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

by

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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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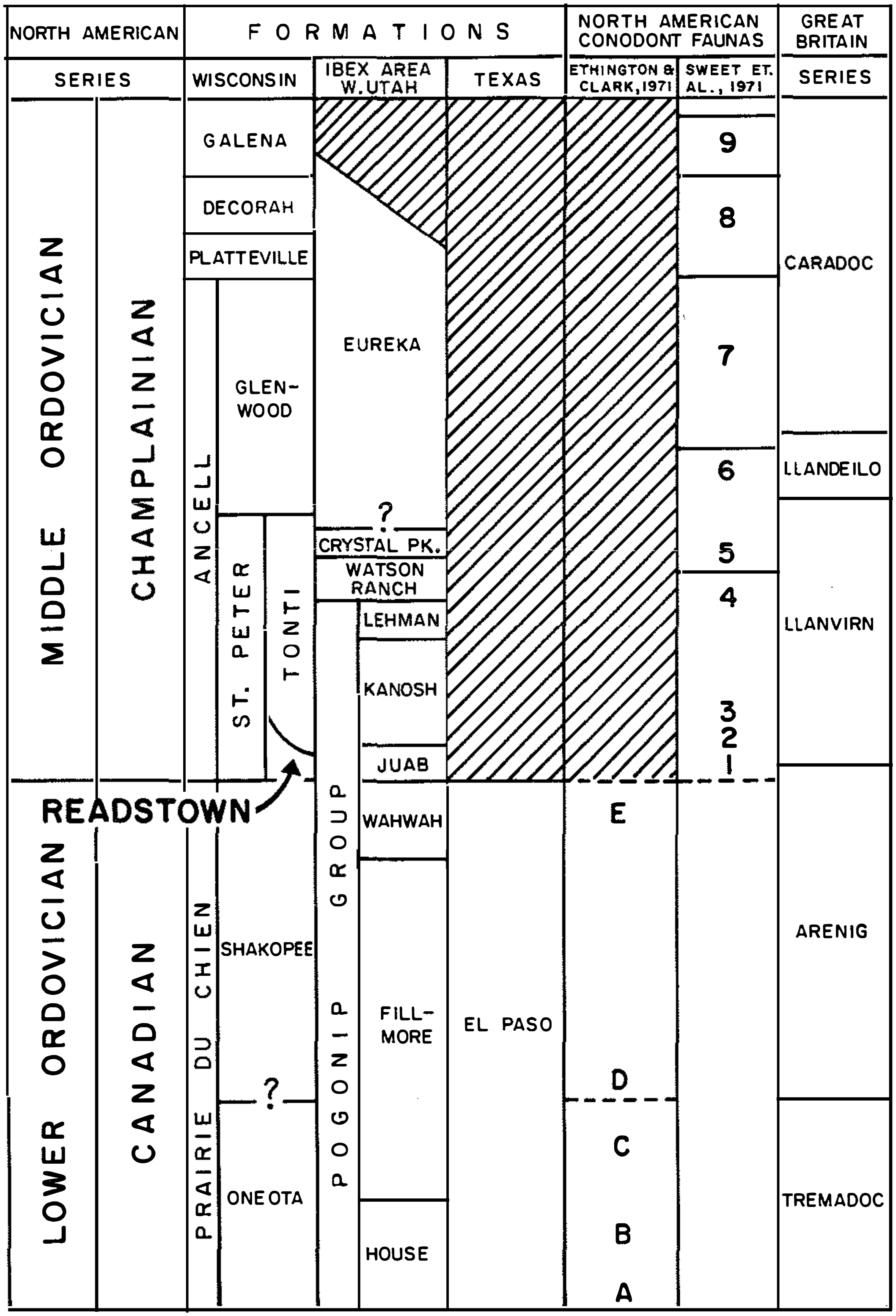

Figure 1. Lower and Middle Ordovician stratigraphy of Wisconsin, its classification and correlation with other important Ordovician stratigraphy and faunal units.

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

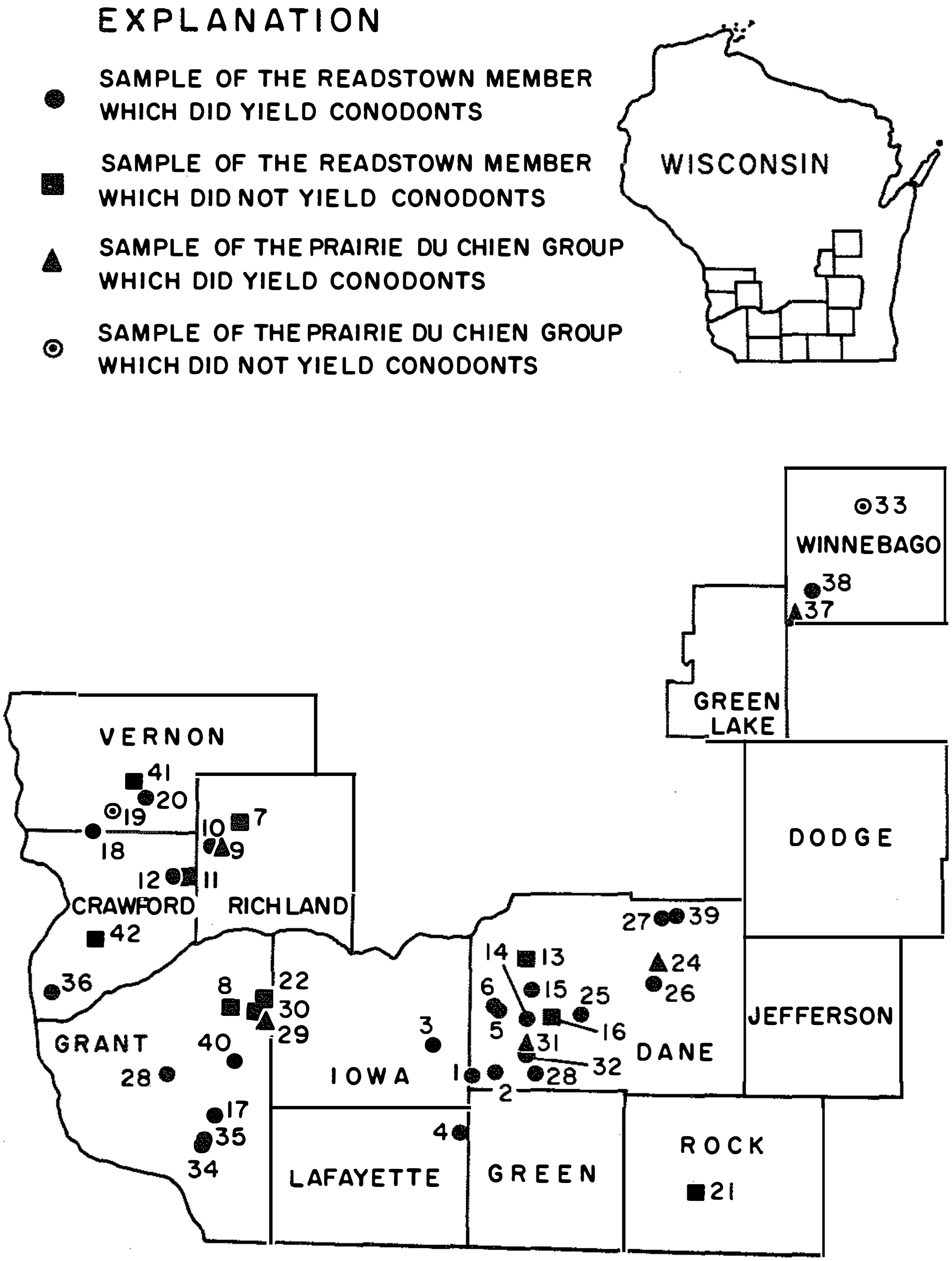

Figure 2. Location of Readstown exposures studied for this report. Occurrence of conodonts at Readstown localities indicated.

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.

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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, SE ¼, 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)
