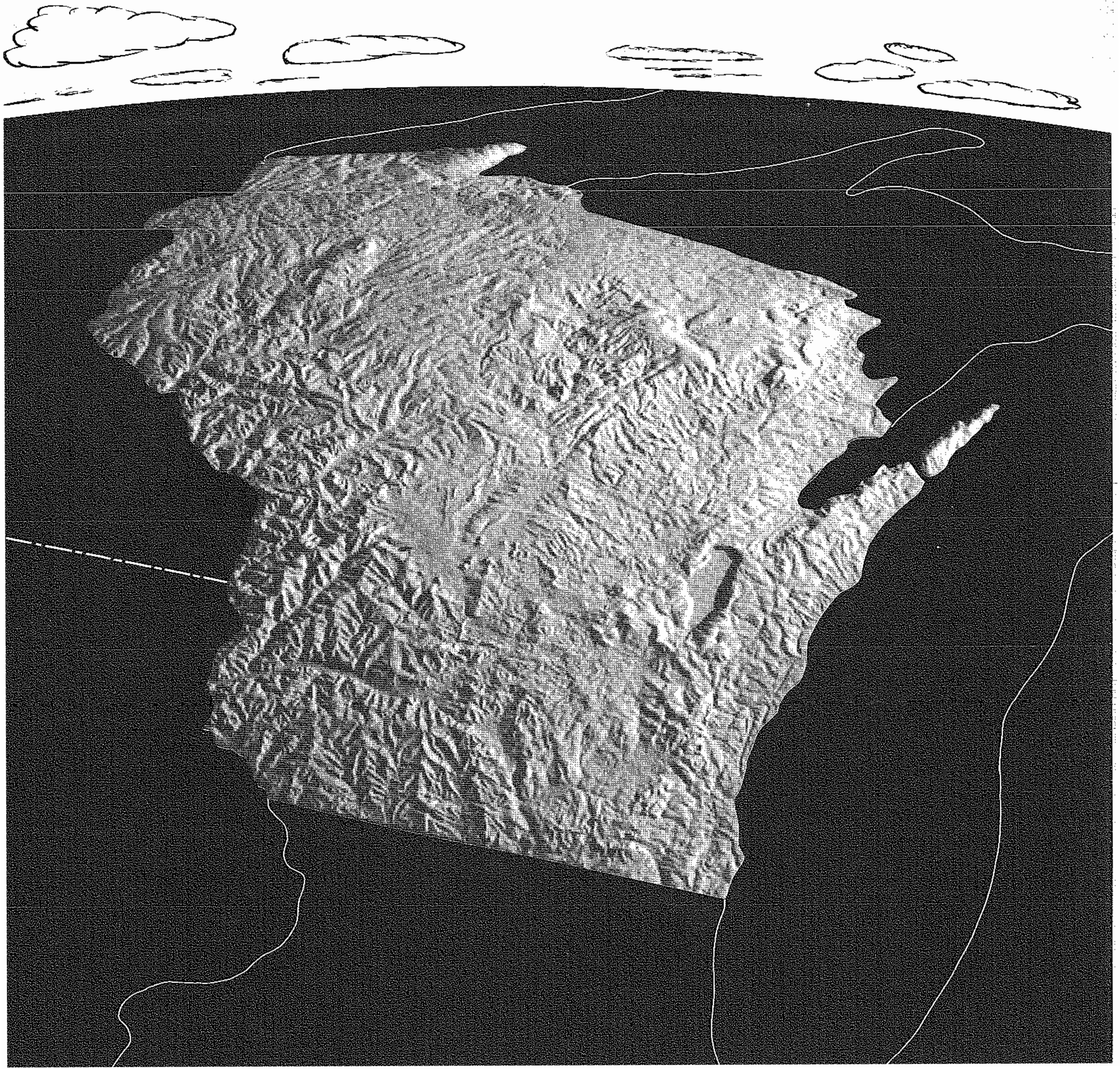
Volume 4
April 1980

University of Wisconsin-Extension
GEOLOGICAL AND NATURAL HISTORY SURVEY

Geoscience Wisconsin



Cover: An oblique photograph of a plastic raised relief map of Wisconsin by Hans J. Stolle a graduate student in the Geography Department, University of Wisconsin - Madison.

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CONODONTS AND STRATIGRAPHIC RELATIONSHIPS OF THE READSTOWN MEMBER OF THE ST. PETER SANDSTONE IN WISCONSIN

by

William J. Grether and David L. Clark

LATE PLEISTOCENE AND HOLOCENE VERTEBRATE FOSSIL RECORD OF WISCONSIN

by

Robert M. West and John E. Dallman

Available from:
University of Wisconsin-Extension
Geological and Natural History Survey
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PREFACE

"Geoscience Wisconsin" is a serial that addresses itself to the geology of Wisconsin -- geology in the broadest sense to include rocks and rocks as related to soils, water, climate, environment, and so forth. It is intended to present timely information from knowledgeable sources and make it accessible with minimal time in review and production to the benefit of private citizens, government, scientists, and industry.

Manuscripts are invited from scientists in academic, government, and industrial fields. Once a manuscript has been reviewed and accepted, the authors will submit a revised copy of the paper. All illustrations will be submitted in final form by the authors. The Geological and Natural History Survey will prepare final camera-ready copy, will publish the paper as funds permit, distribute copies at a nominal cost, and maintain the publication as a part of the Survey list of publications. This will help to insure that results of research are not lost in the archival systems of large libraries, or lost in the musty drawers of an open-file.

The two papers in this issue are oriented towards the fossil record in Wisconsin. William Grether and David Clark add additional confirming evidence that an unconformity exists between the Readstown Member of the St. Peter Sandstone and the basal units of the Prairie du Chien Group. This was achieved by detailed analysis of conodonts recovered from appropriate outcrops. A new species and a new genus are described. Photomicrographs of described conodonts (Plate 1) are found on page 47. Bob West and John Dallman provide summary information and literature references to existing late Pleistocene and Holocene vertebrate fossils. Although the diversity of species of recovered fossils is high, species diversity of fossils in Iowa is higher, probably due to the somewhat less rigorous late Pleistocene environment in Iowa.

We encourage submission of manuscripts relating to Wisconsin geology. Special consideration will be given papers which deal with timely topics, present new ideas, and have regional or statewide implications.

Wisconsin Geological and Natural
History Survey

CONODONTS AND STRATIGRAPHIC RELATIONSHIPS OF THE READSTOWN MEMBER OF THE ST. PETER SANDSTONE IN WISCONSIN

by

William J. Grether[1] and David L. Clark[2]

ABSTRACT

The Readstown Member of the St. Peter Sandstone is a conglomeratic sandy shale that overlies the irregular surface of the Prairie du Chien Group and lines channel-like structures which cut into the Prairie du Chien. These observations, and others, support the interpretation that an unconformity exists between the two units and that the Readstown developed as a partially reworked residuum on the Prairie du Chien surface.

Thirty-nine samples of the Readstown from twenty-five localities yielded conodonts belonging to 27 species and 12 genera. The conodonts of the Readstown correspond to both Fauna C and Fauna D of Ethington and Clark (1971) but the Faunas were never mixed in the same sample. The Readstown directly overlying the Oneota Formation yielded Fauna C (Oneota) conodonts and the Readstown overlying the Shakopee Formation yielded Fauna D (Shakopee) conodonts. Such distributions best support the interpretation that the Readstown fauna is a reworked Prairie du Chien fauna. Thus, the age of the Readstown and the time span represented by the unconformity at its base cannot be determined from the conodont fauna present within the unit.

INTRODUCTION

The St. Peter Sandstone, named by Owen in 1847 (Wilmarth, 1938, p. 1884-1885) for exposures along the Minnesota River (formerly St. Peter's River), is the lower formation of the Ancell Group (Templeton & Willman, 1963, p. 29-45; Ostrom, 1970). In Wisconsin, it consists of a basal conglomeratic shale named the Readstown Member and an overlying mature quartz sandstone named the Tonti Member (Ostrom, 1967). The Readstown Member (Fig. 1) proposed by Ostrom (1967) for exposures near Readstown, Wisconsin, unconformably overlies Lower Ordovician dolomite of the Prairie du Chien Group and contains abundant conodonts. The pronounced unconformity between the St. Peter and the Prairie du Chien is considered the boundary between the Early Ordovician (Canadian) and the Middle Ordovician (Champlainian) rocks in Wisconsin and the Upper Mississippi River Valley in general (Sloss, 1963, p. 95-98, Fig. 1).

Clark and Miller (1971, p. 14) recovered conodonts from the Readstown at a single Wisconsin locality. They found species that are characteristic of the underlying Prairie du Chien Group and also a few species similar to those present in the middle part of the El Paso Formation of West Texas (Ethington and Clark, 1964). Some diagnostic species of the Prairie du Chien (for example,

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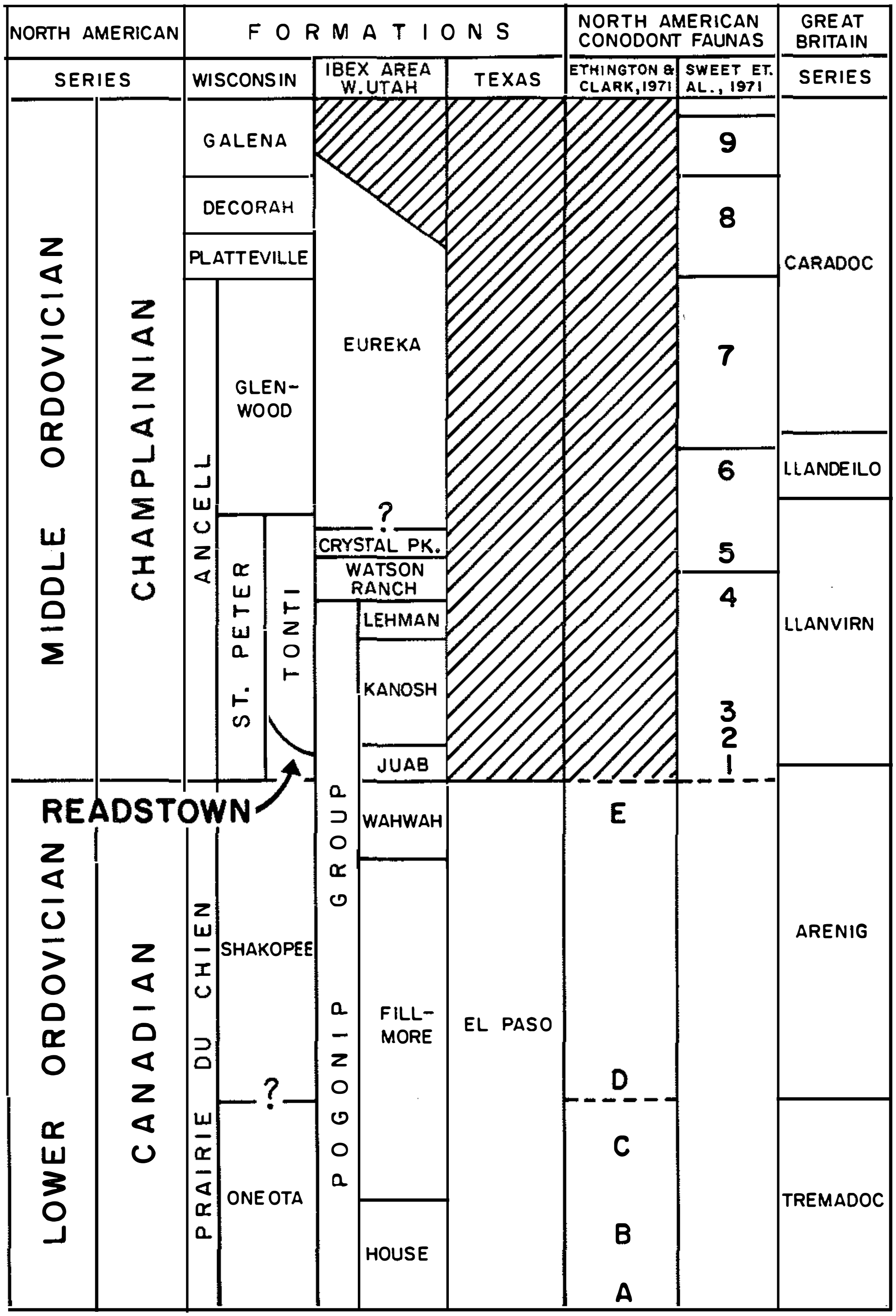

Figure 1. Lower and Middle Ordovician stratigraphy of Wisconsin, its classification and correlation with other important Ordovician stratigraphy and faunal units.

Loxodus and *Acanthodus*) and diagnostic species of the El Paso (for example, *Gothodus* and *Oepikodus*) which first occur in Europe in early Arenigian rocks were absent from the Readstown (Figure 1).

This combination of conodonts actually present, plus those anticipated but absent, suggested that a detailed study of the Readstown could provide firm data on the magnitude and nature of the unconformity between the Prairie du Chien and the St. Peter. Particularly, an indigenous Readstown conodont fauna could help define the age of the overlying and conformable but largely unfossiliferous St. Peter.

STRATIGRAPHY AND PREVIOUS WORK

Description

The Readstown Member was called the Kress Member by Buschbach (1964, p. 51-52) but this name was rejected by Ostrom (1967) because the type section of the Kress was taken from a well instead of an outcrop. The Readstown consists of a chert (in part oolitic) and dolomite-clast conglomerate in a clay or sand matrix interbedded with red and green shale and medium- to coarse-grained sandstone (Buschbach, 1964, p. 52; Templeton and Willman, 1963, p. 45). The Readstown shows considerable lithologic variation laterally and also changes drastically in thickness. In Wisconsin it ranges from a few cm (or total absence) to several meters (Dake, 1921) and in Illinois attains a maximum of 40 meters (Buschbach, 1964, p. 52). Generally the greater thicknesses of the Readstown occur beneath thick sections of overlying pure quartz sandstone of the Tonti Member and also in possible solution depressions and valley channels in the underlying dolomite (Templeton and Willman, 1963, p. 45). In such thick sequences, the Readstown may lie in contact with Cambrian sandstones (Thwaites, 1961, p. 205; Ostrom, 1967) but typically the Readstown overlies dolomite of the Prairie du Chien Group. The upper contact is gradational with the Tonti.

The contact between the Readstown and the underlying Prairie du Chien dolomites in Wisconsin, Iowa, Minnesota, Missouri and Illinois is sharply undulatory showing pronounced relief locally (for example, 70 m of relief between wells a few hundred meters apart has been noted by Buschbach [1964] in Illinois). The top of the St. Peter and the bottom of the Prairie du Chien are parallel and nearly flat lying, however (Trowbridge, 1917, p. 177).

Prairie du Chien-St. Peter Contact

Considerable attention has been focused on the contact zone of the Prairie du Chien and the St. Peter resulting in two interpretations: (1) no depositional unconformity exists between the Prairie du Chien and the Readstown and the *apparent* unconformity resulted from subsurface solution of the Prairie du Chien or from stromatolite-controlled primary deposition; and, (2) the Readstown represents a reworked residuum overlying an unconformity formed by the extensive erosion of the Prairie du Chien and older units. Because of the important sedimentologic differences implied in the two theories, a review of the evidence for each of the two interpretations follows.

1. *No unconformity* -- Flint (1956, p. 396-399) reviewed the literature and cited the early workers, including McGee (1891, p. 330-331), Percival (1855), Hall and Whitney (1851, p. 51; 1862, p. 23-31), Calvin (1894, p. 63), Leonard (1905, p. 243), Chamberlin (1877, p. 268-290; 1883, p. 138-140), and Sardeson

(1916, p. 5-6), who reported no unconformable relations or evidence of extensive subaerial erosion of the Prairie du Chien Dolomite. Flint (1956) examined the contact at 24 localities in Wisconsin and Iowa. He concluded that no unconformity is indicated and that the contact zone is gradational into units both above and below (p. 408, 420). He proposed that the observed irregularity of the contact (in places a local relief of more than 20 m) resulted from compaction of lime muds over resistant algal (stromatolite) domes of the underlying Prairie du Chien. These structures were referred to as "cone domes" by Sardeson (1926, p. 27) and "petrous billows" by Chamberlin (1877, p. 27). According to these authors, this initial relief was accentuated by subsurface solution under considerable load, causing compaction in Shakopee beds. Such interpretations followed from observations that the algal domes which consist of a central brecciated core are draped or mantled with quaquaversal, thin-bedded calcareous strata. Also, the contact zone beds are drag-folded (folds as much as two feet across), the basal St. Peter Sandstone contains shear zones and small scale faults (a few inches of offset), the sandstone beds in the contact zone are "stretched, thinned and pinched off into isolated lenticular blocks", dolomite beds below the contact show "pressure solution fluting on movement surfaces", and shale and sandstone beds "are gently contorted, faulted, slickensided and squeezed" (p. 419). This deformation was explained as internal adjustment of rigid sandstone beds to volume reduction by solution of underlying carbonates.

Flint (1956, p. 420) also concluded that the shales and fine sandstones of the contact zone were derived from solution of the Shakopee and showed no indication of reworking by the St. Peter sea. Evidence for solution included (1) lateral changes in individual carbonate beds from hard crystalline rocks to punky material concentrated in insoluble clay and quartz sand, (2) progressive vertical changes of Shakopee strata just below the contact similar to the above mentioned lateral changes (p. 419), (3) resemblance of the contact zone material to a residuum of clay, silt and sand left from solution of the carbonate fraction of the rock (p. 400), and (4) the advanced leaching of chert to the cotton rock stage and concentration of bedded chert to layers in the contact zone (p. 400). These conclusions were substantiated by Hart (1963). In addition, Hart concluded that "the St. Peter deposition began at or near the close of Prairie du Chien time over much of the area" (p. 134).

2. *Unconformity* -- Early workers who reported the presence of an unconformity between the St. Peter and the Shakopee include Trowbridge (1917, p. 177-182), Dake (1921, p. 206-207), Thwaites (1923, p. 541), Lamar (1928, p. 25) and Stauffer and Thiel (1941). Flint (1956) noted that such interpretations were based primarily on large-scale features of the two formations such as gross combined thickness of the two units (combined thickness is relatively constant but thickness of the separate units is highly variable), magnitude of relief at the contact, and subsurface data from deep wells. He noted that "none of the investigators recorded a specific location of erosionally truncated beds of the Shakopee." Later Ostrom (1967) cited several localities (including the type locality) in southwestern Wisconsin where the Readstown lined erosion channels in the underlying Prairie du Chien (Ostrom, 1965, p. 50; 1970, p. 17, 31, 82-83; 1976). This included a sandstone bed in the Shakopee Dolomite that was deformed downward under a channel like structure cutting out several feet of the Shakopee Formation near Prairie du Chien, Wisconsin. Also, the St. Peter Sandstone and some of the sandstone beds in the Shakopee on the west side of the channel were observed to show small-scale faulting. This same channel structure was observed and described by Hart (1963) but he

attributed this to subsurface solution rather than subaerial erosion. Ostrom interpreted these dipping Shakopee beds to result from pre-St. Peter solution of the Shakopee dolomite beds causing collapse of the sandstone layers toward the channel. He suggested that the deformation in the Shakopee and St. Peter sandstones could have been accomplished at a much later geologic date by additional solution caused by water moving along the permeable channel phase of the St. Peter. Thus, Ostrom combined both subaerial erosion and subsurface solution in his interpretation whereas Hart (1963) and Flint (1956) assumed only subsurface solution.

Thwaites (1961) studied the base of the St. Peter in the same area discussed by Flint. He concluded that the basal beds conformed with and were therefore a part of the overlying St. Peter Sandstone and were unconformable with the underlying Prairie du Chien. Evidence for his conlusions included the occurrence of sandstone layers extending down to the contact and the truncation, by the contact, of older formations down to the Franconia Sandstone (p. 215).

In direct contrast to Flint's interpretation, Thwaites concluded that the conglomerates and shales of the contact zone were a reworked residuum (p. 215). Several lines of evidence were cited by Thwaites to support this hypothesis (1) residual soils developing on modern exposures of the Prairie du Chien Dolomite closely resemble the clays of the contact zone (the modern residual soils have a decidedly brown color, a feature thought by Thwaites to reflect climate differences), (2) some areas of concentrated chert rubble are too free of clay to have formed without reworking, (3) chert fragments are not well rounded but show varying degrees of weathering which occurred prior to deposition, and (4) sand layers or interbeds occur within the contact zone.

Templeton and Willman (1963, p. 45), in support of a reworked residuum hypothesis, cited the presence of "alternating layers of red sandy clay and red argillaceous sandstone at the base of the St. Peter Sandstone" at a number of Illinois and Wisconsin localities. Other localities showed well-bedded red and green shales containing thin (less than a cm) sandstone interbeds.

Buschbach (1964, p. 52) studied subsurface records in seven counties in northeastern Illinois and observed thick sections of the Readstown in many of the wells (p. 68-87). The general appearance and distribution of the Readstown suggested that it formed as an insoluble residuum on a karst surface and later concentrated in solution valleys by St. Peter seas. Buschbach (1961, p. 83-89; 1964, p. 48) proposed that stream erosion, subsurface solution and solution producing karst topography may all have contributed to relief of the sub-St. Peter surface.

Sloss (1963) discussed interregional unconformities in the continental interior of North America and noted the presence of six major unconformities in the sedimentary record. The sub-Tippecanoe unconformity (corresponding to the St. Peter-Prairie du Chien contact) was considered difficult to recognize in some places because (1) the basal Tippecanoe sequence lacks a distinctive basal lithology, (2) confusion exists between the regressive unit of the Sauk and the transgressive unit of the Tippecanoe and (3) karst topography and slump structures developed at the unconformity. Sloss (p. 98) further stated that "it is impossible to make correct interpretations from the data from limited outcrops of small groups of wells, and it is necessary to consider regional relationships through the detailed correlation and tracing of individual rock units."

Summary

The contact of the sub-St. Peter surface is highly irregular but the causes for the irregularity seem to differ in different areas. Interpretations range from Karst solution, stream erosion, stromatolite development and subsurface solution. The extreme relief of the contact and the associated thickness variations of the St. Peter and Prairie du Chien units have been used as criteria indicating the presence of an extensive unconformity. Such relief has been shown by some workers to be formed by stromatolites and subsurface solution and does not necessarily imply the presence of an unconformity (Hart, 1963; Flint, 1956). The different origins suggested for the irregularity and the nature of the contact zone sediment above the irregular surface have resulted in the emergence of two interpretations regarding the genesis of the Readstown: (1) the Readstown represents a reworked residuum overlying an extensive unconformity which may or may not have been modified by subsurface solution and (2) the Readstown was formed by subsurface solution or primary deposition and no sub-St. Peter unconformity exists.

PRESENT STUDY

Because of the different interpretations published for the Readstown and its lower contact, a study of the conodont fauna was initiated. A total of 91 samples was collected from 42 localities in Wisconsin (see Figure 2, and Appendix). Because most localities exposed only a few cm of Readstown, commonly only a single sample represents a locality.

Exposure of the contact zone at most localities required the removal of considerable sand which had weathered from the overlying St. Peter. Once exposed, detailed stratigraphic descriptions of the contact zone sediments were made. Samples (averaging three kilograms) of the prominent shale layers were collected with care to avoid mixing so vertical faunal changes within the Readstown, if present, could be determined. Because of the tendency for the Readstown to become covered by sand from the overlying Tonti Member, exposure of the Readstown in 24 of the localities was restricted to excavations a meter wide or less. Such limited exposure prevented observation of local lateral changes in the unit. Even observations of the 11 better exposed localities were limited by colluvial cover. Sand layers in the contact zone sediment were found to lack conodonts or have very poor yields. Green shale layers and lenses within the Prairie du Chien were sampled for comparison.

RESULTS

Lithologic

Our work confirms that physical aspects of lithology and thickness of the Readstown Member are as reported by previous workers. However, observations made during this study lend support to the presence of unconformity at the base of the St. Peter.

Completely exposed or nearly completely exposed stratigraphic sequences extending from the Prairie du Chien surface to the Tonti Sandstone were present at only 17 of the localities. At 4 localities (4, 7, 13, and 16) the Readstown was present only in the colluvium between laterally separated outcrops of the Prairie du Chien and St. Peter. Six localities (8, 25, 27, 28, 35 and 40) consisted of Prairie du Chien and St. Peter exposures close enough in proximity

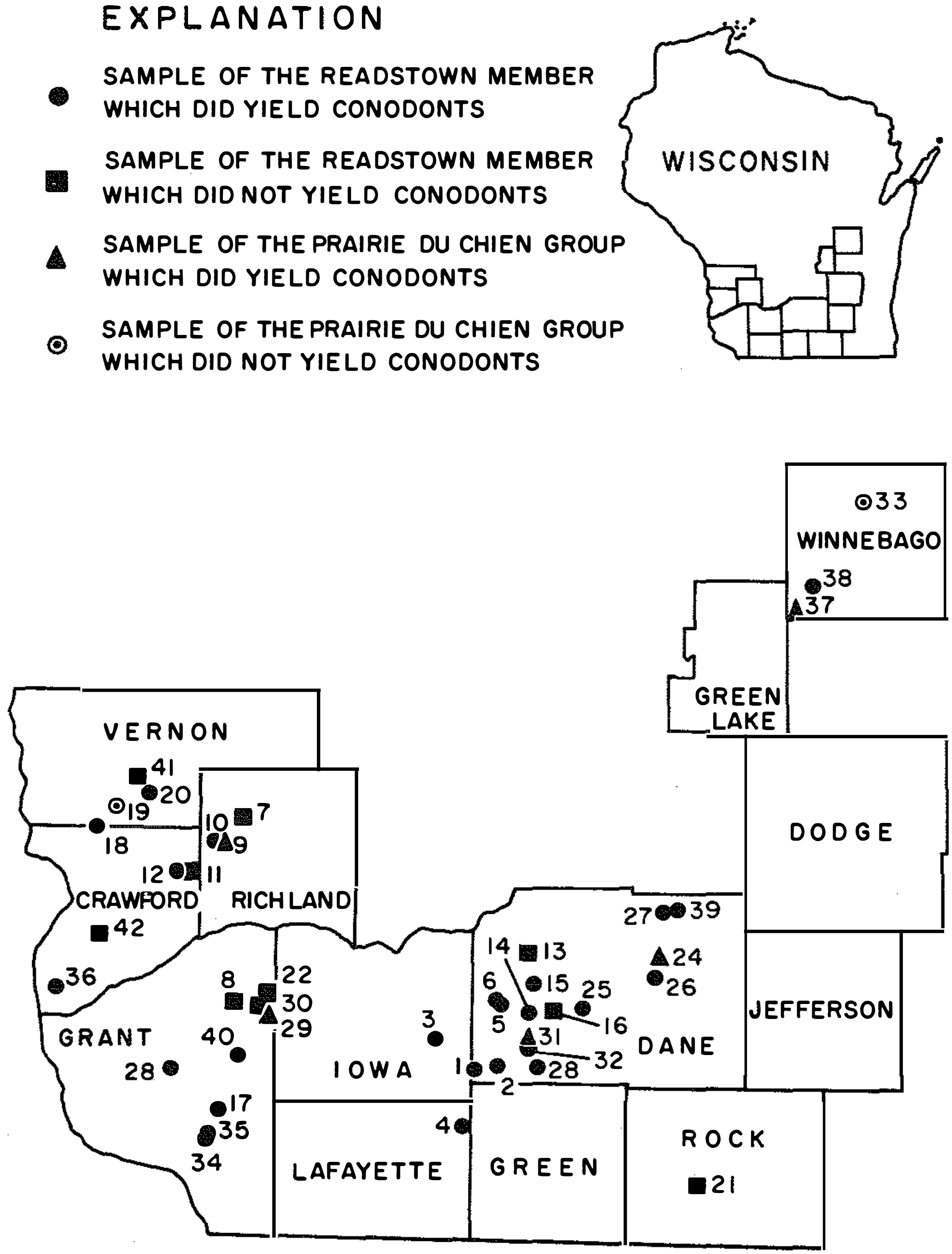

Figure 2. Location of Readstown exposures studied for this report. Occurrence of conodonts at Readstown localities indicated.

to have provided good stratigraphic sections of the Readstown but excessive colluvial cover prevented excavation. Three localities (10, 17 and 18) showed only the contact of the Readstown with the underlying Prairie du Chien and five localities (22, 29, 38, 41 and 42) showed only the contact of green or brown clay of the Readstown with the overlying Tonti Member. A few Prairie du Chien localities were studied for comparative purposes (see Appendix).

Thickness of the Readstown was observed to range from approximately 2 cm (locality 1) to more than 4 m (locality 26). The Readstown generally tends to be thicker in depressions or "channels" in the surface of the Prairie du Chien than on flat or high areas. Lithologic units comprising the Readstown also show considerable variability among the localities. The majority of the Readstown localities consist of a sequence of interbedded sandstones and green or red shales bounded by Prairie du Chien Dolomite below and Tonti Sandstone above. The sandstone and shale interbeds contain varying amounts of oolitic chert, sandstone and dolomite fragments.

Sedimentologic observations supporting the presence of an unconformity at the base of the St. Peter include:

(1) truncation, at seven localities (2, 5, 11, 20, 32, 36, and 39) of the Prairie du Chien Dolomite by channel-like structures filled with St. Peter Sandstone; at two of these localities (20 and 39) the channels occur down to the Sunset Point Member of the Oneota Formation and at three other localities (1, 10 and 18) the Readstown overlies but does not distinctly truncate the Oneota

(2) the occurrence of distinct irregularity of the dolomite surface beneath the Readstown at all localities where the Prairie du Chien was present; the irregularity is both large scale (hundreds of meters) and small scale (about a cm)

(3) the presence of interbeds of often rather pure sand and shale and the presence of variable amounts of oolitic chert, dolomite and sandstone fragments within the sand and shale interbeds of the contact zone

(4) the orientation of planar features such as bedding planes, contacts between interbeds and planar fissility in the shales parallel or subparallel to the dolomite surface

(5) the greater concentration of shale in valleys or channels in the dolomite surface suggesting transport of the shales.

The seven channel-like structures which truncate beds of the Prairie du Chien have certain features in common. Each channel, although filled with sandstone of the Tonti Member, is lined with shale, conglomeratic shale and/or interbedded sand and shale. The contacts between sandstone and shale interbeds within the Readstown and the orientation of planar fissility of the shales parallel the slope of the truncated dolomite surface.

The Readstown consists of clay, chert, and sand which are the insoluable constituents present in the Prairie du Chien and which would be expected to be concentrated at a dolomite surface when subjected to subaerial erosion. Recent residual soils developed on the Prairie du Chien surface consist of similar insoluble constituents. Also, the chert present in the Readstown shows varying degrees of weathering and at some localities the entire Readstown has unsorted and incoherent appearance that characterizes a residual or colluvial deposit.

In addition, the Readstown shows evidence of reworking indicated by the presence of interbedded sand and shale layers, the greater concentration of shale in lows or depressions in the dolomite, and the presence of laminated sandstone, siltstone and shale. Such observations were also made by Thwaites (1961) in Wisconsin, Templeton and Willman (1963) in Illinois and Wisconsin, Buschbach (1964) in Illinois and Ostrom (1967; 1970) in Wisconsin. These features (especially laminations) would be unlikely to develop if subsurface solution is assumed responsible for concentrating the insoluble constituents in the contact zone.

Evidence suggesting subsurface solution was observed at only two localities (26 and 36) during this study. Locality 36 has already been discussed by Ostrom (1970), who suggested that both subsurface solution and subaerial erosion were involved in development of the features observed. Locality 26 is a St. Peter quarry having up to 4 m of Readstown sand and shale interbeds below the pure quartz sand of the Tonti Member. The shale interbeds, which average 15 cm thick, are thinly laminated, well lithified and are irregularly undulatory, having a local relief of a meter in a 3 m lateral interval. Such undulatory shale beds may have resulted from adjustment of the Readstown interbeds to subsurface solution of the underlying dolomite. Lack of exposure of the underlying Shakopee Dolomite prevents a more exact interpretation.

In summary, our field observations confirming an unconformity at the base of the Readstown Member largely agree with those made by Buschbach (1964) in Illinois, Thwaites (1961) in Wisconsin, Templeton and Willman (1963) in Illinois and Wisconsin, and Ostrom (1965; 1967; 1970) in Wisconsin.

Conodonts

Additional evidence for an unconformity is furnished by study of the Readstown conodonts (Tables 1-4). Some 27 species were identified, only 3 of which were definitely identifiable as multielement species (Plate 1). Seven of the 42 localities are of Prairie du Chien and were collected for comparison. Seventy-two samples were taken from the 35 Readstown localities. Only 10 localities yielded no conodonts but the majority of Readstown conodonts in this study were taken from 28 samples at 15 localities. The majority of shales from which these samples were taken are relatively pure. A total of 9060 conodonts was recovered.

Ethington and Clark (1971) examined Early and Middle Ordovician conodonts from the Pogonip Group in the "Ibex Area" of western Utah and designated five faunas (Fauna A through Fauna E). This faunal succession has been used as a standard for correlation with other less continuous conodont occurrences.

Fauna C consists primarily of distacodontids but some of the cordylodids of Fauna B occur with Fauna C. Two compound elements, *Loxodus* and *Acanthodus*, also characterize Fauna C. *Drepanodus* Pander and *Oistodus* Pander first appear in Fauna C and continue as important elements throughout the Ordovician. *Paltodus bassleri* Furnish, *Acodus oneotensis* Furnish and "*Oistodus*"? *tri-*

angularis Furnish probably constitute a multielement species common in Fauna C. Less common Fauna C conodonts include *Clavohamulus densus* Furnish, *Paltodus spurius* Ethington and Clark, *Acontiodus propinquus* Furnish, *Acontiodus staufferi* Furnish and *Chosonodina herfurthi* Müller.

Fauna D consists of a wide variety of distacondontids many of which also occur in Faunas C and/or E. *Drepanodus homocurvatus*, *D. suberectus* and *Acontiodus staufferi* occur in Fauna C through Fauna E. Two undescribed species of *Paltodus* and several form species of *Ulrichodina* are restricted to Fauna D as are three elements constituting a multielement species (*Distacodus stola* Lindström, *Acodus* sp. A, and *Acontiodus* sp. A). The remaining elements of Fauna D, including species of *Drepanodus*, *Oistodus*, *Paltodus* and *Scandodus*, persist into Fauna E where they generally decrease in abundance.

Ethington and Clark (1971, p. 76) cited a number of localities in the thick continental margin sequences from which Fauna D conodonts had been documented. Localities cited included the upper Mons and lower Sarbach Formations of Alberta (Ethington and Clark, 1965), the Tie Gulch Member of the Manitou Formation in central Colorado, the El Paso Formation in southeastern Arizona, the subsurface of the Williston Basin (Lochman, 1966), and the Marathon Formation of west Texas. Fauna D conodonts were also described from the midcontinent by Branson and Mehl (1933) and by Furnish (1938), in the Prairie du Chien, immediately beneath the Readstown.

Our collections from the Readstown contain either Fauna C (Table 1) or Fauna D (Table 2) conodonts but never a mixture of the two. The fauna characteristic of the Prairie du Chien unit immediately underlying the Readstown is the same as the fauna that is found in the Readstown. These observations strongly support the interpretation that the Readstown fauna consists entirely of reworked conodonts of the Prairie du Chien Group and raise questions as to whether any of the Readstown fauna is indigenous.

It is recognized that the time difference between the top of the Prairie du Chien and the Readstown could be very minor, but if there were an indigenous Readstown fauna, the species should be common in the Readstown regardless of whether sediment was deposited on Oneota or Shakopee. Such is not the case.

Another observation is the similarity in color and state of preservation between conodonts in the Readstown and those in the Shakopee and/or Oneota. None of the conodonts in this study showed appreciably greater abrasion than any others, although about 10% of all the conodonts were broken beyond recognition. Also, the relative numbers of different species in each sample of the Shakopee or Oneota sampled at 7 localities were the same as the relative abundances for the species in each of the Readstown samples where this unit overlay either Shakopee or Oneota.

Only a single sample (loc. 3) consisted of typical Fauna D conodonts plus non-D fauna species. This sample yielded three denticulate elements, not found in any of the other samples and evidently new. These elements suggest that the fauna of the sample may represent a slightly younger fauna than the typical Fauna D and could represent the only indigenous Readstown conodont. However, this new species may also be construed as just a new addition to the Shakopee fauna.

Because the Readstown contains almost exclusively a conodont fauna of the underlying Prairie du Chien unit, the time span represented by the unconformity at its base cannot be resolved. The St. Peter is bounded by the Shakopee which contains Fauna D conodonts and the Glenwood which contains Fauna 7 conodonts (Sweet and others, 1971). Fauna D corresponds to the middle Canadian (early Arenigian) Series and Fauna 7 corresponds to the Blackriverian stage or middle Champlainian (Llandeilian) Series. The Readstown, therefore, is somewhere between middle Canadian and middle Champlainian in age (Figure 1).

SPECIAL NOTES REGARDING CONODONT SAMPLES

Of special interest was a peculiar crystalline coating or crust found on conodonts from locality 29 (an Oneota sample). This proved to be carbonate apatite (SEM analysis). The cusps of some of the more stout distacodontids were completely encased in a single, large, clear, hexagonal crystal with the C-axis of the crystal coinciding with the axis of the cusp (See Plate 1, No. 37). To our knowledge crusts of this nature have not been reported by previous workers. On other conodonts the crusts were sugary granular, a condition observed on conodonts from some of the other localities as well. Development of such crusts requires a source of carbonate apatite (possibly other conodonts) and the presence of concentrated solutions allowing transfer and slow recrystallization of the carbonate apatite.

Locality 32 (a Readstown sample) yielded only one conodont identified as the oistodid element of a multielement assemblage named *Drepanodus suberectus* by Bergström and Sweet (1966). The assemblage consists of three form species, *Drepanodus suberectus*, *Drepanodus homocurvatus* and *Oistodus inclinatus*. This assemblage has been found in rocks as low as the base of the Glenwood Member. The two drepanodid elements have been found in older Ordovician rocks but the oistodid element has not. The single specimen found in this sample was taken from a 15 cm brown sand layer overlain by ½ m of sandstone, 15 cm of dark brown siltstone and about 15 cm of Platteville Formation. The specimen is considered to be a contaminant slumped from the dark brown siltstone layer assumed to be the Glenwood.

Samples from locality 34 contain conodonts characteristic of Fauna 8 of Sweet and others (1971). The samples were taken from green shaly sand overlying the Prairie du Chien Dolomite in a ravine. The conodonts are assumed to have washed down the ravine from the overlying Platteville and to have been incorporated into the sediment that was sampled.

Thirty six Readstown samples (locality 32 and 34 excluded) from 23 localities contain conodonts belonging to Faunas C and D Ethington and Clark (1971). The two faunas were never found mixed within the same sample. Five of the samples were taken from localities where the Readstown directly overlies the Oneota Dolomite which was cited by Ethington and Clark (1971, p. 73) as containing Fauna C conodonts (locality 1, 10, 18, 20 and 39). Each of these five samples contained conodonts characteristic of Fauna C. The remaining 31 Readstown samples from 18 localities all overlie the Shakopee Dolomite which Ethington and Clark (1971, p. 76) cited as possessing Fauna D conodonts. All of the 31 samples contained Fauna D conodonts.

Summary

Studies of thick marginal sedimentary sequences in North America have led to the recognition of a succession of five conodont faunas (labeled Fauna A through E) for the Lower Ordovician. These faunal assemblages have allowed correlation with incomplete sections in the midcontinent (Ethington and Clark, 1971). The youngest conodonts recovered from the Readstown Member of the St. Peter Sandstone in Wisconsin correspond to the assemblage recognized as Fauna D (Ethington and Clark, 1971). The Shakopee Formation, which directly underlies the Readstown, also contains Fauna D conodonts suggesting that the Shakopee and Readstown are of comparable Lower Orodovician age. The similarity in age of the two units raises questions regarding (1) the materials and even the presence of the generally accepted large-scale unconformity between the Shakopee and basal St. Peter Sandstone and (2) the placement of the Lower Ordovician - Middle Ordovician boundary at the Shakopee-St. Peter contact. The next conodont bearing unit above the Readstown is the Glenwood Member which contains Middle Orodovician conodonts of Fauna 7 as defined by Sweet and others (1971). Thus, several faunal assemblages (Fauna E of Ethington and Clark and Faunas 1 through 6 of Sweet and others) are absent in the Wisconsin Ordovician section.

CONCLUSIONS

1. The Readstown, in Wisconsin, unconformably overlies the Prairie du Chien and seems to represent a residuum which developed on a subaerial erosion surface and which shows some evidence of partial subaqueous reworking.

2. Evidence strongly suggests that the conodonts of the Readstown in Wisconsin are reworked from the underlying Prairie du Chien. Readstown conodonts overlying the Oneota Formation belong to Fauna C and Readstown conodonts overlying the Shakopee Formation belong to Fauna D.

3. The age of Readstown cannot be determined by examining the conodonts because the conodonts are reworked.

4. The basal St. Peter in Wisconsin may indeed be early Ordovician but because the conodonts are reworked the time span represented by the unconformity between the Prairie du Chien and St. Peter cannot be determined.

ACKNOWLEDGMENTS

Dr. M.E. Ostrom, Wisconsin State Geologist, helped in many ways. Lloyd Pray criticized an earlier draft of this manuscript. Field research during the summer of 1976 was financed by grants from Exxon Oil Company through the Department of Geology & Geophysics, University of Wisconsin-Madison.

SYSTEMATIC PALEONTOLOGY

DREPANODUS n. sp.

Figure 3 No. 20-23

Remarks.--Bergström and Sweet (1966, p. 330) studied Middle Orodovician conodonts of Kentucky and recognized a multielement assemblage consisting of *Drepanodus suberectus* (Branson and Mehl), *Drepanodus homocurvatus* Lindström and *Oistodus inclinatus* Branson and Mehl. Our Lower Ordovician samples have not yielded *Oistodus inclinatus* (except one leak) so the multielement assemblage of Bergström and Sweet cannot be applied here. The two drepanodid elements do occur rather abundantly in our samples and show considerable variation in form. Bergström and Sweet (1966, p. 332) interpreted these two form-species to be completely intergradational because the wide variation expressed by each prevented division into mutually exclusive subordinate groups. Berström and Sweet also observed that these two species occur together in rocks older than the earliest known occurrence of *Oistodus inclinatus*. They suggested that the drepanodid elements in these older strata may represent homeomorphs of younger elements which occur with *Oistodus inclinatus* in the multielement assemblage *Drepanodus suberectus*.

The two drepanodid elements usually occur together in the samples and are assumed to represent an early evolutionary stage of the multielement assemblage which eventually developed an oistodid element.

The ratio of homocurvatid to suberectid elements in samples is 562:65. This is nearly the same as the ratio between the drepanodid elements (6,106:592) of Bergström and Sweet's three element species.

The form-species *D. homocurvatus* shows considerable morphological variation and can superficially appear quite similar to some other species such as *Drepanodus amoenus*, *Drepanodus arcuatus* and *Drepanodus planus*. *D. homocurvatus* can be differentiated from *D. amoenus* by the phrygian-cap-like basal cavity of *D. amoenus* and the straight or only slightly convex basal margin found in *D. homocurvatus*. *D. arcuatus* differs from *D. homocurvatus* in having sub-parallel oral and basal-anterior margins. *D. planus* has a sharper anterobasal angle, shallower basal cavity and more flattened sides than *D. homocurvatus*.

Diagnostic features of the form-species *D. homocurvatus* include: a base extended both anteriorly and posteriorly although in some specimens the anterior extension is most prominent; a cusp which may have one lateral side flattened and depressed at the edges; a blade that is thin, long and curved throughout its length; a base that is flaired laterally more on one side than the other; and a basal cavity that is moderately deep, wide and roughly triangular in outline.

Specimens of the form-species *Drepanodus suberectus* are distinguished by the nearly erect, symmetrical, sharp-edged cusp and the base that is flaired in all directions.

Drepanodus homocurvatus and *Drepanodus suberectus* were found by Ethington and Clark to first occur in Fauna C and to continue as important elements throughout the Ordovician.

Occurrence.--562 specimens of the homocurvatid element from localities 2, 3, 5, 6, 9, 12, 14, 15, 20, 25, 26, 32, 34, 35, 36, 38 and 40; 65 specimens of the suberectid element from samples 3, 5, 6, 14, 15, 20, 23, 25, 29, 32 and 36.

Repository.--UW 1677/6.

NEW GENUS

Plate 1. No. 44, 45

Diagnosis.--A compound, asymmetrical, laterally compressed element with one or three denticles and no prominent cusp. Anteroposterior length at base is equal to or slightly greater than the height. Lower outline is triangular due to lateral deflection of the anterior margin. The anterolateral length of the basal outline is the shortest of the three sides. The basal cavity is shallow but conical with an anteriorly directed, sharp point near the anterior margin. In specimens with the single denticle, the denticle appears to have formed by folding a cusp down, posteriorly onto the base forming a sharp angle between the upper margin and the lower edge of the denticle. The denticle consists of white matter and the base is hyaline. The axes of the denticles of all the specimens parallel or subparallel the plane of the base.

Remarks.--The species occurs in the middle and upper part of Fauna D and in Fauna E in the El Paso, Jefferson City and West Spring Creek Formations in Texas, Missouri and Oklahoma.

Occurrence.--3 specimens from locality 3.

Repository.--UW 1677/21.

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APPENDIX: SAMPLE LOCALITIES

1(BL-DR). Roadcut 3.2 km south of Daleyville on Drumon Valley Road, Blanchardville quadrangle, NE ½, NW ¼, Sec. 30, T. 5 N., R. 6 E. (5 cm of Readstown).

2(BL-F). Roadcut 0.8 km west of Foreward on Dane County Highway A, Blanchardville quadrangle, SE ¼, NE ¼, Sec. 22, T. 5 N., R. 6 E. (Shakopee and ½ m of Readstown).

3(BL-RQ). Ryan quarry 2.7 km NW of Hollandale on State Highway 191, Blanchardville quadrangle, NE ¼, Sec. 24, T. 5 N., R. 5 E., Flint (1956, p. 406) described this locality (Shakopee and 5 cm of Readstown).

4(BL-SM). Roadcut 4.8 km south of Blanchardville, just south of Saw Mill Creek on State Highway 78, Blanchardville quadrangle, NE ¼, SE ¼, Sec. 2, T. 3 N., R. 5 E. Flint (1956, p. 404) described this locality (several cm of Readstown).

5(BM-MC). Roadcut 3.2 km northwest of Mt. Horeb on Dane County Highway JG, Blue Mounds quadrangle, SE ¼, SW ¼, Sec. 35, T. 7 N., R. 6 E. (several cm of Readstown).

6(BM-TK). Sandpit on the Tom Keep farm 0.8 km south of the junction of Dane County Highway JG and North Street, Blue Mounds quadrangle, NW ¼, SE ¼, Sec. 34, T. 7 N., R. 6 E. (Shakopee and 45 cm of Readstown).

7(BZ-CH). Roadcut 1.2 km southwest along Coulter Hollow road from the junction with Richland county road A, Boaz quadrangle, W ½, Sec. 7, T. 11 N., R. 1 W. (several cm of Readstown).

8(BO-CR). Roadcut 3.2 km southwest of Castle Rock, Boscobel quadrangle, SW ¼, NE ¼, Sec. 1, T. 6 N., R. 2 W. (several cm of Readstown).

9(BZ-BS). Roadcut 0.2 km west of Bosstown on U.S. Highway 14, Boaz quadrangle, N ½, NE ¼, Sec. 33, T. 11 N., R. 2 W. (Shakopee).

10(BZ-BT). Roadcut 1.2 km west of Bosstown on U.S. Highway 14, Boaz quadrangle, NW ¼, NW ¼, Sec. 33, T. 11 N., R. 2 W. (Oneota).

11(BZ-RG). Roadcut 2.0 km east of Rolling Ground, Boaz quadrangle, center, Sec. 22, T. 10 N., R. 3 W. (4 m of slumped St. Peter and Readstown).

12(BZ-SH). Roadcut east of Rolling Ground at the intersection of State Highway 171 and sleepy Hollow road, Boaz quadrangle, NW ¼, SW ¼, Sec. 22, T. 10 N., R. 3 W. (½ m of Readstown).

13(Cp-Kp). Roadside 1.2 km northeast of Table Bluff on Dane County Highway KP, Cross Plains quadrangle, SE ¼, NW ¼, Sec. 21, T. 8 N., R. 7 E. (several cm of Readstown).

14(Cp-P). Roadcut 0.8 km north of U.S. Highway 151-18 on Dane County Highway P, south of Klevenville, Cross Plains quadrangle, NE ¼, SW ¼, Sec. 9, T. 7 N., R. 7 E., (½ m of Readstown).

15(Cp-PB). Roadcut 4 km south of Cross Plains, 1.6 km northeast of Pine Bluff Observatory, Cross Plains quadrangle, NW ¼, SW ¼, Sec. 15, T. 7 N., R. 7 E. (several cm of Readstown).

16(Cp-TL). Irrigation ditch 1.2 km north of White School along Timber Lane, Cross Plains quadrangle, SE ¼, SE ¼, Sec. 6, T. 6 N., R. 8 E. (several cm of Readstown).

17(E-E). Roadcut 0.8 km east of Ellenboro on State Highway 81, Ellenboro quadrangle, NW ¼, NW ¼, Sec. 34, T. 4 N., R. 2 W. (½ m of Readstown).

18(GM-B). Roadcut west of Rising Sun on County Road B, dirt road north toward southwest Prairie Church, Gays Mills quadrangle, NE ¼, SE ¼, Sec. 20, T. 11 N., R. 5 W. (several cm of Readstown).

19(GM-F). Roadcut 2.4 km northeast of Fargo on State Highway 27, Gays Mills quadrangle, NW ¼, NE ¼, Sec. 2, T. 11 N., R. 5 W. (Shakopee).

20(GM-RD). Type locality of the Readstown Member (Ostrom, 1967), roadcut 8.6 km northwest of Readstown on U.S. Highway 14, Gays Mills quadrangle, W ½, NE ¼, Sec. 27, T. 12 N., R. 4 W. (several m of slumped St. Peter and Readstown).

21(J-H). Sandpit 0.8 km south of Hanover, Janesville quadrangle, S ½, Sec. 14, T. 2 N., R. 11 E. (several cm of Readstown).

22(Mu-Hi). Roadcut 4.8 km west of Highland, Muscoda quadrangle, SE ¼, Sec. 26, T. 7 N., R. 1 W. (several cm of Readstown).

23(NG-K). Roadcut 0.8 km southeast of Mt. Pleasant across the road from the Kvamme Farm, New Glarus quadrangle, SW ¼, SW ¼, Sec. 23, T. 5 N., R. 7 E. (1 m of Readstown).

24(M-BS). Quarry 0.8 km south of Burke Station, Madison quadrangle, NE ¼, SE ¼, Sec. 26, T. 8 N., R. 10 E. (Shakopee).

25(M-Mc). Housing development excavation at the end of McKenna Boulevard, west and down slope from a Platteville quarry 0.8 km north of Dane County Highway PD, Madison quadrangle, Sec. 1, T. 6 N., R. 8 E. (1 m of Readstown).

26(M-ML). Quarry at the intersection of Milwaukee Street and I-90, Madison quadrangle, SW ¼, Sec. 2, T. 7 N., R. 10E. (1 to 4 m of Readstown).

27(M-W). Ravine 3.2 km north of Maple Grove School in Windsor township, Madison quadrangle, Sec. 13, T. 9 N., R. 10 E. (several cm of Readstown).

28(MH-K). Quarry 0.4 km west of Grant County Highway K, just north of the Grant River, 3.2 km northwest of Lancaster, Mount Hope, and Fennimore quadrangles, NW ¼, SW ¼, Sec. 28, T. 5 N., R. 3 W. (several cm of Readstown.

29(Mu-c). Quarry 2.0 km southwest of Centerville, Muscoda quadrangle, SE¼, SE¼, Sec. 11, T. 6 N., R. 1 W. (Shakopee).

30(Mu-C). Stream bank 3.2 km northwest of Centerville, Muscoda quadrangle, NW ¼, SW ¼, Sec. 2, T. 6 N., R. 1 W. (1 m of Readstown).

31(NG-Mv). Quarry 0.4 km north of Mt. Vernon on State Highway 92, New Glarus quadrangle, SE ¼, NW ¼, Sec. 34, T. 6 N., R. 7 E. (Shakopee).

32(NG-MV). Roadcut on Dane County Highway G, 0.3 km west of Mt. Vernon, New Glarus quadrangle, NW ¼, NW ¼, Sec. 3, T. 5 N., R. 7 E. This roadcut was described by Ostrom (1965) (30-60 cm of Readstown).

33(OK-AG). Quarry, junction of Winnebago County Road AG with State Highway 110, Oshkosh NW quadrangle, SW ¼, Sec. 36, T. 20 N., R. 15 E. (Shakopee).

34(P-R). Natural ravine 2½ miles east of Rockville, Potosi quadrangle, SE ¼, SW ¼, Sec. 17, T. 3 N., R. 2 W. (~ 1 m of Readstown).

35(P-RV). Roadcut 4.0 km east of Rockville on Grant County Road B, Potosi quadrangle, NW ¼, SW ¼, Sec. 17, T. 3 N., R. 2 W. (5 to 15 cm of Readstown).

36(Pc-Pc). Roadcut 2.4 km northeast of Prairie du Chien on State Highway 27, Prairie du Chien quadrangle, NE ¼, Sec. 29, T. 7 N., R. 6 W. This locality was described by Ostrom (1970, p. 82) (~ 1 m of Readstown).

37(R-NN). Roadcut along gravel road 0.2 km west of Winnebago County Road NN, 1½ miles southwest of the Village of Rush Lake, Ripon quadrangle, SW ¼, SW ¼, Sec. 29, T. 17 N., R. 14 E. (Shakopee).

38(R-S). Sandpit due south of Starr School, 0.4 km south of State Highway 116, Ripon quadrangle, NW ¼, SE ¼, Sec. 3, T. 17 N., R. 14 E. (10 cm of Readstown).

39(Sp-No). Quarry 4.8 km north of Sun Prairie at the end of a dead end road called Norway Road, Sun Prairie quadrangle, SE ¼, SE ¼, Sec. 18, T. 9 N., R. 11 E. (8 cm of Readstown).

40(ST-A). Roadcut 0.8 km southwest of Annaton along Grant County Road E, Stitzer quadrangle, N ½, SE ¼, Sec. 18, T. 5 N., R. 1 W. (several cm of Readstown).

41(V-VQ). Small sandpit 1.6 km southeast of Viroqua on Vernon County Road J, Viroqua quadrangle, NE ¼, NW ¼, Sec. 8, T. 12 N., R. 4 W. (several cm of Readstown).

42(WA-O). Small sandpit 4.8 km east of Eastman on State Highway 179, 0.8 km east of Otter Creek, 50 meters north on dirt road joining State Highway 179, SW ¼, SE ¼, Sec. 9, T. 8 N., R. 5 W. (several cm of Readstown).

Table 1. The following conodonts are present in the Readstown where the Readstown overlies the Oneota*. This includes the same species as the assemblage of Fauna C of Ethington and Clark (1971). Localities of occurrence noted in parenthesis.

Cordylodus angulatus Pander (39)

Acodus oneotensis Furnish (1, 10, 18, 20, 39)

- oistodid element (18)
- paltodid element (1, 10, 20, 39)
- scolopodid element (1, 20, 39)

Loxodus bransoni Furnish (20, 39)

Clavohamulus densus Furnish (20)

Acontiodus iowensis Furnish (20, 39)

Acontiodus propinquus Furnish (39)

Oneotodus simplex Furnish (39)

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*Species are also present in the Oneota at localities 9, 24, 29, 31, and 39

Table 2. The following conodonts are present in the Readstown where the Readstown overlies the Shakopee*. This includes the same species as the assemblage of Fauna D of Ethington and Clark (1971). Localities of occurrence noted in parenthesis.

Acodus stola Lindström (3, 23, 38)

Drepanodus conulatus Lindström (3, 5, 14, 23, 25, 28)

?Drepanodus sculponea Lindström (3, 25)

Paltodus sp. (3, 5, 6, 14, 25, 26, 32, 35, 36, 40)

Ulrichodina deflexus Furnish (2, 6, 12, 14, 15, 25, 32, 36)

Ulrichodina prima Furnish (2, 3, 5, 6, 14, 15, 25, 32, 35)

Ulrichodina wisconsinensis Furnish (3, 5, 14)

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*Species present in the Shakopee at localities 2, 3, 6, 14, 25, 32, 36 and 37

Table 3. The following conodonts range through zones C, D, and E of Ethington and Clark (1971) and occur in the Readstown at the localities indicated.

Acontiodus staufferi Furnish (2, 3, 5, 14, 15, 17, 20, 25, 32, 40)

Drepanodus subarcuatus Furnish (2, 3, 5, 12, 14, 15, 20, 23, 25, 26, 32, 35, 36, 39, 40)

Drepanodus n. sp. (2, 3, 5, 12, 14, 15, 20, 23, 25, 26, 32, 35, 36, 38, 40)

(Drepanodus homocurvatus

and Drepanodus suberectus)

New Genus (3)

Table 4. The following conodonts range through zones D and E, according to Ethington and Clark (1971) and occur in the Readstown at the localities indicated, and in the Shakopee.

Drepanodus parallelus Branson and Mehl (2, 5, 6, 15, 23, 25, 32, 36)

Oistodus sp. aff. O. forceps Lindström (3, 25)

Oistodus sp. aff. O. inaequalis Pander (2, 3, 5, 6, 14, 15, 20, 23, 25, 32, 36, 38)

Scolopodus sp. aff. S. cornutiformis Branson and Mehl (2, 3, 5, 26)

Scolopodus quadraplicatus Branson and Mehl (2, 3, 4, 5, 6, 12, 14, 15, 17, 23, 25, 26, 27, 32, 36)

Scolopodus triplicatus Ethington and Clark (2, 3, 5, 6, 12, 14, 15, 17, 23, 25, 26, 32, 36)

Scolopodus triangularis Ethington and Clark (25, 32, 36, 40)

Scandodus furnishi Lindström (2, 3, 5, 6, 15, 25)

LATE PLEISTOCENE AND HOLOCENE VERTEBRATE FOSSIL RECORD OF WISCONSIN

by

Robert M. West[1] and John E. Dallman[2]

ABSTRACT

Wisconsin's late Pleistocene and Holocene vertebrate fossil record has been investigated sporadically since before the Civil War. Much material collected prior to the 1950's has been lost, and records on what remains generally are poor. More recently collected specimens have better data and permit compilation of faunal lists and formulation of some general paleoecologic conclusions.

Vertebrate fossils have been found in Pleistocene sediment, post-glacial streams, ponds and lakes, and fissures in Paleozoic carbonate rocks. Occurrences in post-glacial stream, pond and lake sediments hold substantial promise for articulated larger mammals within a stratigraphic context, while fissures are excellent prospects for the collection of large population samples of smaller vertebrates.

INTRODUCTION

Late Pleistocene and Holocene vertebrate fossils have been known from Wisconsin since before the Civil War and were first published by Hall and Whitney (1862) who reported large mammal remains from Blue Mounds, west of Madison, as well as other areas of southwestern Wisconsin and adjacent parts of Illinois and Iowa. Other specimens were reported through the early part of the Twentieth Century; these are summarized by Hay (1923) who listed specimens held by museums, universities and individuals. Most of these materials came from the southern and western parts of the state.

Repositories were not always indicated by Hay, but the Milwaukee Public Museum, the University of Wisconsin and the Smithsonian Institutions are known to have possessed many of the specimens. Over the course of the last century the rate of loss has been high. Many causes were responsible for the disappearances: the 1878 fire at old Science Hall in Madison, inadequate curatorial practices, and individual negligence. The result is that a substantial portion of the records listed by Hay (1923) cannot be confirmed, either for taxonomic identification or for locality information. In addition, the quality of locality data accompanying the remaining specimens in the older collections is generally inadequate by current standards.

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The specimens reported by Hay (1923) are mainly of large mammals (proboscideans, artiodactyls and carnivores), though some rodents are recorded from southwestern Wisconsin. A lake trout was collected near Menomonie in Dunn County (Hassakof, 1916). The collecting techniques of the time did not promote the discovery of remains of smaller vertebrates.

During the middle part of the Twentieth Century (1920's to 1960's) late Pleistocene and Holocene vertebrates were collected sporadically within Wisconsin, but very little was published. A modest number of specimens were catalogued into the collections of the Milwaukee Public Museum and the University of Wisconsin during this interval. Typical finds were of isolated bones or teeth of large mammals, included in glacial deposits, and usually encountered in the process of large-scale excavation. Most of this material is still extant, so the identifications can be confirmed, but locality data tends to be poor. We are not aware of any systematic programs anywhere in the state for following up on these discoveries other than a 1954 paper by Palmer describing a Holocene bison occurrence excavated in 1936 at Interstate Park in Polk County.

Over the past decade interest in the faunas of the Wisconsin late Pleistocene and Holocene has increased, and several controlled investigations have been undertaken. One of us (Dallman, 1968, 1969 and unpublished) has excavated several proboscideans and a giant beaver near Madison, gathering detailed stratigraphic and paleoecologic data in the process. Palmer (1974, and unpublished) has been examining caves in southwestern Wisconsin. Several new sites, fissures and cavities in porous Paleozoic limestone of the Driftless Area, have produced substantial numbers of specimens of smaller vertebrates and molluscs. This work was initiated by D.L. Rasmussen, then of the University of Kansas, and has been continued as graduate research projects by S. Theiling and R. Foley of the University of Iowa. The Milwaukee Public Museum opened a third small vertebrate locality near Cave of the Mounds in 1977. Teller-Marshall and Bardack (1978) recently reported on a suite of fishes collected in 1966 by J. Emielity of the Milwaukee Public Museum in a sewer excavation in Milwaukee. J. Stoltman of the Department of Anthropology. University of Wisconsin-Madison, is currently investigating a mastodon site for indications of possible human activity. No clear evidence for men killing or using these animals has been reported yet for Wisconsin.

This recent work is producing specimens with adequate geologic information, associated floral and faunal data for paleoecologic analysis, and radiometric dates. Thus it is now becoming possible to correlate Wisconsin localities with better known surrounding areas, to analyze the changing glacial and post-glacial environments, and, to a limited extent, be able to predict promising areas for further investigations.

VERTEBRATE LOCALITIES

The geologic setting of Wisconsin, with its substantial cover of glacial deposits, has had an effect on the Pleistocene and Holocene fossil record. Most, if not all, of the state has been covered by ice within the past several tens of thousands of years. The most recent ice retreat was not more than 10,000 to 13,000 years ago. The deposits left during this last part of the Wisconsinan age have concealed earlier Pleistocene animal remains in all but the Driftless Area in the southwestern part of the state. Thus post-glacial environments have been generally present for only some 10,000 to 13,000 years.

As can readily be seen on the distribution maps (Figs. 1, 2, and 3), Wisconsin's late Pleistocene and Holocene vertebrate localities are concentrated in the southern part of the state. Sixty-six of 78 localities identified at this time are in the three tiers of counties immediately north of the Illinois state line. Several reasons for this pattern may be advanced: (1) The population centers and areas of longest intensive human habitation are in the south. (2) Milwaukee and Madison, the primary cultural and educational centers (which support active professional scientists), are in this region. (3) The southeastern part of the state was freed from glaciation sooner than the northern part, permitting earlier and perhaps denser vertebrate populations.

Three primary environments have preserved most of the late Pleistocene and Holocene vertebrates of Wisconsin. The least informative is glacial deposits; many fragments of animals (Fig. 4) were caught up in the moving glacial materials (both ice and rock), moved from their original location, abraided, and deposited at the time of glacial retreat. Other fossils are parts of animals that lived on the broad glacial outwash plains and were disarticulated and moved by the strong water action. These specimens have no stratigraphic context, and thus are of relatively little geological utility, although they do provide general distributional records, especially for larger vertebrates. Most of the proboscidean and many of the artiodactyl records are from such glacial deposits.

Post-glacial lake and stream deposits produce specimens preserved approximately where the animals died, and occasionally in articulation. These are the most useful large-vertebrate sites within the state, and include both mammals and fish.

The more important Wisconsin large-mammal sites include three proboscidean localities and one Bison locality. Dallman's (1968) excavation of two partially articulated mastodon specimens near Deerfield in Dane County produced significant paleoecological data. The specimens were buried beneath four feet of peat and two feet of clay along the shore of a post-glacial lake that apparently was open water until at least 9,000 years ago. Radiocarbon dates of 9480 ± 100 years of B.P. and 9630 ± 110 years B.P. (Table 1) were derived directly from the mastodon bones. In an adjacent excavation, in the same lake just 100 yards from the first two, a third mastodon (Fig. 5) lay between two dated strata: sticks carried by the modern species beaver (Caston canadensis) and deposited in the old lake bottom were dated at 10,905 ± 105 years B.P.; a spruce log encountered four feet deeper in the same pit gave a date of 13,120 ± 130 years B.P. More than 14 feet of clay underlay the bones. The sediments which held the mastodon remains also contained numerous molluscs and pollen grains, permitting reconstruction of the burial site as lake surrounded by a spruce-dominated boreal forest.

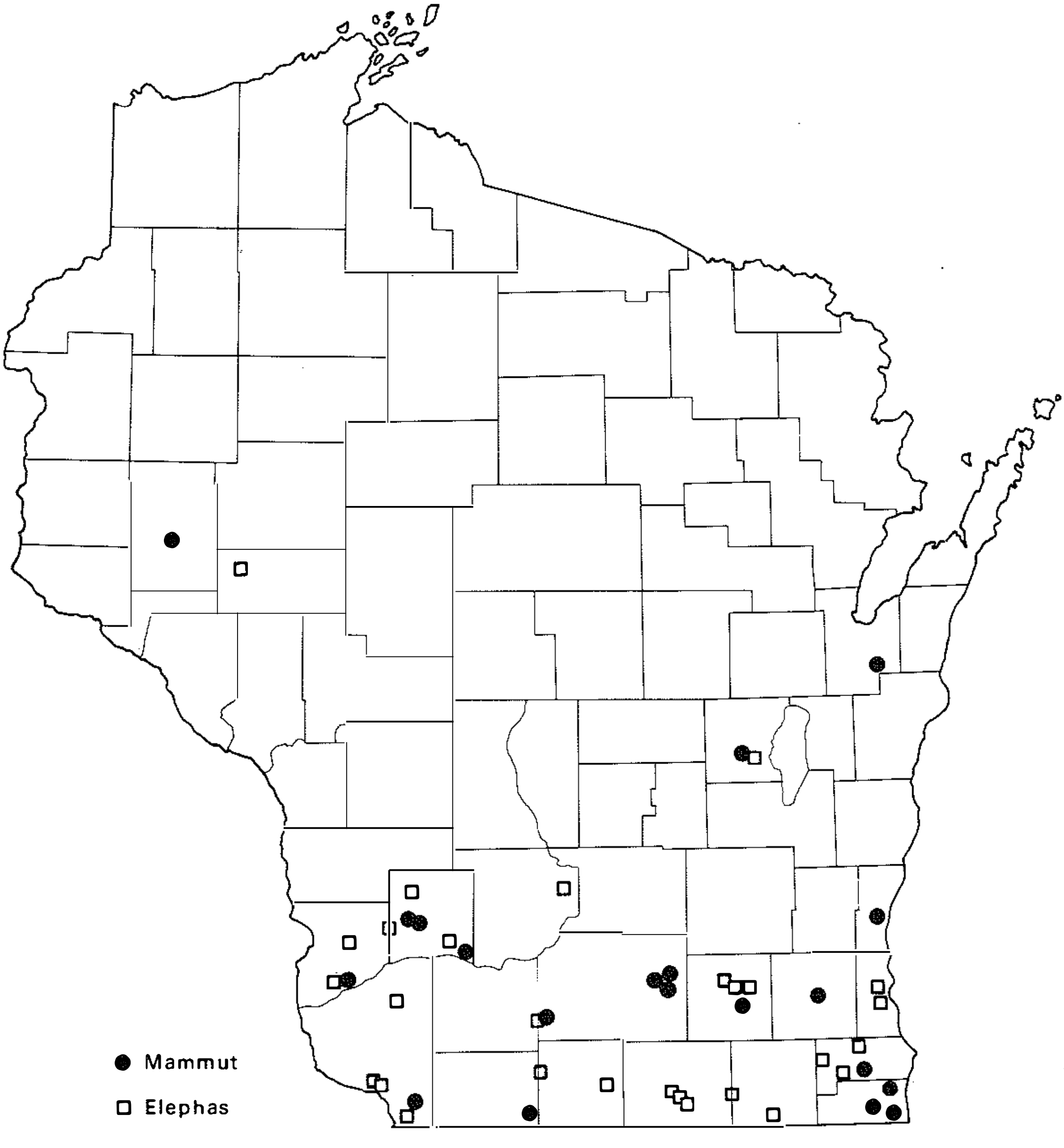

Figure 1. Distribution of proboscidean localities.

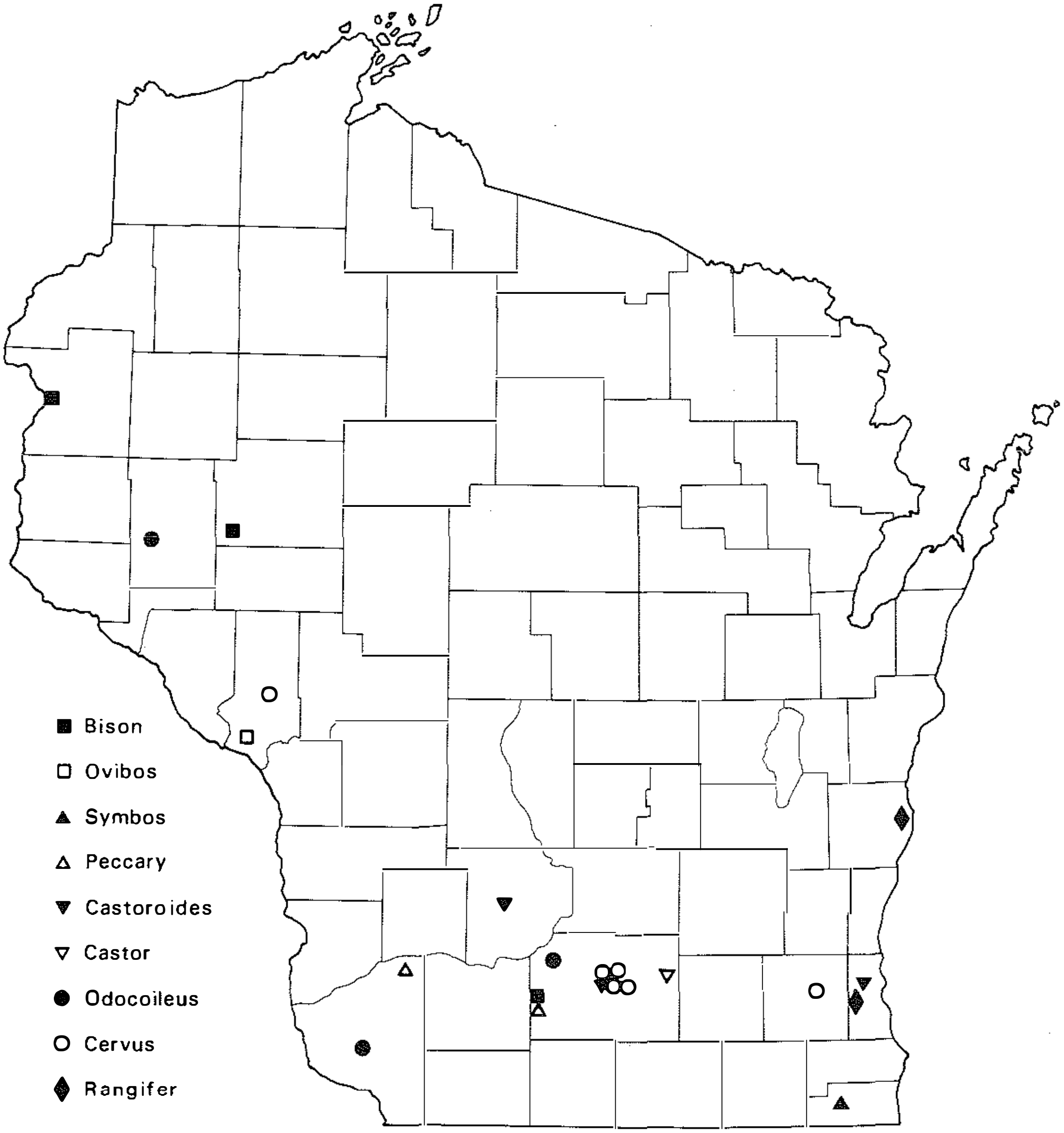

Figure 2. Distribution of large mammal localities.

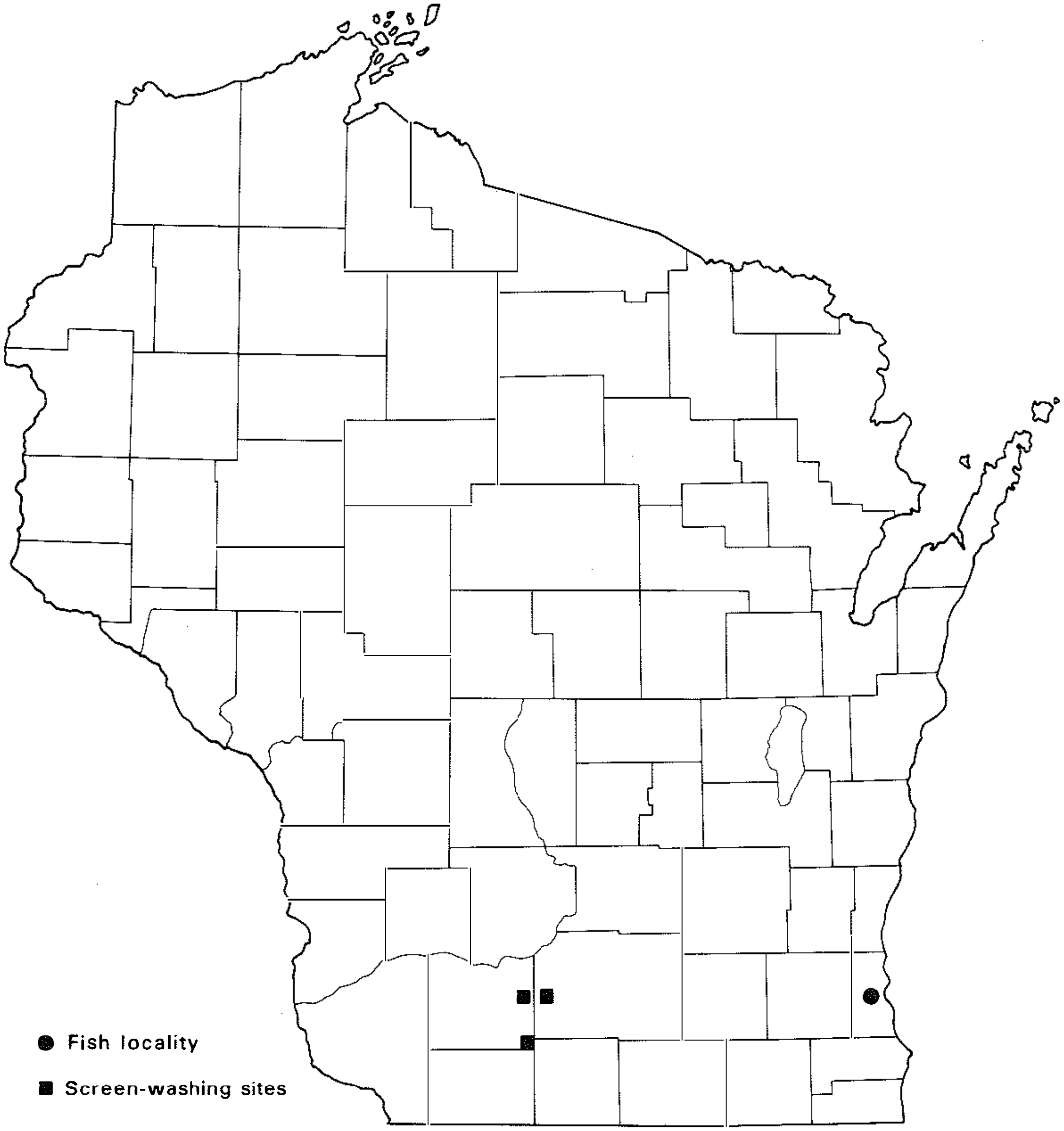

Figure 3. Distribution of small mammal and fish localities.

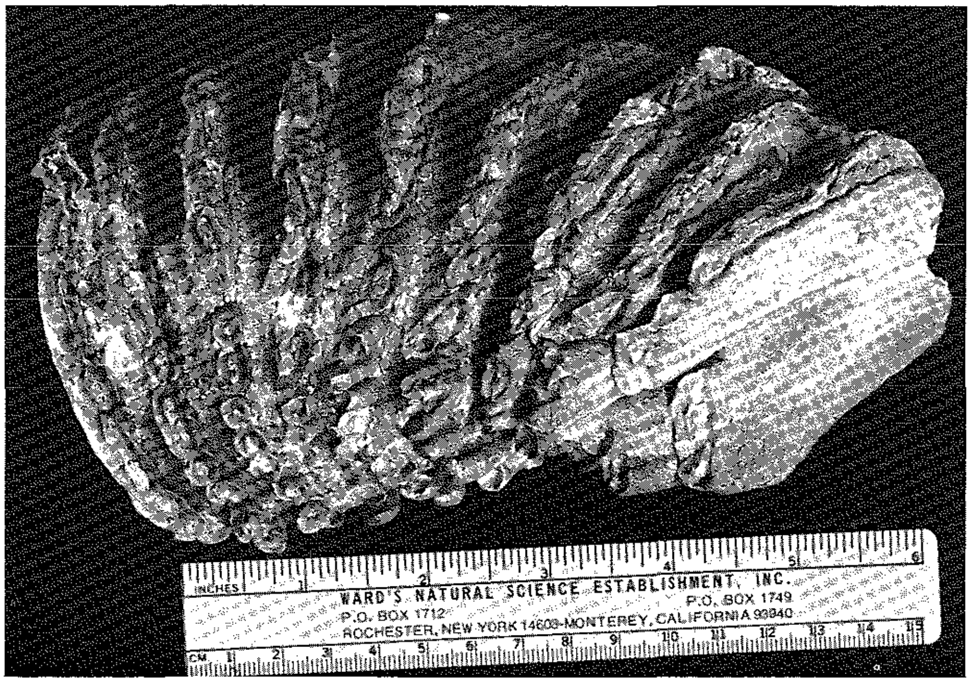

Figure 4. MPM 2, a mastodon molar from Fond du Lac, typical of finds in glacial drift.

Study of the second and third proboscidean localities, near Lake Mills and Jefferson in Jefferson County, is not complete. Each of these sites yielded an incomplete mammoth skeleton occurring under conditions virtually identical to those of the Deerfield mastodons. The bones are in clay rather than in till (the usual matrix for mammoth remains), suggesting that these animals likewise were buried on the fringe of a post-glacial lake. Molluscan remains were not recovered from the matrix surrounding the mammoth remains. Radiocarbon dates (Table 1) and the similar stratigraphic associations suggest that these mammoths were contemporary with the Deerfield mastodons.

A single complete skull with mandibles of the giant beaver, *Castoroides ohioensis* (Fig. 6). was discovered in 1968 during construction of a fish pond near Hope, 10 miles east of Madison (Dallman, 1969). The skull was not discovered until after its removal so that its original location can only be estimated at 4 to 6 feet below the surface in a marly clay deposit somewhat similar to the deposits encountered in the mastodon excavations. No radiocarbon dates were attempted because of the disturbed situation, but the date is presumed to be approximately 10,000 years B.P. Two other fragmentary mandibles of *Castoroides ohioensis* are recorded from Wisconsin, one from the Lincoln-Estabrook area, Milwaukee County and another from Plain, Sauk County.

The Interstate Park (Polk County) *Bison* locality produced approximately 300 *Bison occidentalis* specimens from a depth of three to four feet in a post-glacial peat bog (Palmer, 1954). Unlike the proboscidean localities, paleo-Indian artifacts were found in direct association with the *Bison* bones, but no radiocarbon dating was done. The occurrence is one of the relatively larger known samples of post-glacial *Bison*. The site is no longer available due to development of the park.

A recent study (Teller-Marshall and Bardack, 1978) considered 77 post-glacial fish specimens from a sewer excavation in Milwaukee. An assemblage of eight species was collected 45 to 50 feet below the present ground surface, and 40 to 45 feet above the present level of Lake Michigan. A radiocarbon date on associated wood is 7750 ± 125 years B.P., making this the oldest known fish locality in the Lake Michigan Basin. Molluscs and plant remains occur along with the fish, but they have not yet been thoroughly studied. The species present, plus the nature of the sediment, indicates deposition in a slowly moving prairie stream, well above the level of glacial Lake Chippewa. The completeness of the specimens at this site attests to the calm conditions at the time of death and during the subsequent rapid burial. This site is also now unavailable for further excavation.

The third fossiliferous depositional environment seems to be limited to the Driftless Area where porous Paleozoic carbonate rock is exposed at the surface without a veneer of obscuring drift. Fissures, sink holes and caves in this carbonate rock apparently have been open through much of the late Pleistocene and on into the Holocene, so many have been natural traps which have preserved stratified sequences of Pleistocene life.

Figure 5. UWZP 20500, a mastodon recovered from Deerfield , Wisconsin, representative of specimens found in or adjacent to post-glacial lakes. Skull 89 cm in length.

Table 1

Ages of Wisconsin Late Pleistocene and Holocene Vertebrate Localities

Site		Date, Years B.P.	Laboratory Reference
Lost River Sink	Level 3	2,720 ± 390	Teledyne Isotopes, I-6622
	Level 4	3,970 ± 240	Teledyne Isotopes, I-6623
Milwaukee Fish		7,750 ± 125	Teledyne Isotopes, I-9545
Deerfield Mastodons		9,480 ± 100	Wisconsin - 265
		9,630 ± 110	Wisconsin - 267
		10,095 ± 105	Wisconsin - 424
		13,120 ± 130	Wisconsin - 431
Lake Mills Mammoth		9,065 ± 90	Wisconsin - 704
Moscow Fissure		17,050 ± 1,500	Teledyne Isotopes, I-10,153

Figure 6. UWZP 20000, skull of the giant beaver discovered in post-glacial sediments near Hope, Wisconsin. Maximum skull length, 28 cm.

So far, three places have produced vertebrate fossils: Moscow Fissure, near Blanchardville; Lost River Sink, near Blue Mounds; and an unnamed fissure near Cave of the Mounds. All of these are in Iowa County, at the eastern edge of the Driftless Area, and all yield abundant small-vertebrate remains (Fig. 7) when the sand and clay fillings of the cavities are wet-sieved through screen-bottomed washing boxes.

These microvertebrate sites have produced a much greater diversity of vertebrates than have any of the large vertebrate sites. Moscow Fissure has produced 20 mammalian species, two of which are rodents presently restricted to tundra areas, as well as snakes, frogs and salamanders. Lost River Sink has yielded 27 mammalian species, plus toads, frogs, snakes and lizards. Cave of the Mounds, which has been worked only in a preliminary fashion, has produced four mammals, a bird and a turtle. These abundant specimens already in hand now permit detailed comparisons of Moscow Fissure and Lost River Sink with similar fissure localities elsewhere in North America. The center for sympatry for Lost River Sink is modern southwestern Wisconsin; the fauna is a modern one, which corresponds well with radiocarbon dates on bone of 2720 ± 390 years B.P. and 3970 ± 1500 years B.P. On the other hand, Moscow Fissure gave a date of 17,050 ± 1500 years B.P. and has a zone of sympatry in the area of the southern part of the Ontario-Manitoba boundary, excluding the two species of tundra rodents. The presence of such old fauna and indications of rodent endemism in this assemblage show that the fissures have great potential for pushing the Wisconsin vertebrate record well back into the Wisconsinan and for revealing the nature of community evolution during the Wisconsinan glacial advances and retreats.

DISCUSSION

The diversity of vertebrates already recovered from the Wisconsin late Pleistocene and Holocene is rather high (Tables 2 and 3), especially when compared with geologically similar Michigan, which has been worked much more consistently than has Wisconsin. However, the total number of specimens, particularly of larger vertebrates, is much higher for Michigan. In both Michigan and Wisconsin much of the diversity comes from the few screen-washing sites, and these, other than Moscow Fissure, tend to be considerably younger geologically than the large-mammal sites. Two Michigan sites (Fenton Lake, 1000-3000 years B.P.; and Sleeping Bear Dunes, 730 ± 250 years B.P.) contain 29 of the 53 reported species (Dorr and Eschman, 1969). In Wisconsin, Moscow Fissure (17,500 ± 1500 years B.P.) and Lost River Sink (2720 ± 390 and 3970 ± 240 years B.P.) contain 39 of 60 reported Wisconsin species. The Milwaukee fish locality (7750 ± 125 years B.P.) is the only locality in the state to show any taxonomic diversity of aquatic vertebrates, as all eight species from there are fish.

There is a marked contrast between the Wisconsin-Michigan records and those from Iowa (Table 2). Certainly both the intensity of collecting efforts and the somewhat less rigorous late Pleistocene environment in Iowa account for much of this difference.

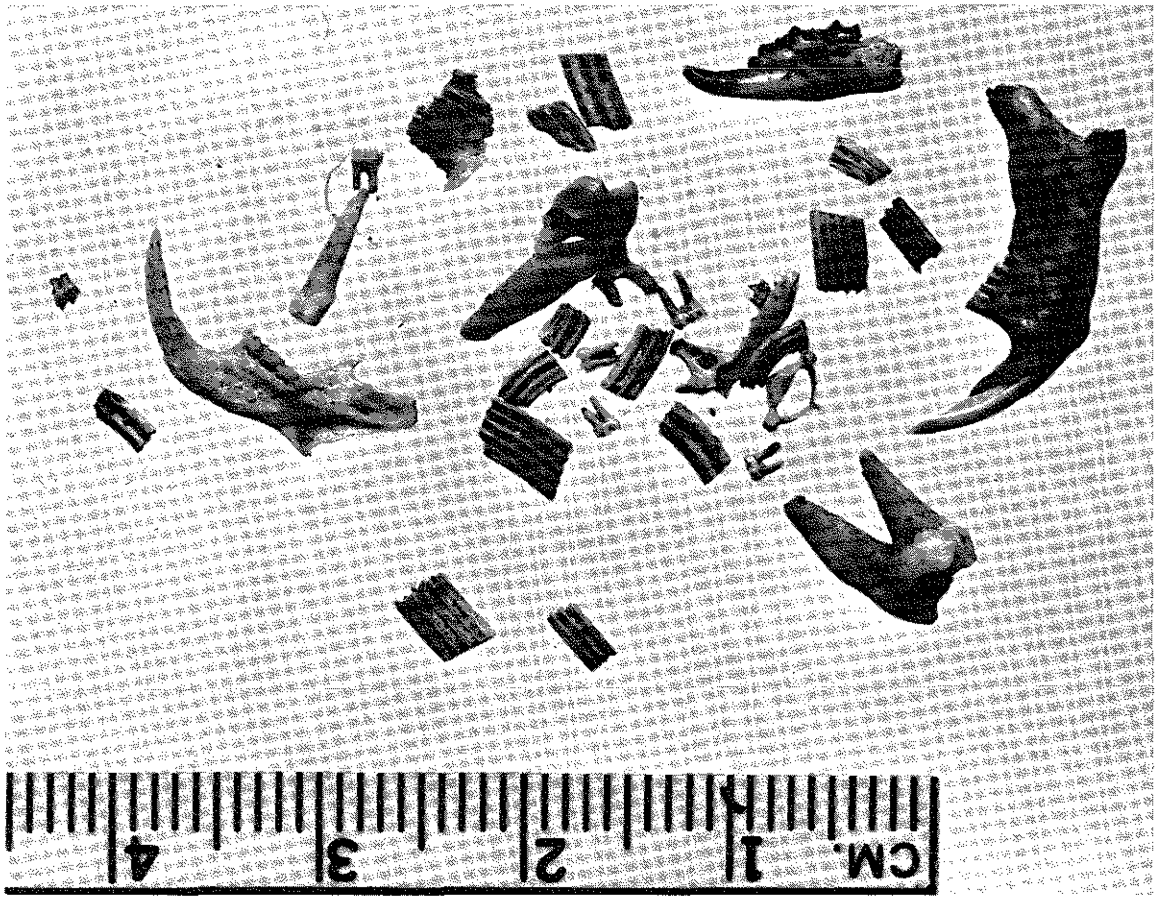

Figure 7. Specimens of small mammals, mostly rodents, from Lost River Sink, representative of collections of vertebrates made from sink holes and fissures in the Driftless Area.

Table 2

Wisconsinan and Holocene Vertebrate Diversity

	Wisconsin		Michigan[1]		Iowa[2]	
	Families	Species	Families	Species	Families	Species
Pisces	6	9	8	11	8	16
Amphibia	2	7	--	--	4	12
Reptilia	3	3	3	4	6	9
Aves	--	--	3	3	6	8
Mammalia						
Insectivora	2	6	1	1	2	8
Edentata	--	--	--	--	1	1
Rodentia	4	16	3	13	7	37
Carnivora	4	5	4	6	5	14
Pinnepedia	--	--	1	1	--	--
Cetacea	--	--	3	3	--	--
Proboscidea	2	2	2	2	1	3
Artiodactyla	3	9	3	9	3	14
Perissodactyla	--	--	--	--	1	1
Chiroptera	1	2	--	--	1	6
Lagomorpha	1	1	--	--	1	2
	28	60	31	53	46	131

[1] Data from Dorr and Eschman, 1969

[2] Data from Leslie P. Fay, personal communication, April 25, 1978

Table 3

Late Wisconsin and Holocene Vertebrates of Wisconsin

ORDER	FAMILY	GENUS AND SPECIES	REFERENCE
Pisces	Umbridae	*Umbra limi*	Teller-Marshall & Bardack 1978
	Esocidae	*Esox* sp.	Teller-Marshall & Bardack 1978
	Catastomidae	Indet.	Teller-Marshall & Bardack 1978
	Ictaluridae	*Ictalurus melas*	Teller-Marshall & Bardack 1978
	Centrarchidae	*Micropterus dolomievi*	Teller-Marshall & Bardack 1978
		Lepomis cyanellus	Teller-Marshall & Bardack 1978
		Lepomis gibbosus	Teller-Marshall & Bardack 1978
		Indet.	Teller-Marshall & Bardack 1978
	Salmonidae	*Cristivomer namaycush*	Hussakof 1916; Hay 1923
		[*Salvelinus namaycush*]	
	Indet.		Theiling 1973
Amphibia			
Anura	Bufonidae	*Bufo* cf. *cognatus*	Theiling 1973
		Bufo americanus	Theiling 1973

ORDER	FAMILY	GENUS AND SPECIES	REFERENCE
		Bufo sp.	Theiling 1973
	Ranidae	*Rana catesbeiana*	Theiling 1973
		Rana pipiens	Theiling 1973
		Rana palustris/sylvatica	Theiling 1973
		Rana sp.	Rasmussen 1971; Theiling 1973
Caudata	Indet.		Rasmussen 1971
Reptilia			
Lacertilia	Anguidae	*Ophisaurus attenuatus*	Theiling 1973
Squamata	Colubridae	Indet.	Theiling 1973
	Crotalidae	Indet.	Theiling 1973
	Indet.		Rasmussen 1971
Aves			
Indet.			Theiling 1973
Mammalia			
Insectivora	Talpidae	*Scalopus aquaticus*	Rasmussen 1971; Theiling 1973
	Soricidae	*Blarina brevicauda*	Rasmussen 1971; Theiling 1973

ORDER	FAMILY	GENUS AND SPECIES	REFERENCE
	Soricidae	*Cryptotis parva*	Rasmussen 1971; Theiling 1973
		Sorex cinereus	Rasmussen 1971; Theiling 1973
		Sorex palustris	Rasmussen 1971
		Microsorex hoyi	Rasmussen 1971
Chiroptera	Vespertilionidae	*Myotis* sp.	Theiling 1973
		Pipistrellus cf. *subflavus*	Theiling 1973
Rodentia	Sciuridae	*Sciurus* sp.	Theiling 1973
		Tamias striatus	Theiling 1973
		Citellus tridecemlineatus	Rasmussen 1971; Theiling 1973
	Cricetidae	*Peromyscus* cf. *maniculatus*	Rasmussen 1971; Theiling 1973
		Peromyscus leucopus	Rasmussen 1971
		Synaptomys cooperi	Theiling 1973
		Synaptomys borealis	Theiling 1973
		Synaptomys sp.	Rasmussen 1971
		Microtus pennsylvanicus	Rasmussen 1971; Theiling 1973
		Microtus ochrogaster	Rasmussen 1971; Theiling 1973

ORDER	FAMILY	GENUS AND SPECIES	REFERENCE
		Pitymys pinetorum	Theiling 1973
		Cleithronomys gapperi	Rasmussen 1971
		Phenacomys cf. *ungava*	Rasmussen 1971
	Geomyidae	*Thomomys talpoides*	Rasmussen 1971
	Castoridae	*Castor canadensis*	Hay 1923
		Castoroides ohioensis	Dallman 1969
Lagomorpha	Leporidae	Indet.	Theiling 1973
		Sylvilagus cf. *floridanus*	Rasmussen 1971
Proboscidea	Mammutidae	*Mummut americanum*	Hay 1914, 1923; Dallman 1968
	Elephantidae	*Elephas primigenius*	Hay 1914, 1923
Artiodactyla	Tayussuidae	*Tayussu*	Hay 1914, 1923
		Platygonus	Palmer 1974
	Cervidae	*Odocoileus*	Hay 1914, 1923
		Cervus canadensis	Hay 1914, 1923
		Rangifer tarandus	Hay 1923; West 1978
	Bovidae	*Bison occidentalis*	Palmer 1954
		Bison bison	Hay 1923
		Ovibos	Unpublished

ORDER	FAMILY	GENUS AND SPECIES	REFERENCE
		Symbos	Unpublished
Carnivora	Ursidae	*Ursus americanus*	Theiling 1973
	Procyonidae	*Procyon lotor*	Theiling 1973
	Mustelidae	*Mephitis mephitis*	Theiling 1973
	Canidae	*Vulpes fulva*	Theiling 1973
		Canis	Allen 1876; Hay 1914

In summary, the late Pleistocene and Holocene vertebrate record of Wisconsin is at this point relatively poorly known. This is due in part to historical accident and in part to the geologic configuration of the state. Those sites and occurrences which have been studied, and those which are under active investigation at present, do, however, give hope for the future. In particular, careful examination of post-glacial lake deposits in southern Wisconsin and late Pleistocene to Holocene caves and fissures in the Driftless Area should be productive. A joint effort of the University of Wisconsin-Madison and the Milwaukee Public Museum is intended to substantially increase our knowledge of the recent part of this state.

ACKNOWLEDGMENTS

We are most grateful for information on unpublished specimens furnished by H. A. Palmer, University of Wisconsin-Platteville, and P. Sander, Kenosha Public Museum. H. Semken and L. P. Fay, University of Iowa, provided lists of Iowa Pleistocene vertebrates and the radiocarbon date for Lost River Sink. The senior author's work on Wisconsin vertebrates is supported by the Friends of the Museum, Inc., Milwaukee.

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Plate 1. Explanation. All figures are SEM micrographs.

1,2 — *Clavohamulus densus* Furnish. 1, posterior view of element coated with calcium phosphate crystals (x70), UW 1677/40; 2, posterior view (x70), UW 1677/39, both from locality 29.

3,12,13 — *Ulrichodina wisconsinensis* Furnish. 3, lateral view (x75), UW 1677/18; 12, posterior view showing flat, rather than depressed, anterobasal extension (x40), UW 1677/17; 13, lateral view showing an atypical projection from the keel like posterior edge (x75), UW 1677/19, all from locality 3.

4,5 — *Ulrichodina prima* Furnish. 4, posterior view (x40), UW 1677/29; 5, lateral view (x50), UW 1677/8, both from locality 25.

6 — *Ulrichodina deflexus* Furnish. Posterior view showing longitudinal posterior groove (x50), UW 1677/7, locality 25.

7-10 — *Paltodus* sp. Lateral views of four different elements showing a sequence of increasing costae development (all x40), UW 1677/11, 12, 24, 25 respectively, all from locality 3.

11 — *Cordylodus angulatus* Pander. Lateral view (x55), UW 1677/4, locality 39.

14,15 — *Oistodus* sp. aff. *O. inaequalis* Pander. 14, lateral view (x50), UW 1677/9, locality 3; 15, lateral view (x70), UW 1677/45, locality 14.

16 — *Oistodus* sp. cf. *O. forceps* Lindström. Lateral view (x85), UW 1677/10, locality 3.

17,25-27 — *Acodus oneotensis* (Furnish). 17, lateral view of *"Oistodus" triangularis* element (x60), UW 1677/64; 25, lateral view of *Acodus oneotensis* element (x70), UW 1677/62; 26, lateral view of *Paltodus bassleri* element (x50), UW 1677/60; 27, lateral view of *Paltodus variabilis* element (x50), UW 1677/61, all from locality 39.

18,19 — *Scolopodus quadraplicatus* Branson & Mehl. 18, posterior view (x25), UW 1677/16; 19, lateral view (x25), UW 1677/15, both from locality 3.

20-23 — *Drepanodus* n. sp. 20, lateral view of homocurvatid element (x50), UW 1677/28, locality 3; 21, lateral view of suberectid element (x70), UW 1677/46, locality 14; 22, lateral view of suberectid element (x50), UW 1677/6, locality 14; 23, lateral view of homocurvatid element (x65), UW 1677/26, locality 3.

24,31-33 — *Acodus stola* (Lindström). 24, lateral view of distacodid element (x60), UW 1677/55, locality 23; 31, lateral view of acodid element (x50), UW 1677/27, locality 3; 32, posterior view of acontiodid element (x70), UW 1677/34, locality 3; 33, lateral view of acontiodid element (x70), UW 1677/33, locality 3.

28 — *Scolopodus* sp. aff. *S. cornutiformis* Branson & Mehl. lateral view (x45), UW 1677/63, locality 5.

29 — *Drepanodus parallelus* Branson & Mehl. Lateral view (x35), UW 1677/37, locality 25.

30 — *Oneotodus simplex* Furnish. Lateral view (x70), UW 1677/52, locality 6.

34,35 — *Scolopodus triplicatus* Ethington & Clark. 34, lateral view (x50), UW 1677/32; 35, lateral view (x50), UW 1677/31, both from locality 3.

36 — *Scandodus furnishi* Lindström. Lateral view (x 45), UW 1677/23, locality 25.

37 — Unidentified distacodontid showing single apatite crystal coating the cusp (x90), UW 1677/42, locality 29.

38 — ?*Drepanodus sculponea* Lindström. Lateral view (x60), UW 1677/65, locality 3.

39 — *Loxodus bransoni* Furnish. Lateral view (x50), UW 1677/2, locality 39.

40,42 — *Drepanodus subarcuatus* Furnish. 40, lateral view (x50), UW 1677/58, locality 2; 42, lateral view (x30), UW 1677/38, locality 25.

41 — *Scolopodus triangularis* Ethington & Clark. Lateral view (x60), UW 1677/56, locality 36.

43 — *Drepanodus conulatus* Lindström. Lateral view (x75), UW 1677/3, locality 3.

44,45 — New genus, new species. 44, lateral view of specimen with single denticle (x85), UW 1677/21; 45, lateral view of specimen with three denticles (x110), UW 1677/22, both from locality 3.

46 — *Acontiodus iowensis* Furnish. Posterior view (x 60), UW 1677/59, locality 20.

47,48 — *Acontiodus bicurvatus* (Stauffer). 47, posterior view (x45), UW 1677/14; 48, lateral view (x45), UW 1677/13, both from locality 3.

49 — *Acontiodus staufferi* Furnish. Posterior view (x 65), UW 1677/47, locality 2.

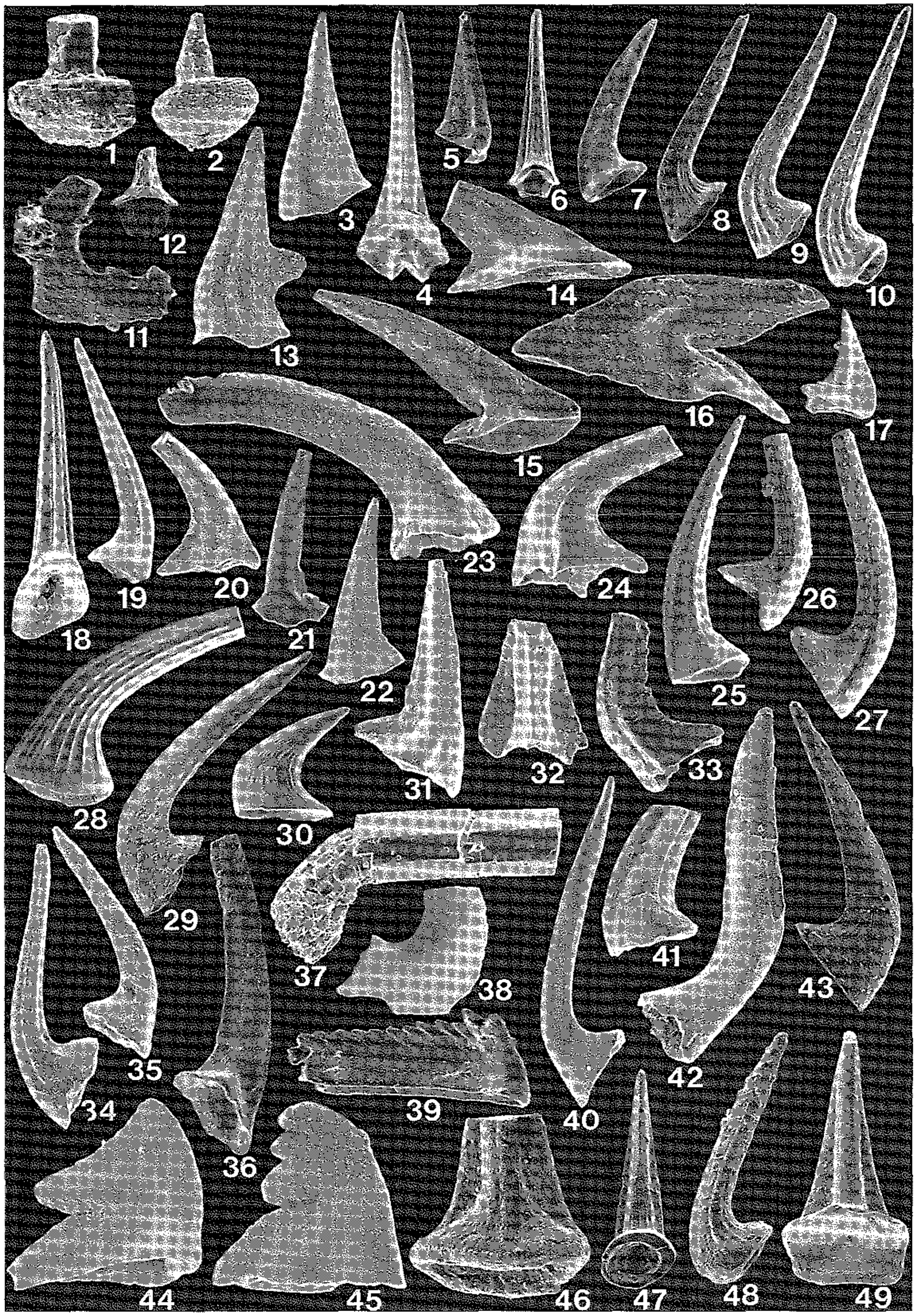

Plate 1. Photomicrographs of described conodonts of Grether and Clark.

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"Geoscience Wisconsin", a report series covering significant geoscience research pertaining to Wisconsin geology, is published by the Wisconsin Geological and Natural History Survey, University of Wisconsin-Extension. The purpose of the series is to provide increased awareness of the geoscience research done in Wisconsin and to provide a vehicle for the communication of scholarly geologic research pertinent to Wisconsin. Although compilations and review papers will be considered for publication, the main object of the series is to publish high-quality, original research papers of general interest on all phases of the geology of Wisconsin.

Scope and Length of Papers

All phases of geoscience research done in Wisconsin or very closely related to Wisconsin interests will be considered for publication. All members of the professional geoscience community are encouraged to submit their scholarly papers for publication in "Geoscience Wisconsin". Students are also encouraged to submit papers on their completed thesis research.

Papers should be no longer than 25 pages in length including all figures, references, abstracts, and so forth. Manuscripts exceeding 25 pages should have the approval of the editors before submission to "Geoscience Wisconsin". Draft copies for review will be double spaced with ample margins; this includes references cited. For final publication, camera-ready copy of all papers will be prepared by the Wisconsin Geological and Natural History Survey. There are no page charges.

Administrative Framework

Editors

Co-editors of the publication series are David M. Mickelson and Michael G. Mudrey, Jr. The co-editors will be responsible for receiving manuscripts which are submitted. The co-editors will examine the manuscript for general style, length requirements and suitability for publication in "Geoscience Wisconsin", The manuscript will then either be rejected, returned to the author for modification, or sent to one of the associate editors for review.

After the manuscript has been reviewed by the associate editor and reviewers (specialists in the field addressed by the paper), a decision on acceptance or rejection will be made by the associate editor and the editors. The manuscript, if accepted, will be returned to the author for modification, based on the recommendations of the associate editor, and for preparation of the final copy. The final manuscript will then be submitted to the co-editors who will see the manuscript through its publication stages.

Associate Editors

Associate editors have been selected from a pool of geoscientists interested in Wisconsin geology. They are:

1. Douglas S. Cherkauer
   University of Wisconsin-Milwaukee
2. C. Patrick Ervin
   Northern Illinois University
3. Gene L. LaBerge
   University of Wisconsin-Oshkosh
4. Robert M. West
   Milwaukee Public Museum

The associate editors receive manuscripts from the co-editors. The manuscripts are reviewed by the associate editor and also sent out to reviewers in the field of interest. The editor will then collate the reviews and with the co-editors make a decision about publication. If the manuscript is rejected, it will be returned to the author with a detailed explanation of why the paper was rejected. If the paper is accepted, the technical editor will collate recommended changes and return the manuscript to the author.

The associate editors serve for two years. This length of term allows new and different technical philosophies and expertise to be introduced into the review process.

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VOLUME 4 GEOSCIENCE WISCONSIN 1980