solution to this confusion (Figure 20).

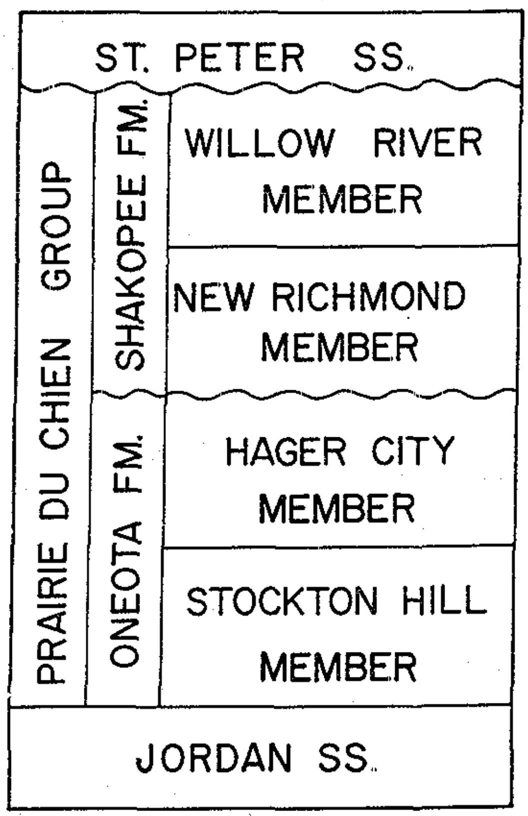


Figure 20. Lithostratigraphic classification proposed for Prairie du Chien Group (Davis, in press).

The results of this study indicate the need for changes in the definition and nomenclature of rock stratigraphic units within the Prairie du Chien Group. The nomenclature and definition of those units as presented here and in a more lengthy companion paper (Davis, in press) is different than any that has been previously proposed. The revised classification, which is based on lithologic variations, provides a meaningful basis for classification of these strata.

All units in the revised classification are easily recognized and can be traced throughout most of the outcrop area of the Upper Mississippi Valley. The term group is retained for the strata between the Jordan and St. Peter Sandstones as is the name Prairie du Chien as designated by Bain (1906) (Figure 21). The group is conveniently divided into two recognizable and distinct mappable formations, the Oneota and the overlying Shakopee. These formations are separated by an unconformity and each is comprised of two members (Figure 20).

This study has been financed by the Wisconsin Alumni Research Foundation, the Society of the Sigma Xi, the Wisconsin Geological and Natural History Survey, and the Western Michigan University Faculty Research Fund.

STRATIGRAPHIC LIMITS OF THE PRAIRIE DU CHIEN GROUP

The base of the Prairie du Chien Group has generally been considered to coincide with the Cambrian-Ordovician boundary although the biostratigraphy has not been worked out in detail. The poor preservation and sparse occurrence of fossils have limited the scope of paleontological studies. However, significant studies were made by Sardeson (1896), Ulrich (1924), Powell (1933), and Stauffer (1937a, 1937b). The Prairie du Chien Group is commonly equated with the Lower Ordovician, Canadian Series, but recent studies of Prairie du Chien conodonts at the University of Wisconsin indicate that these strata are Tremadocian in age (D. L. Clark, personal communication). As yet it has not been resolved as to whether this stage is latest Cambrian or earliest Ordovician.

The contacts at the base and top of the Prairie du Chien are abrupt. The basal contact occurs between the friable, well-sorted, cross-bedded, medium quartz sandstone of the Jordan Formation (Van Oser Member) and the carbonate-cemented quartz sandstone of the overlying Prairie du Chien Group. The basal Prairie du Chien is a dolomite-cemented, medium-bedded, medium quartz sandstone that is more poorly sorted than the underlying Jordan. The contact is also marked by distinct change in weathering profile such that the dolomitic Prairie du Chien beds form a ledge over the friable upper Jordan (Stop #9).

The upper boundary of the Prairie du Chien is easily recognized but exposures are limited in the Upper Mississippi Valley. The boundary is an erosion surface with local relief up to 350 feet which explains the absence of the entire Prairie du Chien Group at some localities.

ONEOTA FORMATION

The Oneota Formation was named from the Oneota River (now Upper Iowa River) by McGee (1891, p. 331) who applied it to the "Main body of limestone" within Owen's (1840) Lower Magnesian limestone. McGee (1891; p. 332) designated the term to include the "magnesian and arenaceous limestone" above the Potsdam (Jordan Sandstone) and below the New Richmond which he included in the St. Peter Sandstone.

The Oneota as defined by McGee, and as used here, includes all of the dolomitic quartz sandstone, sandy dolomite, and dolomite above the pure quartz sandstone of the Jordan and below the New Richmond Member of the

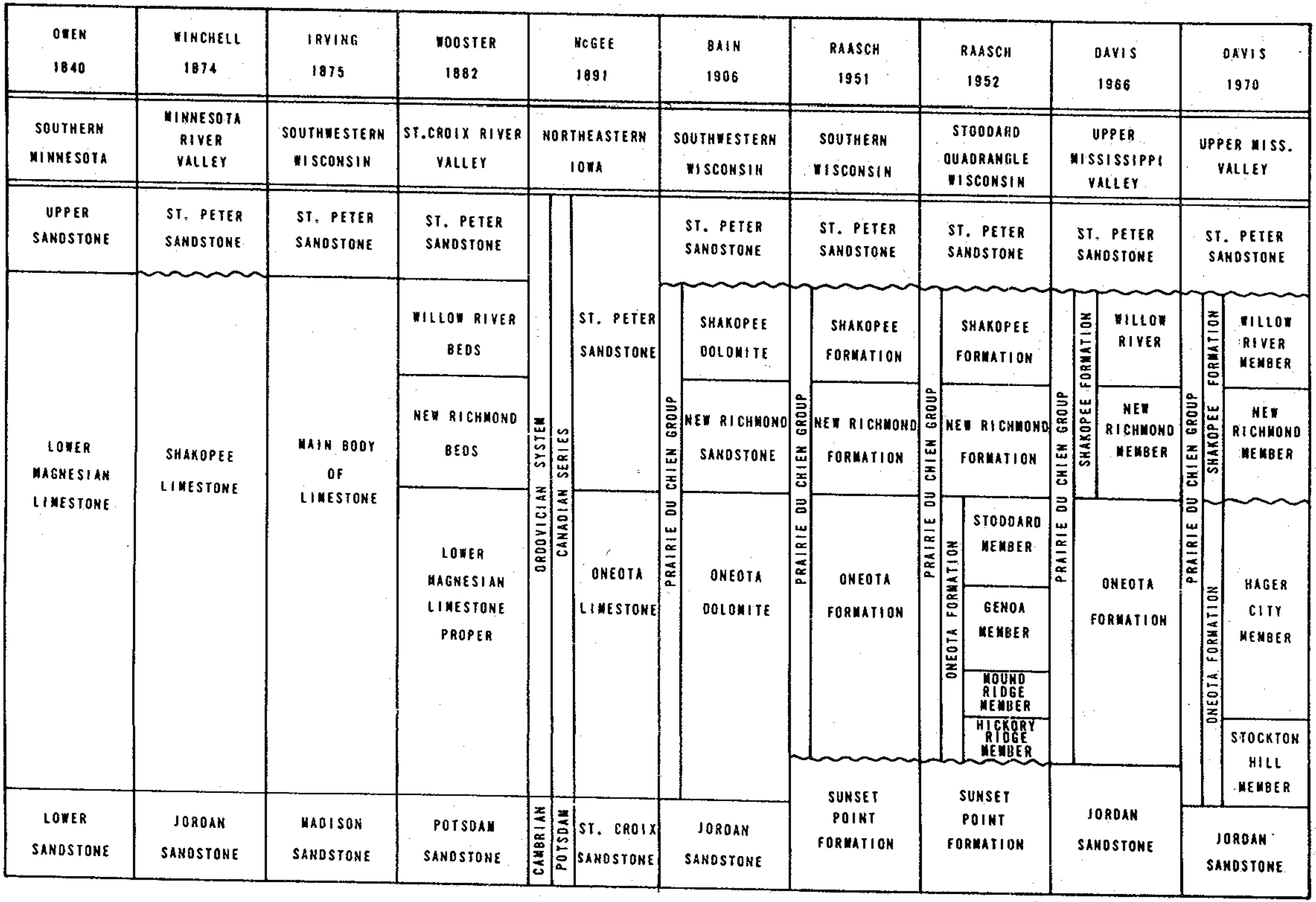


Figure 21. Development of nomenclature for the Prairie du Chien Group in the Upper Mississippi Valley.

Shakopee Formation. It is lithologically distinct and easily recognized. Its thickness reaches a maximum of more than 200 feet in northeastern Iowa. The lower boundary is at an abrupt lithic and profile change, and its upper limit is an erosion surface where there is also a distinct lithic change.

Past workers have considered the dolomitic quartz sandstone and sandy dolomite of the lower portion of this formation to be a separate formation (Raasch, 1935), a part of the Jordan Formation (Stauffer, 1927; Trowbridge and Atwater, 1934; Ostrom, 1965, 1967; Melby, 1967), or a formation or member in the Trempealeau unit (Twenhofel, et. al, 1935; Raasch, 1952; Raasch and Unfer, 1964). It is the author's opinion, based on McGee's original definition and the results of this study, that these lower sandy strata should be included in the Prairie du Chien Group and more specifically in the Oneota Formation. These sandy strata are sedimentologically related to the overlying pure dolomites and together form a distinct and easily mappable unit.

Stockton Hill Member

The Stockton Hill Member (Davis, in press) of the Oneota Formation is named from excellent exposures in roadcuts in Stockton Hill along U.S. Highway 14 west of Winona, Minnesota. It includes all of the dolomitic quartz sandstone above the Jordan and below the pure dolomite of the overlying Hager City Member. It is transitional between the homogenous lithic character of the confining units. Oolites, algal stromatolites, intraclasts, chert, and glauconite occur at various horizons in the Stockton Hill Member throughout the study area. Although there is considerable heterogeneity within the unit, its strata are distinct from adjacent units (Figure 22). Lithology and bedding

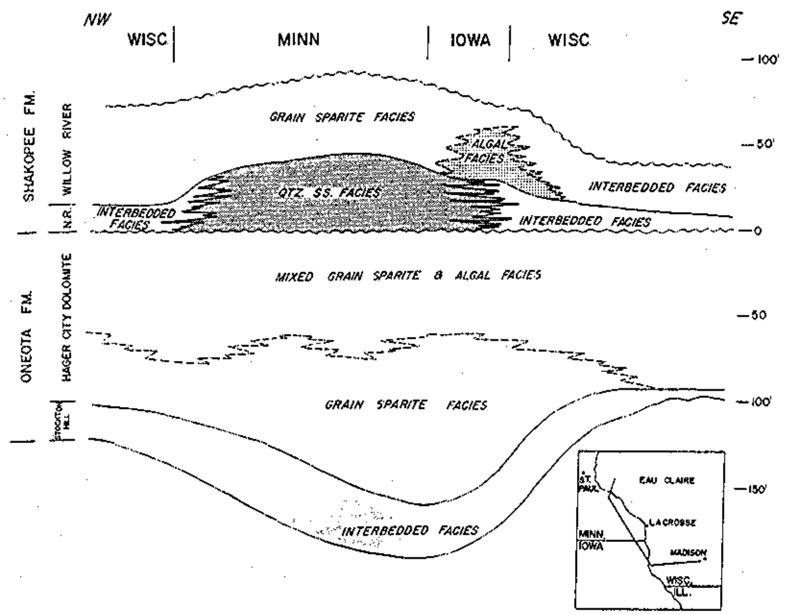


Figure 22. Generalized facies relationships in the Prairie du Chien Group.

character of the Stockton Hill is similar to the Willow River Member of the Shakopee Formation however the Stockton Hill contains more quartz than the Willow River. The unit ranges in thickness from a few feet over the Wisconsin Arch (Figure 22) to more than 50 feet in the Mississippi River area.

The lower portion of the Stockton Hill, the so-called "beds of transition" has been the source of considerable confusion in the literature due in part to the fact that fossils were used to establish rock stratigraphic boundaries and the rocks were not considered in a regional sense. These beds, located between the quartz sandstone of the Jordan and the sandy dolomite in the Oneota of most authors were initially called the Madison Sandstone by Irving (1875). In 1934 Wannemacher, Twenhofel, and Raasch modified Irving's definition. Raasch (1951) proposed that the term Madison Sandstone be replaced by Sunset Point because of confusion with the well-established Madison Formation (Mississippian) of Montana and Wyoming.

In the author's opinion the Sunset Point is extremely difficult to identify and cannot be recognized consistantly in the field or subsurface. In Raasch's definition of the Sunset Point (1935, p. 314) he stated that:

> "The upper boundary of the formation lies at the line of separation between the fine-grained, well-sorted, and in many cases very firmly indurated dolomitic sandstones below and the prominent cobble-conglomerates or ill-sorted, calcareous sandstones and green glauconitic siltstones above. These latter rocks mark the base of the Ordovician Oneota formation..."

According to McGee's original designation and the character of the basal Oneota in northeastern Iowa, Raasch's Sunset Point should properly be included in the Oneota Formation. The reasons for separating the Sunset Point from the Oneota (and therefore from the Prairie du Chien Group) appear to have been based on the occurrence of Cambrian trilobites in these strata and on what Raasch believed to be an erosional unconformity at the top of these strata. The author can find no physical evidence for such an unconformity at this horizon.

In a study of the Stoddard Quadrangle in Vernon County, Wisconsin, Raasch (1952) described a Sunset Point - Oneota boundary and four members within the Oneota Formation on the basis of lithologic criteria such as oolites, chert, algal stromatolites and subtle changes in sorting and grain size. It was his belief on the basis of this study, plus many years of experience in the Upper Mississippi Valley area, that these criteria could be used for correlation in the lower Oneota.

Raasch's boundary between the Sunset Point and Oneota could not be consistently used in the field nor in the subsurface during the course of the present regional study. Thus it is believed that these sandy dolomites and dolomitic quartz sandstones should be combined with those which occur above it in the base of Raasch's Oneota into a single lithostratigraphic unit. This unit can be recognized in the field and subsurface, and is genetically and environmentally related to the overlying pure dolomites of the Oneota. The name Stockton Hill Member is therefore designated (Davis, in press) to include all strata between the pure quartz sandstone of the Jordan Formation and the pure dolomite of the upper Oneota Formation. This unit is equivalent to Raasch's (1951, 1952) Sunset Point Member, Hickory Ridge Member, and all but the upper few feet of the Mound Ridge Member (Figure 21).

Hager City Dolomite Member

The Hager City Member overlies the Stockton Hill Member and is the upper member of the Oneota Formation. It is named (Davis, in press) from exposures in roadcuts along H. S. Highway 63 north of Hager City, Wisconsin. The Hager City Member is mineralogically homogenous with only minor amounts of chert, shale, and secondary calcite in an otherwise pure dolomite. Small percentages of silt and fine sand-sized quartz occur near the area of the Wisconsin Arch and one thin discontinuous bed of quartz sandstone occurs near Hager City, Wisconsin. In northeastern Iowa the Hager City Member reaches its maximum outcrop thickness of 180 feet. It thins to less than a hundred feet to the north and east and thickens to several hundred feet in the subsurface to the south and southwest.

The Hager City is a medium crystalline saccharoidal dolomite in most places. There is little oolitic or intraclastic dolomite in most of the outcrop area. The most diagnostic feature in hand specimen is the absence of detrital quartz. Outcrops of Hager City strata are conspicuous by their thick or poorly bedded character, rough weathering, cavernous zones of poorly preserved algal stromatolites, and in many areas, large secondary calcite crystals.

Although the fauna of the Oneota Formation has been studied intensively (Sardeson, 1896; Powell, 1933), it is meager and poorly preserved so that Hager City fossils are of questionable value to the stratigrapher. A few thin beds with small molds of fossil fragments are present at most exposures.

ONEOTA-SHAKOPEE CONTACT

For several decades there has been disagreement over the character and significance of the contact between the Oneota Formation and the New Richmond Member of the Shakopee Formation. Earlier workers considered the contact to be an unconformity as evidenced by paleontology (Stauffer, 1937b; Furnish, 1938) and physical criteria (Ulrich, 1924; Andrews, 1955). Ulrich (1924) designated this contact as the boundary between his Ozarkian and Canadian systems. Recent workers are divided in their opinion in that Heller (1956) and Shea (1960) believe the Prairie du Chien sequence represents continuous deposition. On the basis of a regional historical interpretation of Cambrian and Ordovician sedimentation Ostrom (1964) believes the sequence is interrupted by an erosion surface. This has been substantiated by field evidence (Davis, 1968).

A variety of observable physical criteria indicate that the Oneota - Shakopee contact is an erosional unconformity at most exposures. The lack of detailed paleontological data prohibits an estimate of its time significance but it is thought to be minor. Evidence for erosion on the upper Oneota surface includes:

1. Up to several inches of relief on the Oneota.
2. Local truncation of Oneota strata.
3. Abrupt change in lithology (Figure 22).
4. Local basal conglomerate with fragments of Oneota-type lithology.

SHAKOPEE FORMATION

Strata which occur between the Oneota Dolomite and the St. Peter Sandstone comprise a distinct and recognizable mappable unit throughout most of the outcrop area in the Upper Mississippi Valley (Davis, 1966).

At most exposures two distinct lithic units can be recognized within this formation. The lower is a pure quartz sandstone in the central portion of the outcrop area (northeastern Iowa and southeastern Minnesota) but displays a prominent change in facies to the north and east of the area (Figure 22). In these regions it is interbedded quartz sandstone, sandy dolomite, and gray-green shale with some oolites, intraclasts and algal stromatolites (Figure 22). This unit is the New Richmond Member.

Above the New Richmond is the Willow River Member, a sequence of sandy dolomites containing significant amounts of oolites, intraclasts, algal stromatolites and some chert.

These two members are identifiable throughout most of the outcrop area except for the northwestern edge of the Upper Mississippi Valley region. The general lithologic similarity in much of the three state area makes subsurface distinctions difficult unless the New Richmond is a relatively pure quartz sandstone.

Thickness of the Shakopee Formation is largely controlled by pre-St. Peter erosion. Maximum outcrop thickness observed is about 100 feet in southeastern Minnesota near the city of Lanesboro.

New Richmond Member

The New Richmond Member of the Shakopee Formation exhibits more lateral change than other units in the Prairie du Chien. In the central area it is a pure quartz sandstone (Fig. 21) and reaches its maximum outcrop thickness of near 50 feet. Adjacent to this region to the north and southeast the New Richmond is composed of interbedded quartz sandstone, sandy dolomite, and gray-green shale with some oolites and algal stromatolites. In these regions it thins considerably and is only six feet thick at some locations. This facies change occurs in less than 20 miles and was cause for confusion by earlier workers.

At exposures where the New Richmond and the overlying Willow River exhibit similar lithologies there is little difficulty in distinguishing between the two units (Stop 12). The New Richmond is characteristically bounded by gray-green shale beds and thus stands out well on a quarry face.

Willow River Member

Sandy and intraclastic dolomite, algal stromatolites and oolitic dolomite with minor amounts of gray-green shale and quartz sandstone characterize the Willow River Member. Each of the above lithic types is present throughout the outcrop area with algal stromatolites abundant in the southeastern portion. Thickness of the Willow River is controlled by the pre-St. Peter erosion surface which cuts through the entire Prairie du Chien at some locations. Maximum thickness exposed is 60 feet.

One of the most discussed problems in past reports on the Prairie du Chien is that of distinguishing between the two dolomite units, namely the Hager City and Willow River members. Previous investigators have expressed the opinion that the two units are essentially identical. However, the Hager City and Willow River can be recognized on the basis of their outcrop appearance and lithology. The following criteria apply:

1. The Hager City Member is massive to poorly-bedded with a generally rough surface whereas the Willow River is commonly medium to thin-bedded.

2. The Hager City is generally a coarser grained dolomite than the Willow River.

3. The Hager City does not contain detrital quartz whereas the Willow River has at least a few quartz grains at almost every horizon. This is the best single distinguishing criterion.

4. There are generally well preserved algal stromatolites in the Willow River.

5. Intraclasts and oolites are less common in the Hager City than in the Willow River.

6. The Hager City commonly contains large calcite crystals and/or vugs lined with drusy quartz. Neither of these are found in the Willow River.

PLATE I. Photomicrographs showing textures and structures in rocks of the Prairie du Chien Group.

A. Grain Sparite; well-sorted and rounded grains which have no preserved internal structure, but were probably biogenic. (Hager City Member, Oneota Formation).

B. Medium-coarsely Crystalline Dolomite; well defined dolomite rhombs which show some zoning. These are probably dolomitized and recrystallized grain sparite. (Hager City Member, Oneota Formation.

C. Intraclastic Grain Sparite; poorly-sorted, heterogenous mixture of grains, aphanocrystalline intraclasts, with sparry cement. (Hager City Member, Oneota Dolomite).

D. Algal Biolithite; thin and regularly laminated algal stromatolite. (Willow River Member, Shakopee Formation).

E. Oosparite; sorted oolites which have lost most of their internal structure. Several have quartz nuclei and composite and quiet water oolites (arrow) are present. (Willow River Member, Shakopee Formation).

F. Quartz Sandstone; moderately well-sorted and rounded, medium-grained and friable with a few chert fragments (New Richmond Member, Shakopee Formation).

G. Conglomeratic Quartz Sandstone; basal quartz sandstone of the New Richmond Member containing fragments of Hager City Dolomite. (New Richmond Member, Shakopee Formation).

H. Contact between Hager City Member of Oneota Formation and the overlying New Richmond Member of the Shakopee Formation. Truncation of dolomite grains can be seen along the contact.

Note: The scale on all photographs is 1.0 mm except for H which is 0.25 mm.

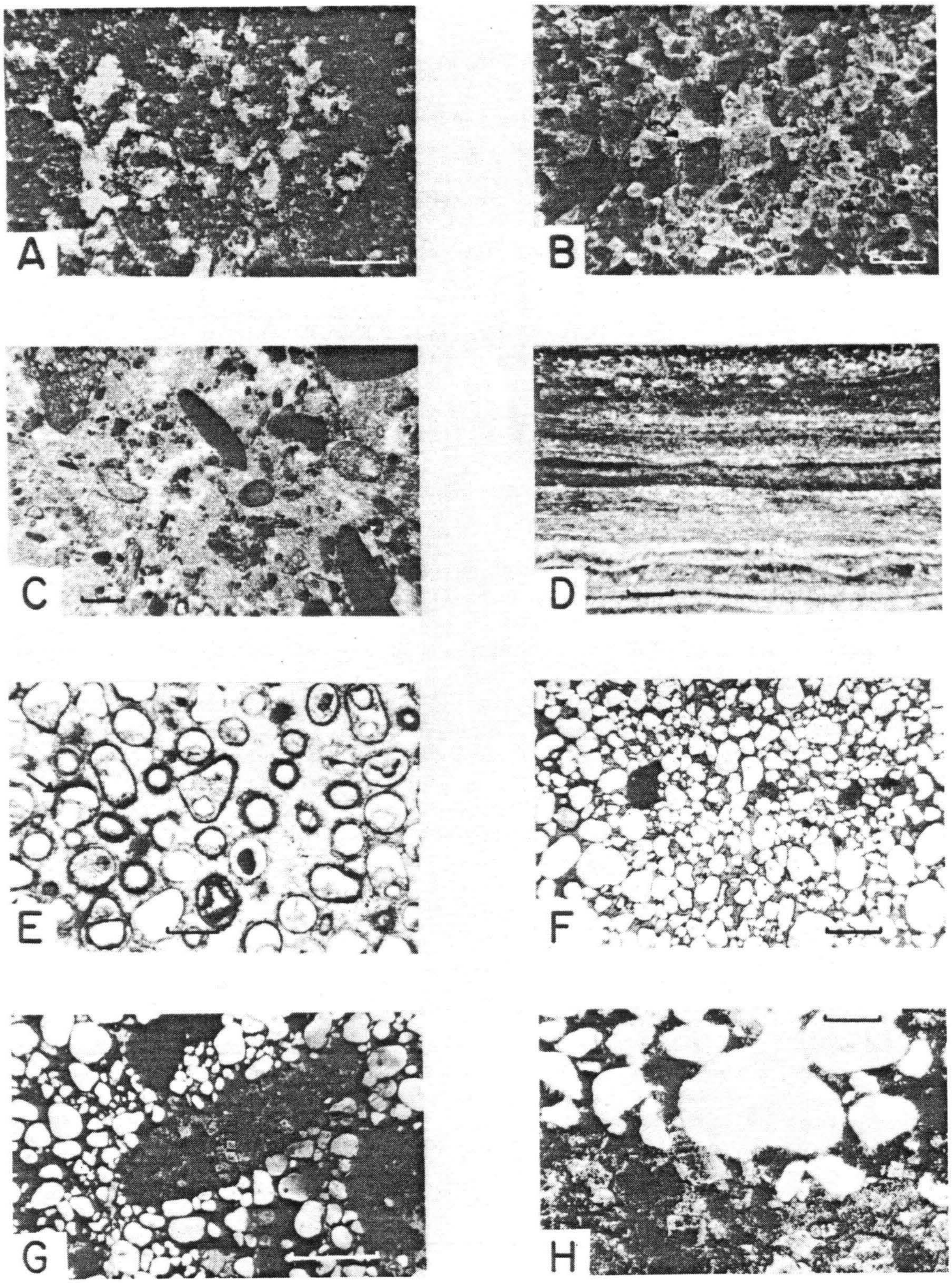


Plate I. Photomicrographs showing textures and structures in rocks of the Prairie du Chien Group.

STRATIGRAPHY AND SEDIMENTATION OF CAMBRIAN AND ORDOVICIAN ROCKS IN WESTERN WISCONSIN

ROAD LOG

Total Mileage	Mileage Between	
0.0	0.0	Main entry to Irvine Park off of U.S. Highway 53 near north side of City of Chippewa Falls. Enter Park and proceed straight ahead (west). Refer to figures 1-6 for geologic and geographic orientation.
0.2	0.2	Cross bridge and turn right. Proceed 0.5 miles north past zoo and picnic areas and stop near bridge on right.
0.7	0.5	STOP 1 (M.E. Ostrom). Stream cut in east bank of Duncan Creek just north of first bridge south of Glen Lock dam in Irvine Park near the north city limits of Chippewa Falls (Figure 3) and in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 31, T.29N., R.8W., Chippewa County (Chippewa Falls 15' topographic quadrangle, 1936). Exposure can be reached by following foot path from northeast side of bridge northward for about 100 yards.

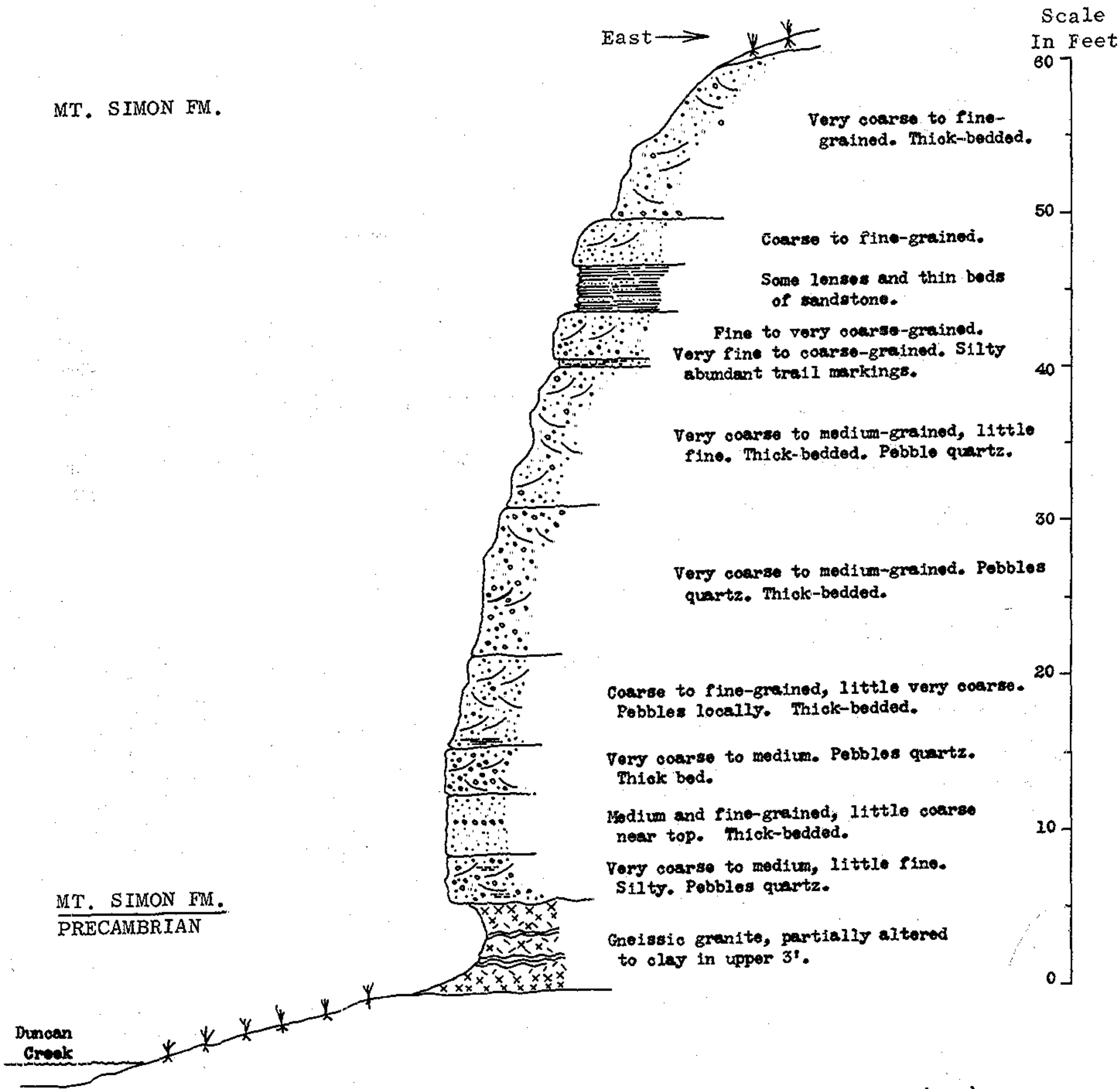
The Mt. Simon Sandstone, presumably the oldest Cambrian formation in Wisconsin, here rests unconformably on weathered Precambrian gneissic granite. This relationship with the Precambrian persists throughout the Paleozoic area of the state except that rock type and altered condition of the Precambrian vary.

Thwaites (1957) constructed a map (Figure 3) based on existing subsurface data to show configuration of the Precambrian surface. Lack of data prevents construction of a coherent "buried" Precambrian geologic map, however drill cuttings reveal that a wide variety of igneous and metamorphic rock types occur beneath the Paleozoic cover. Among the rocks reported are granite, diorite, quartzite, gneiss, schist, iron formation, rhyolite, basalt, slate, shale, and greenstone.

The Mt. Simon Sandstone is believed to have been deposited in a marine littoral and nearshore environment by a transgressing sea which migrated from southeast to northwest over a weathered and eroded Precambrian rock surface (Ostrom, 1964a).

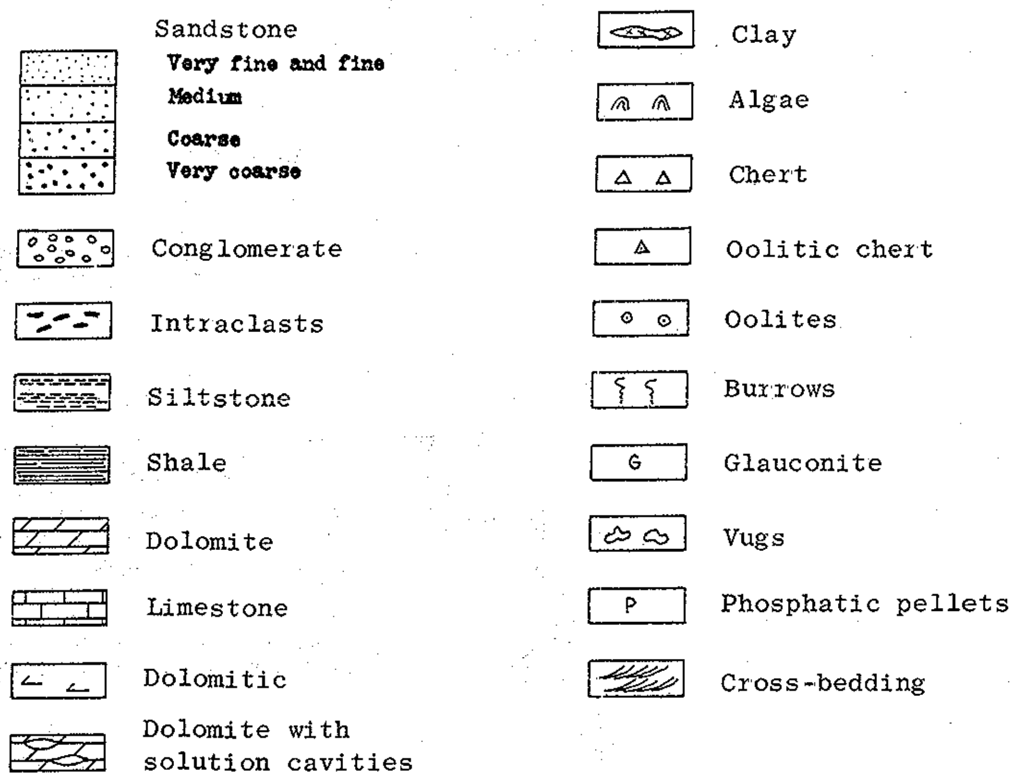
The areal extent of such deposits in the Gulf of Mexico today is limited to the length of the shoreline and a maximum width of about 20 miles (Van Andel and Curray, 1960). The Cambrian and Ordovician sandstones are believed to be a result of spreading out littoral deposits as blankets during transgression (Ostrom, 1964a). For example, Calvert (1962) shows that the Mt. Simon or its lithostratigraphic equivalent the Erwin Sandstone, overlaps to the northwest from Tennessee to Wisconsin, that it was deposited during a period of transgression, and that its age is Early Cambrian in Tennessee and Late Cambrian in Wisconsin.

STOP 1
IRVIN PARK OUTCROP
$NW\frac{1}{4}$, $SW\frac{1}{4}$, Sec. 31, T. 29N., R. 8W.



Described by M.E. Ostrom (1966)

Key to Symbols Used in Stop Diagrams



The Mt. Simon has been considered to be predominantly a quartzarenite with minor shale, siltstone and fine conglomerate and minor feldspar (Crowley and Thiel, 1940; Potter and Pryor, 1960). However, in 1968 a study sponsored by the Wisconsin Geological Survey and used as a PhD dissertation by Virendra Asthana revealed that the feldspar content of the Mt. Simon Sandstone averages 18% of which 81% is potash feldspar, 10% is plagioclase feldspar and 9% is microcline. The range in feldspar content reported is from 2.85% to 40.07%. Asthana reports that all of the microcline and plagioclase grains are detrital as are a part of the potash feldspar grains. Authigenic orthoclase is very common but occurs as rhombic overgrowths on detrital grains. On this basis it appears that the Mt. Simon contains far more feldspar than has been previously noted which fact helps to distinguish it from other Upper Cambrian and Ordovician sandstones in Wisconsin.

The source of the Cambrian sands has long been an enigma. Without going into a lengthy discussion of the various hypotheses involving weathering and long transport of eroded Precambrian rocks to produce a relatively clean quartz sand it should be pointed out that there is a ready source available, namely quartzites of Precambrian age. Distribution of the Baraboo Quartzite today is probably the result of a combination of factors including local and regional variations in intensity of metamorphism, disintegration, and erosion. It has been noted (Ostrom, 1966) that the Baraboo Quartzite disintegrates by some natural process to yield already rounded monocrystalline quartz sand grains and that this and similar quartzites may have been a major source of sand found in Cambrian and Ordovician rocks of the region. Figure 23 is a picture of a quarry located near North Freedom, Wisconsin, and shows steeply tilted beds

Galesville Ss.
Baraboo Qtzt.

Figure 23. Unconformable contact of Galesville Sandstone with Precambrian Baraboo Quartzite in quarry located southwest of North Freedom near hamlet of LaRue in Sauk County, Wisconsin. Here weathering of the quartzite released rounded quartz grains which went to make up the Galesville Sandstone. An excellent example of a Cambrian beach deposit.

of quartzite, weathered in the upper few feet, overlain by flat-lying beds of the Galesville Sandstone. Other quartzites exhibit similar disintegration, namely the Rib Hill and Barron in Wisconsin and the Sioux in Minnesota (Austin, 1969). The fact that these quartzites are extensive, thick, and weather to yield already rounded quartz grains suggests that they may have been a major source of sand supplied to Cambrian and Ordovician seas.

1.4	0.7	Return to park entrance. Stop sign. Entry to Irvine Park. Turn right (south) on U. S. Highway 53 and proceed to Eau Claire.
2.8	1.4	Cross Chippewa River.
11.4	8.6	Enter city of Eau Claire.
12.1		Enter Eau Claire County.
14.7	2.6	Take ramp on right before underpass to County Highway "Q".
14.8	0.1	Stop. Turn west (right) and follow to stop sign.
15.9	1.1	Stop sign. Turn north (right) on Dewey Street.
16.0	0.1	Turn west (left) on Eddy Street and follow across railroad bridge.

16.4	0.4	Stay to left on Sheridan Road.
16.7	0.3	Turn diagonal north (right) on Snelling Street.
17.1	0.4	<u>STOP 2</u> (M.E. Ostrom). Type section of the Mt. Simon Sandstone formation. Exposure in bluff of Chippewa River and in hill called Mt. Simon in the City of Eau Claire in the SW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 8, T.27N., R.9W., Eau Claire County (Elk Mound topographic quadrangle, 1934). Section includes all rock exposed from top of hill called Mt. Simon northward to base of river bluff.

The Mt. Simon Sandstone at its type exposure grades upward from well-sorted, thick-bedded, coarse-grained, sandstone in the lower part to finer-grained, thinner-bedded, transitional beds at the top. Although the formation contains brachiopod shells in its upper few feet it is assigned to the Mt. Simon rather than the Eau Claire on the basis of lithologic similarity. The Mt. Simon is assigned a Dresbachian age because it is transitional with the overlying Eau Claire Formation which has a Dresbachian fauna (Crepicephalus and Cedaria).

Older mineralogical analyses of the Mt. Simon at this site indicate a range in feldspar content of from 2.06% to 5.0% (Stauffer & Thiel, 1941; Crowley & Thiel, 1940; Potter & Pryor, 1961). However, a recent study by Asthana (1968) sponsored by the Wisconsin Geological Survey shows that the range in feldspar content of samples collected at regular 5-foot intervals from this exposure is from 1.4% to 40.0% with an average of 17.5%. Combined plagioclase-microcline percentages range from 0.64% to 12.7%.

Predominant heavy minerals in the Mt. Simon Sandstone are ilmenite, leucoxene, zircon, tourmaline, and garnet (Tyler, 1936).

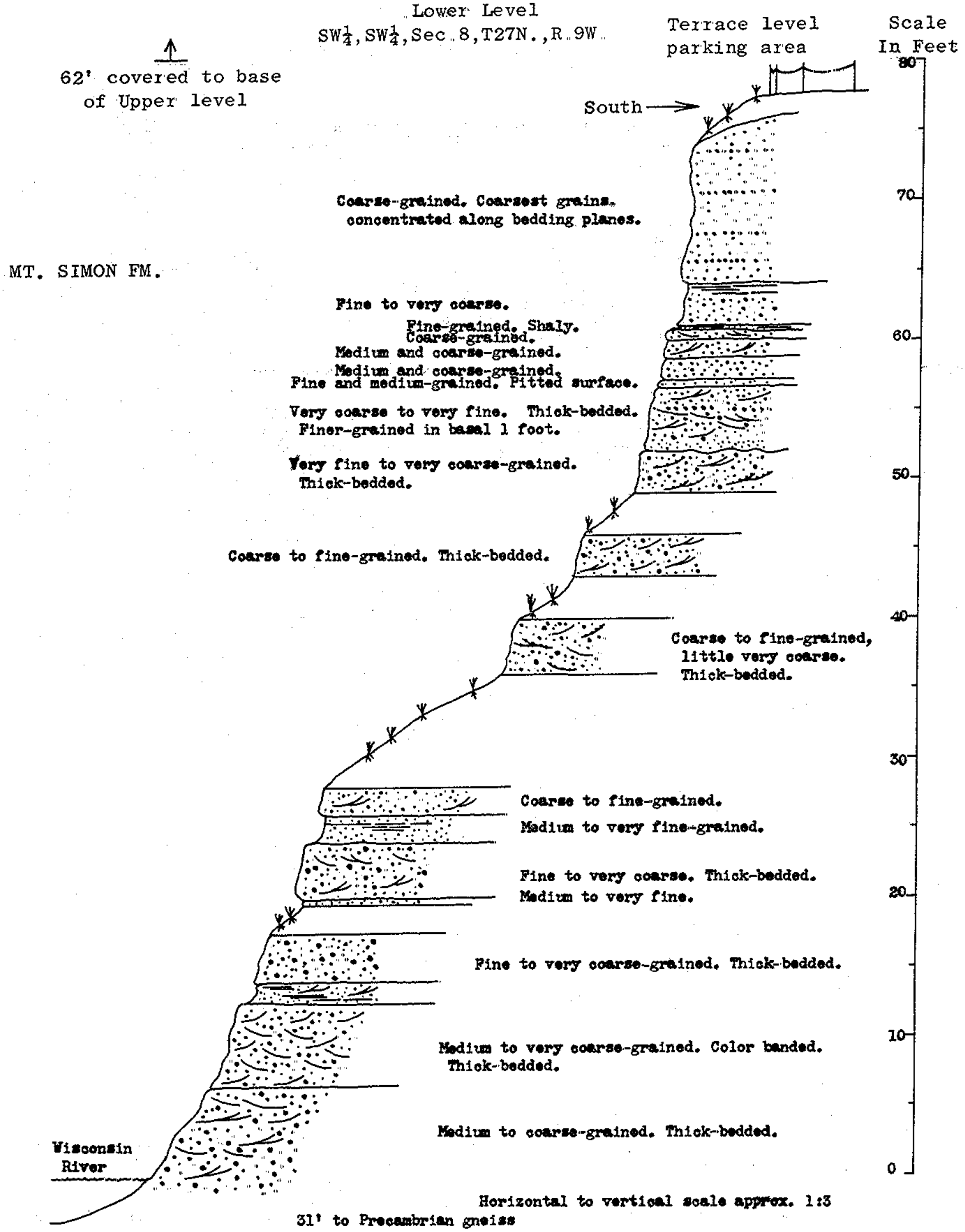
The overlying Eau Claire Formation where sampled near its base at Mt. Washington (type section of the Eau Claire Formation) has a minimum feldspar content of 42% and a combined plagioclase/microcline content of 12%.

The only other mineralogical information available on the Eau Claire Formation is an analysis by Potter & Pryor (1961) which indicates 12.5% feldspar in outcrops near Merrillan in northwestern Jackson County. Other analyses from scattered outcrops of the Eau Claire show variable amounts of tourmaline and zircon, ilmenite, magnetite, and garnet, but all are present.

Of particular interest at this exposure are the transitional beds which are also well-exposed at Stop 3. These have been recognized at many outcrops in this vicinity but have not been traced to other areas due to lack of outcrops revealing this part of the section.

The transition beds are believed to have formed in a nearshore marine environment located seaward of the beach. The transition beds are characterized by wide range in grain size from clay to very coarse sand and granules, well-defined bedding, different lithology from bed to bed, uniform lithology of individual beds, and by vertical burrows which are confined to certain beds.

STOP 2
MT. SIMON OUTCROP
Lower Level
SW¼, SW¼, Sec. 8, T27N., R. 9W.

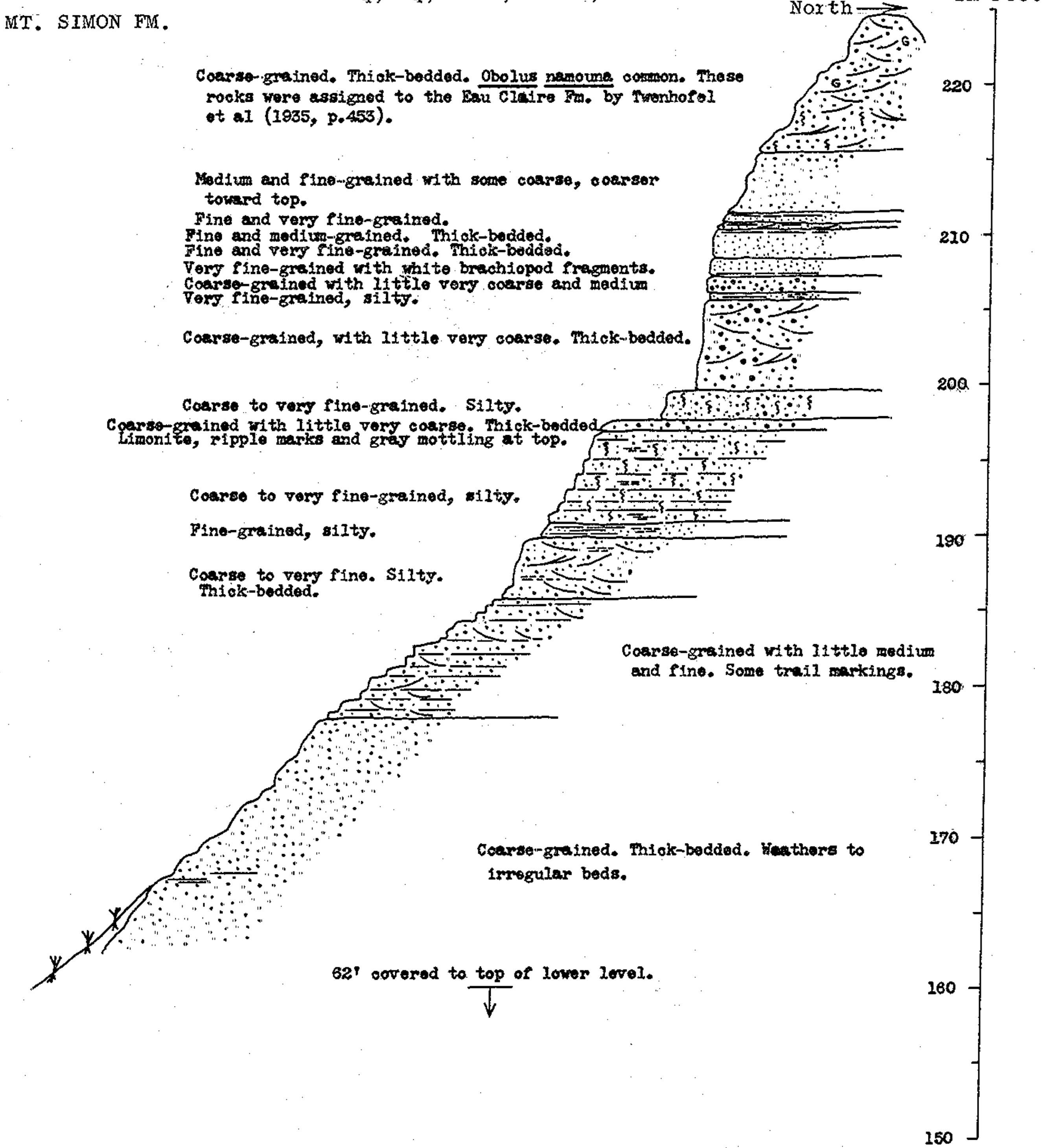


Refer to STOP 1 for key to symbols

Described by M. E. Ostrom and V. Asthana, modified from Ostrom (1966).

STOP 2
MT. SIMON OUTCROP
Upper Level
SW$\frac{1}{4}$,SW$\frac{1}{4}$,Sec. 8,T. 27N.,R.9W.

Scale In Feet



Horizontal to vertical scale approx. 1:3

Refer to STOP 1 for key to symbols

Described by M. E. Ostrom & V. Asthana, modified from Ostrom (1966).

		Retrace route to U. S. Highway 53 (mileage 14.8).
19.4	2.3	Turn south (right) on Highway 53.
21.4	2.0	Bridge over U. S. Highway 12.
24.2	2.8	Bridge over Interstate Highway 93.
24.5	0.3	Turn west (right) on County Highway "II".
24.7	0.2	Proceed straight west where "II" turns south.
25.0	0.3	STOP 3 (M. E. Ostrom). Beginning of exposures of Mt. Simon and Eau Claire formations in roadcuts on east-west asphalt road 0.8 miles due west of junction of U.S. Highway 53 with County Highway "II". Located south of Eau Claire on the north line of the NW¼, SE¼, sec. 2, T.26N., R.9W., Eau Claire County. (Chippewa Falls topographic quadrangle, 1936).

At this exposure the contact relations of the Mt. Simon and Eau Claire formations are clearly shown. The Mt. Simon consists primarily of medium and coarse-grained sandstone with some fine-grained sandstone. The upper approximately 20 feet of the formation consists of transitional beds composed of particles ranging in size from silt to granules. Certain of these beds are thoroughly burrowed. The upper few feet of the transition beds commonly contain brachiopods.

The Eau Claire Formation is distinguished from the Mt. Simon by its generally finer grain size and thin-bedding, and by the presence of glauconite, trilobites, and abundant shale. Commonly the contact is marked by iron oxide enrichment in a zone about one foot thick.

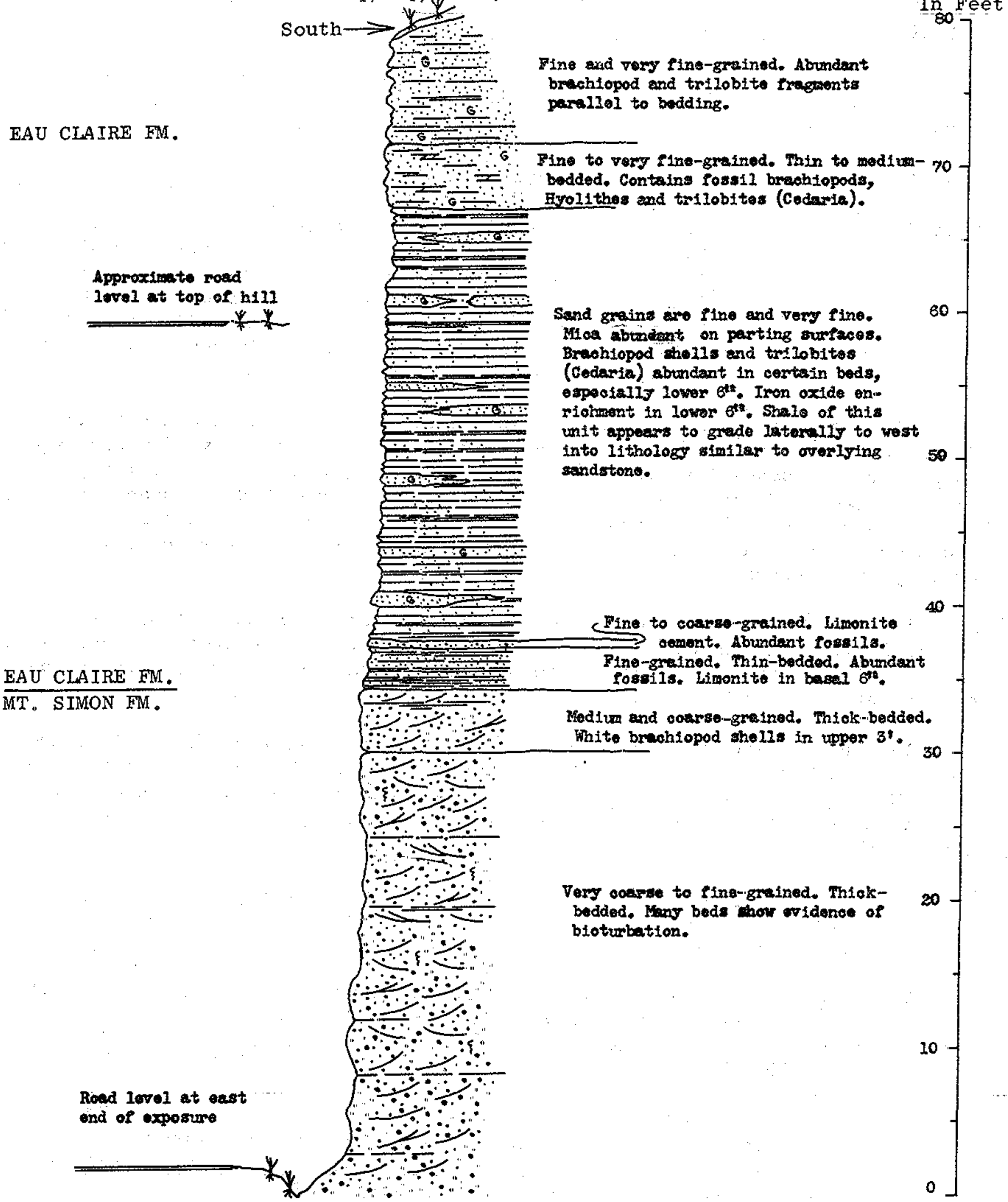
In a recent study of the Eau Claire Formation in western Wisconsin sponsored by the Wisconsin Geological Survey and used by Bradford Morrison (1968) for a Master's Degree at the University of Wisconsin it was determined that the Eau Claire could conveniently be subdivided into 5 laterally persistent lithologic units which are:

E. Upper Thick-Bedded Unit. Sandstone, fine and very fine-grained, thick to medium-bedding, glauconitic; Upper unit at STOP 4; missing at STOP 7. About 20' thick.

D. Upper Thin-Bedded Unit. Sandstone, fine and very fine-grained, thin distinct bedding, very glauconitic. Described as "usually missing from sections." Lower Unit at STOP 4 and upper unit at STOP 7. About 15' thick.

C. Lower Thick-Bedded Unit. Sandstone, fine and very fine-grained, thick-bedded, locally very glauconitic. A few very clay-rich irregularly-bedded units separating the more characteristic thick-bedded units. Thick-bedded unit at entry at STOP 7. About 25' thick.

STOP 3
TOWN ROAD EXPOSURE
NW¼, SE¼, Sec. 2, T. 26N., R. 8W.



Refer to STOP 1 for key to symbols

Described by M. E. Ostrom

B. Lower Thin-Bedded Unit. Sandstone, fine and very fine-grained, mixed thin and thick beds, thin beds regular and distinct, glauconitic, high clay content, mica common. Abundant fossils and trail markings. Unit at top of exposure at STOP 3 and at path level and below springs at grotto at STOP 7. About 20' thick.

A. Shaly beds. Shaly sandstone and shale, very fine and fine-grained and, very thin-bedded, individual beds often indistinct and seldom over 3" thick. Abundant fossils and trail markings. Lower unit at STOP 3. About 15' thick.

Whereas the transition beds in the top of the Mt. Simon are believed to have formed in a nearshore environment located near to but seaward of the beach the Eau Claire Formation, by way of contrast, is believed to have formed in an offshore area of lower energy located seaward of the nearshore environment. This interpretation, is suggested by uniform but thin and laterally persistent beds, presence of glauconite, presence of marine animals in a variety of forms and abundant trail markings, and small scale cross-bedding. Bedding character is interpreted to indicate brief episodes of higher energy and the increase in carbonate content indicates conditions of light and water depth were conducive to formation of carbonate.

The history suggested by these rocks is one of deepening waters probably caused by subsidence of the land surface and northward transgression by the sea over the land (Ostrom, 1964a). Thus beach deposits (thick-bedded Mt. Simon) are mantled by nearshore deposits (transitional Mt. Simon) which are in turn mantled by offshore deposits (Eau Claire). A recurrence at higher levels of any of the lithologies noted would indicate regression. That this happened can be seen at STOP 4 where the Mt. Simon lithology is repeated in the Galesville Sandstone Formation.

25.3	0.3	Roadcut on south side exposing contact of Mt. Simon and Eau Claire formations.
25.5	0.2	Roadcut at top of hill exposing Eau Claire Formation.
25.6	0.1	Roadcut on north side and at west end exposing Eau Claire/ Mt. Simon contact. Proceed west to junction with State Highway 93.
26.7	1.1	Stop sign. Junction Highway 93. Turn south (left).
26.8	0.1	Abandoned quarry in Mt. Simon and Eau Claire on east side of road (left).
32.3	5.5	Junction with County Highway "HH".
33.9	1.6	Exposures of Wonewoc Formation for next 2 miles.
37.4	3.5	Exposures of rocks of Tunnel City Group for next mile.
38.9	1.5	Exposure of contact of Wonewoc Formation with Lone Rock Formation.
39.5	0.6	Exposure Eau Claire Formation.

40.4	0.9	Enter Village of Eleva.
40.8	0.4	Stop sign. Turn east (left) on State Highway 10.
44.9	4.1	Enter Strum. Turn south (right) on County Highway "D".
45.7	0.8	Turn East and follow County Highway "D". Note asphalt plant to north working in glacial deposit. Floor of pit is in Eau Claire Formation.
46.5	0.8	Turn south following County Highway "D".
47.8	1.3	Turn south and follow Highway "D".
49.0	1.2	Exposure of contact of Wonewoc Formation with Lone Rock Formation.
49.5	0.5	Exposure of contact of Wonewoc Formation with Eau Claire Formation.
50.0	0.5	Exposure of contact of Wonewoc Formation with Eau Claire Formation about 20' above road level at top of massive unit.
50.4	0.4	STOP 4 (M.E. Ostrom). Bruce Valley quarry (abandoned) located at east side of County Highway "D" 1.2 miles north of Bruce Valley School in the NE¼, NW¼, NW¼ of sec. 9, T.23N., R.8W., Trempealeau County (Whitehall 15' topographic quadrangle, 1929).

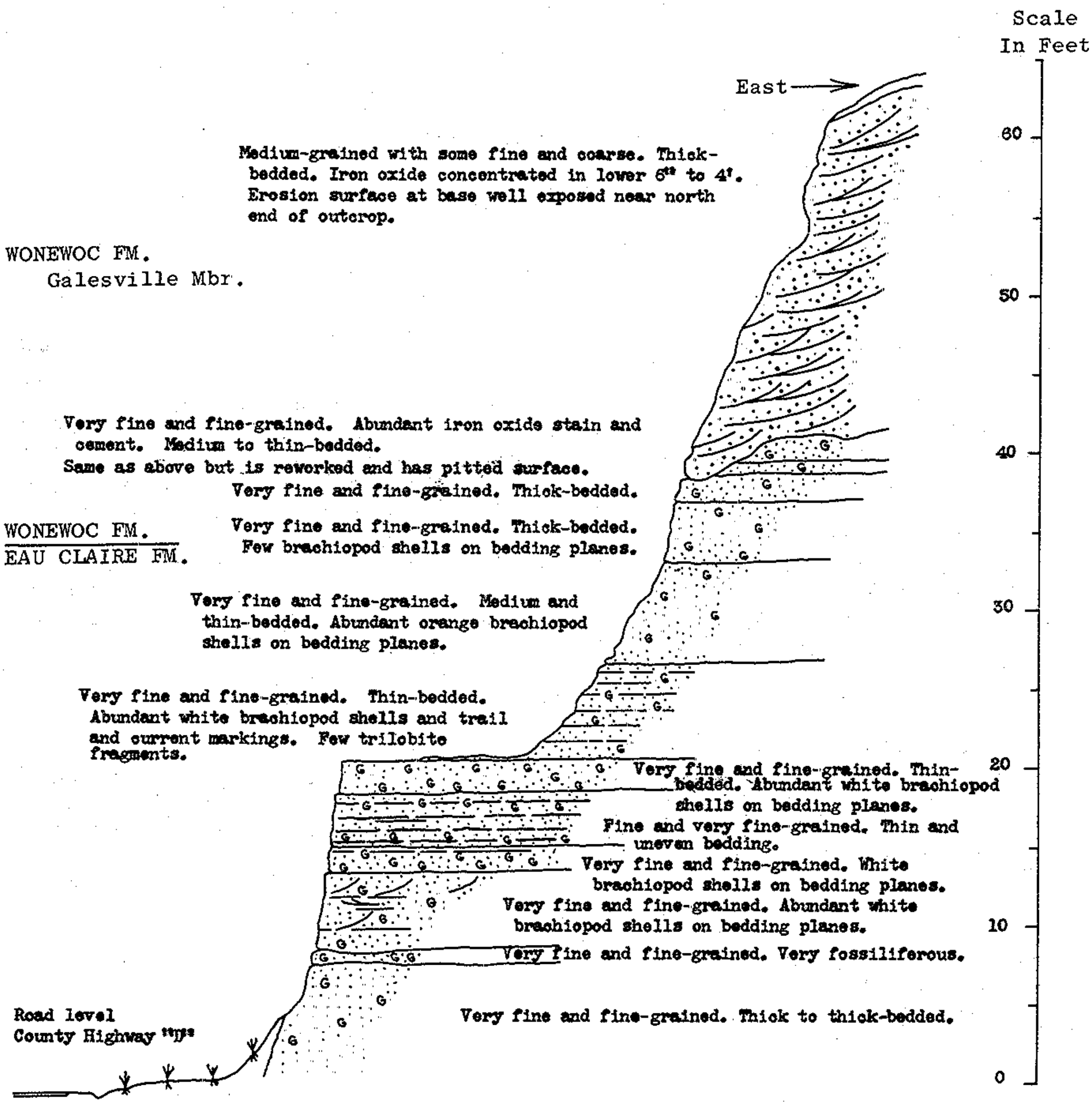
At this site the contact of the Eau Claire Formation with the overlying Galesville Formation is marked by an unconformity (Figure 10) which is especially well shown near the top at the north end of the quarried face. The unconformity is interpreted to signify regression and erosion. The Galesville is believed to have formed by a process of intermingling of beach deposits during the succeeding transgressive episode (Ostrom, 1964a).

Close examination of this contact indicates sharp and marked lithologic and/or textural change and often erosion of the top of the Eau Claire. The lower few feet of the Galesville quite often contains clasts of Eau Claire sandstone and shale. An excellent example of these features will be seen at STOP 7, the type section of the Galesville Formation.

Additional discussion of the relationships and significance of the rocks shown at this exposure is given under STOP 1.

53.3	2.9	Bear to east (left) and follow County Highway "D".
54.9	1.6	Stop sign. Turn east (left) and follow Highway "D".
56.3	1.4	Turn south (right) and follow Highway "D".
59.8	3.5	Junction with County Highway "O". Continue south (ahead) on Highway "D".

STOP 4
Bruce Valley Quarry
$NE\frac{1}{4}, NW\frac{1}{4}$, Sec. 9, T.23N., R.8W.



Horizontal to vertical scale approx. 1:2

Refer to STOP 1 for key to symbols

Described by M. E. Ostrom

59.9 0.1 STOP 5 (M.E. Ostrom). Exposure of geologic section beginning with Lone Rock Formation at top and extending downward to Eau Claire Formation at base in roadcuts located north of Whitehall on County Highway "D" and 1.7 miles north of its juncture with State Highway 53 in the SW$\frac{1}{2}$, SW$\frac{1}{4}$, sec. 12, T.22N., R.8W., Trempealeau County (Whitehall 15' topographic quadrangle, 1929).

This is an excellent exposure to show the interrelationships of the various lithostratigraphic units beginning with the Eau Claire Formation and extending upward into the Lone Rock Formation. The section is complete except for about 15 feet of covered interval midway in the Ironton Member.

Beginning with the sharp and unconformable contact of Galesville on Eau Claire near the base, one can proceed upwards through the remainder of the section without evidence of major erosional break.

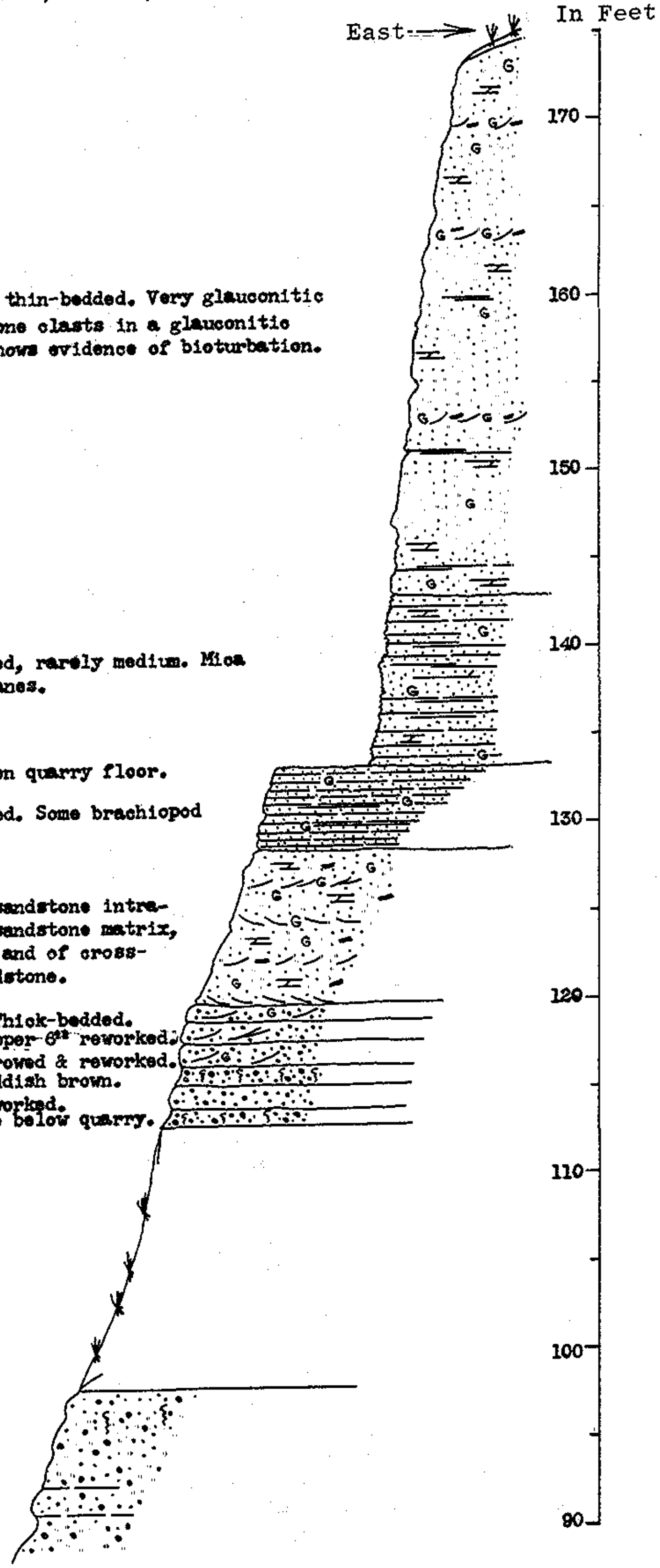
Regionally the Eau Claire Formation thins to the east until in the vicinity of Wisconsin Dells it is not recognized. North and northwest of the Dells what is believed to be thin Eau Claire can be seen at Friendship Mound, north of Friendship, and at Sheep Pasture bluff located south of Mauston.

At Friendship Mound there is a one-foot bed of fine-grained, silty, iron-oxide, cemented sandstone that separates two thick-bedded, medium-grained, well-sorted sandstone units. The upper of these two units is positively identified as the Galesville Sandstone. At Sheep Pasture Bluff the situation is similar except that the thickness assignable to the separating unit is 7 feet and it contains only minor iron oxide. Also at Sheep Pasture Bluff, sandstone clasts occur in the base of the Galesville. The possibility exists that the separating unit is the Eau Claire Formation thinned by pre-Galesville erosion and that the lower sandstone unit is the Mt. Simon Sandstone.

A study of the Mt. Simon Sandstone by Asthana (1968) indicates that its feldspar content ranges from 3 percent to 40 percent and averages 18 percent. On the other hand it is known from numerous analyses of the Galesville Sandstone that it seldom contains more than 1 percent feldspar. Asthana (1968) determined that the feldspar content of the sandstone unit below the Eau Claire is higher than that above by a factor of 2 at Sheep Pasture bluff and of 9 at Friendship Mound. This sharp decrease in feldspar content corresponds to a similar difference between the feldspar content of the Mt. Simon and Galesville sandstones elsewhere and is interpreted to indicate that at these exposures the Eau Claire is much reduced in thickness probably due to post-Eau Claire erosion. Thus, it appears that the Eau Claire thins eastward and that thinning is due to pre-Galesville erosion.

The Eau Claire-Galesville contact marks the end of one transgressive/regressive sequence and the beginning of the transgressive phase of the subsequent sequence. The Galesville Sandstone formed during transgression as the result of a process of coalescing of littoral zone deposits. Rather persistent high energy conditions are indicated by a noticeable lack of clay, silt and very fine sand and a total lack of fossils.

STOP 5
WHITEHALL ROADCUT
SW¼, SW¼, Sec. 12, T.22N., R.8W.



LONE ROCK FM.
Reno Mbr.

Fine-grained. Thick to thin-bedded. Very glauconitic beds consist of sandstone clasts in a glauconitic sandstone matrix and shows evidence of bioturbation.

Tomah Mbr.

Fine-grained. Thin-bedded, rarely medium. Mica abundant on bedding planes.

Level of farm road on quarry floor.

Fine-grained. Thin-bedded. Some brachiopod shell fragments.

Birkmose Mbr.

Fine-grained. Beds of sandstone intraclasts in glauconitic sandstone matrix, of reworked sandstone, and of cross-bedded glauconitic sandstone.

LONE ROCK FM.

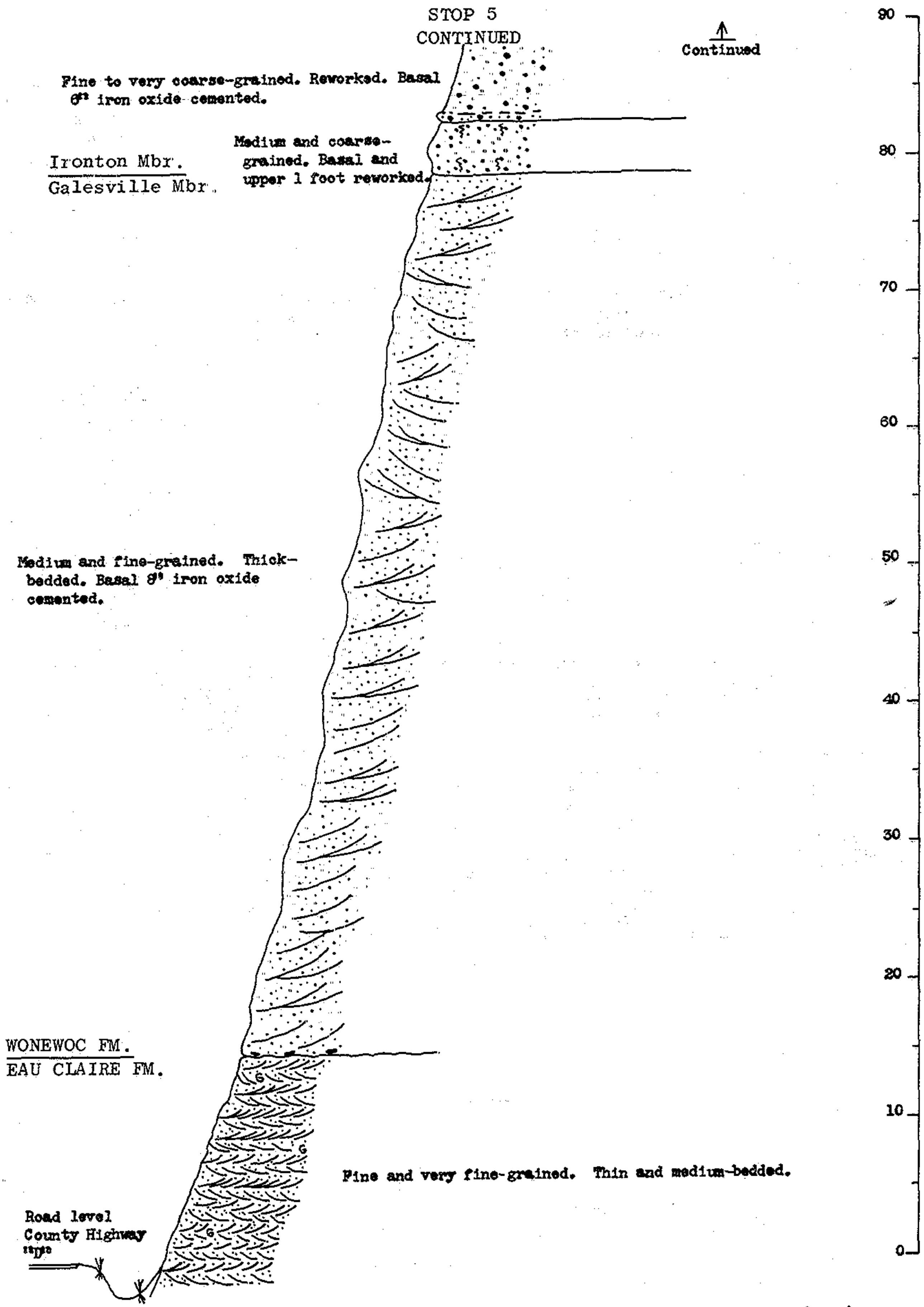
WONEWOC FM.
Ironton Mbr.

Medium and coarse-grained. Thick-bedded.
Medium and coarse-grained. Upper 6" reworked.
Very fine to very coarse. Burrowed & reworked.
Medium and coarse-grained. Reddish brown.
Very fine to very coarse. Reworked.
Base of upper roadcut exposure below quarry.

Very fine to very coarse-grained. Reworked.

Continued

Refer to STOP 1 for key to symbols



Described by M. E. Ostrom (1966)

Above and transitional with the Galesville is the Ironton Member. The Ironton is interpreted to have formed in an environment located seaward of the beach where high and low energy conditions alternated. Whereas the Galesville is thick-bedded, the Ironton is medium-bedded and even-bedded. Silt and other fine particles are abundant in certain beds. Burrows are common and fossils are present locally. Also, there is commonly carbonate cement and glauconite in the upper few feet of the unit. Alternate beds are commonly well-sorted, clean, medium and coarse-grained, cross-bedded quartzarenite on the one hand and poorly-sorted, reworked and burrowed quartzarenite on the other. Emrich (1966) traced certain of the burrowed beds for as much as 100 miles in the outcrop area of western Wisconsin which is interpreted to signify a broad and flat shelf bottom on which the effects of storm or quiet were widely impressed.

The Ironton Member thins toward the Wisconsin Dome to the east. At this exposure the Ironton is about 40 feet thick. Traced east and south it thins to disappearance as can be seen at exposures south of Lone Rock in the south bluff of the Wisconsin River. Further to the southeast in northeastern Illinois the Ironton increases to a maximum of 150 feet in thickness (Buschbach, 1964; Emrich, 1966). The Ironton thickens westward into Minnesota. It is assigned a Franconian age on the basis of fossils.

At this exposure the Ironton is in sharp contact with and lithologically markedly different from the overlying fine-grained glauconitic, shaly and thin-bedded Lone Rock Formation of the Tunnel City Group. The Tunnel City Group consists of two distinct facies in the Upper Mississippi Valley area, namely a glauconitic facies, the Lone Rock Formation, and a nonglauconite facies, the Mazomanie Formation (Trowbridge & Atwater, 1934; Wanenmacher et al, 1934; Twenhofel et al, 1934; Ericson, 1951; Berg, 1954; Ostrom, 1966, 1967). The Lone Rock facies intertongues with and is laterally and vertically transitional with the Mazomanie facies in the direction of the Wisconsin Dome as is shown in Figures 15 and 16 (Ostrom, 1966). The Mazomanie facies will be seen at STOP 18.

Abundant burrows and trails in the Lone Rock indicate prolific animal life. Thin bedding and fine particles suggest persistent low energy conditions. Occasional beds, up to 2 feet thick and rarely up to 8' thick, of sandstone clasts in a greensand matrix suggest occasional episodes of high energy such as storms. The environment of Lone Rock deposition is interpreted to have been located seaward of that of the Ironton in an area of deeper water and lower overall available energy as attested to by thin beds, fine sediment, abundant fossils and lateral persistence of beds.

The similarity of the lower part of the Lone Rock Formation at this site to the lower part of the Eau Claire at STOP 3 is believed to be significant. In both cases the upward change is from transitional beds characterized by medium and persistent beds of medium and coarse-grained quartzarenite to fine-grained, shaly glauconitic sandstone with abundant trail markings on bedding surfaces. The two units are interpreted as the manifestation of a single environment repeated by two episodes of transgression separated by a minor regression which is marked by the Galesville Sandstone and the erosion surface at its base (Ostrom, 1964).

60.4	0.5	Base of outcrop exposure at Stop #5.
61.4	1.0	Quarry in Eau Claire Formation on left.
61.7	0.3	Stop sign. Junction with State Highway 53. Turn west (right) toward Whitehall.
62.1	0.4	Enter Village of Whitehall.
62.7	0.6	Road jogs to right; follow County Highway "D" south.
62.9	0.2	Exposure of Eau Claire Formation on right.
63.6	0.7	Exposure of Eau Claire Formation on left.
64.3	0.7	Exposure of contact of Eau Claire and Galesville formations in quarry on left.
65.0	0.7	Quarry in Eau Claire on left.
67.4	2.4	Small quarry in Lone Rock Formation on right at road junction.
68.5	1.1	Turn west (right) on County Highway "N" and follow to junction with State Highway 93.
69.5	1.0	Turn west (right) and follow Highway "N" up hill at church.
69.6	0.1	Exposure of Lone Rock Formation on right (north).
70.0	0.4	Quarry on left exposes Lone Rock, St. Lawrence and Jordan formations. Detailed description given in Appendix at mileage 70.0.
70.4	0.4	Quarry on left in St. Lawrence Formation.
70.7	0.3	Exposure of Lone Rock Formation on left.
71.2	0.5	Exposure of Lone Rock on left.
71.8	0.6	Exposure of Lone Rock Formation on left.
71.9	0.1	Exposure of Wonewoc Formation on right.
72.7	0.8	Wonewoc Formation exposed on right.
72.8	0.1	Stop sign. Junction with State Highway 93. Turn west (right).
72.9	0.1	Exposure of contact of Galesville and Eau Claire formations showing some cutout.

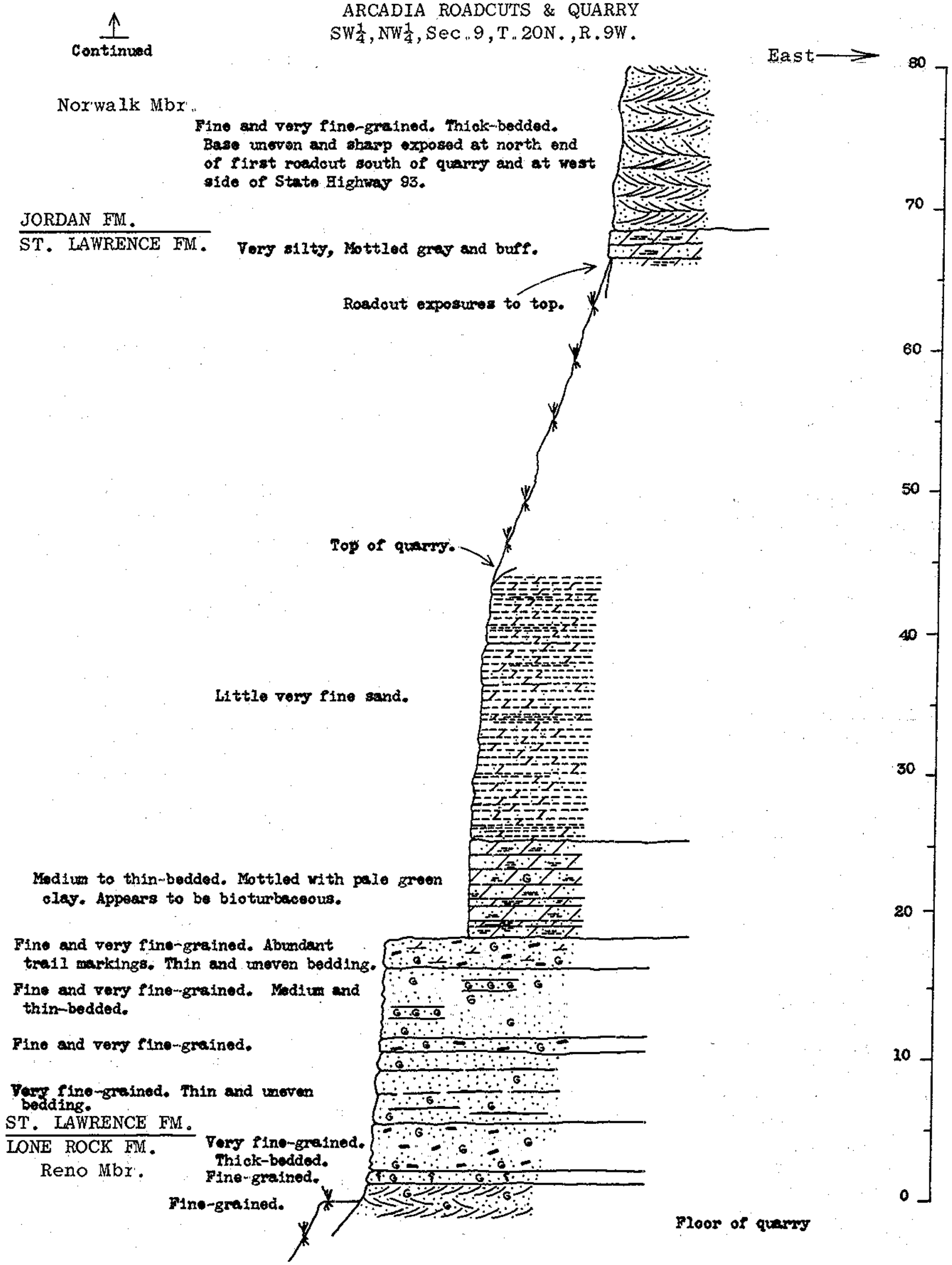
77.5	4.6	Wonewoc Formation exposed on left.
77.8	0.3	Turn south (left) and follow Highway 93.
78.3	0.5	Quarry on left in Wonewoc Formation.
79.3	1.0	STOP 6 (M. E. Ostrom). Composite section from outcrops and quarries located along State Highway 93 and extending from about 1.5 miles to about 3.2 miles south of Arcadia. Section begins with quarry exposure of Lone Rock and St. Lawrence and ends at top of hill with quarries in the Oneota Dolomite in SE$\frac{1}{4}$, NW$\frac{1}{4}$, sec. 9, T.20N., R.9W., Trempealeau County (Galesville 15' topographic quadrangle, 1929).

This stop displays the St. Lawrence and Jordan formations to good advantage and it also illustrates one of the problems in the Upper Cambrian Stratigraphy in Wisconsin, namely determining the limits and relationships of the Black Earth Dolomite and Lodi Siltstone members of the St. Lawrence Formation.

Nelson (1956) studied these units in the Upper Mississippi Valley area. He defined the Black Earth as "...sandy dolomite and interbedded dolomitic siltstone and fine-grained sandstone" and in the vicinity of Black Earth and Madison and at localities along the Mississippi Valley as dolomite that is "...generally massive, brown to buff, slightly glauconitic...(with)... algal structures locally." The Lodi Member consists of "...siltstone, generally dolomitic, and dolomitic sandstone."

The fact that his definitions indicate both the Black Earth and the Lodi can consist of dolomitic siltstone and fine-grained sandstone is reason why it is commonly very difficult to distinguish the two members as can be seen at this exposure. Here Nelson assigned the lower 17 feet of the St. Lawrence to the Lodi the middle 12-foot portion to the Black Earth, and an overlying 15-foot section to the Lodi for a total thickness of about 44 feet. Close examination of the outcrop reveals that if a Black Earth Dolomite occurs here it is probably the 7 feet of very silty dolomite in the interval from 19 feet to 26 feet above the base of the exposure. However, there does not appear to be any marked difference in lithology such as would suggest the presence of Black Earth lithology rather than Lodi. The Wisconsin Geological and Natural History Survey recognizes the Black Earth as a medium to thick-bedded, medium to coarsely-crystalline dolomite that is locally silty, sandy and glauconitic with fossil algae and with the possible exception of several thin beds assigns all of the St. Lawrence Formation of this exposure to the Lodi Member. The Norwalk Member of the Jordan Formation consists of very fine and fine-grained non-silty sandstone which is thick-bedded to thin-bedded. At this exposure it is separated from the underlying silty and dolomitic Lodi by a sharp and uneven surface interpreted to indicate post-Lodi erosion. At the majority of outcrops of this interval in Wisconsin the contact appears to be completely gradational. However, the fact that the Norwalk and Van Oser constitute a thick body of sandstone similar in character to the Galesville and others of the Cambrian and Ordovician sandstones of this region suggests that the Jordan probably had a similar origin, namely that it formed on an

STOP 6
ARCADIA ROADCUTS & QUARRY
SW$\frac{1}{4}$,NW$\frac{1}{4}$,Sec.9,T.20N.,R.9W.



Refer to STOP 1 for key to symbols.

STOP 6
CONTINUED

ONEOTA FM. (Upper part not described)
Stockton Hill Mbr.

Medium-grained. Appears to be brecciated locally.

Medium-grained, friable.

Medium-grained.

Fine to medium-grained.

Coarse and fine-grained. Few white siliceous bands.

Coarse and fine-grained.
Shale with little sand.
Fine-grained.
Fine and medium-grained. Some iron oxide.
Fine and coarse-grained. Friable.

Coarse and fine-grained.
Medium-grained. Friable.
Fine-grained. Carbonate & silica concretions.

Medium-grained. Scattered carbonate concretions.

Medium and fine-grained. Pea-sized carbonate concretions at base.

Medium-grained.

Medium and fine-grained.

Medium and fine-grained. Some silica concretions.

Medium-grained. Abundant carbonate concretions.

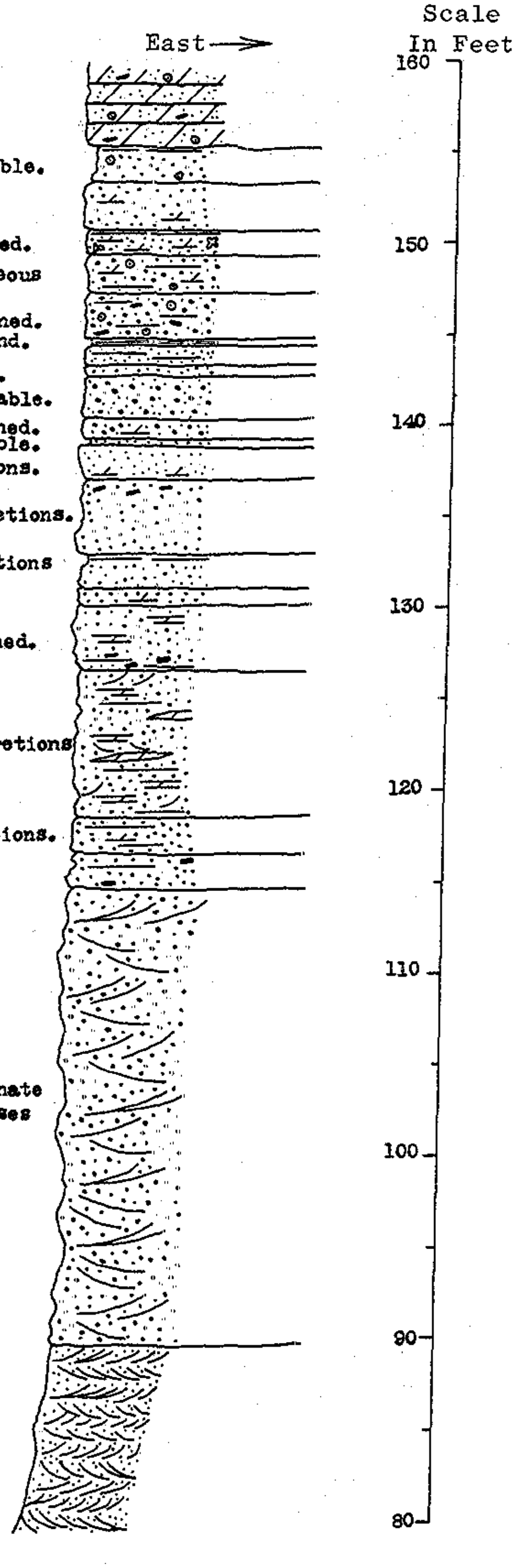
Medium-grained. Friable, White & brown.

ONEOTA FM.
JORDAN FM.
Van Oser Mbr.

Coarse and medium-grained. Pea-sized carbonate concretions near top grading to large masses toward base. Thick-bedded.

Norwalk Mbr.

Fine and very fine-grained. Thick-bedded.



Continued

Refer to STOP 1 for key to symbols.

Described by M. E. Ostrom: Modified from Twenhofel (et al, 1935), Nelson (1956), and Melby (1967).

erosion surface by a process of coalescing of beach deposits in a transgressing sea, but that in at least this area erosion was a minor factor.

The Van Oser Member of the Jordan Sandstone is characterized by medium-grained sandstone with some coarse and a little fine. Contact of the Van Oser with the Norwalk is commonly though not always sharp. At this exposure the contact is slightly uneven. Contact relations of overlying beds will best be examined at subsequent stops.

79.5	0.2	Outcrops on right and then left of Van Oser and Norwalk members of the Jordan Formation.
79.7	0.2	Outcrop on left of Jordan/Oneota contact.
79.9	0.2	Oneota Formation exposed on right.
80.4	0.5	Several quarries in Oneota Formation.
80.9	0.5	Exposure of Oneota Formation.
81.0	0.1	Contact of Jordan Sandstone with the Oneota Formation.
82.3	1.3	Exposure of Wonewoc Formation on left.
85.5	3.2	Galesville Member of Wonewoc Formation exposed on left.
90.1	4.6	Galesville Member of Wonewoc Formation exposed on left.
91.1	1.0	Stop sign. Junction with State Highway 35. Turn east (left) and follow to Galesville.
95.8	4.7	Enter Galesville.
96.8	1.0	Turn left at lake edge.
97.0	0.2	Stop sign. Proceed straight ahead and park in city park.

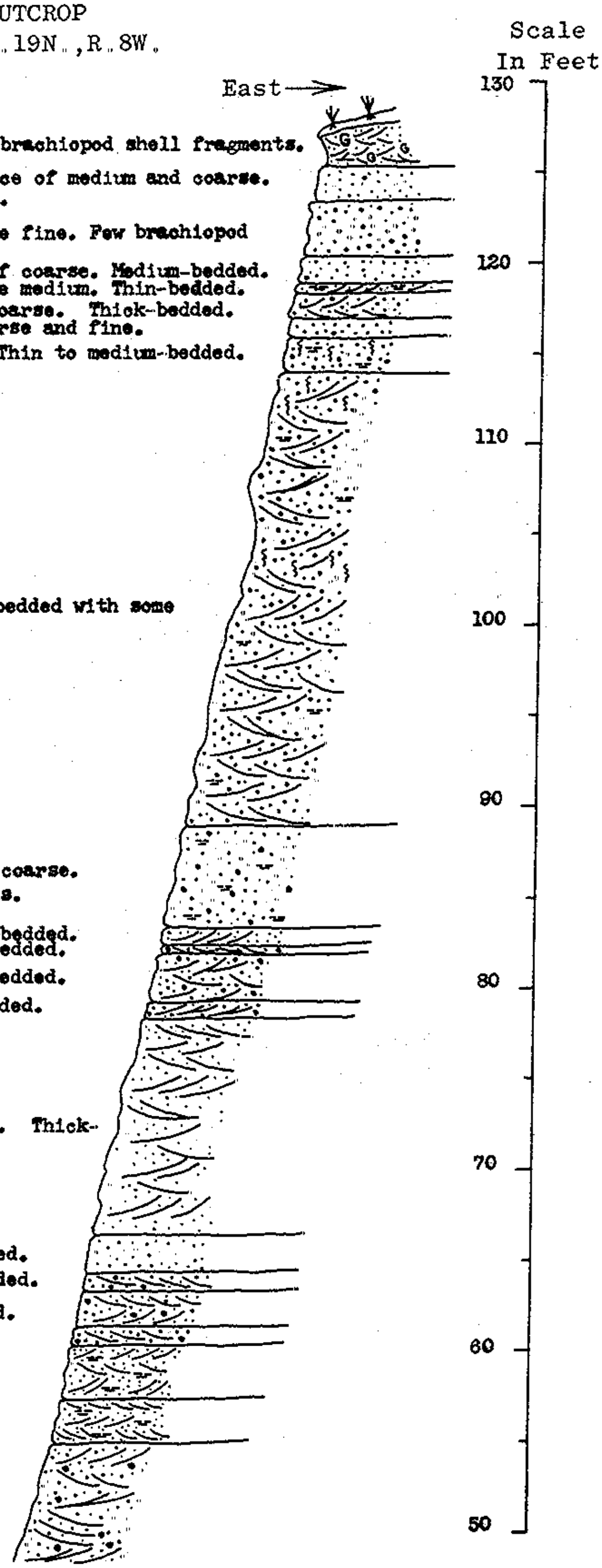
STOP 7 (M.E. Ostrom). Type section of the Galesville Sandstone exposed in bluff in the NE¼, NW¼, sec. 33, T.19N., R.8W., Trempealeau County (Galesville 15' topographic quadrangle, 1929).

Outcrop is reached by walking north across highway bridge and thence east along north side of Beaver Creek. Assemble at path gate.

To leave circle park and turn south (left) on State Highway 53. Follow 53 south through city toward LaCrosse.

Discussions presented for stops numbers 3, 4 and 5 apply equally to this exposure. Of special interest here is the Eau Claire-Galesville contact

STOP 7
GALESVILLE OUTCROP
NE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 33, T. 19N., R. 8W.



LONE ROCK FM.
Birkmose Mbr.

Fine-grained. Thin-bedded. Some brachiopod shell fragments.

WONEWOC FM.
Ironton Mbr.

Fine and very fine-grained, trace of medium and coarse. Few brachiopod shell fragments.

Medium and coarse-grained, little fine. Few brachiopod shell fragments. Thick-bedded.

Medium and fine-grained, trace of coarse. Medium-bedded.

Fine and very fine-grained, trace medium. Thin-bedded.

Fine and medium-grained, trace coarse. Thick-bedded.

Medium-grained, trace coarse and fine.

Medium-grained, little coarse and fine. Thin to medium-bedded.

Coarse to medium-grained, trace fine. Thick-bedded with some thin beds.

Galesville Mbr.

Fine to medium-grained, little coarse. Thick-bedded with few thin beds.

Fine to very fine-grained, trace medium. Thin-bedded.

Coarse to medium-grained, little fine. Thick-bedded.

Fine to medium-grained, little coarse. Thick-bedded.

Medium-grained, little fine and coarse. Thick-bedded.

Fine to very fine-grained, trace medium. Thick-bedded.

Medium to fine-grained. Thick-bedded.

Medium-grained, little fine and coarse. Thick-bedded.

Fine-grained, little medium and coarse. Thick-bedded.

Medium-grained, little fine & coarse. Thick-bedded.

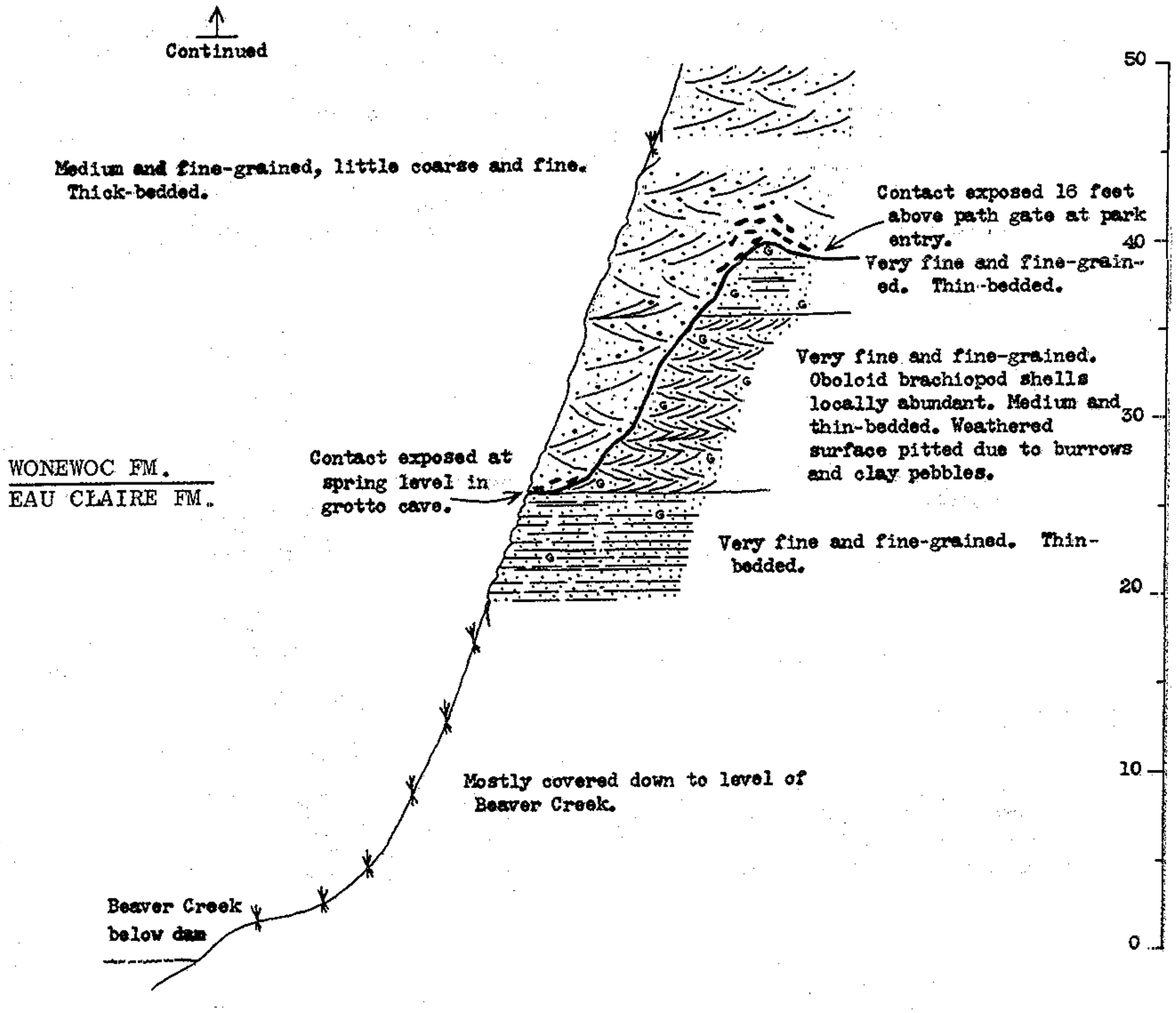
Fine-grained, little very fine. Thick-bedded.

Fine-grained, little very fine. Thick-bedded.

Medium and fine-grained, little very coarse and very fine. Thick-bedded.

Continued
↓

STOP 7
CONTINUED



Refer to STOP 1 for key to symbols

Described by M. E. Ostrom (1966)

surface which is sharp along the outcrop face and is markedly uneven. At this exposure erosion of the Eau Claire is obvious on the basis of cut-out and the presence of clasts in the base of the Galesville (Figure 24).

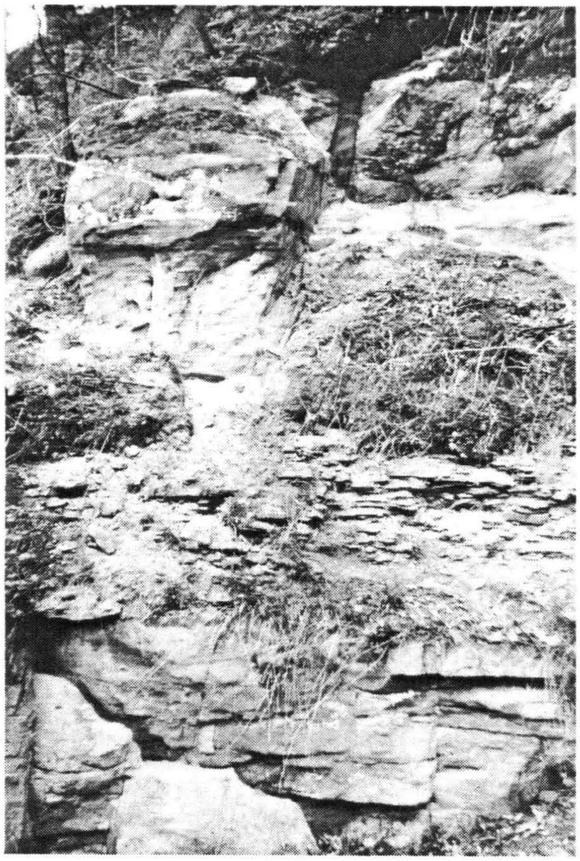


Figure 24. Unconformable contact of Galesville Sandstone with Eau Claire Sandstone at type section of Galesville in Galesville, Wisconsin (Stop 7). Note sandstone clasts in lower 3 feet of Galesville above thin beds near center of picture.

Early descriptions of this outcrop (Trowbridge and Atwater, 1934; Twenhofel et al, 1935) did not recognize the unconformable relationship between the Galesville and Eau Claire. Twenhofel et al (1935) stated that "There does not seem to be any definite evidence of physical change at this boundary." Critical examination here reveals marked physical change and in fact an unconformable relationship produced by pre-Galesville erosion of the Eau Claire. The relationship revealed here, namely that of quartzarenite resting with erosional unconformity on older rocks, is common in the Cambrian and Ordovician strata of Wisconsin and is one factor which led to a cyclic interpretation to explain the history of sedimentation of Upper Cambrian and Lower and Middle Ordovician rocks in the Upper Mississippi Valley area (Ostrom, 1964a).

Because the contact of the Eau Claire with the Galesville is one of erosional unconformity one must re-examine the position of the Galesville with respect to its assignment to the Dresbachian Stage rather than to the younger Franconian Stage. The Galesville is separated from older rocks by an unconformity (Figures 10 and 24), it contains no diagnostic fossils, and it is transitional with the overlying Ironton Member which contains Franconian fossils. Furthermore, the Aphelaspis trilobite zone which closes the Dresbachian and which should occur in the top of the Eau Claire is missing in Wisconsin. Absence of this zone tends to support the contention of post-Eau Claire erosion.

The Birkmose Member in the base of the Lone Rock Formation thins toward the Wisconsin Arch from 15 feet just east of Galesville to less than 6 inches at Ferry Bluff north of Mazomanie (Berg, 1954). The Birkmose is one of several units in the Upper Cambrian and Lower and Middle Ordovician which thin eastward toward the Wisconsin Dome. Some of the others are the Ironton, St. Lawrence, Sunset Point, and Glenwood units.

97.5	0.5	Galesville Member exposed on left.
99.0	1.5	Decorah Pass. Contact of Wonewoc and Lone Rock Formation exposed.
99.5	0.5	Galesville exposed on left.
103.3	3.8	Bluff to east (left) of road contains rocks ranging from Galesville at base to Oneota at top.
106.6	3.3	Bluffs to east (left) of road contain rocks ranging from St. Lawrence at base to Oneota at top.
107.9	1.3	Holmen city limits.
113.2	5.3	Onalaska city limits.
115.3	2.1	Turn right (west) off of U. S. Highway 53 onto Interstate Highway 90.
118.8	3.5	Turn right (north) off of Interstate 90 onto U.S. Highway 61 to LaCrescent.
119.1	0.3	Stop signs (2). Turn left (south) at second stop sign and follow U.S. Highway 61 to LaCrescent.
120.9	1.8	LaCrescent city limits.
121.6	0.7	Stop light at LaCrescent, Minnesota (Houston Co.) at intersection of U.S. Highways 14, 16 and 61. Proceed south on U.S. 14. On left (east) is Upper Mississippi Wildlife Refuge.
122.0	0.4	Galesville Sandstone outcrops on right (west) to intersection with Minnesota Highway 26 and for about 1 mile beyond.
123.9	1.9	Intersection of U.S. Highway 16 with Minnesota Highway 26. Continue on U.S. 16.

125.8	1.9	Cross Root River.
126.9	1.1	City limits of Hokah, Minnesota.
127.2	0.3	Intersection of U.S.Highway 16 with Minnesota 44 in Hokah. Take Minnesota 44 south.
128.3	1.1	Tunnel City Sandstone on right side of road. High in left bluff is a quarry in the Prairie du Chien Group, probably Oneota Formation (Hager City Member).
128.6	0.3	High on right slope are ledges of Jordan Sandstone.
131.5	2.9	Tunnel City Sandstone exposed on right side of road.
132.7	1.2	Black Earth (?) Member of St. Lawrence on right.
133.3	0.6	Jordan Sandstone on both sides of the road. Here we begin to ascend out of the Mississippi River Valley.
133.8	0.5	Oneota Formation exposed in roadcuts.
140.0	6.2	Intersection with Minnesota Highway 76 straight ahead.
140.7	0.7	City limits of Caledonia, Minnesota (Houston Co.).
143.3	2.6	Intersection of Minnesota Highways 44 and 76. Turn left (south) and continue on Minnesota 76.
144.6	1.3	Oneota Formation exposed in roadcut on left (east).
146.3	1.7	STOP 8 (R.A. Davis). Exposure of Prairie du Chien strata in roadcut at left (east) side of Minnesota Highway 76 showing the New Richmond Member of the Shakopee Formation unconformably overlying the Oneota Formation. Located in the NW¼, sec. 12, T.10N., R. 6E., Houston County, Minnesota.

This exposure shows only a limited Prairie du Chien section but it does afford good opportunity for close examination of the contact between the Oneota and overlying Shakopee formations. Here the pure dolomite of the Hager City Member is overlain unconformably by the sorted and rounded medium quartz sandstone of the New Richmond Member.

This contact was first described as an erosional surface by Ulrich (1924) who designated it as the boundary between his Ozarkian and Canadian systems. More recent workers (Powers, 1935; Heller, 1956; Shea, 1960) have interpreted this horizon as representing continuous deposition within the Prairie du Chien Group. Regional study of this horizon by Davis (1968) has shown the Oneota - Shakopee contact to be an erosional unconformity at most exposures.

At this location there is subtle relief on the upper surface of the Oneota and an abrupt lithic change. About 30 miles to the northwest at Lanesboro, Minnesota there are large fragments of Oneota lithology incorporated in the basal New Richmond.

STOP 8
ROADCUT ON HIGHWAY 76
NW¼,Sec.12,T.10N.,R.6W.

SHAKOPEE FM.
New Richmond Mbr.

Medium-grained, bedded, friable, grades into overlying soil.

Medium-grained, shaly, poorly-bedded.

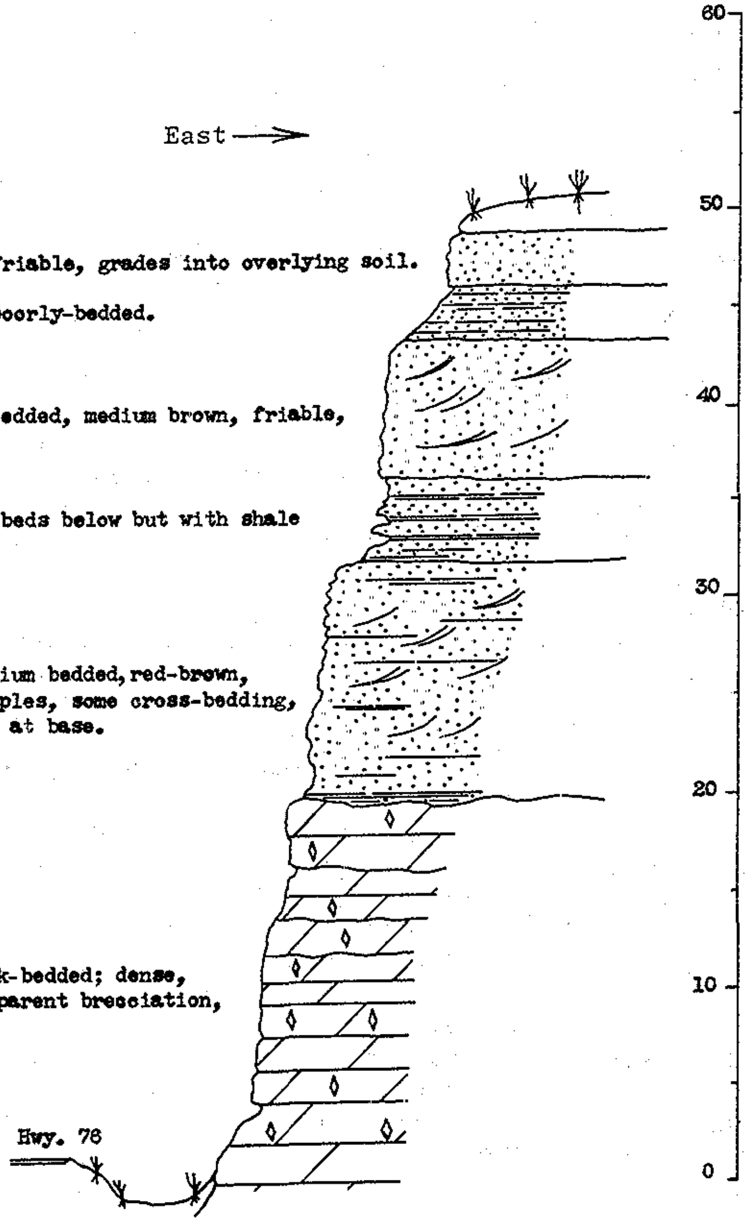
Medium-grained, poorly-bedded, medium brown, friable, ripples.

Medium gray, similar to beds below but with shale interbeds.

Medium-grained, thin-medium bedded, red-brown, sorted, well-formed ripples, some cross-bedding, somewhat friable, shaly at base.

SHAKOPEE FM.
ONEOTA FM.
Hager City Mbr.

Medium-crystalline, thick-bedded; dense, gray, some pods with apparent brecciation, much calcite spar.



Described by R.A. Davis, 1966.

150.8	4.5	Village of Eitzen, Minnesota (Houston Co.).
151.4	0.6	Minnesota-Iowa state line.
153.4	2.0	Begin descending into the Upper Iowa River Valley (formerly Oneota River). Many exposures of the Oneota Formation are present on both sides of the road.
153.6	0.2	Jordan Sandstone on right (west) side of road.
154.0	0.4	Intersection with Iowa Highway 19.
157.8	3.8	Cross Upper Iowa (Oneota)River.
158.4	0.6	STOP 9 (R.A.Davis). Excellent exposure of the contact between the Jordan Sandstone and the overlying Oneota Formation in exposure at west side of Iowa Highway 76 in the SW corner of sec.1, T.99N., R.6W., Allamakee County, Iowa. (Figure 25.)

This, and the succeeding two stops will cover the entire Prairie du Chien Group with the exception of the Willow River Member of the Shakopee Formation. This is the type area of the Oneota as designated by McGee (1891). Exposures are excellent and nearly continuous but accessibility is limited at some horizons.

The abrupt lithic and profile change at this stop marks the contact between the Van Oser Member of the Jordan Formation and the Stockton Hill Member of the Oneota Formation. The character of this contact is rather uniform throughout the Upper Mississippi Valley. It marks the introduction of the first major Paleozoic carbonate sequence in the upper Midwest.

The Stockton Hill Member is a heterogenous unit of dolomitic quartz sandstone and quartzitic dolomite with algal stromatolites, oolites, intraclasts, and some chert. Although it is internally varied the Stockton Hill Member is distinct from units above and below.

STOPS 9-11
UPPER IOWA RIVER SECTION
ALONG HIGHWAY 76
Secs. 11-14 & 23, T.99N., R.6W.
CONTINUED

Hager City Mbr. continued

Medium-crystalline, thick-bedded, buff, homogenous, bio-turbate structures in lower portion, small molds of fossil fragments in lower 16'.

Medium-crystalline, tan-gray, some mottling.

Stockton Hill Mbr.

Medium-grained, tan, dolomite cement.

Medium-crystalline, tan-gray, trace glauconite.

Medium-grained, tan, thin-bedded, dolomite cement, intraclasts.

Medium-crystalline, buff-tan, poorly-bedded, trace glauconite.

Medium-grained, buff, bedded.

Medium-grained, tan, gray-green shale interbeds.

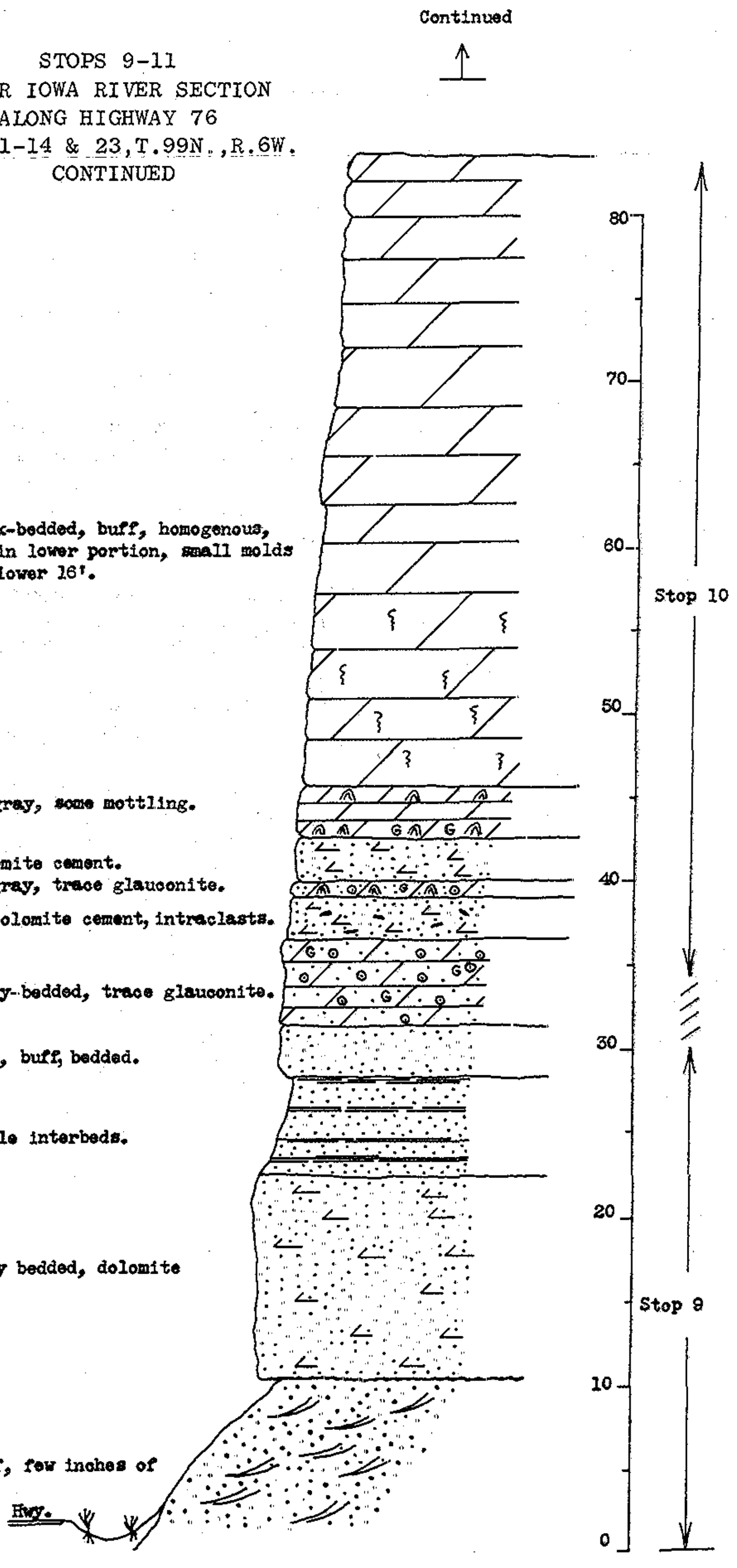
Medium-grained, buff, massive-poorly bedded, dolomite cement.

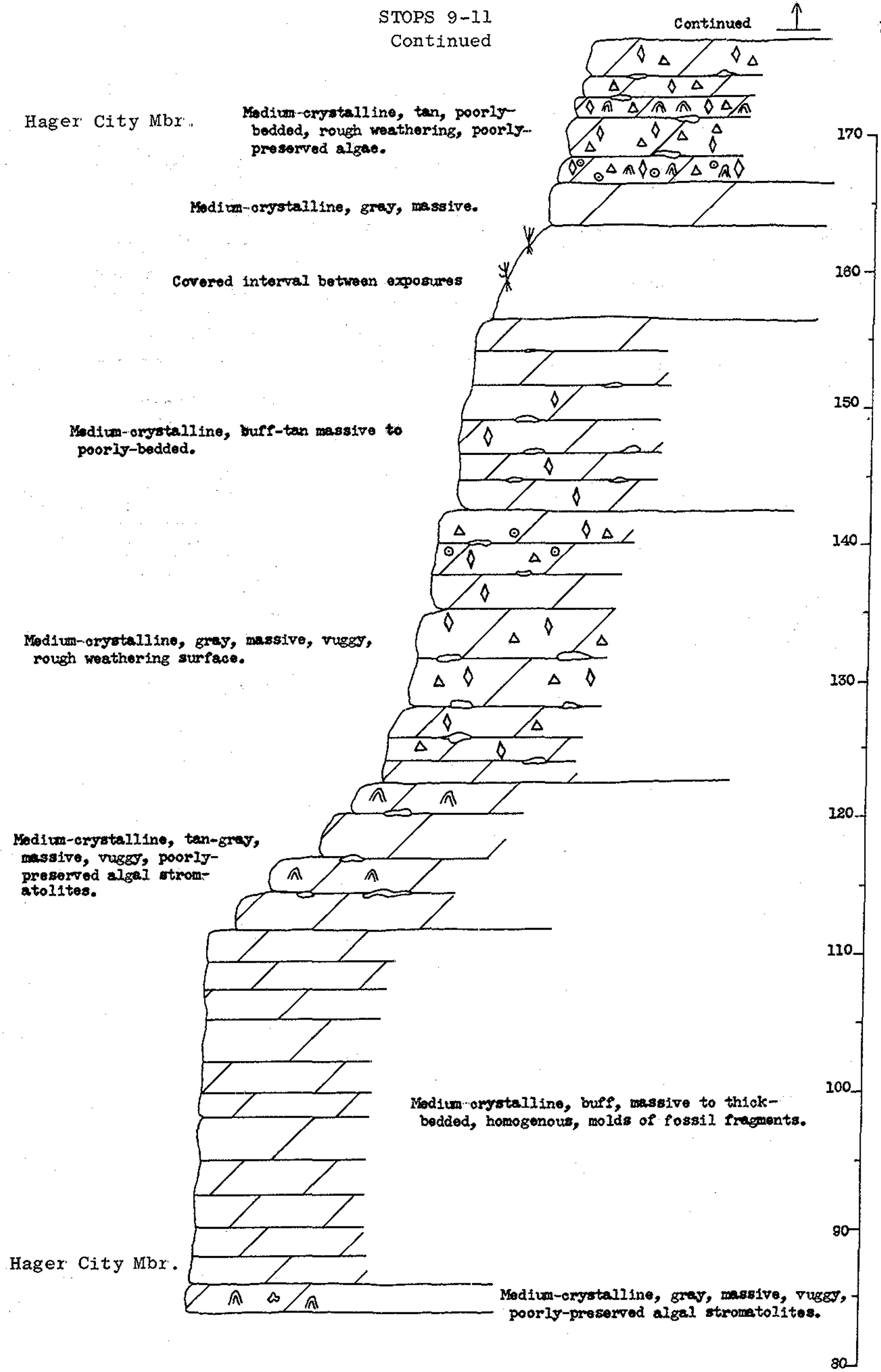
ONEOTA FM.

JORDAN FM.

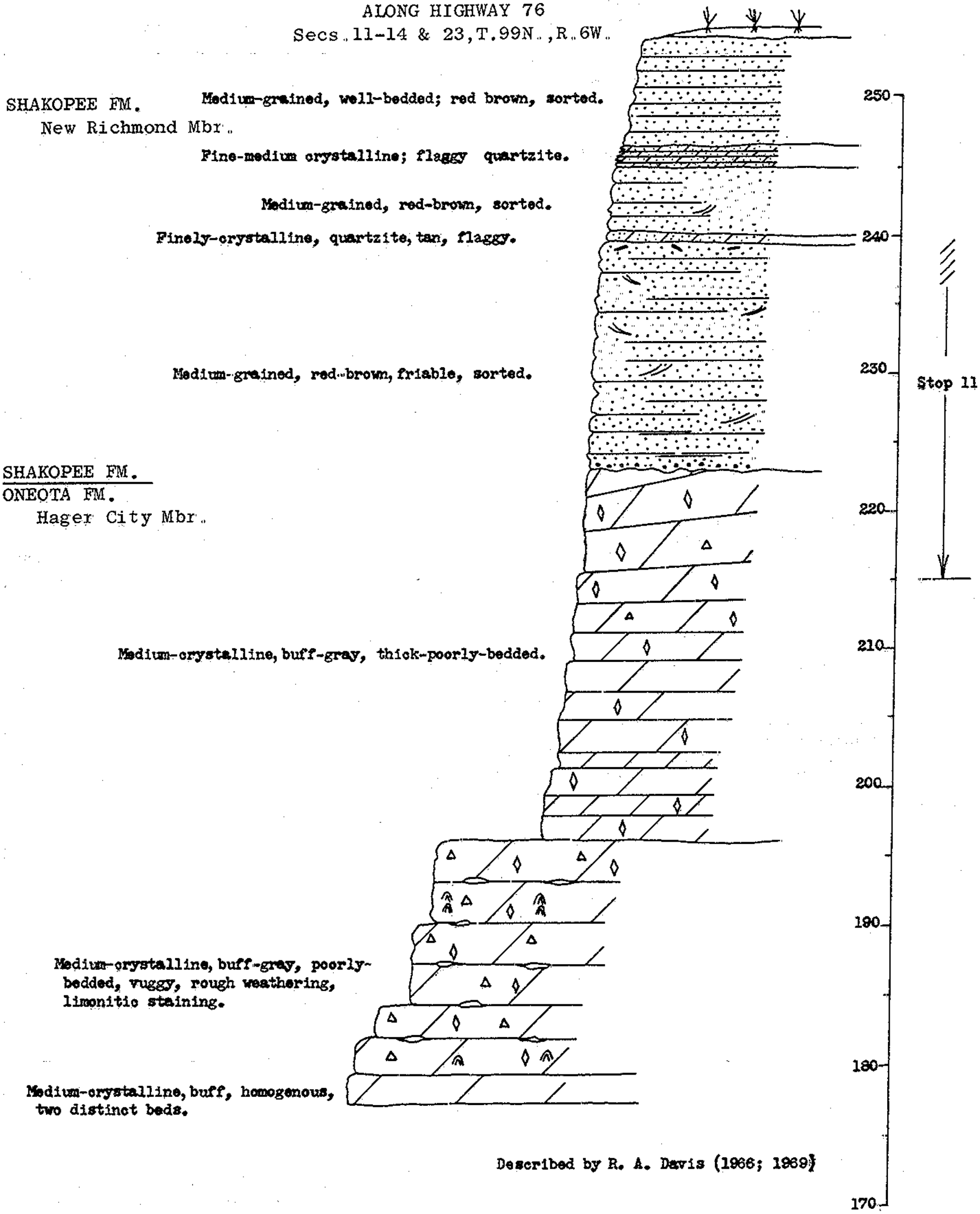
Van Oser Mbr.

Medium-coarse grained, friable, buff, few inches of relief on upper surface.




Continued
Hager City Mbr.
Medium-crystalline, tan, poorly-bedded, rough weathering, poorly-preserved algae.
Medium-crystalline, gray, massive.
Covered interval between exposures
Medium-crystalline, buff-tan massive to poorly-bedded.
Medium-crystalline, gray, massive, vuggy, rough weathering surface.
Medium-crystalline, tan-gray, massive, vuggy, poorly-preserved algal stromatolites.
Medium-crystalline, buff, massive to thick-bedded, homogenous, molds of fossil fragments.
Hager City Mbr.
Medium-crystalline, gray, massive, vuggy, poorly-preserved algal stromatolites.
170
160
150
140
130
120
110
100
90
80

STOPS 9-11
UPPER IOWA RIVER SECTION
ALONG HIGHWAY 76
Secs. 11-14 & 23, T.99N., R.6W.



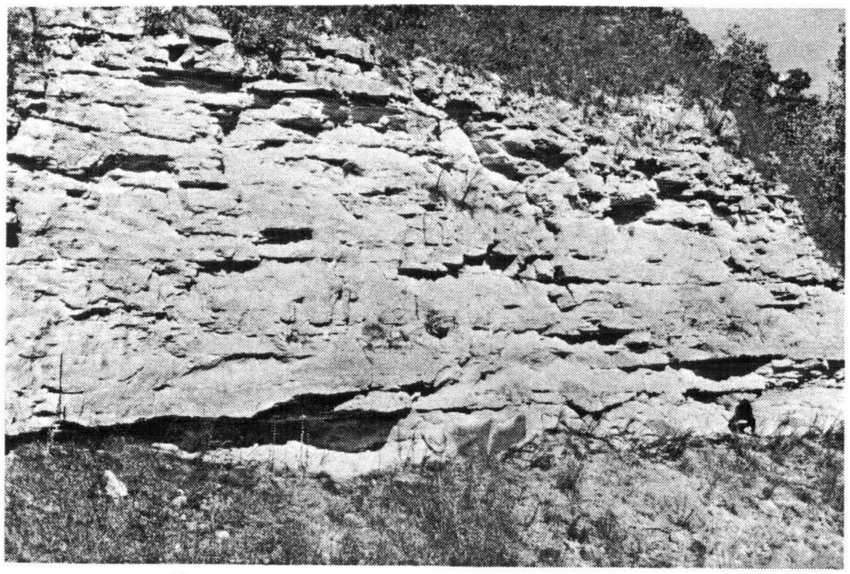
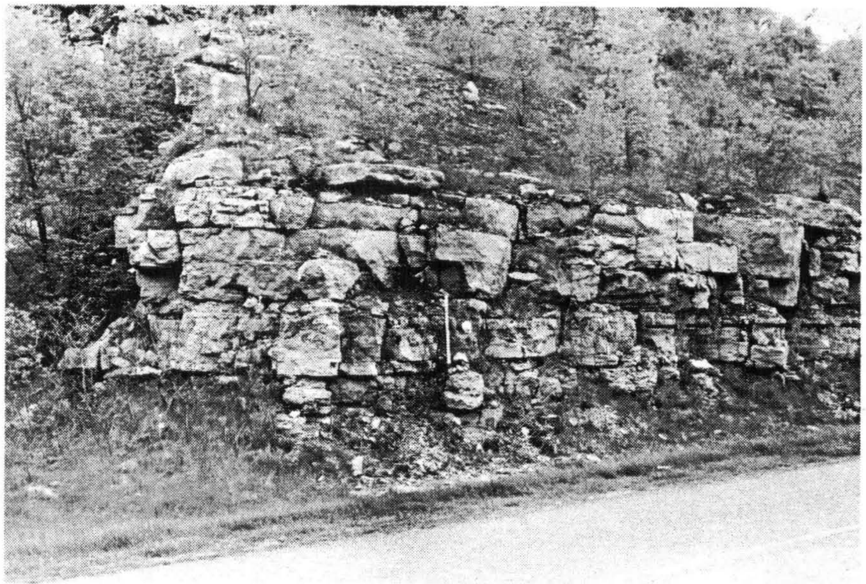


Figure 25. Contact of the Jordan Sandstone with the Oneota Formation at west side of Highway 76 about 4.8 miles south of intersection with Iowa Highway 19 and about 7.5 miles south of Eitzen, Minnesota (Stop 9).

159.0 0.6 STOP 10 (R.A. Davis). Contact between the Stockton Hill and the Hager City members of the Oneota Formation in abandoned quarry at east side of Iowa Highway 76 in the SE$\frac{1}{4}$, NW$\frac{1}{4}$, sec. 12, T.99N., R.6W., Allamakee County, Iowa. (Figure 26).

Emphasis at this stop is the contact between the Stockton Hill and Hager City members of the Oneota Formation and also the homogenous nature of Hager City Dolomite. The contact between these two members is not evident in the weathered profile which shows no break; however, a distinct lithologic change is present. The contact occurs about 5 feet above the quarry floor at the southwest corner of the quarry and is that horizon below which detrital quartz is abundant and above which it is absent.

Although the Hager City Member is mineralogically homogenous there are some differences in bedding, texture, and minor constituents. The lower 65-70 feet of this unit is medium crystalline, thick and well-bedded, buff dolomite. This is the "buffy-bedded zone" described by Raasch (1952) and it occurs at several exposures along the Mississippi river area. The upper part of this member is a rough weathering, vuggy dolomite containing much chert, sparry calcite vug fillings, and poorly preserved algal stromatolites.



Hager City Mbr.
Stockton Hill Mbr.

Figure 26. Roadcut at Stop 10 displaying the subtle profile change between the Stockton Hill and Hager City members of the Oneota Formation. Staff is 5 feet long and hard hat rests on the contact.

161.0 2.0 STOP 11 (R.A. Davis). Unconformable contact of the Oneota Formation and the overlying New Richmond Member of the Shakopee Formation (Figure 27) in roadcut at east side of Iowa Highway 76 in the SW$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 23, T.99N., R.6W., Allamakee County, Iowa.

Unconformable contact of the Oneota Formation (Hager City Member) with the Shakopee Formation (New Richmond Member). This exposure exhibits lithologic character similar to Stop 8 but shows more evidence for erosion prior to deposition of the New Richmond. Nearly the entire New Richmond Member is exposed on the east side of the road. What is apparently the contact between the New Richmond and Willow River members of the Shakopee Formation is poorly exposed on the west side of the road.

In addition to the distinct lithologic change and small amount of relief on the Oneota surface there is truncation of a few feet of dipping Oneota and fragments of Oneota type lithology in the basal New Richmond (Figs. 27 and 28). Note the homogenous nature of the New Richmond at this stop. The next exposure of this unit will exhibit a distinct lithologic change.

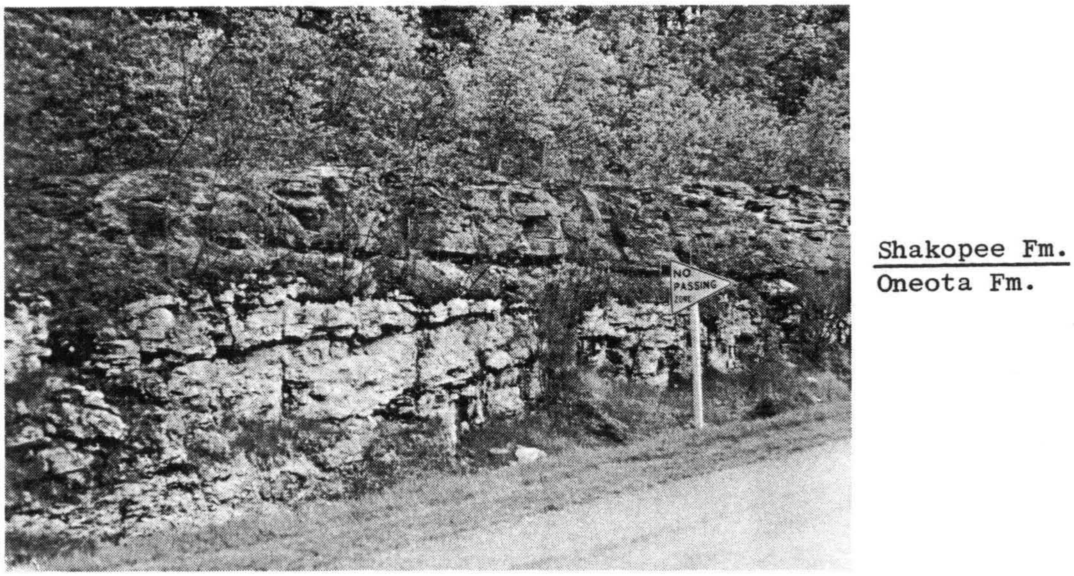


Figure 27. Unconformable contact of New Richmond Sandstone with Oneota Formation in roadcut at east side of Iowa Highway 76 about 7 miles south of Eitzen, Minnesota and 7.8 miles north of Waukon, Iowa (Stop 11).

161.3	0.3	Mostly concealed contact between the New Richmond and Willow River members of the Shakopee Formation.
162.0	0.7	St. Peter Sandstone on the left (east) with Platteville Dolomite above.
168.8	6.8	Waukon, Iowa (Allamakee Co.) city limits. Stay on Iowa 76 (Iowa 13 of old highway maps).

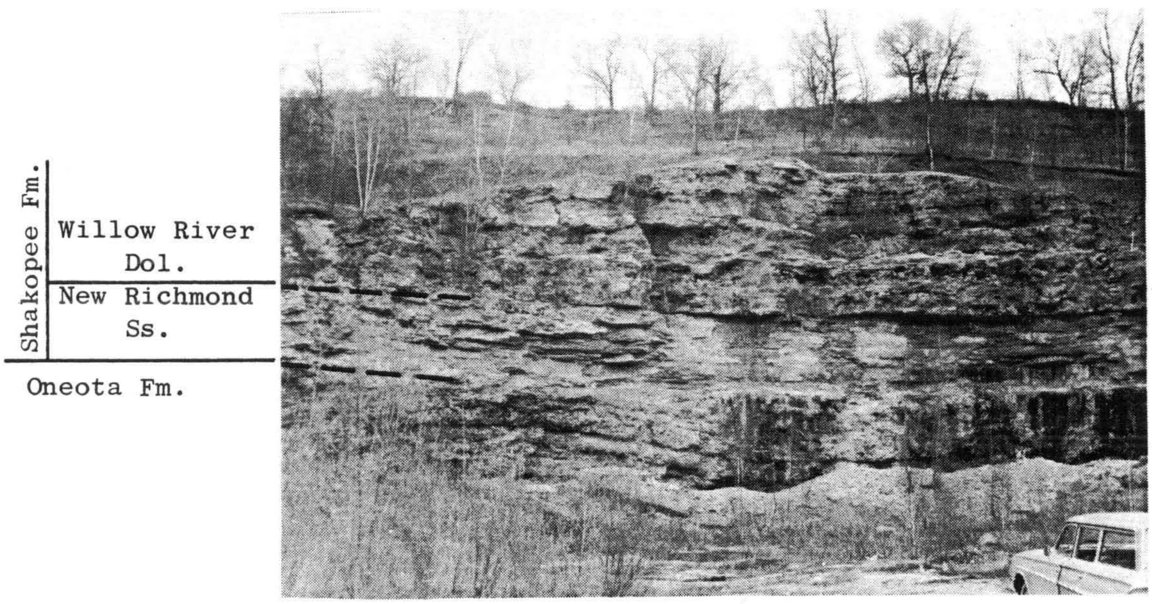


Figure 28. Eastman Quarry (NW$\frac{1}{4}$, Sec. 17, T.8N., R.5W.) located on north side of State Highway 179, 2.7 miles east of village of Eastman (Vernon County) Wisconsin. This is one of the few exposures in the area that shows the relationship between the members of the Shakopee and the truncation of upper Oneota strata.

169.3	0.5	Intersection of Iowa 76 and Iowa 9. Turn left (east) on Main Street.
169.9	0.6	Stop light in downtown Waukon where Iowa 76 and 9 separate. Continue straight east on Main Street and leave Waukon via blacktop road.
172.5	2.6	Quarry in Platteville Dolomite on left (north) side of road.
172.7	0.2	St. Peter Sandstone on the right (south).
173.1	0.4	More St. Peter on right.
180.9	7.8	Platteville Dolomite quarry on left.
183.3	2.4	STOP SIGN. Intersection with blacktop road. Turn right (south).
187.5	4.2	St. Peter on right side of road.
189.1	1.6	Begin decent into the Mississippi River valley.
189.3	0.2	Shakopee Formation on the left (north). We will be passing through the entire Prairie du Chien Group as we decend. The valley floor is at the level of the Jordan Sandstone in this vicinity.
191.3	2.0	STOP SIGN at intersection with Iowa Highway 364 just before entering Harper's Ferry, Iowa. Turn right (south) on 364. For the next several miles we will pass Jordan Sandstone near road level with high bluffs of overlying Prairie du Chien.
195.6	4.3	Railroad crossing at Waukon Junction, Iowa. You just passed it!
197.2	1.6	Oneota Formation. This formation is quite similar here to the previous stop and unless the group wishes to stop briefly at the Stockton Hill Member we will continue to the next stop at the Shakopee Formation.
197.5	0.3	<u>STOP 12</u> (R.A. Davis). Excellent exposure of Shakopee Formation in roadcut at west side of Iowa Highway 364 in the SW¼, sec. 16, T.96N., R.3W., Allamakee County, Iowa.

The travel route for the last part of the trip is shown in Figure 6.

Excellent exposure of Shakopee Formation in west roadcut (Figure 29).

STOP 12
WAUKON JUNCTION ROADCUT
Along Highway 364
Sec. 16, T.96N., R.3W.

West ⟶

SHAKOPEE FM.
Willow River Mbr.

Medium-crystalline, buff, partially covered.

Medium-grained, red-brown, sorted.

Medium-crystalline, tan, thin-bedded.

Medium-crystalline, tan-pinkish brown, massive.

Fine-medium crystalline, tan-gray, massive.

Medium crystalline, tan to pinkish brown, massive.

Medium-crystalline, buff-tan.

Fine-crystalline, tan, planar, stromatolites.

Fine/medium-crystalline, brown clay pockets.

Medium-crystalline, tan-brown, digitate stromatolites.

Medium-crystalline, tan, massive.

Fine/medium-crystalline, buff-tan.

Fine-crystalline, tan-gray, bedded at base.

Fine-crystalline, tan-buff, chert nodules.

New Richmond Mbr.

Gray-green, interbedded with dolomite & quartz sandstone.

Fine-crystalline.

Medium-crystalline, buff, bedded.

Medium-grained, tan, dolomite cement.

Medium-grained, buff-tan, dolomite cement.

Medium-crystalline, buff.

Medium grained, buff, sorted, clay seams, friable.

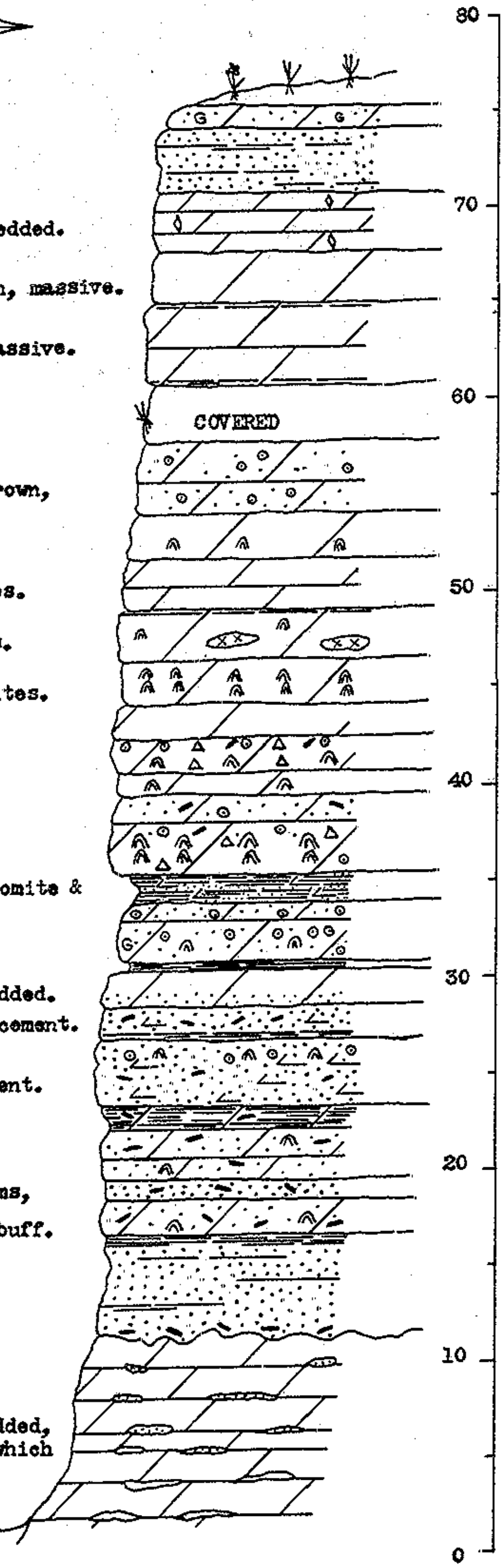
Fine-medium crystalline, buff.

Medium-grained, buff, sorted, bedded, friable.

SHAKOPEE FM.

ONEOTA FM.
Hager City Mbr.

Medium-crystalline, buff-gray, poorly-bedded, vuggy; upper few feet have quartz sand which is in pockets, apparently sifted down from above.



Described by R. A. Davis, (1969)

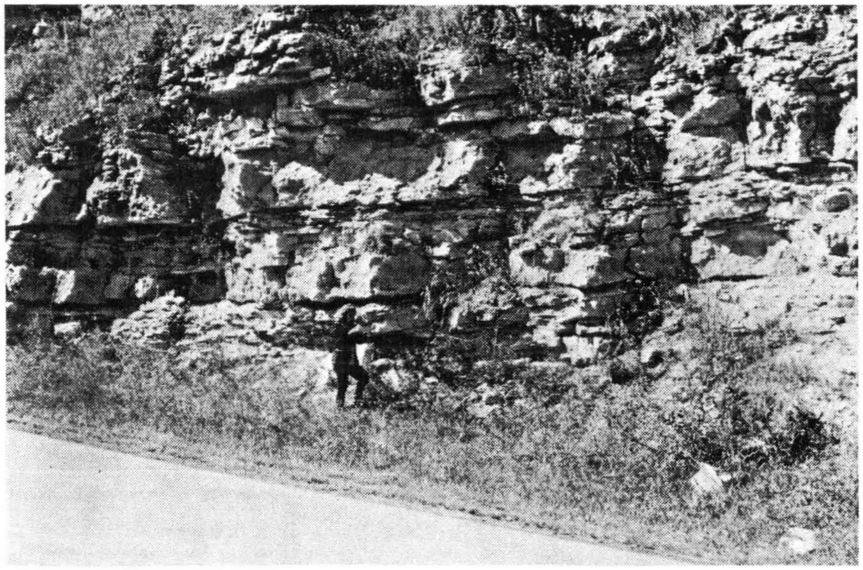


Figure 29. Roadcut at Stop 12 showing New Richmond Member of the Shakopee Formation as an interbedded facies in marked contrast to its character at Stop 11. Top of New Richmond Sandstone coincides with top of greenish shaly zone about 5 feet above head of person in picture.

At this location the contact of the Oneota and Shakopee formations is poorly exposed. Digging provides some opportunity for observing a badly weathered contact. The upper few feet of the Oneota (Hager City Member) are vuggy and contain friable quartz sand which apparently filtered down during or subsequent to deposition of the basal New Richmond.

This exposure of the New Richmond shows striking contrast to the previous stop (25 miles to the northwest). The New Richmond has changed from a red-brown, medium, sorted, quartz sandstone to an interbedded unit composed of quartz sandstone, gray-green shale, and dolomite with minor amounts of oolites, intraclasts, and algal stromatolites. From this location eastward toward the Wisconsin Arch this unit retains this character and is characteristically bounded by gray-green shale beds; look for them in the quarry exposures at the next few stops.

This stop provides the only good and accessible exposure of the Willow River Member. Throughout the entire Upper Mississippi Valley area this unit is comprised of various interbedded dolomite types with some local thin beds of chert, gray-green shale, and quartz sandstone. Carbonates are dolomitized algal biolithite, "grain" sparite, intrasparite and oosparite. Carbonate mud was apparently present in small quantities or was recrystallized to coarser textures. Algal stromatolites comprise a large portion of the section here and at adjacent exposures (Stop 15). This is interpreted as being an algal bank separating a shallow bay to the east and a normal marine shelf to the northwest (Davis, 1966).

197.8	0.3	St. Peter Sandstone in ditch on the right.
197.9	0.1	Intersection of Iowa 364 and 19. Stop and turn left.
199.5	1.6	Shakopee Formation exposed on both sides of the road.
200.2	0.7	Effigy Mound National Monument on left.
200.3	0.1	Bridge over Yellow River.
200.4	0.1	Jordan Formation along the highway.
203.5	3.1	Village of Marquette, Iowa (Allamakee Co.). Pass under interstate bridge and turn right.
203.6	0.1	STOP SIGN. Proceed straight ahead one block and turn sharp right following U.S. 18 via bridge across Mississippi River.
203.9	0.3	West end of bridge.
204.2	0.3	Enter Wisconsin.
205.1	0.9	Leave bridge and enter city of Prairie du Chien.
205.8	0.7	STOP LIGHT. Intersection of state highways 27, 35 & 60. Proceed straight ahead on State Highway 27.
206.4	0.6	Quarry in lower Oneota Dolomite on right.
207.2	0.8	Quarry on left exposes Oneota and Shakopee formations.
207.4	0.2	STOP 13 (L.M. Cline) Unconformity at base of St. Peter Sandstone in roadcut at north side of Wisconsin Highway 27. Formations exposed are Shakopee, St. Peter and Platteville. Located in the NW$\frac{1}{4}$,SW$\frac{1}{4}$,NE$\frac{1}{4}$,Sec.29, T7N, R6W, Crawford County (Prairie du Chien 15' topographic quadrangle, 1932)

A well-developed U-shaped channel of St. Peter Sandstone cuts out several feet of Shakopee dolomite and sandstone in a cutbank on the north side of the road (Figure 12). Just east of the channel the sheet phase of the St. Peter rests disconformably on several feet of dolomite in the upper part of the Shakopee. Below the dolomite member, but also in the Shakopee Formation, are several thick beds of sandstone. As these horizontal beds of Shakopee are traced westward toward the St. Peter channel, the upper dolomite disappears and the sandstone in the Shakopee curves downward toward the channel. The dips in the Shakopee are believed to be secondary, being due, in part, to pre-St. Peter solution of carbonate in the Shakopee with a corresponding reduction in volume and collapse toward the channel. Insoluble argillaceous residues of the Shakopee carbonate beds may be seen just east of the channel. The same relationship may be seen just west of the channel where sandstones in the Shakopee dip eastward toward the channel; the latter dips have been accentuated by some small-scale post-St. Peter faulting. There is strong possibility that pre-St. Peter solution of Shakopee carbonate below road level is partly responsible for some of the dips. The possibility should not be overlooked that ground water, moving freely along the permeable channel phase of the St. Peter, may have accomplished additional solution of the Shakopee at a much later geologic date; this is suggested by the small scale faulting along the west wall of the St. Peter channel.

The New Richmond Sandstone occurs at a lower stratigraphic position in a quarry about 200 yards west and on the north side of the road. In this quarry well-bedded sandstones and dolomites of the New Richmond may be seen about midway in the west face where they rest on the more massive, cavernous and biostromal dolomites of the Oneota. Note here the thin green shaly bed which marks the top of the New Richmond.

Upslope from the St. Peter channel and just out of sight around the bend in the road, the Platteville Formation is nicely exposed in a cutbank on the north side of the highway. Thick-bedded, blue-gray, buff-weathering dolomites of the Pecatonic Member of the Platteville constitute the lower few feet of the cut. The overlying argillaceous, nodular calcitic limestones belong to the McGregor Member. The McGregor offers very good fossil collecting in contrast to the relatively barren Pecatonica Dolomite.

		Turn around and retrace route back to Prairie du Chien.
208.7	1.3	Enter Prairie du Chien.
209.1	0.4	STOP LIGHT. Turn left (south) and follow U.S. 18.
212.9	3.8	Prairie du Chien Dolomite exposed in roadcut on left.
213.5	0.6	Traveling on top of Bridgeport terrace.
214.7	1.8	Intersection of U. S. Highway 18 and State Highway 60. Proceed straight ahead on U.S. 18.
215.1	0.4	Prairie du Chien Dolomite exposed in roadcut on right. Cross Wisconsin River bridge.
215.9	0.8	Turn right (west) on County Highway "C" toward Wyalusing State Park.
216.7	0.8	Prairie du Chien Dolomite exposed in roadcut on left.
217.3	0.6	Prairie du Chien Dolomite exposed in roadcut on right.

217.7	0.4	STOP 14 (M.E. Ostrom). Contact relationships of St. Peter, Glenwood and Platteville formations exposed in roadcuts at north side of County Highway "C" in the SE¼,NW¼,NE¼, Sec. 22, T.6N., R.6W., Grant County (Bagley 7.5' topographic quadrangle, 1962).

At this site all four lithotopes of the uppermost cycle, which has the St. Peter Sandstone in its base, are exposed.

At STOP 13 the erosion surface at the base of the St. Peter was especially well shown. Dapples (1955) demonstrated that this erosion surface could be traced over a broad area extending from western Tennessee to Wisconsin. A map by Ostrom (Figure 18) shows the geology of the pre-St. Peter surface in Wisconsin and indicates that the St. Peter rests on successively older rocks as one proceeds from western Wisconsin to the vicinity of Milwaukee. It is postulated that there was pre-St. Peter uplift in the vicinity of Milwaukee and that the uplifted surface was subsequently eroded. Although data are sparse there is very good agreement between thick sections of St. Peter which are interpreted to coincide with pre-St. Peter erosion channels and the occurrence of older rocks on the pre-St. Peter surface which were likely exposed by erosion. The data suggest stream drainage to the southwest away from the Milwaukee area.

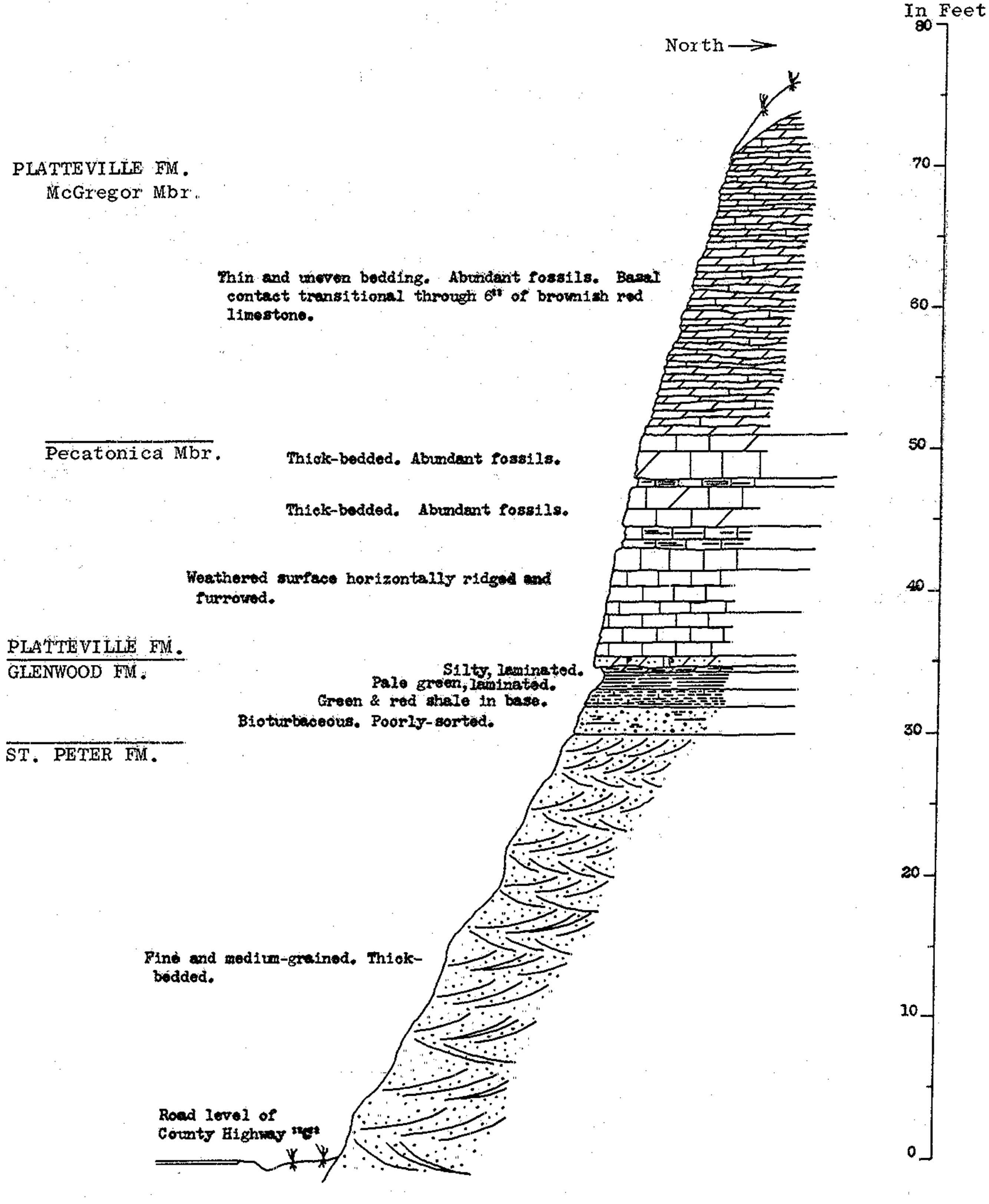
The thick-bedded quartzarenite is represented by the St. Peter Sandstone and the reworked poorly-sorted quartzarenite by the lower 2 feet of the Glenwood Formation (bed 2, Appendix). The reworked quartzarenite is transitional through about 1.4 feet of siltstone and shale into the shale lithotope (beds 4 and 5, Appendix) and this is in sharp contact with the base of the overlying carbonate lithotope which is the Platteville Formation.

The Glenwood Formation in Wisconsin thins to the east toward the Wisconsin Arch from a maximum thickness of about 13 feet in the vicinity of Beetown, located 15 miles southeast of STOP 14, to less than a foot near New Glarus. A study by Ostrom (1969) showed that as one proceeds eastward the upper or shale unit thins to disappearance and the underlying poorly-sorted reworked quartzarenite is in direct contact with the overlying carbonate lithotope. Traced further to the east, in the vicinity of New Glarus south of Madison, the reworked quartzarenite thins to less than 1 foot.

The contact of the Glenwood Formation with the Platteville Formation is one of apparent unconformity. This relationship is attributed to lateral variations in environmental conditions at the time of formation rather than to post-Glenwood erosion because there is no evidence except the apparent regional truncation described above that would indicate the Glenwood was eroded.

219.0	1.3	Turn right and follow County Highway "X".
220.0	1.0	Turn left and follow Highway "X" to Wyalusing.
220.3	0.3	Prairie du Chien Dolomite exposed in low roadcut on right.
220.5	0.2	Platteville Formation exposed in roadcut on right.

STOP 14
ROADCUT ON COUNTY TRUNK "C"
NW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 22, T. 6N., R. 6W.



Refer to STOP 1 for key to symbols

Described by M. E. Ostrom (1969)

220.6	0.1	St. Peter Sandstone exposed in series of low roadcuts on right for half mile.
221.2	0.6	Shakopee Formation exposed in low roadcut on right.
221.6	0.4	Upper shale beds of New Richmond Member of Shakopee Formation exposed in low roadcut on right.
222.4	0.8	STOP 15 (L.M. Cline). Chicago, Burlington and Quincy Railroad quarry at north edge of the community of Wyalusing in the $NW\frac{1}{4}, SW\frac{1}{4}$, sec. 31, T.6N., R.6W., Grant County, Wisconsin (*Clayton 7½' topographic quadrangle*, 1962).

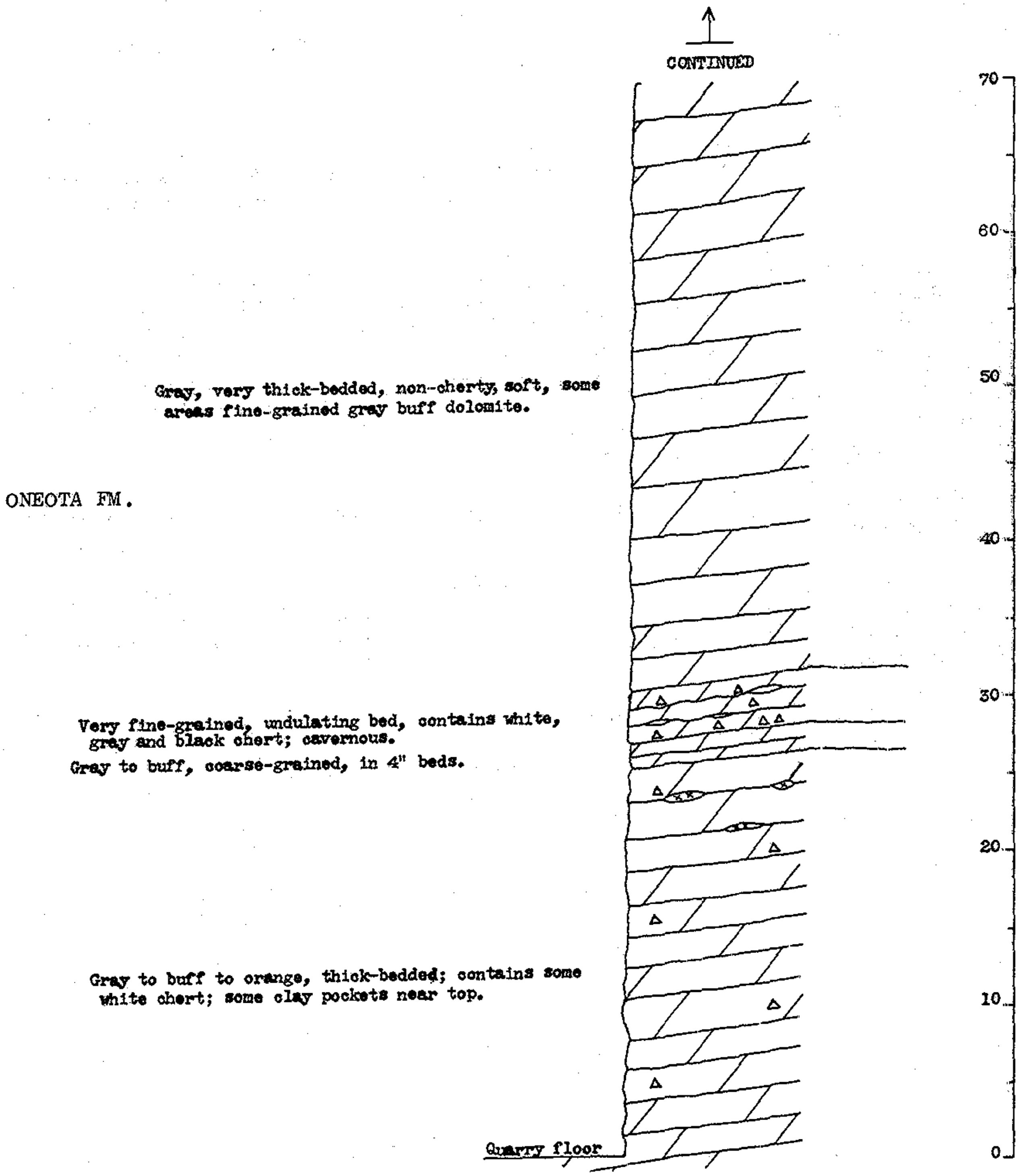
This quarry, exposing approximately 185 feet Prairie du Chien strata, is probably the most nearly complete exposure of the Prairie du Chien in the state of Wisconsin. George Starke (1949) described the rocks exposed in this quarry and estimated that the floor of the quarry lies some 30 feet above the base of the Oneota Formation. His diagrammatic representation of the stratigraphic section is reproduced in this guidebook in Figure 30 and on the left side of the regional cross section of Figure 31. Starke's description is reproduced in the Appendix.

The Willow River Formation at this site was studied in detail by Carozzi and Davis (1964).

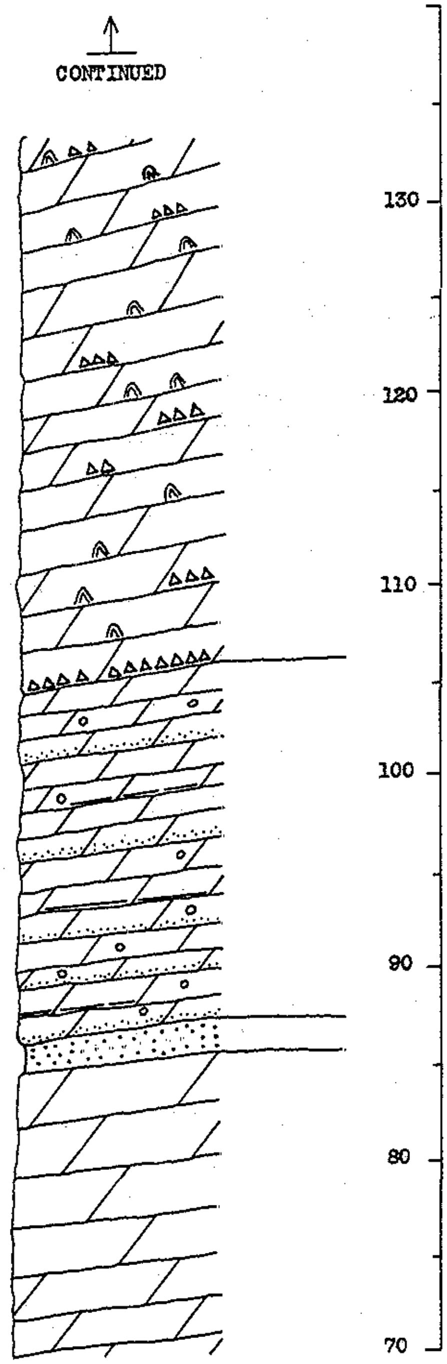
Angular unconformity of beds at the Oneota/New Richmond contact is clearly shown on the high southeast quarry face (Figure 11). Here eastward dipping beds of Oneota Dolomite are overlain by flat-lying beds of the New Richmond Member.

		Retrace route to U.S. Highway 18 when leaving.
224.6	2.2	STOP SIGN. Turn right and follow CTH "C".
225.6	1.0	Follow Highway "C" to left at Y in road.
228.6	3.0	STOP SIGN. Intersection with U.S. Highway 18. Turn left (north) and proceed to junction with State Highway 60.
229.9	1.3	Junction with Highway 60. Turn right (east) and proceed toward Gotham.
231.1	1.2	Prairie du Chien Dolomite exposed in roadcut on right.
231.6	0.5	Jordan-Oneota contact exposed in roadcut on left.
232.9	1.3	Jordan-Oneota contact exposed in roadcut on right.
234.5	1.6	Gran Grae Creek crossing.
236.4	1.9	Bush Creek crossing.

STOP 15
CHICAGO, BURLINGTON AND QUINCY RAILROAD QUARRY
NW$\frac{1}{4}$,SW$\frac{1}{4}$,Sec.31,T.6N.,R.6W.



STOP 15
CONTINUED



Algal structures profuse; stringers of chert throughout; basal foot is weathered chert.

Conglomeratic with dark gray pebbles; well-bedded with some green shale partings and some clean white quartzose beds.

White, medium-grain; some green specks.

Gray, very thick-bedded, non-cherty, soft, some areas fine-grained gray buff dolomite.

STOP 15
CONTINUED

ST. PETER FM.

White, stained brown, medium-grained, well-sorted and rounded grains.

SHAKOPEE FM.
Willow River Mbr.

Gnarled appearance, thick 1' beds with some stringers of sandstone.

Brecciated.

6 inch beds separated by gray shale.

Thinly-bedded, green shale partings; floating grains of quartz sand.

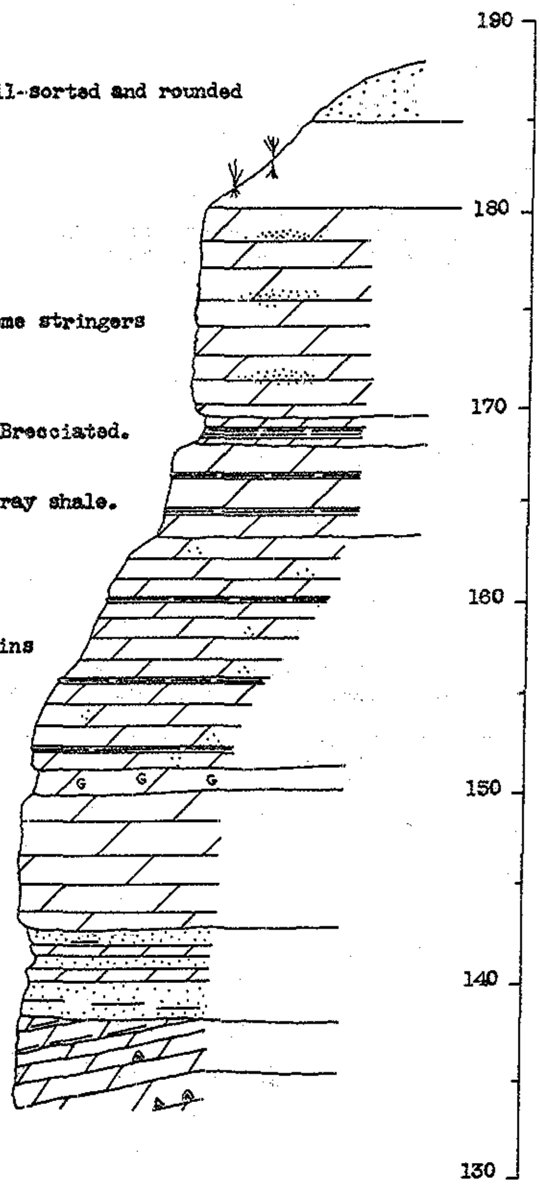
Green, glauconitic.

Fine-grained; weathers to irregular surface.

New Richmond Mbr.

ONEOTA FM.

Weathers to irregular surface; some algal structures.



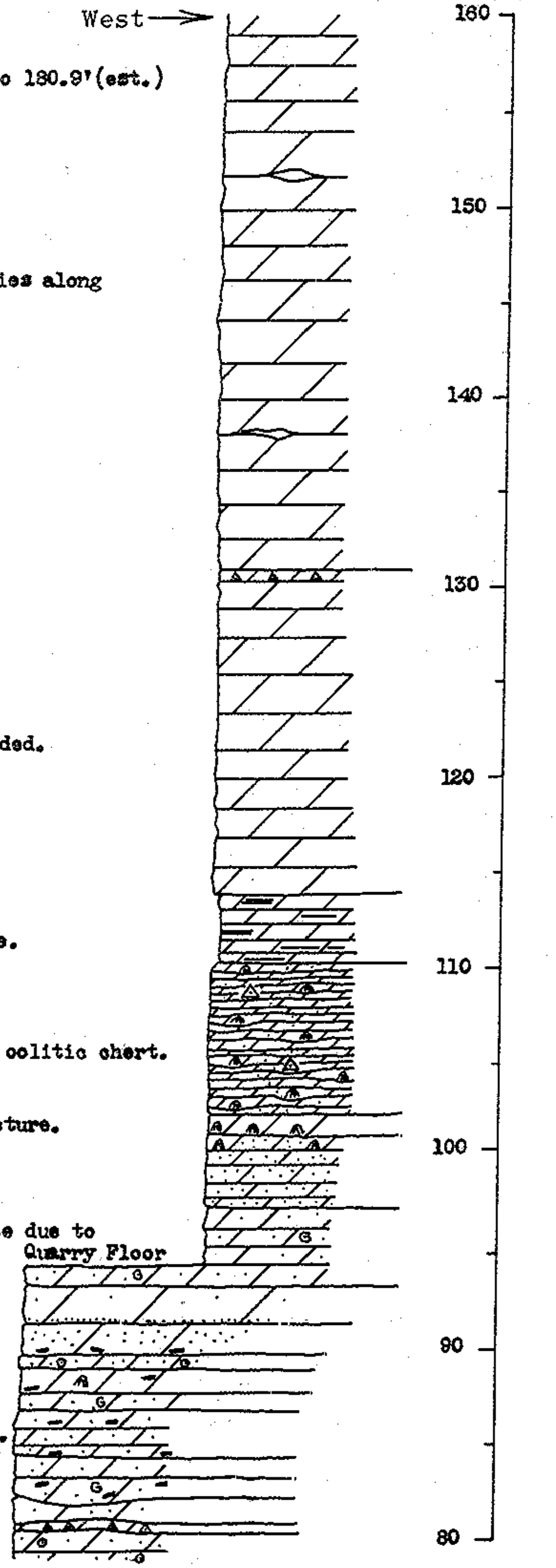
Described by George Starke, 1949
Modified by L. M. Cline, 1959, 1960

236.6	0.2	Jordan-Oneota contact exposed in low roadcut and bluff on left.
236.8	0.2	Jordan-Oneota contact exposed in high cut on left.
237.7	0.9	Jordan Sandstone exposed in roadcut on left.
238.3	0.6	Little Kickapoo Creek crossing.
238.5	0.2	Jordan Sandstone exposed in outcrop on left.
240.3	1.8	Enter Wauzeka. Follow State Highway 60.
241.7	1.4	Leave Wauzeka.
242.4	0.7	Kickapoo River crossing.
242.6	0.2	Junction with State Highway 131 north. Proceed east on Highway 60.
246.0	3.4	Black Earth Dolomite exposed in roadcut on left.
250.1	4.1	Lodi Siltstone exposed in roadcut on left.
250.6	0.5	Turn left (north) on County Highway "E" and proceed up hill to large quarry on left.
250.9	0.3	Black Earth Dolomite exposed in roadcut on left.
251.0	0.1	Van Oser and Norwalk members exposed.
251.1	0.1	Contact of Jordan and Oneota ormations.
251.2	0.1	Contact of Sunset Point and Oneota embers.
251.3	0.1	STOP 16 (L.M. Cline and M.E. Ostrom). Large quarry in Oneota Formation and roadcut along County Trunk Highway E. Located in SW$\frac{1}{4}$,NE$\frac{1}{4}$, sec. 21, T.8N., R. 3W., Crawford County, Wisconsin (Boscobel 15' topographic quadrangle, 1933). Examine contact between Norwalk, Van Oser, and Oneota in detail. Refer to discussion at mileage 252.1.

The main objective of Stop 16 and the description of the section in Easter Rock (mileage 252.1)is to study the Jordan Sandstone and the "transition beds" in the base of the Stockton Hill Member of the Oneota Formation. There are several distinctive lithologic horizons in the Stockton Hill namely an oolitic chert bed and a dolomite bed speckled with green shale, which persist eastward and northeastward as far as the Green Bay area in northeastern Wisconsin as was shown by Starke (1949). In tracing the zones eastward from Boscobel, Starke (op. cit.; Figures 30 & 31) has shown gradual

STOP 16
ROADCUT AND QUARRY ALONG COUNTY TRUNK "E"
SW¼, NE¼, Sec. 21, T. 8N., R. 3W.

ONEOTA FM.



Inaccessible. Thick-bedded. Solution cavities along some bedding planes.

Inaccessible. Medium and thick-bedded.

Inaccessible.

Composed of thin algal laminae with nodules of oolitic chert.

Algal biostrome, "honeycomb" structure.

Medium and irregularly-bedded. Pits on weathered surface due to weathering of glauconite pellets.

Green clay "speckling" in lower 3".

Conglomeratic. Abundant white silica as encrustations on pellets, oolites & possibly as fossils.

Some green clay "speckling". Glauconite pellet pits on surface.

Medium and even-bedded. Green clay speckling.

Green clay "speckling".

ONEOTA FM.

Continued

STOP 16
CONTINUED

↑
Continued

Fine-grained. Green clay in pellets and along cross beds and bedding planes.

Even-bedded and medium-bedded. Pitted surface in lower 1 foot.

ONEOTA FM.

JORDAN FM.
Van Oser Mbr.

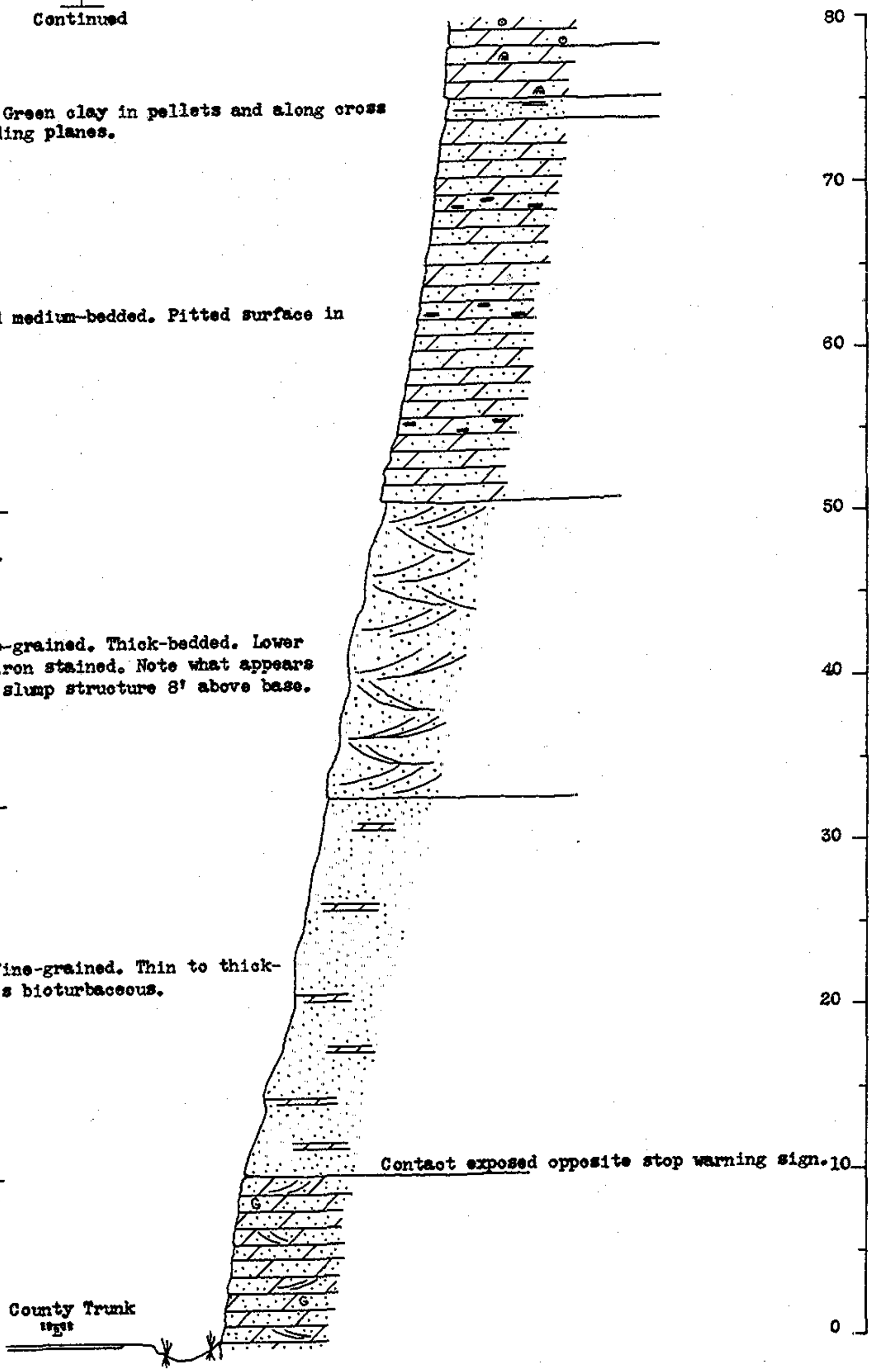
Medium and fine-grained. Thick-bedded. Lower 6" to 1 foot iron stained. Note what appears to be fold or slump structure 8' above base.

Norwalk Mbr.

Very fine and fine-grained. Thin to thick-bedded. Much is bioturbaceous.

JORDAN FM.

ST. LAWRENCE FM.



Refer to STOP 1 for key to symbols

Description by L. M. Cline & M. E. Ostrom

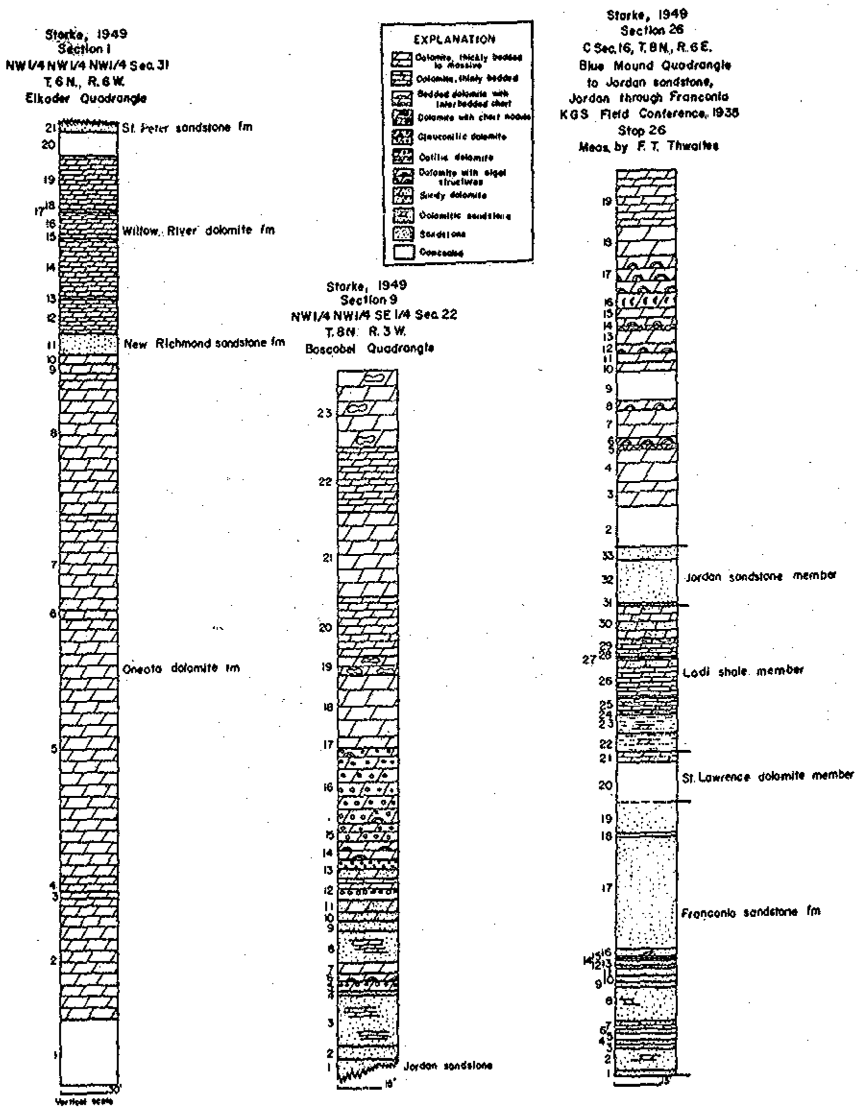


Figure 30. Stratigraphic sections of Stop 15 (quarry at Wyalusing), Easter Rock Bluff north of Boscobel (about 0.5 miles southeast of Stop 16), and Stop 18 (bluff and quarries in Mazomanie, respectively) as taken from Starke (1949).

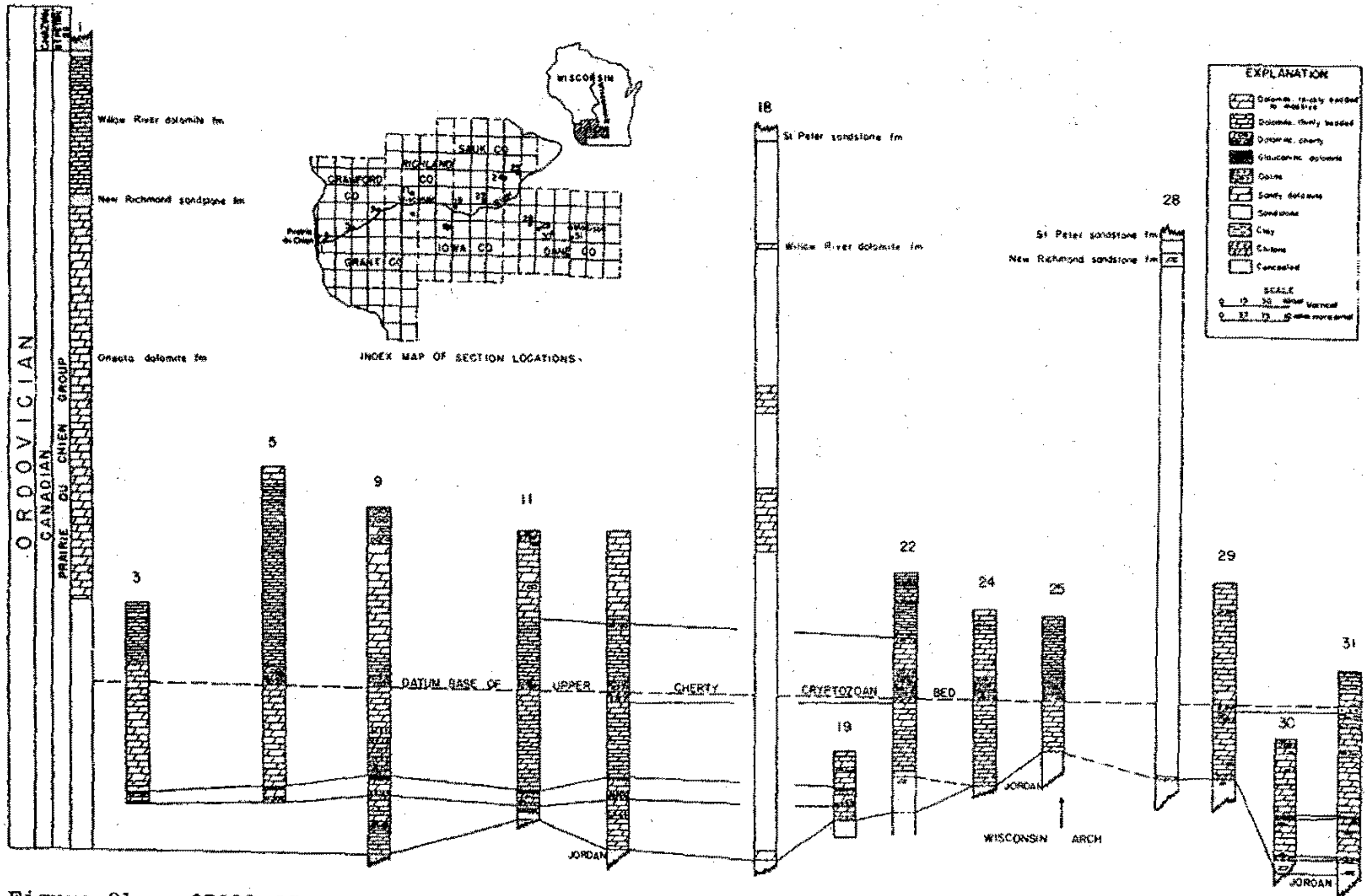


Figure 31. CROSS SECTION OF THE PRAIRIE DU CHIEN GROUP FROM THE TYPE SECTION EASTWARD TO MADISON SHOWING THE PRINCIPLE PERSISTENT LITHOLOGIC HORIZONS

by
George Starke
University of Wisconsin, 1949

overlap of these zones by younger Oneota strata until about 40 feet of basal Oneota is overlapped along the axis of the Wisconsin Arch (refer to STOP 19).

The contact of the Jordan and Oneota Formations and the lithology of the lower part of the Oneota (Sunset Point) are especially well shown in the road cut along Highway "E".

		Retrace route back down hill to State Highway 60.
251.9	0.6	STOP SIGN. Junction with State Highway 60. Turn left (east) and follow 60 to Gotham.
252.1	0.2	Easter Rock on left at junction of State Highway 60 with U.S. Highway 61. It was here that Starke (1949) described the oolitic chert bed and "green-speckled" bed seen to better advantage at Stop 16. His description of Easter Rock is given in the Appendix at Mileage 252.1 and his stratigraphic section is reproduced diagrammatically as the middle column in Figure 30. Note about 20 feet above road level the contact of the Tunnel City Sandstone with the overlying St. Lawrence Formation.

It appears that deposition of the Jordan Sandstone gradually gave way to the dolomite deposition of the Oneota. There are ripple marks and mud cracks in beds 2, 3, and 4, which one might take as evidence of shoaling conditions but it is perhaps just as reasonable to assume gradually deepening waters from Jordan into Oneota time, thus making it possible for fine-grained sediments to settle out, preserving the ripples and making it possible for shrinkage cracks to be developed and preserved. Minor amounts of quartz sand continued to accumulate in the Oneota carbonate-forming zone, at least as high as bed 15.

253.1	1.0	Lone Rock Formation exposed at base of roadcut and bluff on left.
253.3	0.2	Turn right on State Highway 60 toward Gotham.
253.8	0.5	Lone Rock Formation exposed in outcrop on left.
254.5	0.7	Lone Rock - St. Lawrence contact exposed in roadcut on left.
254.8	0.3	Note high bluff on left capped by Oneota with Jordan face.
255.1	0.3	Lone Rock Formation exposed in roadcut on left.
255.8	0.7	Enter Richland County.
257.6	1.8	Knapps Creek crossing.
260.9	3.3	Junction with County highways "X" and "T" at bridge south to Blue River. Continue straight ahead on Highway 60 east.

261.1	0.2	Enter Port Andrews.
266.8	5.7	Junction with State Highway 193 north. Proceed right on Highway 60 east.
268.4	1.6	Mill Creek crossing.
268.6	0.2	Junction with State Highway 80. Continue straight ahead on Highway 60.
269.2	0.6	Enter Orion.
270.0	0.8	Indian Creek crossing.
271.4	1.4	Lone Rock Formation exposed in low roadcut on left.
272.0	0.6	Ironton and Galesville exposed in roadcut on left.
272.5	0.5	Ironton Member exposed in roadcut on left.
273.4	0.9	Lone Rock Formation exposed in roadcut on left.
274.3	0.9	Note high bluff on left with Oneota Dolomite cap and Jordan Sandstone face.
275.2	0.9	Wonewoc Formation exposed in hill behind barn on left.
276.1	0.9	Pine River crossing.
276.3	0.2	Enter Gotham.
276.6	0.3	STOP SIGN. Junction with U.S. Highway 14. Turn right and follow U.S. 14 to Spring Green.
278.4	1.8	Wayside on left.
279.5	1.1	Bear Creek crossing.
281.2	1.7	Junction with State Highway 130 north. Continue straight ahead on U.S. 14.
281.8	0.7	Junction with State Highway 130 south. Continue straight ahead on U.S. 14.
282.2	0.3	Enter Sauk County.
288.1	5.9	Turn left on State Highway 23 at junction with U.S. 14 near north edge of Village of Spring Green. Next stop is quarry which can be seen near top of bluff to right front.
289.8	1.7	Roadcuts and quarries exposing section beginning with Lone Rock Formation at base and extending to Oneota Dolomite at top.

289.9 0.1 Turn sharp right on quarry road where highway starts downhill. Follow to quarry.

290.8 0.9 STOP 17 (M.E. Ostrom). Davis and Richardson Stone Quarry located in the Wisconsin River bluff about 1 mile north of Spring Green in the SE¼, SW¼, Sec. 31, T.9N., R.4E., Sauk County (Spring Green 15' topographic quadrangle, 1960).

This stop is intended to show the lateral persistence of certain beds in the lower part of the Stockton Hill Member of the Oneota Formation as was demonstrated by Starke (1949) and shown at STOP 16. Although this quarry was not used by Starke in his correlation it clearly shows the oolitic white chert bed and the "green speckled" bed which he used as key markers. For a more detailed discussion refer to STOP 16 in the road guide and Appendix and to figures 30, 31, and 32.

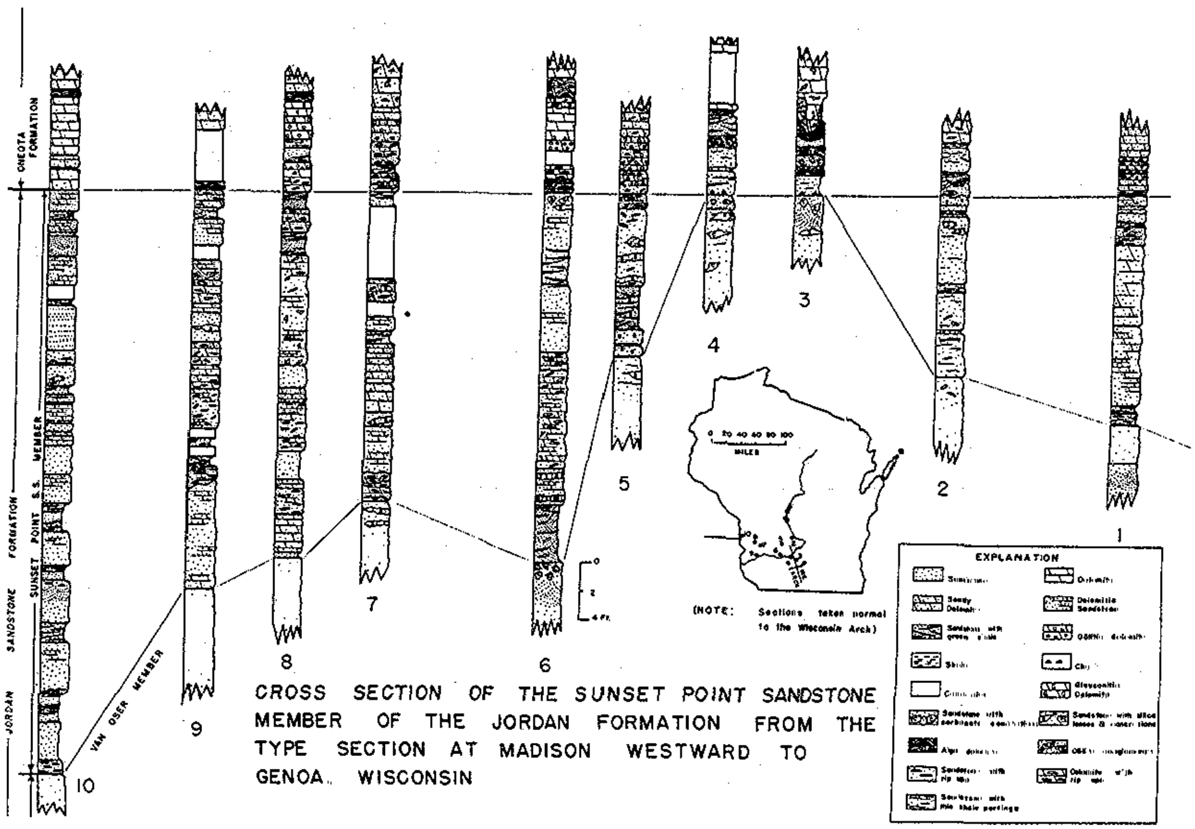
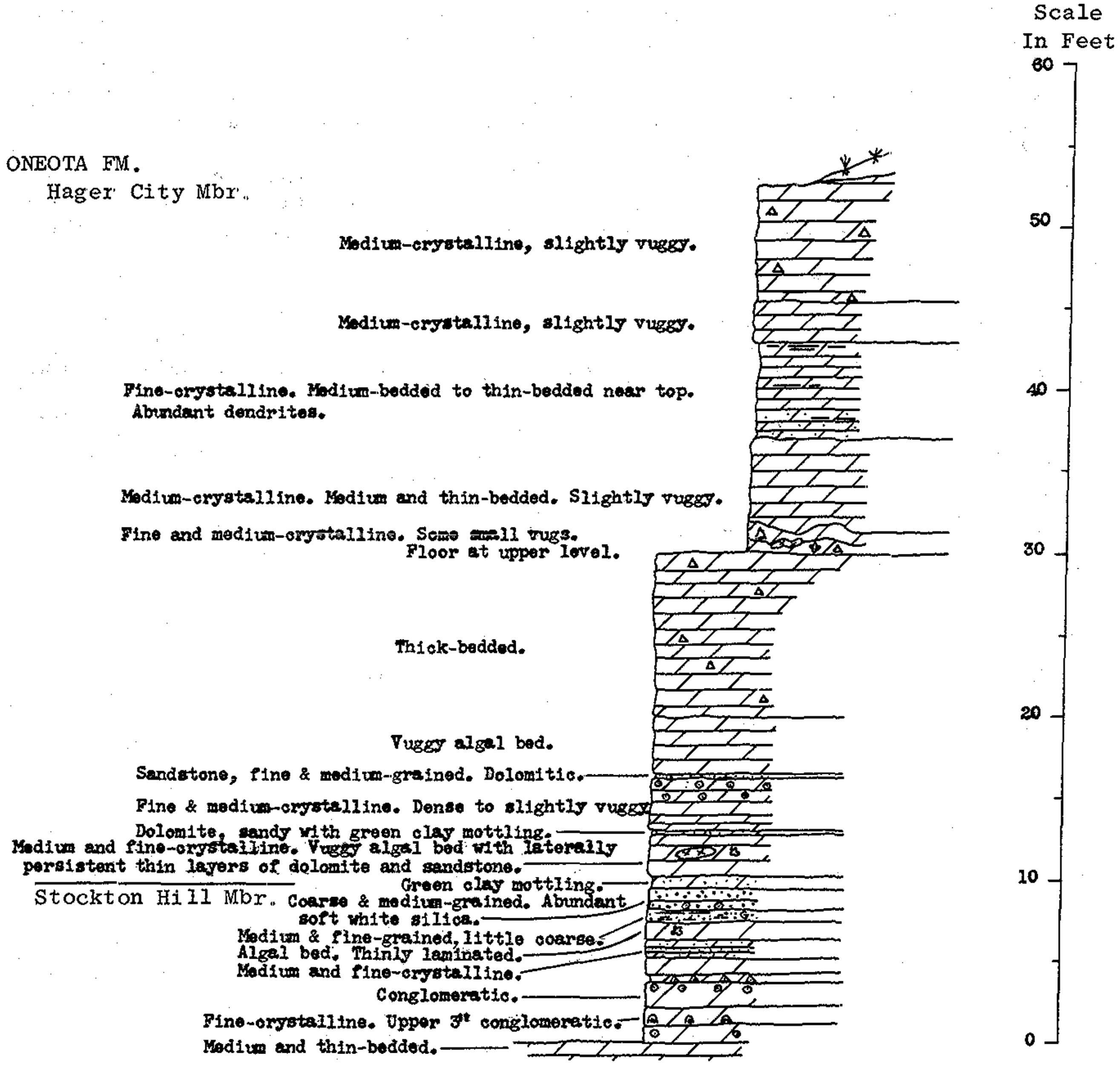


Figure 32. Cross section of the Sunset Point Sandstone Submember of the Oneota Formation from the type section at Madison westward to Genoa, Wis. (Melby, 1967).

Of special interest at this stop are certain red clay bodies which occur in the dolomite (Clay Minerals Society, 1964). These clay bodies are similar to those which occur in the Oneota Dolomite elsewhere and which have been described as fillings of solution cavities in the dolomite. X-ray diffraction analyses of the clay indicates that it consists predominantly of mixed-layer

STOP 17
DAVIS & RICHARDSON STONE QUARRY
SE¼, SW¼, Sec. 31, T. 9N., R. 4E.



Refer to STOP 1 for key to symbols

Described by M. E. Ostrom

expansible varieties and that it compares favorably with analyses reported for residual clays believed to have developed as soils on the top of the dolomite throughout much of southwestern Wisconsin (M.L. Jackson, personal communication). One explanation for the clay bodies in the dolomite is that possibly the residual clays circulated downward in groundwaters and were redeposited in solution cavities.

However, close examination of the clay bodies here and elsewhere in the Oneota Dolomite raise some serious questions with regard to this theory as has previously been pointed out (Ostrom, 1964b). If examined closely it can be seen that certain thin non-calcareous layers in the dolomite, composed of chert, sandy or silty laminae, or green clay beds, persist through the clay bodies. This is difficult to explain in terms of cavity filling.

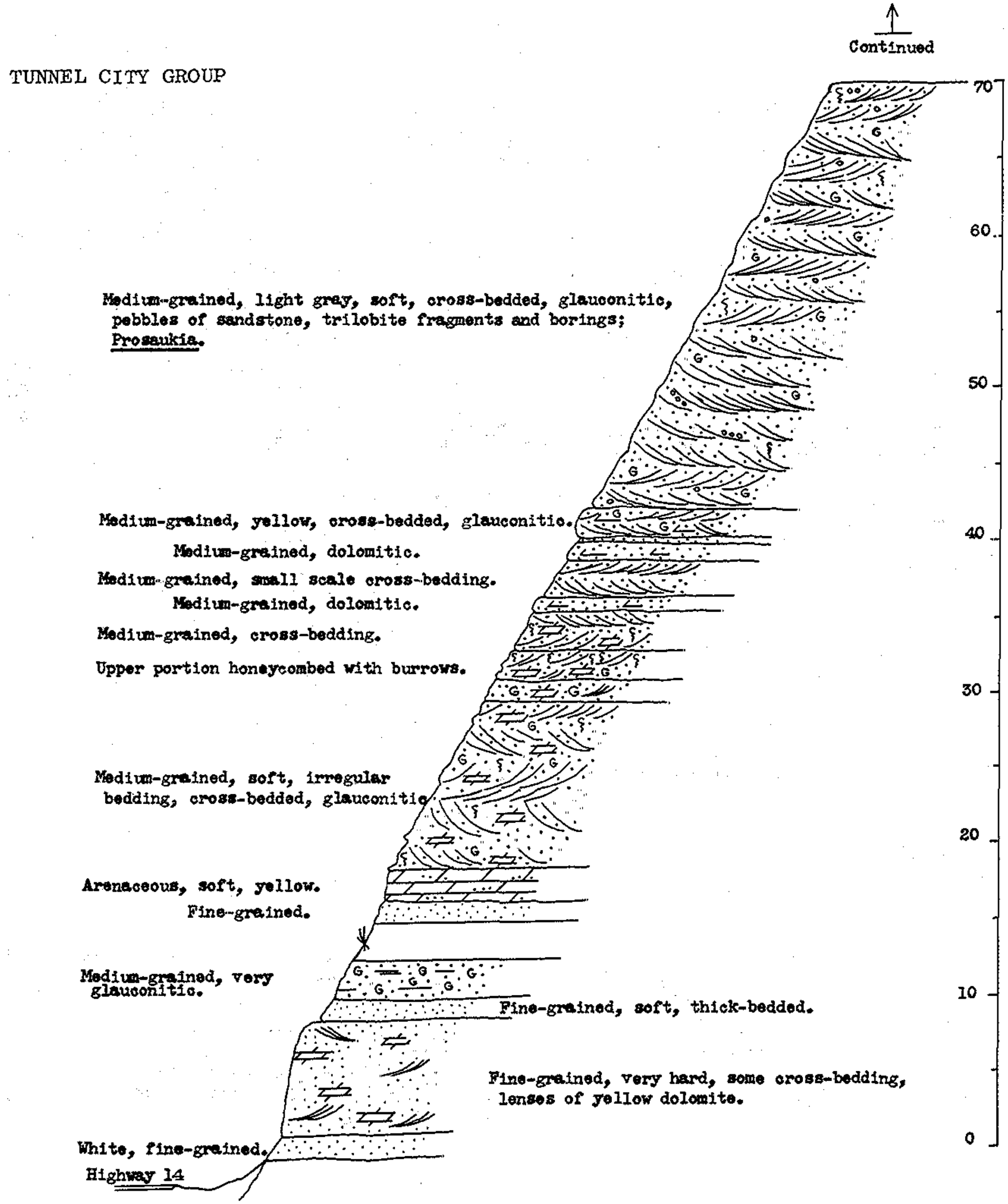
As an alternative it has been suggested (op.cit.) that the clay bodies formed by a process of replacement in the dolomite and that the residual soils at the surface formed, at least in part, as a lag concentrate developed as the carbonate was leached away.

If it is true that this clay actually formed by a replacement process in the dolomite, then closer study may provide a clue as to the mode of formation of other clays, such as bauxite, where they occur associated with carbonate rocks.

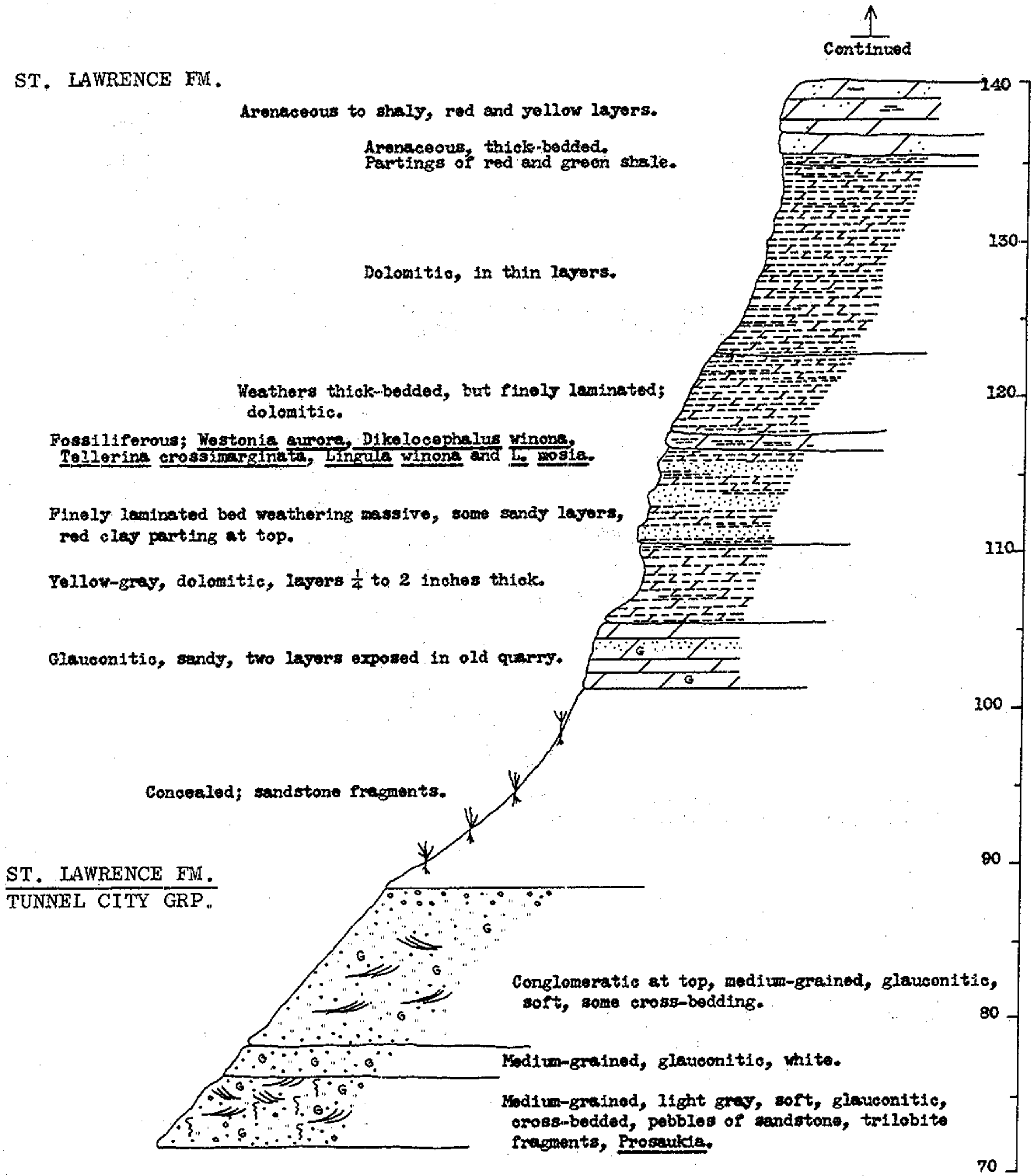
291.5	0.7	STOP SIGN. Junction with State Highway 23. Turn left and proceed to Spring Green.
293.4	1.9	STOP SIGN. Junction with U.S. Highway 14. Turn left and proceed toward Madison.
295.3	1.9	Bridge over Wisconsin River.
296.6	1.3	Road to Tower Hill State Park on right.
300.7	4.1	Wayside on left.
301.9	1.2	Enter Arena.
304.2	2.3	Blue Mounds Creek crossing.
307.8	3.6	Enter Mazomanie.
308.3	0.5	STOP 18 (L.M. Cline). Mazomanie Bluff, Mazomanie, Wisconsin. Located in the SE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 16, T.8N., R.6E., Dane County (Mazomanie 7.5' topographic quadrangle, 1962). Description by L. M. Cline modified after Thwaites (1935) and Starke (1949).

The main purpose of this stop is to observe the effect of the Wisconsin Arch on the Jordan-Oneota interval but it also offers a good opportunity to see the Mazomanie Sandstone, St. Lawrence Dolomite, and the overlying Lodi Siltstone. The Wisconsin Arch evidently was positive throughout much of the Upper Cambrian and Lower and Middle Ordovician time as is shown by the thinning of many of the units over the arch (Starke, 1949; Ahlen, 1952; Emrich 1962; Ostrom 1966, 1969; Melby 1967). The Jordan Sandstone, for example,

STOP 18
MAZOMANIE BLUFF SECTION
SE$\frac{1}{4}$,NW$\frac{1}{4}$,Sec.16,T.8N.,R.6E.



STOP 18
CONTINUED



STOP 18
CONTINUED

ONEOTA FM.

Gray to buff, thick-bedded, badly weathered.

Contains algal structures.

Gray, contains fragment of chitons.

Buff, fine-grained, wavy-bedded, cherty.

Mottled, biostromal.

Gray, fine-grained.

(Old Quarry Face)

Buff, fine-grained, wavy-bedded.

Arenaceous.

Thick-bedded, wavy-bedded, lower part cherty.

Gray, thick-bedded, brecciated.

ONEOTA FM.
JORDAN FM.
Van Oser Mbr.

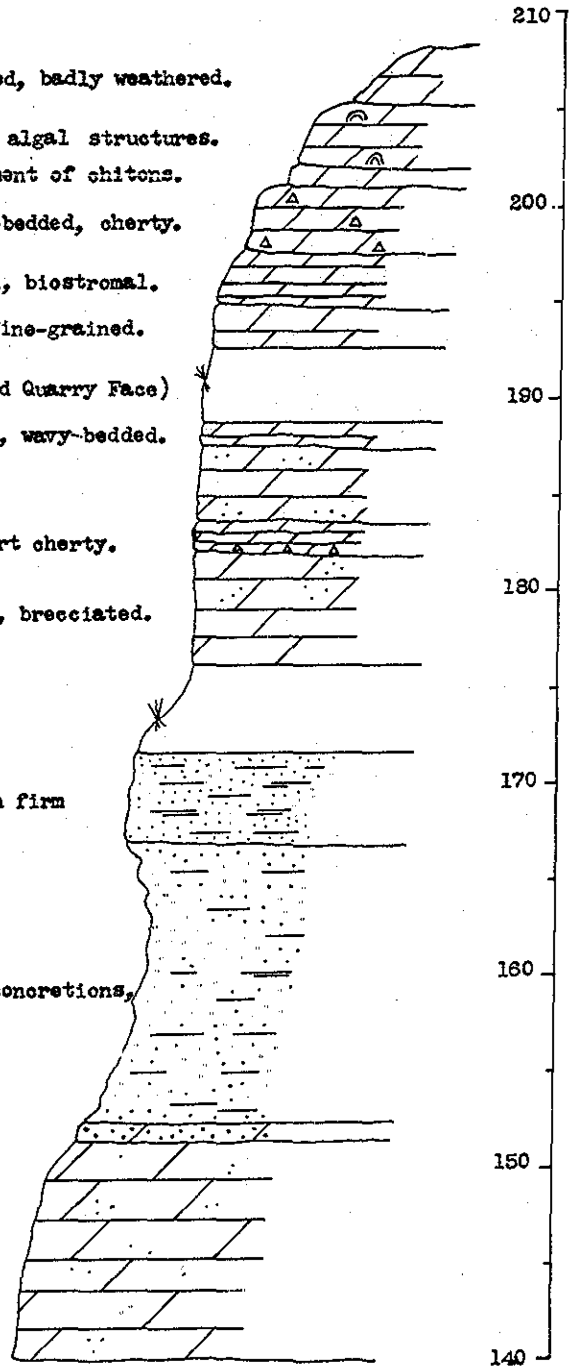
Light gray, fine-grained, thin firm layers.

White, soft, medium-grained, contains calcite concretions, in even beds.

JORDAN FM.
ST. LAWRENCE FM.

Coarse-grained, dolomitic, brownish-yellow, hard.

Yellowish-gray, arenaceous some red streaks.



Described by George Starke, 1949
Modified by L. M. Cline, 1959, 1960

thins to 18 feet over the arch. The marked change in lithology and sharp contact between the St. Lawrence Formation and Jordan Sandstone at STOP 18 could be interpreted as indicating pre-Jordan erosion as was suggested by Ostrom (1964a). The Oneota rests with apparent unconformity on the Jordan on the basis of the fact that the "transition beds" of the basal Oneota are absent as was shown by Starke (1949) who ascribed the relationship to pre-Oneota erosion of the Jordan sands. However, the absence of these beds can also be accounted for by assuming that as the sea transgressed so did the lithic boundary separating the "transition beds" from the underlying "sand beds". Thus, the lithic boundary would cross time boundaries. By this method individual beds among the "transition beds" would represent approximately time intervals and successively younger beds would reach further landward to form an overlapping pattern (Ostrom, 1964a).

Twenhofel, et al. (1935) assigned the upper 25 feet of the Tunnel City Sandstone at this exposure (Franconian) to the Reno Member. Ninety-three feet of the underlying section were referred to the Mazomanie and Birkmose members without attempt at differentiation. It is noteworthy that zone 24 (refer to Appendix), which is in the Lodi Siltstone 120 feet above the base of the outcrop, has yielded the world-famous Dikelocephalus fauna described by Ulrich and Resser (1916), although the genus is not restricted to the Lodi. Fossils are rare.

Glacial note - Black Earth Creek valley immediately above Mazomanie contains many feet of outwash sand and dolomitic gravel graded to the high sand terrace in the Wisconsin River valley.

309.4	1.1	Junction with State Highway 78 north. Proceed straight ahead and to right.
310.8	1.4	Exposure of section from Black Earth at base to Oneota at top in hillside above barn on left.
311.0	0.2	Black Earth Dolomite exposed in roadcut on left.
311.3	0.3	Enter Village of Black Earth.
311.6	0.3	Junction with Highway 78 south. Continue straight ahead on U.S. Highway 14.
311.8	0.2	Black Earth Creek crossing.
312.4	0.6	Roadcut and bluff on left reveal section extending from Lone Rock Formation at base to Oneota Dolomite at top.
313.1	0.7	Lone Rock-St. Lawrence contact exposed in roadcut on left.
314.9	1.8	Black Earth Dolomite exposed in roadcut on left.
315.0	0.1	St. Lawrence through Oneota formations exposed on left.
315.2	0.2	Contact of Lone Rock Formation with St. Lawrence Formation in roadcut on left.

315.6	0.4	Oneota Dolomite quarry exposed in distance to right front.
316.4	0.8	Enter Village of Cross Plains.
318.3	1.9	Lodi-Jordan contact exposed in roadcut on left. Bluffs capped by Oneota.
319.0	0.7	Gravel pit in glacial outwash on left.
319.3	0.3	West edge of glacial till occurrence.
320.4	1.1	STOP 19. Roadcut at north side of U.S. Highway 14 (Figure 33) four miles west of Middleton, Wisconsin in the SW¼, SE¼, Sec. 7, T.7N., R.8E., Dane County (Cross Plains topographic quadrangle, 1962). Jordan-Oneota contact. Last stop of trip. Proceed on to Milwaukee. Note Oneota Dolomite quarry in distance to southeast.

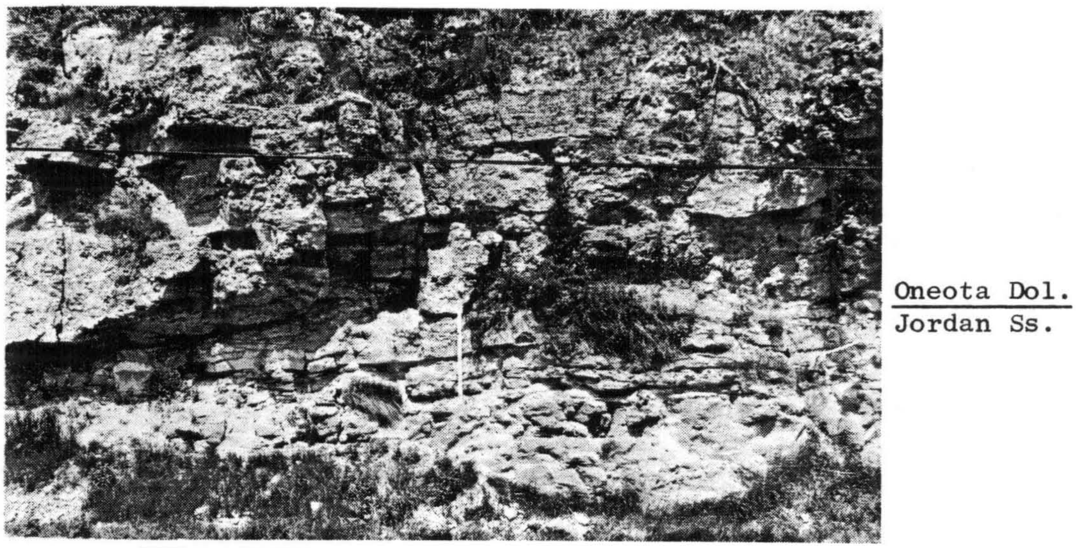
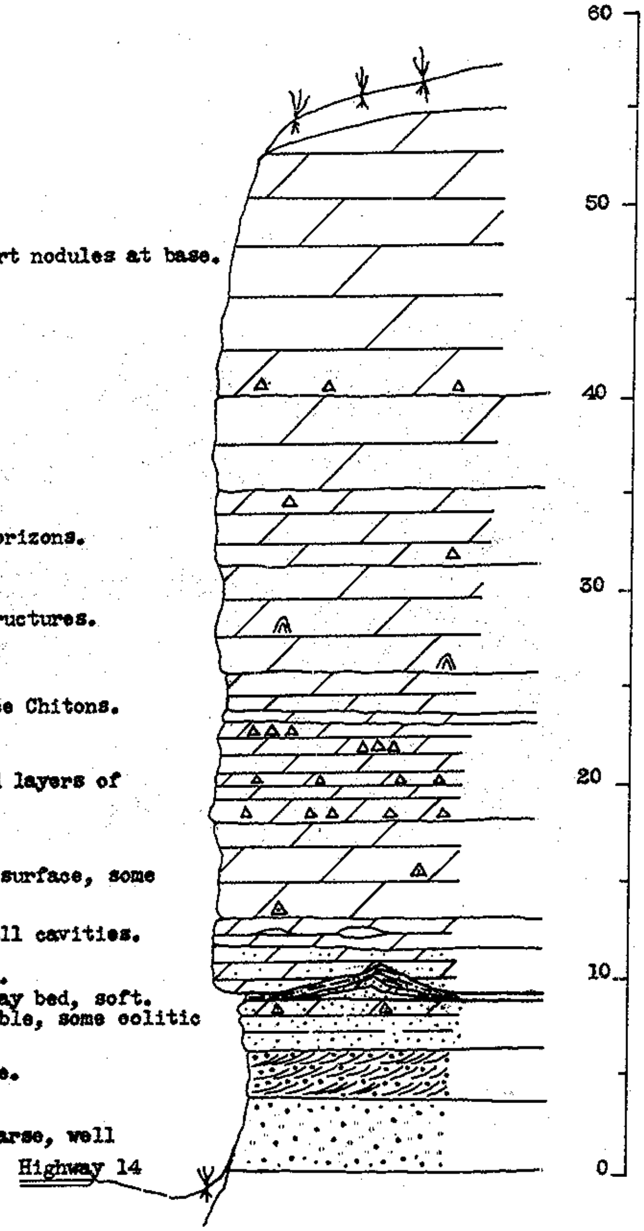


Figure 33. Contact of Jordan Sandstone with Oneota Dolomite in roadcut at north side of U. S. Highway 14 about 4 miles west of Middleton.

STOP 19, so far as can be determined, represents the approximate crest of the north-south trending Wisconsin Arch during the time the Jordan and lower Oneota formations were being deposited. That this is the case is well illustrated by the work of Starke (1949; refer to Figures 30 & 31) and Melby (1967; refer to Figure 32).

Both Starke and Melby indicate that approximately 40 feet of lower Oneota Formation is missing at this exposure. Starke accounts for the missing strata with the hypothesis of progressive overlap of a pre-Oneota erosion surface by carbonates from west to east onto the Wisconsin Arch.

STOP 19
3.5 MILES WEST OF MIDDLETON ON U.S. HIGHWAY 14
NE$\frac{1}{4}$,SW$\frac{1}{4}$,SE$\frac{1}{4}$,Sec.7,T7N.,R.8E.



ONEOTA FM.

Buff, massive, with a few large chert nodules at base.

Buff, massive.

Pitted, some chert at one or two horizons.

Massive, may contain some algal structures.

Pitted and mottled weathered surface Chitons.

Gray, with stringers or interbedded layers of orange chert.

Buff to gray, weathers to a pebbly surface, some chert.

Wavy bioherm structures forming small cavities.

Buff to gray, sandy, may be bioherm.

Thin green clay bed, soft.

JORDAN FM.
Van Oser Mbr.

White to buff, clean, friable, some oolitic chert at top.

White, cross-bedded, coarse.

White, clean, medium to coarse, well rounded grains.

Described by George Starke, 1949
Modified by L. M. Cline, 1959, 1960

By this process the lower portion of the carbonate would not be present over topographically higher areas. Melby, on the other hand, accepts the theory of overlap but follows the reasoning of Ostrom (1964a) that there is no unconformity between the Jordan and Oneota formations but rather that the overlap is the product of transgression in which time lines cross lithic lines such that portions of the lower Oneota Dolomite formation are equivalent, in time, to portions of the Jordan Sandstone developed in the nearshore area. Preliminary data on contacts obtained from Melby's samples and identified by D. L. Clark and J. Miller (Department of Geology and Geophysics, University of Wisconsin, Madison) tend to support the latter hypothesis.

322.0	1.6	Flat plain of former Glacial Lake Middleton can be seen on left. Lake formed between glacial ice on the east and topographically high broken ridge of Prairie du Chien Dolomite on the west. Drainage was to the west via the Black Earth creek valley.
324.0	2.0	Turn left on US highways 12-14 east before underpass and at west city limits of Middleton. Follow US Highway 12 to Interstate Highway 90 north and then Interstate Highway 94 east to Milwaukee.

APPENDIX

<u>Mileage 0.7, STOP 1 (M.E. Ostrom)</u>. Stream cut in east bank of Duncan Creek just north of first bridge south of Glen Lock dam in Irvine Park near the north city limits of Chippewa Falls and in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 31, T.29N., R.8W., Chippewa County (Chippewa Falls 15' topographic quadrangle, 1936).

Exposure can be reached by following foot path from northeast side of bridge northward for about 100 yards.

Cambrian System
Elk Mound Group
Mt. Simon Formation

14.	50.8'-59.8'	9'	Sandstone, light yellow brown, grain size ranges from very coarse to fine, massive. Conglomeratic in basal 3 inches with pebbles scattered throughout but chiefly along cross-bedding planes.
13.	47.8'-50.8'	3'	Sandstone, gray, coarse to fine, massive-bedded, cross-bedded. Bottom not seen.
12.	44.8'-47.8'	3'	Shale, green gray, with some lenses and beds of sandstone. Upper part covered.
11.	41.8'-44.8'	3'	Sandstone, light brown, grain size ranges from fine to very coarse, lower 2" conglomeratic, medium-bedded, some cross-bedding. Appears thin-bedded where weathered.
10.	41.3'-41.3'	0.5'	Sandstone, light brown streaked pale green gray, very fine to coarse, silty, thin-bedded. Bedding surfaces show evidence of reworking by animals and are marked by numerous trails.
9.	32.3'-41.3'	9'	Sandstone, yellow gray, conglomeratic, grain size of sand ranges from very coarse to medium with little fine; massive-bedded and cross-bedded, some cross beds conglomeratic.
8.	22.8'-32.3'	9.5'	Conglomerate, yellow gray, mostly subrounded to rounded quartz pebbles in a quartz sand matrix; massive-bedded and cross-bedded. Finer grained toward top.
7.	16.8'-22.8'	6'	Sandstone, very light yellow gray, coarse to fine-grained with little very coarse, locally conglomeratic, massive-bedded to thick-bedded, cross-bedded. Lower 8" locally shaly with rolling or mildly contorted bedding.
6.	13.8'-16.8'	3'	Conglomerate, yellow gray, mostly subrounded to rounded quartz pebbles in a matrix of chiefly quartz sand; massive-bedded and cross-bedded. Beds are not laterally continuous and some contain only scattered pebbles.
5.	7.3'-13.8'	6.5'	Sandstone, yellow gray, medium and fine-grained, some coarse near top, moderately well-sorted, subangular, with rare conglomeratic beds one pebble in thickness; massive-bedded with some cross-bedding. Weathers to thin beds of $\frac{1}{4}$" to $\frac{1}{2}$" thickness.
4.	6.0'-7.3'	1.3'	Conglomeratic, yellow gray, mostly subrounded to subangular quartz pebbles in a matrix of sand and silt with a trace of clay; some cross-bedding. Basal contact is sharp and even.

Precambrian

3.	3.0'-6.0'	3'	Gneiss, highly weathered, blue green to light yellow brown, with much blue green clay.
2.	1.0'-3.0'	2'	Gneiss, highly weathered, pink. Uneven upper surface with 6" to 1' relief.
1.	0.0'-1.0'	1'	Gneissic granite, highly weathered, green gray with some pink, appears gneissic. BASE OF EXPOSURE at stream level.

<u>Mileage 17.1, STOP 2 (M.E. Ostrom and V. Asthana, modified from Ostrom, (1966)</u>. Type section of the Mt. Simon Sandstone Formation. Exposure in bluff of Chippewa River and in hill called Mt. Simon in the City of Eau Claire in the SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 8, T.27N., R.9W., Eau Claire County (Elk Mound 15' topographic quadrangle, 1934). Section includes all rock exposed from top of Mt. Simon northward to base of river bluff.

Cambrian System
Elk Mound Group
Mt. Simon Formation

41.	215.5'-224.5'	9.0'	Sandstone, light yellow gray, predominantly coarse-grained, massive-bedded and cross-bedded. Contains abundant brachiopods (<u>Obolus namouna</u>). Trace of glauconite. Some beds are burrowed. These are the only rocks at this

			exposure assigned by Twenhofel, Raasch, and Thwaites, (1935, p. 453), to the Eau Claire Formation.
40.	211.5'-215.5'	4.0'	Sandstone, very light yellow gray, predominantly medium and fine-grained with some coarse grains. Becomes coarser-grained toward top.
39.	210.8'-211.5'	0.7'	Sandstone, very light yellowish gray, fine and very fine-grained, in single bed with green shale layer at top.
38.	210.5'-210.8'	0.3'	Sandstone, yellow gray to white, fine and medium-grained, massive-bedded and cross-bedded, with 2" green shale layer at top.
37.	208.5'-210.5'	2.0'	Sandstone, light yellow brown to light yellow gray, fine and very fine-grained, thick and massive-bedded. Bed of sandstone with thin green shale layer in upper 6".
36.	207.1'-208.5'	1.4'	Sandstone, light yellow brown, very fine-grained, thin-bedded, with green gray shale layer up to 2" thick at base. Contains brachipod fragments.
35.	206.1'-207.1'	1.0'	Sandstone, light yellow gray, predominantly coarse-grained with little very coarse and medium.
34.	205.6'-206.1'	0.3'-0.7'	Sandstone, light yellow gray, very fine-grained, silty, with green shale partings.
33.	199.6'-205.6'	6.0'	Sandstone, pink orange, predominantly coarse-grained with little very coarse, massive-bedded, cross-bedded.
32.	197.6'-199.6'	2.0'	Sandstone, light yellow gray, grains range from coarse down to very fine sand; silty and burrowed.
31.	196.9'-197.6'	0.7'	Sandstone, predominantly coarse-grained with little very coarse, massive-bedded. Upper limit marked by concentration of iron oxide. Upper surface ripple marked and when viewed from above has a mottled gray coloration.
30.	190.9'-196.9'	6.0'	Sandstone, light yellow gray, grain size ranges from coarse down to very fine sand, silty, burrowed, in beds 6" to 8" thick separated by thin green shale layers.
29.	189.9'-190.9'	1.0'	Sandstone, light yellow gray, fine-grained, silty, very argillaceous with green gray shale turning to reddish brown toward top.
28.	185.9'-189.9'	4.0'	Sandstone, light yellow gray, grain size ranges from coarse to very fine sand, slightly silty, massive-bedded with low angle cross-bedding.
27.	177.9'-185.9'	8.0'	Sandstone, light yellow gray, predominantly coarse-grained with little medium and fine, appears massive-bedded but weathers thin-bedded and even-bedded with laterally persistent thin layers of green gray shale along bedding planes, cross-bedded. Some trail markings. Weathers in stair-step pattern.
26.	167.3'-177.9'	10.6'	Sandstone, light yellow brown, coarse-grained, massive-bedded, weathers to irregular beds.
	105.3'-167.3'	62.0'	COVERED INTERVAL. Base of covered interval at parking lot level north of Mt. Simon marks approximate base of Eau Claire Formation according to Templeton (1951).
25.	95.3'-105.3'	10.0'	Sandstone, light yellow brown, predominantly coarse-grained with granules; coarsest grains concentrated along bedding planes and cross beds. Weathers to regular beds 2" to 1' in thickness.
24.	92.3'-95.3'	3.0'	Sandstone, forms marked reentrant; light yellow brown, sand grain size ranges from fine to very coarse with scattered granules, cross-bedded. Persistent green shale in upper 16 inches.
23.	92.0'-92.3'	0.3'	Sandstone, light yellow brown, fine-grained with thin horizontal shale partings.
22.	91.3'-92.0'	0.7'	Sandstone, light yellow brown, predominantly coarse-grained with scattered granules, massive-bedded and cross-bedded at top of prominent ledge.
21.	89.8'-91.3'	1.5'	Sandstone, light yellow brown, medium and coarse-grained with some very coarse grains and granules in base, massive-bedded and cross-bedded.
20.	88.2'-89.8'	1.6'	Sandstone, yellow green, predominantly medium-grained with abundant coarse grains and granules in lower 2" and scattered throughout upper part, massive-bedded and cross-bedded.
19.	87.5'-88.2'	0.7'	Sandstone, light yellow brown, fine and medium-grained with small pits on weathered surface.
18.	87.0'-87.5'	0.5'	Sandstone, light yellow gray, sand grain size ranges from very coarse down to very fine, granules concentrated along cross beds and may be locally abundant in beds up to 5" thick, becomes finer-grained toward top, massive-bedded and cross-bedded. Cross-bedding is very low angle.
17.	85.5'-87.0'	1.0'-4.0'	Sandstone, same as no. 18, noticeably cross-bedded, occurs as single bed ranging from 1'0" to 4.0" in thickness; cross beds sharply truncated at top.
16.	84.0'-85.5'	0.5'-3.5'	Sandstone, same as no. 18. Thins beneath unit #17.
15.	83.0'-84.0'	0.5'-1.0'	Sandstone, light yellow brown, fine-grained with little medium, scattered granules, massive-bedded.

14.	80.0'-83.0'	3.0'	Sandstone, light yellow brown, grain size ranges from very fine to very coarse with some granules which are concentrated along cross beds, massive-bedded; uneven top.
	77.0'-80.0'	3.0'	COVERED INTERVAL
13.	74.0'-77.0'	3.0'	Sandstone, light yellow gray, grain size ranges from coarse to fine, horizontally streaked yellow brown, massive-bedded and cross-bedded.
	71.0'-74.0'	3.0'	COVERED INTERVAL
12.	76.0'-71.0'	4.0'	Sandstone, light yellow gray, grain size ranges from coarse to fine with little very coarse and few granules concentrated along cross beds.
	59.0'-67.0'	8.0'	COVERED INTERVAL
11.	57.0'-59.0'	2.0'	Sandstone, light yellow brown, grain size ranges from coarse to fine with little very coarse, massive-bedded and cross-bedded; forms a prominent ledge.
10.	55.0'-57.0'	2.0'	Sandstone, light yellow gray with thin horizontal green gray shale layers, medium to very fine-grained; forms prominent reentrant.
9.	51.0'-55.0'	4.0'	Sandstone, very light yellow brown, fine to very coarse-grained with scattered granules, massive-bedded and cross-bedded; occurs as a prominent ledge between two equally prominent reentrants.
8.	50.5'-51.0'	0.5'	Sandstone, yellow gray, medium to very fine-grained, massive; occurs beneath prominent overhang.
	48.5'-50.5'	2.0'	COVERED INTERVAL
7.	45.0'-48.5'	3.5'	Sandstone, yellow gray, coarse to fine-grained with little very coarse and some granules in lower 6". Cross-bedded in beds 2" to 6" thick, massive-bedded.
6.	43.5'-45.0'	1.5'	Sandstone, yellow brown, streaked with pale green gray clay, cross-bedded. Forms reentrant on weathered surface.
5.	37.5'-43.5'	6.0'	Sandstone, light yellow brown, medium to very coarse-grained with little fine, massive-bedded with horizontal color banding and distinct cross-bedding.
4.	31.0'-37.5'	6.5'	Sandstone, light yellow brown, grain size ranges from medium to coarse with little fine, massive-bedded with horizontal color banding and some low angle cross-bedding. BASE OF EXPOSURE near water level at location of concrete water intake structure.

Following section is reported from a well in the area (Twenhofel, Raasch, and Thwaites, 1935, p. 453).

3.	3.0'-31.0'	28.0'	Sandstone, light gray and light yellow gray, coarse to fine-grained.
2.	0.0'-3.0'	3.0'	Sandstone with granules to $\frac{1}{4}$" diameter.

Precambrian

1.			Gneiss

<u>Mileage 25.0, STOP 3 (M.E. Ostrom)</u>. Exposures of Mt. Simon and Eau Claire formations in roadcuts on east-west asphalt road 0.8 miles due west of junction of State Highway 53 with County Highway "II" located south of Eau Claire on the N line of the NW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 2, T.26N., R.9W., Eau Claire County (Chippewa Falls 15' topographic quadrangle, 1936).

9.	78.9'-79.9'	1'	Soil Cover

Cambrian System
Elk Mound Group
Eau Claire Formation

8.	72.9'-78.9'	6'	Inaccessible. Appears thin-bedded and shaly. Probably same as underlying.
7.	71.9'-72.9'	1'	Sandstone, light yellowish gray, fine and very fine-grained, abundant linguloid brachiopod and trilobite fragments parallel to bedding. Abundant shale partings up to $\frac{1}{4}$" and 15% of total rock. Little very fine glauconite.
6.	67.3'-71.9'	4.6'	Sandstone, light greenish gray, fine and very fine-grained, dolomitic, thin to medium-bedding (6" maximum) which weathers uneven. Little very fine glauconite. Greenish gray shale occurs as thin parting layers and discontinuous thin partings. Surface texture and mottling suggest bioturbartion. Fossil fragments locally abundant and include linguloid brachiopods, hyolithes and less commonly trilobites (Cedaria sp.).

5.	37.9'-67.3'	29.4'	Shale, very sandy, and sandstone, very shaly. Bluish green to gray with thin to medium discontinuous beds of sandstone that are light yellowish gray, very fine and fine-grained and slightly glauconitic. Mica is abundant on parting surfaces. Some sand beds contain abundant fossil bachiopods and trilobites. Shale of this unit appears to grade laterally to west into litholgy similar to overlying sandstone. Iron oxide enrichment in lower 8"; fossils abundant in lower 6".
4.	37.4'-37.9'	0.2'-0.7'	Sandstone, reddish brown, fine to coarse-grained, iron oxide cement, abundant fossil brachiopods.
3.	34.4'-37.4'	3.0'	Sandstone, light yellowish brown, fine-grained, in thin to medium beds separated by thin greenish gray shale layers. Very fossiliferous. Thin underlying iron oxide layer at base associated with gray clay.

Mt. Simon Formation

2.	30.4'-34.4'	4.0'	Sandstone, yellowish brown, medium and coarse-grained, cross-bedded and medium to massive-bedded with several 1" to 6" clayey sandstone layers in upper 3 feet at west end of outcrop but no clay at east end of outcrop. At east end sandstone is massive and cross-bedded and contains fossil brachiopods in upper few feet.
1.	0'-30.4'	30.4'	Sandstone, light yellowish gray to brown, very coarse to fine-grained, massive and thick-bedded and cross-bedded; many beds show evidence of bioturtation. Pale green shale along some bedding planes. BASE OF EXPOSURE at east end.

Mileage 50.4, STOP 4 (M. E. Ostrom). Bruce Valley quarry (abandoned) located at east side of CTH "D" 1.2 miles north of Bruce Valley School in the NE$\frac{1}{4}$, NW$\frac{1}{4}$, NW$\frac{1}{4}$, of Sec. 9, T.23N., R.8W., Trempealeau County (Whitehall 15' topographic quadrangle, 1929).

61.1'-63.1'	2.0'	Soil cover.

Cambrian System
Elk Mound Group
Wonewoc Formation
Galesville Member

13.	41.1'-61.1'	20.0'	Sandstone, yellowish brown, predominantly medium-grained with some fine and coarse, well-sorted, thick-bedded and cross-bedded. Cross beds inclined northward, some iron oxide enrichment especially in lower 6 inches to 4 feet. Contact with underlying is unconformable and shows up to 2.5 feet of relief near north end of exposure.

Eau Claire Formation

12.	39.7'-41.1'	1.4'	Sandstone, yellowish brown, fine and very fine-grained, glauconitic, much brown iron oxide stain and cement. Medium to thin-bedded and horizontal and even-bedded.
11.	38.9'-39.7'	0.8'	Sandstone (reworked bed), color and texture same as bed #12, pitted weathered surface. Some small scale cut and fill in base.
10.	37.1'-38.9'	1.8'	Sandstone, yellowish brown, very fine and fine-grained, glauconitic, thick-bedded and cross-bedded. Base of Galesville extends to 0.3' below top this unit.
9.	33.4'-37.1'	3.7'	Sandstone, same as bed #10, horizontally-bedded and occurs as massive ledge. Few brachiopods parallel to bedding.
8.	26.8'-33.4'	6.6'	Sandstone, same as bed #10, medium and thin-bedded, abundant orange brachiopod shells parallel to bedding. Thicker-bedded in lower part.
7.	20.8'-26.8'	6.0'	Sandstone, brownish grey, very fine and fine-grained, glauconitic, abundant white phosphatic brachiopod shells parallel to bedding. Bedding thin and gently undulating with pale greenish gray clay on parting surfaces. Abundant trial and current workings on bedding planes. Some trilobite fragments on bedding planes. Base at top of lower quarry level. Grades down to.
6.	18.9'-20.8'	1.9'	Sandstone, grayish green, very fine and fine-grained, very glauconitic, thin-bedded and flat-bedded. Abundant white brachiopod shells parallel to bedding. Grade down to.
5.	15.5'-18.9'	3.4'	Sandstone, yellowish brown, fine and very fine-grained, very glauconitic, thin-

			bedded, bedding uneven and discontinuous. Pale greenish gray shale on abundant parting surfaces. Grades down to.
4.	13.8'-15.5'	1.7'	Sandstone, grayish green, very fine and fine-grained, very glauconitic with white brachiopod shells parallel to bedding. Several thin pale greenish gray shale stringers parallel to bedding especially in upper 0.5: Base slightly uneven.
3.	8.6'-13.8'	5.2'	Sandstone, same as bed #4 but has less glauconite with several pale greenish gray clay partings 1" to 2" thick and abundant which Oboloid brachiopod shells parallel to bedding. Some cross-bedding.
2.	8.0'-8.6'	1.0'-0.4'	Sandstone, same as bed #4, very glauconitic, dark greenish gray, very fossiliferous, cross-bedded. Pale greenish gray shale parting 1" to 2" thick in base. Becomes less glauconitic where thin.
1.	5.0'-8.0'	3.0'	Sandstone, greenish gray, very fine and fine-grained, very glauconitic, thick to massive-bedded.
	0.0'-5.0'	5.0'	Covered interval to road level. BASE OF EXPOSURE

Mileage 59.9, STOP 5 (M. E. Ostrom). Exposure of geologic section beginning with Eau Claire Formation at base and extending upward into the Lone Rock Formation at top in roadcuts located north of Whitehall on County Trunk Highway "D" and 1.7 miles north of its juncture with State Highway 53 in the SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 12, T.22N., R.8W., Trempealeau County (Whitehall 15' topographic quadrangle, 1929).

Cambrian System
Lone Rock Formation
Reno Member

14.	142.9'-172.9'	30.0'±	Sandstone, light yellowish brown, fine-grained, dolomitic, glauconitic, thick to thin-bedded. Glauconitic beds cross-bedded. Several beds very glauconitic at 3', 10' and 20' below top. These beds appear to be a mixture of sandstone intraclasts in a glauconitic sand matrix and of bioturbate.

Tomah Member

13.	133.1'-142.9'	9.8'	Same as overlying but with abundant shale. Beds are thin and rarely medium. Mica abundant on bedding planes. Top about 10' above quarry floor. LEVEL OF FARM ROAD
12.	128.5'-133.1'	4.6'	Sandstone, very shaly, fine-grained, Glauconitic, thin-bedded, abundant shale in parting layers. Some brachiopod fossils.

Birkmose Member

11.	119.9'-128.5'	8.6'	Sandstone, greenish gray, fine-grained, dolomitic and very glauconitic. Consists of beds of sandstone intraclasts in glauconitic sandstone matrix and of bioturbate both interbedded with beds of cross-bedded and even-bedded glauconitic sandstone.

Wonewoc Formation
Ironton Member

10.	118.9'-119.9'	1.0'	Sandstone, light yellowish gray, medium and coarse-grained, thick-bedded and cross-bedded, slightly glauconitic.
9.	117.6'-118.9'	1.3'	Same as overlying but with no glauconite.
8.	116.4'-117.6'	1.2'	Same as bed #10. Upper 6" may be bioturbaceous.
7.	115.1'-116.4'	1.3'	Sandstone, light yellowish gray, poorly-sorted, very fine to coarse-grained. Burrowed or bioturbate bed.
6.	114.0'-115.1'	1.1'	Sandstone, light yellowish gray, mottled reddish brown, medium and coarse-grained.
5.	113.0'-114.0'	1.0'	Same as bed #7. BASE OF UPPER EXPOSURE
	98.0'-113.0'	15.0'	COVERED INTERVAL
4.	83.0'-98.0'	15.0'	Sandstone, poorly-sorted, very fine to very coarse-grained, bioturbaceous. Solid ledge 7' from top with concave outcrop surface beneath. Base of concavity is solid iron oxide cemented sandstone ledge about 6" thick.

3. 79.0'-83.0' 4.0' Sandstone, light yellowish gray, medium and coarse-grained, well-sorted, with bioturbaceous poorly-sorted layers about 1 foot thick at top and bottom.

Galesville Member

2. 15'-79.0' 64.0' Sandstone, light yellowish gray, medium and fine-grained, well-sorted, massive-bedded and cross-bedded. Basal 8" iron oxide cemented and hard. Discontinuous conglomerate up to 3" thick in base.

Eau Claire Formation

1. 0'-15' 15.0'± Sandstone, light yellowish gray, fine and very fine-grained, little glauconite, thin and medium-bedded, cross-bedded.
BASE OF EXPOSURE

Mileage 70.0 (M. E. Ostrom). Quarry at east (left) side of County Highway "N" about 2.2 miles northeast of Oakdale School in the SW$\frac{1}{4}$, NE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 21, T.21N., R. 8W., Trempealeau County (Whitehall 15' topographic quadrangle, 1929).

1.0'± Overburden.

Jordan Formation
Norwalk Member

11. 42.1'-46.1' 4.0' Sandstone, light yellowish gray and light yellowish brown, very fine and fine-grained, thick-bedded to thin-bedded where weathered, horizontally and even-bedded. Lower 6" cemented with iron oxide, hard and dark brown.

St. Lawrence Formation
Lodi Member

10. 34.1'-42.1' 8.0' Siltstone, light yellowish brown with MnO dendrites, little pale green gray clay on some bedding planes. Some beds and lenses due to light gray color appear to be bleached. Beds thin to medium, even and horizontal.

9. 33.1'-34.1' 1.0' Siltstone, light gray, very dolomitic with oboloid brachiopod fragments. Has uneven wavy surface and irregular bedding planes with black coated surfaces.

8. 29.1'-33.1' 4.0' Sandstone, very light yellowish brown mottled and streaked pale green, very dolomitic. Locally consists of sandy dolomite. Appears to be bioturbaceous.

7. 26.1'-29.1' 3.0' Siltstone, yellowish brown, dolomitic, thick ledge with few thin pale grayish green shaly partings.

6. 25.5'-26.1' 0.0-1.2' Discontinuous bioturbaceous bed of intraclasts.

5. 19.5'-25.5' 6.0' Siltstone, light yellowish brown, dolomitic, some dendrites. Bedding thin and discontinuous. Lower foot consists of gray, dolomitic, siltstone.

4. 16.5'-19.5' 3.0' Siltstone, very dolomitic, light gray, thin-bedded but appears as massive ledge with alternating layers of gray and brown color. Unit undulates gently along outcrop. Lower 1 foot looks reworked; locally has clasts and abundant glauconite.

Lone Rock Formation
Reno Member

3. 13.5'-16.5' 3.0' Dolomite, very silty, reddish brown, thick-bedded, horizontal to slightly cross-bedded, mostly reworked. Abundant intraclasts.

2. 1.5'-13.5' 12.0' Sandstone, brown, very fine-grained, glauconitic, thin-bedded, uneven-bedded, with pale greenish gray shale in partings. Two beds of greensand 1.5' thick at 1.3' and 5' below top.

1. 0.0'-1.5' 1.5' Sandstone intraclasts in glauconitic sandstone matrix tightly cemented with dolomite.
BASE OF EXPOSURE

Mileage 79.3, STOP 6 (M. E. Ostrom, modified from Twenhofel et. al., 1935, Nelson, 1956, and Melby, 1967). Composite section from outcrops and quarries located along State Highway 93 and extending from about 1.5 miles to about 3.2 miles south of Arcadia. Section begins with quarry exposure of Lone Rock and St. Lawrence and ends at top of hill with quarries in the Oneota Formation in SE¼, SW¼, NW¼, Sec. 9, T.20N., R.9W., Trempealeau County (Galesville 15' topographic quadrangle, 1929). Upper part of Oneota Formation not described.

Ordovician System
Prairie du Chien Group
Oneota Formation
Stockton Hill Member

35.	163.0'-164.0'	1.0'	Dolomite, greenish brown, medium-crystalline, abundant glauconite.
34.	162.0'-163.0'	1.0'	Dolomite, medium- to coarse-crystalline, gray to brown, abundant oolites and secondary sparry calcite. Luster mottling.
33.	157.0'-162.0'	5.0'	Dolomite, sandy to dolomitic sandstone, medium-grained. Scattered intraclasts and oolites. Appears brecciated in places.
32.	155.0'-157.0'	2.0'	Sandstone, yellow, medium-grained, friable, scattered oolites and green shale seams near the top.
31.	152.5'-155.0'	2.5'	Sandstone, dolomitic, yellow, medium-grained.
30.	150.7'-152.5'	1.8'	Sandstone, very dolomitic, fine- to medium-grained, mottled tan. Scattered green shale near the top. Vuggy.
29.	148.7'-150.7'	2.0'	Sandstone, dolomitic, coarse- and fine-grained, yellow and tan. Scattered white bands, green shale partings and oolites.
28.	145.2'-148.7'	3.5'	Sandstone, dolomitic, coarse- and fine-grained, tan. Scattered intraclasts and green shale seams. Abundant oolites.
27.	144.9'-145.2'	0.2-0.3'	Shale, brown, gumbo, scattered sand partings. Pinch and swell.
26.	143.9'-144.9'	1.0'	Sandstone, fine-grained, yellow, scattered brown shale partings.
25.	143.4'-143.9'	0.5'	Sandstone, fine- and medium-grained, buff and tan. Irregular brown iron cement.
24.	140.9'-143.4'	2.5'	Sandstone, fine- and coarse-grained, yellow and brown, friable.
23.	139.9'-140.9'	1.0'	Sandstone, dolomitic, coarse- and fine-grained, yellow.
22.	139.4'-139.9'	0.5'	Sandstone, friable, yellow, medium-grained.
21.	137.4'-139.4'	2.0'	Sandstone, dolomitic at base, fine-grained. Carbonate and silica concretions at top.
20.	133.4'-137.4'	4.0'	Sandstone, medium-grained, light yellow to white. Upper and lower foot is conglomeratic. Scattered carbonate concretions.
19.	131.4'-133.4'	2.0'	Sandstone, medium- and fine-grained, white to buff. Abundant green shale at top and pea size carbonate concretions at base.
18.	130.6'-131.4'	0.8'	Sandstone, dolomitic, medium-grained, yellow.
17.	127.1'-130.6'	3.5'	Sandstone, friable to hard, white and buff, medium- and fine-grained. Green shale and intraclasts at base. Scattered dolomitic sandstone.
16.	119.1'-127.1'	8.0'	Sandstone, medium- and fine-grained, yellow, abundant carbonate lenses and bands, interbedded with 1" to 6" friable shale rich sandstone bands. Scattered cross-bedding and silica concretions. Concretions are pinch and swell to nodular.
15.	117.1'-119.1'	2.0'	Sandstone, medium-grained, yellow, scattered green shale and abundant carbonate concretions.
14.	114.6'-117.1'	2.5'	Sandstone, friable, alternating white and brown, medium-grained. Scattered green shale partings and intraclasts.

Jordan Formation
Van Oser Member

13.	89.6'-114.6'	25'	Sandstone, light yellowish gray, medium to coarse-grained, with little fine, well-sorted, massive-bedded and cross-bedded. Basal surface slightly uneven. Scattered pea sized concretions at top grading downward to large nodular masses about 10' below top.

Norwalk Member

12.	68.6'-89.6'	21'	Sandstone, light yellowish gray, fine and very fine-grained, massive-bedded and cross-bedded. Basal contact uneven and sharp. Exposed in first roadcut at west side of highway and south of quarry.

St. Lawrence Formation

11.	66.6'-68.6'	2'	Dolomite, very silty, light yellow brown mottled gray, some sand grains.
10.	43.6'-66.6'	23'	COVERED INTERVAL (Top of exposure, north end of quarry, 1.5 miles south of Arcadia)
9.	25.6'-43.6'	18'	Siltstone, yellowish gray, little very fine sand, dolomitic. Thin-bedded with massive 3 foot bed 4 feet below top.
8.	18.6'-25.6'	7'	Dolomite, very silty and sandy, yellowish gray and unevenly mottled pale green with clay, trace of glauconite. Medium to thin-bedded and even-bedded. Appears to be bioturbaceous.
7.	16.6'-18.6'	2'	Sandstone, very dolomitic, fine and very fine-grained, glauconitic, weathers reddish brown. Contains abundant trail markings and intraclasts of fine-grained sandstone. Undulating bedding.
6.	11.6'-16.6'	5'	Sandstone, yellowish brown, fine and very fine-grained, glauconitic, medium to thin-bedded. Few dark horizontal glauconitic sandstone beds.
5.	10.6'-11.6'	1'	Sandstone, fine and very fine-grained, glauconitic, with abundant clasts of nonglauconitic sandstone.
4.	5.6'-10.6'	5'	Sandstone, yellowish brown, very fine-grained, glauconitic, thin-bedded and interbedded with pale green shale partings. All beds uneven and undulating.

Lone Rock Formation
Reno Member

3.	2.1'-5.6'	3.5'	Sandstone, yellowish brown, very fine-grained, glauconitic with clasts of sandstone. Massive-bedded.
2.	1.3'-2.1'	0.8'	Sandstone, yellowish gray, fine-grained, glauconitic with vertical burrows. Grades down to
1.	0.0'-1.3'	1.3'	Sandstone, yellowish gray, fine-grained, glauconitic, horizontally-bedded and cross-bedded. BASE OF QUARRIED EXPOSURE

Mileage 97.0, STOP 7 (M. E. Ostrom and G. Emrich, 1960). Type section of the Galesville Sandstone exposed in bluff in High Cliff Park above dam over Beaver Creek in city of Galesville in the NE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 33, T.19N., R.8W., Trempealeau County (Galesville 15' topographic quadrangle, 1929).

Cambrian System
Tunnel City Group
Lone Rock Formation
Birkmose Member

28.	125.5'-127.0'	1.5'	Sandstone, light green gray, fine-grained, glauconitic; thin-bedded and cross-bedded; some brachiopod fragments.

Elk Mound Group
Wonewoc Formation
Ironton Member

27.	123.5'-125.5'	2.0'	Sandstone, light yellow gray, fine to very fine-grained with trace of medium and coarse; some brachiopod fragments.
26.	120.5'-123.5'	3.0'	Sandstone, light yellow gray, medium and coarse-grained with little fine; some brachiopod fragments.
25.	119.0'-120.5'	1.5'	Sandstone, brown, medium and fine-grained with trace of coarse, massive-bedded.
24.	118.5'-119.0'	0.5'	Sandstone light yellow brown, fine and very fine-grained with trace of medium, silty, thin-bedded and flaggy, cross-bedded.
23.	117.0'-118.5'	1.5'	Sandstone, brown, fine and medium-grained with trace of coarse, massive-bedded and cross-bedded.
22.	116.0'-117.0'	1.0'	Sandstone, light yellow brown, medium-grained with trace of coarse and fine.
21.	114.0'-116.0'	2.0'	Sandstone, light yellow gray, medium-grained with little coarse and fine, slightly silty to silty, beds 3" to 4" thick. Bioturbaceous.
20.	89.0'-114.0'	25.0'	Sandstone, yellow brown to red brown, coarse to medium-grained with trace of fine, massive-bedded with some thin beds (2"), cross-bedded, uneven weathered surface. Upper few feet and a 2 foot zone approximately 10' below top of this bed are bioturbaceous.

Galesville Member

19.	83.5'-89.0'	5.5'	Sandstone, light yellow gray, fine to medium-grained with little coarse, silty, massive with few thin beds.
18.	82.5'-83.5'	1.0'	Sandstone, light yellow gray, fine to very fine-grained with trace of medium, silty thin-bedded with little cross-bedding.
17.	82.0'-82.5'	0.5'	Sandstone, light yellow gray, coarse to medium-grained with little fine. Some grains appear to have been derived from Baraboo quartzite. Massive-bedded and cross-bedded.
16.	79.5'-82.0'	2.5'	Sandstone, light yellow gray, fine to medium-grained with a little coarse, medium to massive-bedded and cross-bedded.
15.	78.5'-79.5'	1.0'	Sandstone, light yellow gray, medium-grained with little fine and trace coarse, massive-bedded and cross-bedded.
14.	66.5'-78.5'	12.0'	Sandstone, very light yellow gray, fine to very fine-grained with trace of medium, massive-bedded and cross-bedded.
13.	64.5'-66.5'	2.0'	Sandstone, very light yellow gray, medium to fine-grained, massive-bedded.
12.	63.5'-64.5'	1.0'	Sandstone, very light yellow gray, medium-grained with little fine and coarse, massive-bedded and cross-bedded, grades down to
11.	61.5'-63.5'	2.0'	Sandstone, very light yellow gray, fine-grained with little fine and coarse, massive-bedded and cross-bedded, grades down to
10.	60.5'-61.5'	1.0'	Sandstone, very light yellow gray, medium-grained with little fine and coarse, massive-bedded with a few thin beds and cross-bedded.
9.	57.5'-60.5'	3.0'	Sandstone, very light yellow gray, fine-grained with little very fine and silt, massive-bedded and cross-bedded.
8.	55.0'-57.5'	1.5-3.0'	Sandstone, very light yellow gray, fine-grained with little very fine and silt, massive-bedded and cross-bedded.
7.	47.0'-55.0'	7.5-9.0'	Sandstone, very light yellow gray, medium and fine-grained with little very coarse and fine, massive-bedded and cross-bedded.
	44.0'-47.0'	3.0'	COVERED INTERVAL
6.	40.0'-44.0'	4.0'	Sandstone, light yellow gray, fine-grained, massive. Base uneven. Well developed basal conglomerate at north park entry and at east end of foot bridge across Beaver Creek. Galesville rests on different part of Eau Claire at these two sites. Also, contact has relief of up to 10'-15' along outcrop face.
4.	36.0'-40.0'	4.0'	Sandstone, very fine and fine-grained, thin-bedded, shaly, glauconitic. Occurs near entry gate to trail at base of bluff. Youngest Eau Claire at this exposure. Removed by pre-Galesville erosion from rest of outcrop.
3.	26.0'-36.0'	10.0'	Sandstone, massive, cross-bedded, fine and very fine-grained, little glauconite and locally abundant oboloid brachiopods. Weathered surface is pock-marked some of which are due to animal burrows and others to weathering-out of clay pebbles. Thins due to pre-Galesville erosion as one proceeds along the path.
2.	20.0'-26.0'	6.0'	Sandstone, very fine and fine-grained, very shaly, thin-bedded. Galesville rests unconformably on this unit at the grotto spring. Here rip-ups are prominent in the basal 1 foot of the Galesville. Further along the outcrop to the southwest at about the location of the south end of the foot bridge across Beaver Creek the erosion surface rises to where the Galesville rests on Bed #3.
1.	0.0'-20.0'	20.0'±	Remainder of section down to stream level is undescribed.
			STREAM LEVEL

Log of Village Well #2, located in the NW$\frac{1}{4}$, Sec. 33, T.19N., R.8W., Galesville (description by F. T. Thwaites). Elevation = approximately 720'. Base of outcrop 10' below top of well.

Alluvium

0'-5'	5.0'	No sample.
5'-20'	15.0'	Sand, brown yellow, grain size ranges from medium sand down to silt.

Eau Claire Formation

20'-25'	5.0'	Shale, green gray, silty.
25'-35'	10.0'	Siltstone, yellow gray.
35'-45'	10.0'	Siltstone, gray.
45'-50'	5.0'	Siltstone, yellow gray.
50'-60'	10.0'	Shale, gray, silty.
60'-80'	20.0'	Siltstone, yellow gray.
80'-95'	15.0'	Siltstone, gray.
95'-100'	5.0'	No sample.

100'-130'	30.0'	Shale, gray, silty.
130'-135'	5.0'	Siltstone, light gray.
135'-145'	10.0'	Sandstone, light gray, grain size range from medium sand down to silt.

Mt. Simon Formation

145'-150'	5.0'	Sandstone, light gray, grain size ranges from coarse sand down to silt.
150'-160'	10.0'	Sandstone, light gray, medium and coarse-grained.
160'-210'	50.0'	Sandstone, light gray, coarse and medium-grained.
210'-215'	5.0'	Sandstone, light gray, grain size ranges from coarse sand down to fine.
215'-225'	10.0'	Sandstone, light gray, coarse and medium-grained.
225'-230'	5.0'	Sandstone, light gray, grain size ranges from medium sand down to silt.
230'-235'	5.0'	Siltstone, light gray.
235'-240'	5.0'	Sandstone, light gray, grain size ranges from medium sand down to silt.
240'-245'	5.0'	Sandstone, light gray, grain size ranges from coarse sand down to silt.
245'-252'	7.0'	Sandstone, light gray, grain size ranges from fine sand down to silt. BOTTOM OF HOLE

Mileage 146.3/161.0, STOPS 8-11 (R. A. Davis, Jr.). Upper Iowa River Section.

Exposure in nearly continuous roadcuts along Iowa State Highway 13, approximately 10 miles north of Waukon, Iowa in Secs. 11-14, 23, T.99N., R.6W., (Houston County, Minnesota).

Prairie du Chien Group
Shakopee Formation
New Richmond Member

26.	244.5'-252.5'	8.0'	Quartz sandstone, red-brown, medium-grained, sorted and rounded, bedded, friable.
25.	242.9'-244.5'	1.6'	Dolomite, buff to brown, fine to medium crystals, flaggy, quartz, intraclasts.
24.	238.3'-242.9'	4.6'	Quartz sandstone, red-brown, medium-grained, sorted and rounded, less well bedded than #26.
23.	237.7'-238.3'	0.6'	Dolomite, tan, fine crystals, flaggy, quartz.
22.	221.2'-237.7'	16.5'	Quartz sandstone, red-brown, medium-grained, sorted and rounded, bedded, friable, intraclasts at top, shale seams near base, basal conglomerate with Oneota fragments.

Oneota Formation
Hager City Dolomite Member

21.	194.4'-221.2'	26.8'	Dolomite, gray with buff mottles, medium crystals, poorly-bedded, chert, calcite spar, upper beds truncated by overlying unit.
20.	177.5'-194.4'	16.9'	Dolomite, gray-buff, medium crystals, poorly-bedded, chert, calcite spar, limonite staining, vuggy.
19.	175.5'-177.5'	2.0'	Dolomite, buff, fine-medium crystals, bedded.
18.	165.0'-175.5'	10.5'	Dolomite, tan, fine to medium crystals, poorly-bedded, rough weathered surface, much chert, algal stroms., oolites, calcite spar.
17.	142.0'-165.0'	23.0'	Dolomite, buff to tan, medium crystals, massive to poorly-bedded, few vugs.
16.	122.0'-142.0'	20.0'	Dolomite, gray, medium crystals, massive, many vugs, chert abundant, calcite spar, rough weathering surface.
15.	111.0'-122.0'	11.0'	Dolomite, gray to tan, medium crystals, massive, vuggy, scattered tiny molds of fossil fragments (?), poorly preserved algal stromatolites.
14.	85.0'-111.0'	26.0'	Dolomite, buff to tan, fine to medium crystals, massive to thick-bedded, smoother weathering surface than above molds of fossil fragments, "buffy beds" of Raasch.
13.	83.0'-85.0'	2.0'	Dolomite, gray, medium crystals, massive, vuggy, poorly preserved algal stromatolites.
12.	45.0'-83.0'	38.0'	Dolomite, buff, fine to medium crystals, thick-bedded homogenous, burrow structures in lower part.
11.	44.0'-45.0'	1.0'	Dolomite, buff, medium crystals, well preserved algal stromatolites.
10.	43.0'-44.0'	1.0'	Dolomite, buff to gray, medium crystals, some mottling.
9.	42.0'-43.0'	1.0'	Dolomite, buff to gray, medium crystals, poorly preserved algal stromatolites, trace of glauconite.

Stockton Hill Member

8.	39.5'-42.0'	2.5'	Quartz sandstone, tan, medium-grained, moderate sorting, dolomite cement.

7. 38.6'-39.5' 0.9' Dolomite, tan to gray, medium crystals, quartz, oolite, some algal stromatolites, trace of glauconite.

6. 36.0'-38.6' 2.6' Quartz sandstone, tan, medium-grained, moderate to well-sorted, thin-bedded dolomite cement, large intraclasts.

5. 21.0'-36.0' 5.0' Dolomite, buff to tan, medium-grained, moderate to well-sorted, poorly-bedded, oolites, quartz, trace of glauconite.

4. 28.0'-31.0' 3.0' Quartz sandstone, buff, medium-grained, moderate sorting, bedded, forms ledge over underlying beds.

3. 22.0'-28.0' 6.0' Quartz sandstone, tan, medium-grained, interbedded with gray-green shale, poorly-bedded.

2. 10.0'-22.0' 12.0' Quartz sandstone, buff, medium-grained, moderate sorting, massive to poorly-bedded, dolomite cement.

Jordan Formation
Van Oser Member

1. 0'-10.0' 10.0' Quartz sandstone, buff, medium to coarse, friable, cross laminations, upper surface has few inches of relief.
ROAD LEVEL

Mileage 197.5, STOP 12 (R. A. Davis, Jr.). Waukon Junction Section. Exposure in roadcut on the northwest side of Iowa Highway 364, 2 miles south of Waukon Junction, in Secs. 9 and 14, T.96N., R.3W., Allamakee County, Iowa.

Prairie du Chien Group
Shakopee Formation
Willow River Member

30. 201.8'-203.3' 1.5' Dolomite, buff, medium-crystalline, glauconitic, quartz partially covered.

29. 198.6'-201.8' 3.2' Quartz sandstone, red-brown, medium-grained, sorted, rounded, thin-bedded.

28. 195.5'-198.6' 3.1' Dolomite, tan, medium crystalline, thin-bedded, calcite spar.

27. 192.9'-195.5' 2.6' Dolomite, tan to pinkish brown, medium-crystalline, massive.

26. 188.6'-192.9' 4.3' Dolomite, tan to gray-brown, fine to medium-crystalline, massive, thin gray-green shale seams.

25. 185.6'-188.6' 3.0' Covered.

24. 181.8'-185.6' 3.8' Dolomite, tan to pinkish brown, medium-crystalline, massive, some quartz and oolites.

23. 179.5'-181.8' 2.3' Dolomite, tan to buff, algal stromatolites, gray-green shale at top.

22. 176.9'-179.5' 2.6' Dolomite, tan, fine crystals, distinct beds, some planar stromatolites.

21. 174.2'-176.9' 2.7' Dolomite, buff to tan, fine to medium-crystalline, some algal biscuits, gray-green shale seam at top with local pockets of brown clay.

20. 171.6'-174.2' 2.3' Dolomite, tan to brown, medium-crystalline vertical weathering suggests digitate stromatolites, few fossil fragments.

19. 170.3'-171.6' 1.6' Dolomite, tan, medium-crystalline, massive.

18. 170.2'-170.3' 0.1' Chert, gray, oolites, quartz, intraclasts.

17. 168.5'-170.2' 1.7' Dolomite, buff to tan, fine to medium-crystalline few chert nodules, algal stromatolites near base.

16. 167.3'-168.5' 1.2' Dolomite, tan to gray, fine-crystalline, some bedding near base, small algal stromatolites.

15. 163.2'-167.3' 4.1' Dolomite, tan to buff, fine-crystalline, mostly large algal stromatolites, some quartz, intraclasts, scattered chert nodules.

New Richmond Member

14. 151.6'-163.2' 1.6' Shale, gray-green, interbedded dolomite and quartz sandstone, well-laminated.

13. 160.5'-161.6' 1.1' Dolomite, buff, fine-crystalline, quartz oolites, quartz sandstone stringers.

12. 158.5'-160.5' 2.0' Dolomite, buff to tan, medium-crystalline quartz, oolites, intraclasts, poorly preserved algal stromatolites, trace glauconite.

11. 158.1'-158.5' 0.4' Shale, gray-green, laminated, quartz.

10. 156.3'-158.1' 1.8' Dolomite, buff, medium-crystalline, well-bedded, is quartz sandstone near base.

9. 154.9'-156.3' 1.4' Quartz sandstone, tan, medium-grained, sorted, rounded dolomite cement, clasts, gray green shale seam.

8. 151.4'-154.9' 3.5' Quartz sandstone, buff to tan, medium-grained, dolomite cement, oolites at top between scattered algal beads, intraclasts, shale seams, some dolomite beds.

7. 147.6'-151.4' 3.8' Dolomite, buff, medium-crystalline, quartz, intraclasts, shaley at top, partly algal (?).

6.	146.4'-147.6'	1.2'	Quartz sandstone, light buff, medium-grained, sorted, rounded, friable, upper surface irregular intraclasts, some clay seams.
5.	144.7'-146.4'	1.7'	Dolomite, buff, fine to medium, massive, quartz, large intraclasts, some algal stromatolites.
4.	139.5'-144.7'	5.2'	Quartz sandstone, buff, medium-grained, sorted, rounded, bedded, friable, shaly at top and bottom, lots of large intraclasts near base.

Oneota Formation
Hager City Dolomite Member

3.	87.6'-139.5'	51.9'	Dolomite, buff to gray, medium-crystalline, poorly-bedded, some chert and shaly seams, poorly preserved algal stromatolites, upper few feet have abundant quartz which appears to be vadose in origin from the New Richmond.
2.	51.4'-87.6'	36.2'	Dolomite, buff to gray, medium-crystalline, saccrioidal, calcite spar, chert, poorly-bedded, some horizons of algal stromatolites.
1.	0'-51.4'	51.4'	Dolomite, buff, fine to medium-crystalline, generally well-bedded, "buffy" beds of Raasch (1952) basal Oneota covered.

Mileage 207.4, STOP 13 (L. M. Cline). Unconformity at base of St. Peter Sandstone. Formations exposed are Shakopee, St. Peter and Platteville. Located in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 29, T.7N., R.6W., Crawford County (Prairie du Chien 15' topographic quadrangle, 1932).

A well-developed U-shaped channel of St. Peter sandstone cuts out several feet of Shakopee dolomite and sandstone in a cutbank on the north side of the road.

Upslope from the St. Peter channel and just out of sight around the bend in the road, the Platteville Formation is nicely exposed in a cutbank on the north side of the highway. Massive, blue-gray, buff-weathering dolomites of the Pecatonic Member of the Platteville constitute the lower few feet of the cut. The overlying argillaceous, nodular calcitic limestones belong to the McGregor Member.

Mileage 217.7, STOP 14 (M. E. Ostrom). Contact relationships of St. Peter, Glenwood and Platteville formations. Located in the SE$\frac{1}{4}$, NW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 22, T.6N., R.6W., Grant County (Bagley 7.5' topographic quadrangle, 1962).

Ordovician System
Sinnipee Group
Platteville Formation
Mac Gregor Member

14.	50.9'-70.9'	20'+	Limestone, dolomitic, bluish gray, uneven thin bedding weathers to nodular appearance, abundant fossils. Basal contact transitional through 6" of brownish red limestone.

Pecatonica Member

13.	47.9'-50.9'	3.0'	Limestone ledge, dolomitic, massive, bluish gray, very fossiliferous, fossils gray.
12.	47.2'-27.9'	0.7'	Shaley limestone reentrant.
11.	44.7'-47.2'	2.5'	Limestone ledge, similar to bed #13.
10.	43.2'-44.7'	1.5'	Limestone reentrant, shaly, bluish gray.
9.	41.5'-43.2'	1.7'	Limestone, single ledge.
8.	38.5'-41.5'	3.0'	Limestone ledge, bluish gray and light yellowish brown, undulatory bedding surfaces, weathered outcrop surface is horizontally ridged and furrowed.
7.	35.5'-38.5'	3.0'	Limestone ledge, massive, similar to bed #8 but has no ridges or furrows on weathered surface.
6.	34.9'-35.5'	0.6'	Dolomite, calcareous, sandy, with phosphate pellets, bottom even to slightly uneven and smooth.

Ancell Group
Glenwood Formation

5.	34.7'-34.9'	0.2'	Calcareous shale and shaly and silty dolomite, thinly laminated.
4.	33.4'-34.7'	1.3'	Shale, pale green, thinly laminated.
3.	32.0'-33.4'	1.4'	Siltstone, calcareous. light yellowish brown. Grades down through green and/or red shale to
2.	30.0'-32.0'	2.0'	Sandstone, poorly-sorted, white to light yellowish brown, shows evidence of extensive reworking by burrowing animals. Basal contact transitional down to

St. Peter Formation

1.	0.0'-30.0'	30.0'+	Sandstone, white to light yellowish brown, well-sorted, fine and medium-grained, massive and thick-bedded, cross-bedded.

Mileage 222.4, STOP 15 (L. M. Cline after G. Starke, 1949). Stratigraphic section exposed in quarry on north side of County Highway "X" in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 31, T.6N., R.6W., Grant County, Wisconsin (Clayton 7.5' topographic quadrangle, 1962).

Ordovician System
Ancell Group
St. Peter Formation

21.			Sandstone; white, strained brown, medium-grained, well-rounded, well-sorted grains.
20.	180.3'-185.3'	5.0'	Concealed, approximately.

Prairie du Chien Group
Shakopee Formation
Willow River Member

19.	170.3'-180.3'	10.0'	Dolomite; gray massive dolomite with some stringers of sandstone; gnarled appearance; in well developed 1' beds.
18.	169.4'-170.3'	0.9'	Dolomite; gray, massive, brecciated throughout.
17.	168.4'-169.4'	1.0'	Dolomite; gray, very fine-grained, in thin beds separated by green shale partings.
16.	163.9'-168.4'	4.5'	Dolomite; gray with buff mottling, in beds six inches thick and separated by gray shale.
15.	163.0'-163.9'	0.9'	Dolomite; fine-grained, light gray with orange-stained areas.
14.	151.0'-163.0'	12.0'	Dolomite; gray, fine-grained, thinly-bedded and with green shale partings; floating grains of quartz sand.
13.	150.5'-151.0'	0.5'	Dolomite; green, glauconitic, coarse-grained.
12.	143.5'-150.5'	7.0'	Dolomite; gray to reddish, fine-grained; weathers to irregular surface.

New Richmond Sandstone

11.	139.2'-143.5'	4.3'	Sandstone; white, weathers brown, in beds 4" to 1½' thick and with interbedded fine-grained dolomite.

Oneota Formation
Hager City Dolomite Member

10.	137.1'-139.2'	2.1'	Dolomite; light buff with dark specks throughout, in beds 3 to 6 inches thick separated by green clay partings.
9.	135.1'-137.1'	2.0'	Dolomite; gray, fine-grained, weathers to irregular surface; some algal structures.
8.	105.8'-135.1'	29.3'	Dolomite; buff, relatively soft; algal structures profusely developed; in beds 3 to 4 feet thick with stringers of chert throughout; basal foot is weathered chert.
7.	85.8'-105.8'	20.0'	Dolomite; conglomeratic dark gray pebbles embedded in buff-colored matrix; well bedded with some green shale partings and some clean white quartzose beds several inches thick.
6.	84.1'-85.8'	1.7'	Sandstone; white, clean quartz grains of medium size; some green specks.
5.	30.1'-84.1'	54.0'	Dolomite; gray, non-cherty, relatively soft, very massive; encloses some areas up to 15 feet in diameter of fine-grained, gray-buff dolomite.

4.	26.7'-30.1'	3.4'	Dolomite; very fine-grained, undulating beds; includes white, gray and black chert; cavernous.
3.	25.2'-26.7'	1.5'	Dolomite; gray to buff, coarse-grained; in 4-inch beds.
2.	0'-25.2'	25.2'	Dolomite; gray to buff to orange-colored, massive; includes some white chert and near the top some clay pockets.
1.			Concealed; below quarry level.

Mileage 251.3, STOP 16 (L. M. Cline and M. E. Ostrom). Nearly continuous exposure commencing with the St. Lawrence Formation and extending upward into the Oneota Formation. Located in a roadcut and quarry on County Trunk Highway "E" in the SW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 21, T.8N., R.3W., Crawford County (Boscobel 15' topographic quadrangle, 1933).

Ordovician System
Prairie du Chien Group
Oneota Formation
Hager City Member
(Section in quarry near hilltop)

24.	130.9'-180.9'	50.0'±	Dolomite, inaccessible, thick-bedded with solution cavities along some bedding planes.
23.	113.9'-130.9'	17.0'	Dolomite, inaccessible, buff, medium and thick-bedded, even-bedded, thin bed of white chert at top.
22.	110.4'-113.9'	3.5'	Shaly dolomite, inaccessible, prominent reentrant in quarry face.
21.	102.4'-110.4'	8.0'	Dolomite, composed of thinly laminated algal beds with scattered nodules of oolitic white chert.
20.	101.4'-102.4'	1.0'	Dolomite, vertically weathered digitate algal bed.
	Stockton Hill Member		
19.	97.4'-101.4'	4.0'	Dolomite, sandy, with small algal heads in upper foot.
18.	94.2'-97.4'	3.2'	Dolomite, slightly sandy, medium and irregular-bedded.
			Base of quarry exposure; overlaps with Bed #18 of roadcut.
			Top of section in roadcut downhill south of quarry entrance.
18.	93.4'-97.4'	4.0'	Dolomite, top coincides approximately with top of bed #18 in quarry. Uneven and medium-bedded, slightly sandy, scattered pits on weathered surface believed to be glauconite pellet conities.
17.	91.4'-93.4'	2.0'	Dolomite, massive, with few sand grains. Basal 3" is speckled green with clay and has abundant sand grains.
16.	89.8'-91.4'	1.6'	Dolomite, conglomerate, very sandy with rip-ups of dolomite in lower part and abundant white weathered silica which appears to occur as encrustations on pebbles, as oolites and possibly as fossils.
15.	89.0'-89.8'	0.8'	Dolomite, sandy, oolitic.
14.	87.7'-89.0'	1.3'	Dolomite, speckled green with clay, some algae and rip-ups.
13.	86.9'-87.7'	0.8'	Dolomite, sandy, glauconitic, surface pitted where glauconite pellets have apparently weathered out.
12.	84.4'-86.9'	2.5'	Dolomite, sandy, with rip-ups, medium and even-bedded, speckled with green clay.
11.	83.4'-84.4'	1.0'	Dolomite, sandy, green speckled with clay.
10.	82.4'-83.4'	1.0'	Dolomite, sandy, with rip-ups and pebbles, glauconitic.
9.	80.9'-82.4'	1.5'	Dolomite, sandy, bed thickens varies down to 0.8'.
8.	80.7'-80.9'	0.2'	Oolitic white chert.
7.	78.5'-80.7'	2.2'	Dolomite, sandy, oolitic.
6.	75.5'-78.5'	3.0'	Dolomite, sandy, some algae.
5.	74.2'-75.5'	1.3'	Sandstone, white with green shale in small pockets and along cross-beds and bedding planes, fine-grained, well-sorted.
4.	51.0'-74.2'	23.2'	Consists mainly of even-bedded and medium-bedded sandy dolomite with some beds of rip-ups. Pitted zone up to 1 foot thick occurs in base. Bottom contact sharp and gently rolling.
	Jordan Formation		
	Van Oser Member		
3.	33.0'-51.0'	18.0'	Sandstone, light gray, medium and fine-grained, well-sorted, massive and cross-bedded. Lower 6" to 1' iron stained. Note what appears to be fold or slump feature about 8' above base. Basal contact sharp.

Norwalk Member

2.	10.0'-33.0'	23.0'	Sandstone, light gray to light yellowish brown, very fine and fine-grained, thin-bedded to massive where burrowing has disrupted bedding. Some beds calcareous.

St. Lawrence Formation

1.	0.0'-10.0'	10.0'+	Dolomite, very sandy and sandstone very dolomitic to slightly dolomitic, light pinkish brown, trace glauconite pellets. Weathered surface reveals cross-bedding. Exposure occurs opposite warning sign for stop. BASE OF ROADCUT EXPOSURE

Mileage 252.1 (L. M. Cline after G. Starke, 1949). Jordan-Oneota stratigraphic sequence exposed in Easter Rock at the north end of bridge over Wisconsin River at Boscobel. Location in NW¼, NW¼, SE¼, Sec. 22, T. 8N., R. 3W., Boscobel Quadrangle, Wisconsin.

	Feet	Top
Prairie du Chien Group		
Oneota Formation		
23.	59.2'-67.2'	Dolomite; gray, thick-bedded; contains some large chert nodules.
22.	52.4'-59.2'	Dolomite; light gray, extremely fine-grained.
21.	43.4'-52.4'	Dolomite; buff, fine-grained, in thick beds.
20.	37.7'-43.4'	Dolomite; gray, some buff stringers, in 6-inch beds.
19.	35.3'-37.7'	Dolomite; contains cryptozoan structures; cherty; persistent bed.
18.	27.8'-35.3'	Dolomite; gray, fine-grained, thick-bedded.
17.	Not measured	Dolomite; gray, some fossil fragments (Starke does not give thickness).
16.	19.8'-27.8'	Dolomite; gray to buff, fine-grained, oolitic throughout, some small bioherms.
15.	17.8'-19.8'	Dolomite; oolitic, arenaceous, with white cherty areas.
14.	16.0'-17.8'	Dolomite; fine-grained, undulating beds, biohermal.
13.	14.0'-16.0'	Dolomite; arenaceous, upper part green and glauconitic.
12.	11.7'-14.0'	Dolomite; buff, oolitic at base, upper surface pillow-like.
11.	10.4'-11.7'	Dolomite; orange; includes some lenses of white quartz sandstone.
10.	9.6'-10.4'	Dolomite; buff, arenaceous.
9.	8.6'-9.6'	Sandstone; white.
8.	5.2'-8.6'	Dolomite; fine-grained, very arenaceous, some oolite.
7.	4.1'-5.2'	Dolomite; gray to buff, fine-grained, some scattered orange pebbles.
6.	3.4'-4.1'	Dolomite; buff, fine-grained, biohermal.
5.	2.4'-3.4'	Dolomite; gray, hard, fine-grained, becoming arenaceous and oolitic in upper three inches.
4.	1.9'-2.4'	Sandstone; white, medium-grained.
3.	1.5'-1.9'	Sandstone; buff, dolomitic, grains frosted; some cross-bedding.
2.	0.0'-1.5'	Sandstone; gray, with pockets of green clay.
Trempealeau Group		
Jordan Formation		
1.	Not measured	Sandstone; thick-bedded, buff with lenses of white, cross-bedded. No thickness given but, as you can see, it makes a nice cliff.

Mileage 290.8, STOP 17 (M. E. Ostrom). Davis and Richardson Stone Quarry located in the Wisconsin River bluff about 1 mile north of Spring Green in the SE¼, SW¼, Sec. 31, T. 9N., R. 4E., Sauk County (Spring Green 15' topographic quadrangle, 1960).

Ordovician System
Prairie du Chien Group
Oneota Formation
Hager City Dolomite Member

22.	45.5'-52.5'	+7.0'	Dolomite, thick-bedded, light reddish brown, medium-crystalline, slightly vuggy, with locally abundant white chert.
21.	43.0'-45.5'	2.5'	Same as #22, but has no chert.
20.	37.0'-43.0'	6.0'	Dolomite, light yellowish gray, finely-crystalline, dense with green clay along bedding planes especially in upper 1'. Abundant dendrites. Sandy near base. Locally fine- and medium-crystalline. Medium-bedded becoming thin-bedded to top. Beds persistent and gently undulating.
19.	32.0'-37.9'	5.0'	Dolomite, gray mottled and streaked light yellowish brown, medium-crystalline, slightly vuggy, appears thick-bedded but is medium- and thin-bedded. Upper contact sharp and even.
18.	30.0'-32.0'	2'±1'	Dolomite, brown, fine- and medium-crystalline, moderately vuggy, irregular thickness, with large subspherical bodies (12") of white chert with gray centers. No oolites detected in chert. Upper contact irregular. Some reddish brown clay bodies. Base of upper quarry ledge.
17.	20.0'-30.0'	10'	Dolomite, grayish brown mottled pale orange, thick-bedded with abundant chert. Top of lower quarry ledge.
16.	17.0'-20.0'	3'	Dolomite, gray mottled light yellowish brown, vuggy stromatolitic.
15.	16.8'-17.0'	0.2'±0.1'	Sandstone, light yellowish gray, very dolomitic, fine- and medium-grained, dense, blocky fracture.
14.	12.8'-16.8'	4'	Dolomite, brownish gray mottled light yellowish brown, fine- and medium-crystalline, dense to slightly vuggy, persistent lateral beds, somewhat irregular beds. Upper 18" very oolitic.
13.	12.7'-12.8'	0.1'±0.1'	Dolomite, gray mottled brownish gray and moss green, sandy and glauconitic, slightly conglomeratic, in top of bed #11.
12.	10.2'-12.7'	2.5'	Dolomite, gray mottled light yellowish brown, medium- and finely-crystalline, very porous, appear to be digitate, vertically weathered, algal structures with laterally persistent thin (1") beds of sandy and glauconitic dolomite and of siltstone. Appears to have altered in some areas to reddish brown waxy clay except for thin glauconitic and sandy layers which persist through the clay.

Stockton Hill Member

11.	9.5'-10.2'	0.7'	Dolomite, gray mottled and streaked pale reddish brown, dense to slightly porous, single bed, appears dark on weathered surface with moss-green clay, very sandy.
10.	8.6'-9.5'	0.9'±0.3'	Sandstone with siliceous cement, moderately well-cemented, coarse- to medium-grained, massive, with abundant white specks and stringers. Few relict oolites.
9.	8.4'-8.6'	0.2'±0.1'	Sandstone with siliceous cement, coarse- to medium-grained, white, scattered oolites, varies from hard to soft.
8.	7.5'-8.4'	0.9'	Sandstone, light yellowish gray, medium- and fine-grained with little coarse and very fine, silty, poorly-sorted, dolomitic, trace glauconite, Irregular blocky fracture. Thin green shale stringers in top.
7.	6.4'-7.5'	1.1'	Dolomite, massive, fine- and medium-crystalline, porous, stromatolitic with thin laminae. Occurs as single bed.
6.	5.2'-6.4'	1.2'±0.3'	Dolomite, light gray medium- and finely-crystalline, dense, very sandy, inter-bedded with sandstone, white, fine- and medium-grained with somewhat discontinuous beds.
5.	4.1'-5.2'	1.1'	Dolomite, gray mottled brownish gray, finely-crystalline, dense, slightly porous in top.
4.	3.8'-4.1'	0.3'	Chert, white, oolitic.
3.	2.2'-3.8'	1.6'	Dolomite, brownish gray, weathers light yellowish grey on surface, irregular fracture, slightly porous. Upper part very oolitic. Oolites are light yellowish brown. Conglomeratic.
2.	1'-2.2'	1.2'	Dolomite, light brownish gray, very finely-crystalline, dense, cryptozoa with convoluted thin laminae. Surface weathers very light yellowish gray. Upper 3" very conglomeratic.
1.	0'-1'	+1.0'	Dolomite, brownish gray, fine- and medium-crystalline, dense, medium- and thin-bedded, regularly-bedded, very oolitic. Oolites light yellowish brown. BASE OF EXPOSURE AT QUARRY FLOOR.

<u>Mileage 308.3, STOP 18 (L. M. Cline after Thwaites, 1935, and Starke, 1949)</u>. School Section Bluff, Mazomanie, Wisconsin. Location - SW¼, NW½, Sec. 16, T.8N., R.6E., Sauk County (Mazomanie 7.5' topographic quadrangle, 1962).

Prairie du Chien Group
Oneota Formation

51.	204.0'-		Dolomite, gray to buff, thinly-bedded, thickness not given.
50.	201.0'-204.0'	3.0'	Dolomite; gray, massive, badly weathered.
49.	198.0'-201.0'	3.0'	Dolomite; gray, algal structures throughout.
48.	197.2'-198.0'	0.8'	Dolomite; gray, fine-grained, fragmentary chitons.
47.	196.2'-197.2'	1.0'	Dolomite; buff, contains some chert.
46.	195.1'-196.2'	1.1'	Dolomite; buff, fine-grained, wavy-bedded, lower 4" very cherty.
45.	193.7'-195.1'	1.4'	Dolomite; grey to buff, fine-grained, mottled, biostromal.
44.	192.9'-193.7'	0.8'	Dolomite; buff to gray, fine-grained, wavy-bedded.
43.	191.9'-192.9'	1.0'	Dolomite; gray, fine-grained.
42.	191.1'-191.9'	0.8'	Dolomite; buff, fine-grained, mottled, biostromal.
41.	188.1'-191.1'	3.0'	Concealed.
40.	187.1'-188.1'	1.0'	Dolomite; buff, fine-grained, wavy-bedded.
39.	184.3'-187.1'	2.8'	Dolomite; buff and gray, arenaceous.
38.	183.5'-184.3'	0.8'	Dolomite; gray, fine-grained, massive, wavy-bedded.
37.	183.0'-183.5'	0.5'	Dolomite; buff, fine-grained, cherty.
36.	179.9'-183.0'	3.1'	Dolomite; gray, fine-grained, some arenaceous areas.
35.	177.1'-179.9'	2.8'	Dolomite; gray, fine-grained, brecciated, massive.
34.	172.9'-177.1'	4.2'	Concealed.

(Starke's zone 1 is the Jordan sandstone)

Cambrian System
Jordan Sandstone Formation
Van Oser Member

33.	168.4'-172.9'	4.5'	Sandstone; fine-grained, light gray, thin firm layers (Thwaites used the term "Madison member" for this zone).
32.	155.4'-168.4'	13.0'	Sandstone; medium-grained, white, soft, contains calcite concretions; in even, heavy beds.
31.	154.4'-155.4'	1.0'	Sandstone; coarse-grained, brownish-yellow, hard, dolomitic.

St. Lawrence Formation
Lodi Siltstone Member

30.	143.9'-154.4'	10.5'	Dolomite; arenaceous, yellowish gray, some red streaks.
29.	141.4'-143.9'	2.5'	Dolomite; arenaceous to shaly, red and yellow layers.
28.	138.9'-141.4'	2.5'	Dolomite: arenaceous, spotted pink and yellow, massive.
27.	137.2'-138.9'	1.7'	Dolomitic siltstone; pink spots and bands, partings of red and green shale at top and bottom.
26.	125.2'-137.2'	12.0'	Siltstone; dolomitic, in thin layers.
25.	121.2'-125.2'	4.0'	Siltstone; dolomitic, massive weathering but finely laminated, finer grained at top and bottom.
24.	119.5'-121.2'	1.7'	Siltstone; yellowish to buff, very dolomitic, reddish stains. Fossiliferous;has yielded Westonia aurora, Dikelocephalus winona, Tellerina crassimarginata, Linguella winona and L. mosia.
23.	113.5'-119.5'	6.0'	Siltstone; dolomitic, finely laminated bed weathering massive, streaked with yellow and light brown, some sandy layers, red clay parting at top.
22.	108.1'-113.5'	5.4'	Siltstone; yellow-gray, dolomitic, in layers ¼ to 2" thick.

Black Earth Member

21.	104.1'-108.1'	4.0'	Dolomite; mottled gray and yellow, glauconitic, sandy, two layers exposed in old quarry.
20.	91.1'-104.1'	13.0'	Concealed; sandstone fragments.

Lone Rock Formation
Reno Member

19.	81.1'-91.1'	10.0'	Sandstone; medium-grained, white to yellow, glauconitic, conglomeratic at top, soft, some cross-bedding.
18.	79.1'-81.1'	2.0'	Sandstone; medium-grained, white, glauconitic, one bed.
17.	43.1'-79.1'	36.0'	Sandstone; medium-grained, light gray, soft, cross-bedded, glauconitic, pebbles of sandstone, trilobite fragments and borings; Prosaukia has been found in the zone.
16.	41.1'-43.1'	2.0'	Sandstone; medium-grained, yellow, dolomitic, cross-bedding dipping northeast, glauconitic, forms shoulder of bluff.

Mazomanie Member

15.	40.6'-41.1'	0.5'	Sandstone; medium-grained, soft, yellow-gray.
14.	39.8'-40.6'	0.8'	Sandstone; medium-grained, yellow, dolomitic.
13.	37.8'-39.8'	2.0'	Sandstone; medium-grained, white and yellow gray. Small scale cross-bedding affecting layers less than a foot thick, dips to east of north and south of west common.
12.	37.1'-37.8'	0.7'	Sandstone; medium-grained, yellow, dolomitic.
11.	34.6'-37.1'	2.5'	Sandstone; medium-grained, white to yellow soft, thin lenses of dolomite, cross-bedded, fossils and burrows.
10.	32.6'-34.6'	2.0'	Sandstone; medium-grained, soft, white to yellow, bedding irregular, cross-bedding with random dips, lenses of more dolomitic rock 1 to 2" thick; glauconitic; upper portion honeycombed with burrows.
9.	31.2'-32.6'	1.4'	Sandstone; much like zone 10 but is pink and contains much glauconite.
8.	20.2'-31.2'	11.0'	Sandstone; like zone 10.
7.	17.7'-20.2'	2.5'	Dolomite; yellow, soft, arenaceous; resembles the Lodi.
6.	16.2'-17.7'	1.5'	Sandstone; fine-grained, gray and yellow mottled.
5.	13.7'-16.2'	2.5'	Concealed.

Reno Member

4.	11.2'-13.7'	2.5'	Sandstone; medium-grained, gray, very glauconitic, in 3 to 6 inch layers.

Mazomanie Member

3.	9.7'-11.2'	1.5'	Sandstone; fine-grained, soft, yellow to pink, massive.
2.	1.9'-9.7'	7.8'	Sandstone; fine-grained, very hard, light yellow-gray, some cross-bedding, lenses of yellow dolomite.
1.	0.0'-1.9'	1.9'	Sandstone; white, fine-grained.

Mileage 320.4, STOP 19 (Melby, 1967). Four miles west of Middleton, Wisconsin in SW¼, SE¼, Sec. 7, T.7N., R.8E., Dane County (Cross Plains 15' quadrangle, 1962).

Ordovician System
Prairie du Chien Group
Oneota Formation

9.	11.2'-19.2'	8.0'	Dolomite, brown to gray, conglomeratic to brecciated. Some algal structures near the base. Scattered chert, ±2' of relief at base.
8.	10.5'-11.2'	0.3/1.0'	Sandstone, greenish white, fine-grained, abundant thin green shale partings and Ordovician conodonts.
7.	9.3'-10.5'	1.0/1.3'	Sandstone, medium- and fine-grained. Abundant siliceous oolites and scattered limonite after marcasite.
6.	8.7'-9.3'	0.5/0.7'	Sandstone, medium-grained, white.
5.	8.3'-8.7'	0.0/0.7'	Sandstone, medium- and coarse-grained. Scattered green shale partings and silicified oolite bands.
4.	7.6'-8.3'	0.6/0.8'	Sandstone, medium- and fine-grained, white. Scattered pea and marble size carbonate concretions.
3.	7.1'-7.6'	±0.5'	Sandstone, coarse- and fine-grained, abundant silicified oolites, white. cherty.
2.	6.0'-7.1'	1.0/1.2'	Sandstone, medium- and fine-grained, white, friable. Scattered coarse grains and clay partings. Cherty near base.

Jordan Formation
Van Oser Member

1.	0.0'-6.0'	+6.0'	Sandstone, coarse- and medium-grained, white. Scattered pea size carbonate concretions at the top and larger silica cemented pods near the center. Cross bedded.

List of References

1. Ahlen, J.L., 1952, The regional stratigraphy of the Jordan Sandstone in west central Wisconsin: Unpub. master's thesis, Wisconsin Univ.

2. Andrews, G.W., 1955, Unconformity at base of New Richmond Sandstone: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 329-333.

3. Asthana, Virendra, 1969, The Mt. Simon Formation (Dresbachian Stage) of Wisconsin: Unpub. doctor's thesis, Wisconsin Univ., 159 p.

4. Austin, George S., 1969, Weathering of the Sioux Quartzite near New Ulm, Minnesota, as related to Cretaceous climates: Jour. Sed. Petrology (in press).

5. Bain, H.F., 1906, Zinc and lead deposits of the Upper Mississippi Valley: U.S. Geol. Survey Bull. 294, p. 17-19.

6. Bell, W.C., Berg, R.R., and Nelson, C.A., 1956, Croixan type area - Upper Mississippi Valley: XX Congreso Geologico Internacional, XX Sesion, Part II, p. 415-446.

7. Berg, R.R., 1954, Franconia Formation of Minnesota and Wisconsin: Geol. Soc. America Bull., v. 65, p. 857-882.

8. Berg, R.R., Nelson, C.A., and Bell, W.C., 1956, Upper Cambrian rocks in southeastern Minnesota: Geol. Soc. America Field Trip Guidebook No. 2, Minneapolis, p. 1-23.

9. Boardman, D.C., 1952, Sedimentation and stratigraphy of the Jordan and Madison sandstones in central Wisconsin: Unpub. master's thesis, Wisconsin Univ.

10. Boebel, R.W., 1950, Sedimentology of St. Lawrence Dolomite and relation to Wisconsin Arch: Unpub. master's thesis, Wisconsin Univ.

11. Buschbach, T.C., 1964, Cambrian and Ordovician strata of Northeastern Illinois: Illinois Geol. Survey Rept. Inv. 218, 90 p.

12. Cady, G.H., 1919, Geology and mineral resources of the Hennepin and LaSalle Quadrangles: Illinois Geol. Survey Bull. 37, 136 p.

13. Calvert, W.L., 1962, Sub-Trenton rocks from Lee County, Virginia, to Fayette County, Ohio: Ohio Geol. Survey Rept. Inv. no. 45, 57 p.

14. Carozzi, A.V. and Davis, R.A., Jr., 1964, Pétrographie et paléoécologie d'une série de dolomies á stromatolithes do l'Ordovicien inférieur du Wisconsin, U.S.A.: Archives des Sciences, Genéve, v. 17, p. 47-63.

15. Cline, L.M., Tyler, S.A., and Black, Robert F., 1959, Southwestern Wisconsin, <u>in</u> Guidebook for 23rd Ann. Tri-State Field Conference, Madison, Wisconsin.

16. Cloud, P.E., 1952, Facies relationships of organic reefs: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 2125-2149.

17. Crowley, A.J., and Thiel, G.A., 1940, Precambrian and Cambrian relations in east-central Minnesota: Am. Assoc. Petrol. Geologists Bull., v. 24, p. 744-749.

18. Curray, J.R., 1960, Sediments & history of Holocene transgression, Continental Shelf, northwest Gulf of Mexico, in Recent sediments, northwest Gulf of Mexico: Am. Assoc. Petroleum Geologist, Tulsa, p. 221-266.

19. Dapples, E.C., 1955, General lithofacies relationships of St. Peter Sandstone and Simpson Group: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 444-467.

20. Davis, Richard A., Jr., 1966a, Revision of Lower Ordovician nomenclature in the Upper Mississippi Valley: Jour. Geology, v. 74, no. 3, p. 361-365.

21. Davis, Richard A., Jr., 1966b, Willow River Dolomite: Ordovician analogue of modern algal stromatolite environments: Jour. Geology, v. 74, no. 6, p. 908-923.

22. Davis, R.A. 1968, "Canadian-Ozarkian" unconformity in the Upper Mississippi Valley: abstract in Am. Assoc. Petroleum Geologists Bull., v. 52, p. 524.

23. Davis, Richard A., Jr., 1969, (Abs) Stratigraphy of the Prairie du Chien Group (Lower Ordovician), Upper Mississippi Valley: North Central Section, Geol. Soc. America, Columbus, Ohio, May, 1969.

24. Davis, R.A., in press, Lithostratigraphy of the Prairie du Chien Group, Upper Mississippi Valley: Geol. Soc. America Bull.

25. Dott, R.H., and Murray, G.E., 1954, Geologic cross section of Paleozoic rocks, central Mississippi to northern Michigan: Am. Assoc. Petroleum Geologists, Tulsa, 32 p.

26. Driscoll, E.G., 1959, Evidence of transgressive-regressive Cambrian sandstones bordering Lake Superior: Jour. Sed. Pet., v. 29, no. 1, p. 5-15.

27. Du Bois, E.P., 1945, Subsurface relations of the Maquoketa and "Trenton" Formations in Illinois: Illinois Geol. Survey Rept. Inv. 105, p. 7-33.

28. Eardley, A.J., 1951, Structural geology of North America: Harper & Bros., New York, 624 p.

29. Ekblaw, G.E., 1938, Kankakee Arch in Illinois: Geol. Soc. America Bull., v. 49, p. 1425-1430.

30. Emrich, Grover H., 1966, Ironton and Galesville (Cambrian) sandstones in Illinois and adjacent areas: Illinois Geol. Survey Circ. 403, 55 p.

31. Erickson, D.M., 1951, The detailed physical stratigraphy of the Franconia Formation in southwest Wisconsin: Unpub. master's thesis, Wisconsin Univ.

32. Fairbridge, R.W., 1950, Recent and Pleistocene coral reefs of Australia: Jour. Geology, v. 58, no. 4, p. 330-401.

33. Farkas, S.E., 1958, Analysis of cross-lamination in the Upper Cambrian Franconia Formation of Southwestern Wisconsin: Unpub. master's thesis, Wisconsin Univ.

34. Freeman, L.B., 1949, Regional aspects of Cambrian and Ordovician subsurface stratigraphy in Kentucky: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 1655-1681.

35. Furnish, W.M., 1938, Conodonts from the Prairie du Chien (Lower Ordovician) beds of the Upper Mississippi Valley: Jour. Paleont., v. 12, no. 4, p. 318-340.

36. Gilluly, James, Waters, A.C., and Woodford, A.O., 1951, Principles of Geology: W.H. Freeman and Company, San Francisco, 631 p.

37. Grohskopf, J.G., 1955, Subsurface geology of Mississippi Embayment in southeast Missouri: Missouri Geol. Survey, v. 37, 2nd ser., 133 p.

38. Heller, R.L., 1956, Status of Prairie du Chien problem: Guidebook for field trips, Minneapolis, Geol. Soc. America, Field Trip No. 2, p. 29-40.

39. Illing, L.V., 1954, Bahaman calcareous sands: Am Assoc. Petroleum Geologists Bull., v. 38, p. 1-95.

40. Irving, R.D., 1875, Note on some new points in the elementary stratification of the primordial and Canadian rocks of south central Wisconsin: America Jour. Sci., 3rd Series, v. 9, p. 440-443.

41. Johnson, J.W., 1956, Nearshore sediment movement: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2211-2232.

42. Kansas Geological Society, 1935, Guidebook to Ninth Annual Field Conference; Kansas Geological Society.

43. King, P.B., 1959, The evolution of North America: Princeton Univ. Press, Princeton, New Jersey, 190 p.

44. Kraft, John C., 1956, A petrographic study of the Oneota-Jordan contact zone: Guidebook for field trips, Minneapolis, Geol. Soc. America, Field Trip No. 2., p. 24-28.

45. Ladd, H.S., and Hoffmeister, J.E., 1936, A criticism of the glacial-control theory: Jour. Geology, v. 44, p. 74-92.

46. Lee, Wallace, 1943, The stratigraphic and structural development of the Forest City Basin: Kansas Geol. Survey Bull. 51, 142 p.

47. Ludwig, J.C., and Walton, W.R., 1957, Shelf-edge calcareous prominences in northeastern Gulf of Mexico: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 2054-2101.

48. McGee, W.J. 1891, The Pleistocene history of northeast Iowa: U.S. Geol. Survey, 11th Annual Report, p. 187-577.

49. Melby, John H., 1967, The stratigraphy of the Sunset Point Sandstone in Western Wisconsin: Unpub. master's thesis, Wisconsin Univ., 95 p.

50. Morrison, Bradford C., 1968, Stratigraphy of the Eau Claire Formation of west-central Wisconsin: Unpub. master's thesis, Wisconsin Univ., 41 p.

51. Nelson, C.A., 1956, Upper Croixan stratigraphy: Geol. Soc. America Bull., v. 67, p. 165-184.

52. Ostrom, Meredith E., 1964a, Pre-Cincinnatian Paleozoic cyclic sediments in the Upper Mississippi Valley: a discussion: Kansas Geol. Survey Bull. 169, v. II, p. 381-398.

53. Ostrom, Meredith E., 1964b, in Guidebook to field trips for the First meeting of The Clay Minerals Society, Madison, Wisconsin, Oct. 1964, p. 26-27.

54. Ostrom, Meredith E., 1965, Cambro-Ordovician stratigraphy of southwest Wisconsin; Guidebook to twenty-ninth annual Tri-State Field Conference: Wisconsin Geol. and Natural Hist. Survey Info. Circ. No. 6, 57 p.

55. Ostrom, Meredith E., 1966, Cambrian stratigraphy in Western Wisconsin; Guidebook to the Michigan Basin Geological Society 1966 Annual Field Conference: Wisconsin Geol. and Natural Hist. Survey Info. Circ. No. 7, 79 p.

56. Ostrom, Meredith E., and Slaughter, Arthur E., 1967, Correlation problems of the Cambrian and Ordovician outcrop areas, Northern Peninsula of Michigan: Michigan Basin Geological Society 1967 Annual Field Excursion, 82 p.

57. Ostrom, Meredith E., 1967, Paleozoic stratigraphic nomenclature for Wisconsin: Wisconsin Geol. and Natural Hist. Survey Info. Circ. No. 8.

58. Ostrom, Meredith E., 1969, Champlainian Series (Middle Ordovician) in Wisconsin: Am. Assoc. Petroleum Geologist Bull., v. 53, no. 3, p. 672-678.

59. Owen, D.D., 1840, Report of a geological exploration in part of Iowa, Wisconsin and Illinois: House Executive Doc. 239, 26th Cong., 1st session.

60. Parker, R.H., and Curray, J.R., 1956, Fauna and bathymetry of banks on Continental Shelf, northwest Gulf of Mexico: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2428-2439.

61. Potter, Paul Edwin, and Pryor, Wayne A., 1960, Dispersal centers of Paleozoic and later clastics of the Upper Mississippi Valley and adjacent areas: Geol. Soc. American Bull., v. 72, no. 8, p. 1195-1250.

62. Powell, L.H., 1933, *A study of the Ozarkian faunas of southeastern* Minnesota: Sci. Bull. No. 1, The Sci. Museum of the Saint Paul Inst., 80 p., 17 pl.

63. Powers, E.H., 1935, The Prairie du Chien problem: Iowa Univ. Studies Nat. Hist., v. 16, p. 421-448.

64. Quick, J.V., 1959, Troy Grove aquifer storage project, in Report to the A.G.A. Committee on Underground Storage: Northern Illinois Gas Company, 20 p.

65. Raasch, G.O., 1935, Stratigraphy of the Cambrian system of the Upper Mississippi Valley: Kansas Geol. Soc. Guidebook, Ninth Ann. Field Conf., p. 302-315.

66. Raasch, G.O., 1939, Cambrian Merostomata: Geol. Soc. America Spec. Paper No. 19, 146 p.

67. Raasch, Gilbert O., 1951, Revision of Croixan Dikelocephalidae: Illinois State Acad. Science Trans., v. 44, p. 137-151.

68. Raasch, Gilbert O., 1952, Oneota Formation, Stoddard Quadrangle, Wisconsin: Illinois Acad. Science Trans., v. 45, p. 85-95.

69. Raasch, Gilbert O., and Unfer, Louis, Jr., 1964, Transgressive-regressive cycle in Croixan sediments (Upper Cambrian), Wisconsin: Kansas State Geological Survey Bull. 169, v. II, p. 427-440.

70. Sardeson, F.W., 1896, *The fauna of the Magnesian Series: Minnesota* Acad. Sci. Bull., v. 4, p. 92-106.

71. Sardeson, F.W., 1934, The Shakopee Formation: Pan-Amer. Geologist, v. 62, p. 29-34.

72. Sardeson, F.W., 1935, Defense of Shakopee Title: Pan-Am. Geologist, v. 64, p. 279-285.

73. Shea, James H., 1960, Stratigraphy of the Lower Ordovician New Richmond Sandstone in the Upper Mississippi Valley: Unpub. master's thesis, Wisconsin Univ., 90 p.

74. Shepard, F.P., and Moore, D.G., 1955, Central Texas coast sedimentation: characteristics of sedimentary environment, recent history, and diagenesis: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 1463-1593.

75. Sloan, Robert E., Assoc. Ed., 1956, Guidebook for field trips, Minneapolis, Geol. Soc. America, Field Trip No. 2, p. 1-110.

76. Starke, G.W., 1949, Persistent lithologic horizons of the Prairie du Chien Formation from the type section eastward to the crest of the Wisconsin Arch: Unpub. master's thesis, Wisconsin Univ.

77. Stauffer, C.R., 1927, Age of the Red Clastic series of Minnesota: Geol. Soc. America Bull., v. 38, p. 469-477.

78. Stauffer, C.R., 1934, Type Paleozoic sections in the Minnesota Valley: Jour. Geology, v. 42, p. 337-357.

79. Stauffer, C.R., 1937a, A diminutive fauna from the Shakopee Dolomite (Ord.) at Cannon Falls, Minnesota: Jour. Paleont., v. 11, p. 55-60.

80. Stauffer, C.R., 1937b, Mollusca from the Shakopee Dolomite (Ord.) at Stillwater, Minnesota: Jour. Paleont., v.11, p. 61-68.

81. Stauffer, C.R., and Thiel, G.A., 1941, The Paleozoic and related rocks of Southeastern Minnesota: Minnesota Geol. Survey Bull. 29. 261 p.

82. Stetson, H.C., 1953, The sediments of the western Gulf of Mexico: Part I - The Continent Terrace of the western Gulf of Mexico; its surface sediments, origin, and development, in Papers in Phys. Oceanog. and Meteorol.: Mass. Inst. Tech. and Woods Hole Oceanog. Inst., v. 12, no. 4, p. 3-45.

83. Swann, D.H., and Willman, H.B., 1961, Megagroups in Illinois: Am. Assoc. Petroleum Geologists Bull., v. 45, p. 471-483.

84. Templeton, J.S., 1951, The Mt. Simon Sandstone in Northern Illinois: Illinois State Geological Survey Circ. 170, 9 p.

85. Templeton, J.S., and Willman, H.B., 1963, Champlainian Series (Middle Ordovician) in Illinois: Illinois Geol. Survey Bull. 89, 260 p.

86. Thwaites, F.T., 1935, Road log for Wednesday afternoon, August 28. Post-Conference Alternate Trip No. 2, in Kansas Geol. Soc. Guidebook, 9th Ann. Field Conf., p. 116-118.

87. Thwaites, F.T., 1957, Map of buried Precambrian of Wisconsin: Wisconsin Geol. and Natural Hist. Survey. Single sheet (8½" X 11").

88. 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.

89. Tyler, S.A., 1936, Heavy minerals of the St. Peter Sandstone in Wisconsin: Jour. Sed. Pet., v. 6, p. 77-79.

90. Tyler, S.A., Marsden, R.W., Grout, F.F., and Thiel, G.A., 1940, Studies of the Lake Superior Pre-Cambrian by accessory-mineral methods: Geol. Soc. America Bull., v. 51, No. 10, p. 1429-1537.

91. Twenhofel, W.H., Raasch, G.O., and Thwaites, F.T., 1935, Cambrian strata of Wisconsin: Geol. Soc. America Bull., v. 46, p. 1687-1743.

92. Ulrich, E.O., 1924, Notes on new names in the table of formations and on physical evidence of breaks between Paleozoic Systems in Wisconsin: Wisc. Acad. Sci., Art., and Letters, Trans., v. 21, p. 71-107.

93. Ulrich, E.O., and Resser, C.E., 1930, The Cambrian of the Upper Mississippi Valley, part I: Milwaukee Pub. Museum Bull., v. 12, no. 1, p. 1-22.

94. Van Andel, Tj.H., 1960, Sources and dispersion of Holocene sediments, northern Gulf of Mexico, in Recent sediments, northwest Gulf of Mexico: Am. Assoc. Petroleum Geologists, Tulsa, p. 34-55.

95. Van Andel, Tj.H., and Curray, J.R., 1960, Regional aspects of modern sedimentation in northern Gulf of Mexico and similar basins, and paleogeographic significance, in Recent sediments, northwest Gulf of Mexico: Am. Assoc. Petroleum Geologists, Tulsa, p. 345-364.

96. Wanenmacher, J.M., Twenhofel, W.H., and Raasch, G.O., 1934, The Paleozoic strata of the Baraboo area, Wisconsin: Amer. Jour. Sci., v. 228, p. 1-30.

97. Willman, H.B., and Templeton, J.S., 1952, Cambrian and Lower Ordovician exposures in northern Illinois: Illinois Geol. Survey Circ. 179, p. 109-125.

98. Woodward, H.P., 1961, Preliminary subsurface study of southeastern Appalachian Interior Plateau: Am. Assoc. Petroleum Geologists Bull., v. 45, p. 1634-1655.

99. Workman, L.E., and Bell, A.H., 1948, Deep drilling and deeper oil possibilities in Illinois: Am. Assoc. Petroleum Geologists Bull., v. 32, p. 2041-2062.