Biostratigraphy and Paleoecology of Late Ordovician Conodonts from a Composite Section in the Subsurface of Saskatchewan [1]

Godfrey S. Nowlan [2] and F.M. Haidl

Nowlan, G.S. and Haidl, F.M. (2001): Biostratigraphy and paleoecology of Late Ordovician conodonts from a composite section in the subsurface of Saskatchewan; *in* Summary of Investigations 2001, Volume 1, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 2001-4.1.

1. Introduction

This paper reports on the biostratigraphy and paleoecology of conodonts recovered from Upper Ordovician strata in four wells in southeastern Saskatchewan (Figure 1). The cored intervals from these wells represent a composite section through the Yeoman, Herald, and Stony Mountain formations (Figure 2). Sixty-six samples have yielded more than 5000 conodont elements assignable to a variety of species. Despite the generally small size of the samples (average 408 grams), more than 95% of the samples have produced conodonts, although many samples produce very few specimens.

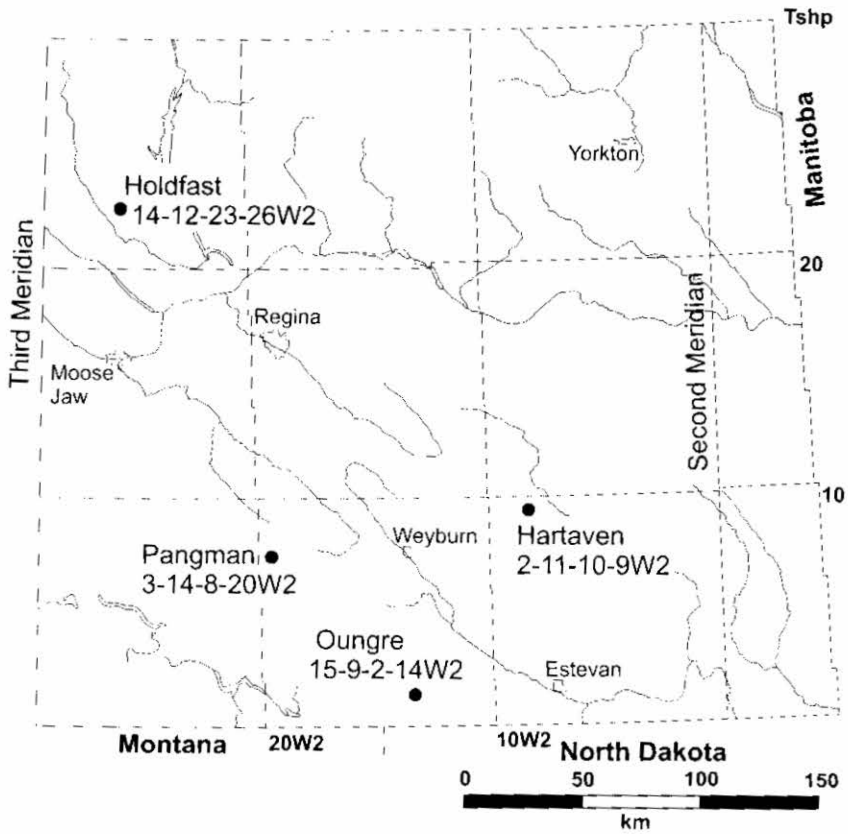


Figure 1 - Location map of wells sampled for this study.

Previous work on Upper Ordovician conodont biostratigraphy in the subsurface of Saskatchewan has focused on the Ordovician-Silurian boundary interval (Norford *et al.*, 1998; Nowlan and Haidl, 1999). An analysis of conodonts in the Late Ordovician of Alberta has been submitted for publication (Nowlan, in review). A paper on the paleontology of the Fort Garry Member of the Red River Formation in Manitoba (Elias *et al.*, 1988) is the only other published record of conodonts in this interval in the Canadian part of the Williston Basin.

2. Stratigraphy

Middle to Upper Ordovician strata in the study area comprise a basal clastic unit (Winnipeg Formation) and an overlying sequence characterized by repetition of carbonate and evaporite lithologies (Yeoman, Herald, Stony Mountain, and Stonewall formations) (Figure 2).

a) Winnipeg Formation

A time gap between the Winnipeg and Yeoman formations is generally implied, but no biostratigraphic data to support this are available from Saskatchewan. The earliest report on conodonts from the Winnipeg Formation was that of Furnish *et al.* (1936) which demonstrated its Middle Ordovician age, and that it is therefore much younger than the underlying Deadwood Formation. Later reports on conodonts from the Winnipeg Formation include those of Amsden and Miller (1942) in Wyoming, Carlson (1960) in North Dakota, and Oberg (1966) from the outcrop belt in Manitoba. More recently, the Icebox and Roughlock members

[1] Geological Survey of Canada Contribution No. 2000292.

[2] Geological Survey of Canada, 3303 - 33rd Street NW, Calgary, AB T2L 2A7.

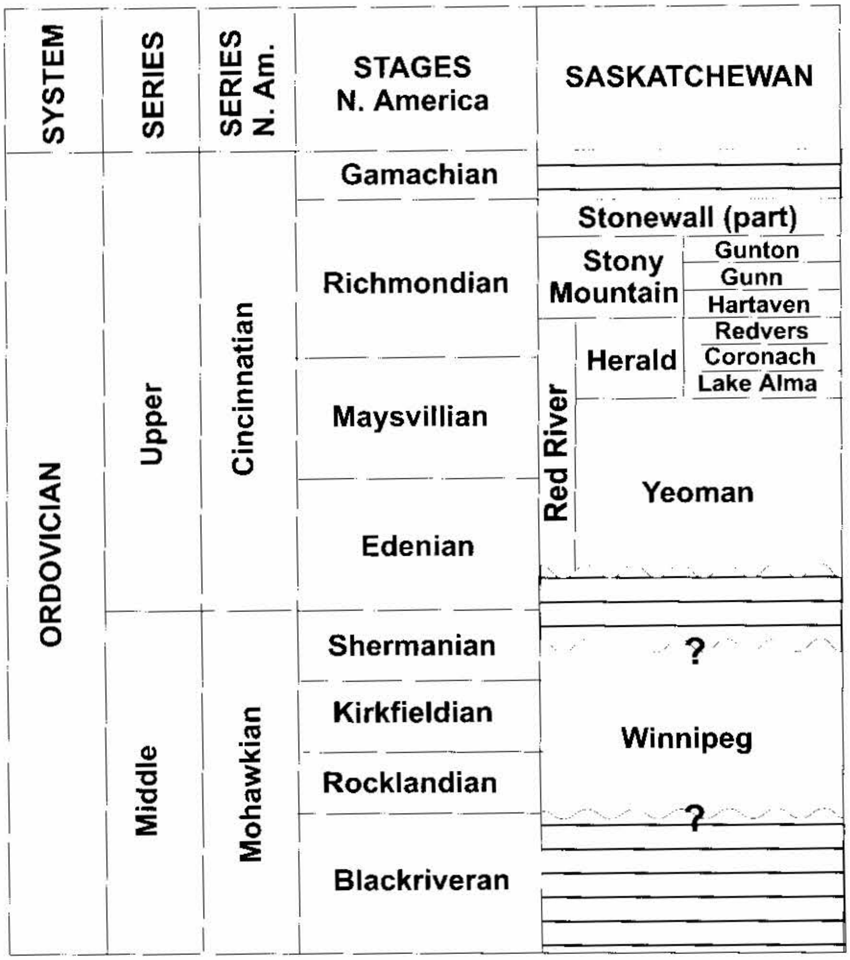


Figure 2 - Correlation of Saskatchewan strata with Middle and Upper Ordovician stages.

of the Winnipeg Formation in South Dakota have been shown to be Rocklandian to Kirkfieldian, and Kirkfieldian to earliest Shermanian in age respectively (Sweet, 1982). However, data for North Dakota as reported by Kessler (1991) may indicate that the Red River is in depositional continuity with the Winnipeg in southern North Dakota and that, therefore, the Roughlock in northern North Dakota may be Edenian. The rocks in the upper part of the Winnipeg Formation in the few Saskatchewan cores of the Yeoman/Winnipeg boundary zone examined to date are not suitable for acid digestion and so no samples were taken for conodont analyses. However, the question of a hiatus between the Winnipeg and Yeoman needs to be addressed, especially in the southeastern corner of Saskatchewan where Kreis (2000) has indicated the presence of the Roughlock Member.

b) Red River (Yeoman and Herald Formations)

The stratigraphic nomenclature established for Red River strata in southeastern Saskatchewan reflects the interpretation that the repetition of carbonate and evaporite strata represents three brining-upward cycles. The Yeoman Formation and the lower Herald (Lake Alma Member) form the oldest cycle, and the upper Herald relates to the middle (Coronach Member) and youngest (Redvers Unit) cycles (Kendall, 1976). New core and geophysical log data from the more than 300 wells drilled into the Red River since 1976 suggest a more complex depositional history than the current stratigraphic breakdown implies (Pratt *et al.*, 1996; Haidl *et al.*, 1997; Kreis and Kent, 2000). However, further work is required to establish a detailed sequence stratigraphic framework for Ordovician and Silurian strata in the Williston Basin before formal stratigraphic nomenclature can be revised.

Yeoman Formation

The Yeoman Formation is composed primarily of burrow-mottled fossiliferous lime mudstones and wackestones which have been dolomitized to varying degrees. The burrows which give a mottled appearance to the rocks are large *Thalassinoides*-like structures within which are small cylindrical burrows (*Planolites, Chondrites, Paleophycus, Skolithos)* (Kendall, 1976, 1977; Pratt *et al.*, 1996; Canter, 1998; Kissling, 1999; Pak *et al.*, this volume). Other trace fossils include *Trychophycus* (Pak *et al.*, this volume). Tabulate corals and solitary and colonial rugose corals, cephalopods, brachiopods, bryozoans, echinoderms, stromatoporoids, and gastropods are the most commonly observed macrofossils in core (Brindle, 1960; Kendall, 1976; Pratt *et al.*, 1996; Haidl *et al.*, 1997). Conodonts from this formation in Saskatchewan have not been reported before, although Sweet (1979) has detailed them from equivalent strata in Wyoming and South Dakota. The micro-alga *Gloeocapsomorpha prisca*, of probable cyanobacterial origin (Stasiuk, 1991; Stasiuk *et al.*, 1993), is the primary component of organic-rich kerogenites (kukersites) which are preserved as thin but widespread layers in the upper one-third of the Yeoman.

Herald/Yeoman Contact

The contact between the Yeoman and the overlying Herald (Lake Alma Member) is difficult to pick both in core and on geophysical logs. In core, strata between the burrow-mottled rocks typical of the Yeoman and the laminated to thinly bedded dolostones which characterize the lower Lake Alma are variable in lithology. This thin (<1 m to 8 m) transitional unit is composed of variably dolomitized, poorly mottled, irregularly bedded lime mudstones with texturally variable fossiliferous, peloidal and/or coated grain layers (Kendall, 1976; Longman and Haidl, 1996; Pratt *et al.*, 1996, Haidl *et al.*, 1997; Kissling, 1997; Kreis and Kent, 2000). An 8 m thick reefal sequence in the LVR et al Steelman 7-28-4-4W2 well includes a stromatoporoid dolorudstone and a microbial doloboundstone (Pratt *et al.*, 1996; Haidl *et al.*, 1997). At the two wells of this study in which this contact is cored (15-9-2-14W2 and 14-12-23-26W2), the "transitional unit" is placed in the Yeoman Formation; i.e. the Herald/Yeoman contact is placed at the base of the lowermost laminated dolomudstone bed. Other workers interpret the "transitional unit" as the lowermost unit of the Lake Alma Member of the Herald Formation (e.g. Kreis and Kent, 2000).

Herald Formation

Conodonts have not been reported previously from this unit in Saskatchewan. However conodonts from the Bighorn Group in Wyoming (Stone and Furnish, 1959; Sweet, 1979) are at least partially equivalent. Conodonts have also been reported from the Fort Garry Member of the Red River Formation in the outcrop belt of Manitoba (Elias *et al.*, 1988), a probable equivalent of the Herald Formation. The conodonts indicate a Richmondian age, at least for the upper part of the Fort Garry Member.

Lake Alma Member

The Lake Alma Member comprises laminated to bedded, commonly slightly argillaceous, dolomudstones and calcareous dolomudstones. Interbedded with the dolomudstones in some wells, including the Cal-Stan Holdfast 14-12-23-26W2 well in this study, are beds of burrow-mottled and/or fossiliferous dolostone. In the extreme eastern part of Saskatchewan (Range 2W2 and eastward), beds of coated grain dolostone, which may have originated as oolitic grainstones, are interbedded with the laminated dolomudstones (Kent, 1960; Kendall, 1976; Haidl *et al.*, 1997; Kent and Haidl, 1999; Kreis and Kent, 2000).

The Lake Alma anhydrite, the upper unit of the Lake Alma Member, is composed of nodular, bedded, and laminated anhydrite with interbeds of dolomudstone (commonly anhydritic). This is the most widespread of the Lower Paleozoic evaporite units. It extends from the basin centre in North Dakota to as far north as Township 33, as far west as Range 10W3 and into Manitoba to the east (Kent, 1960; Kendall, 1976; Norford *et al.*, 1994; Longman and Haidl, 1996).

Coronach Member

Where fully developed (as in the 15-9-2-14W2 and 2-11-10-9W2 cores), the Coronach Member comprises: 1) a basal, slightly argillaceous dolomudstone, locally with scattered quartz grains; 2) a fossiliferous, commonly burrowed, wackestone or dolowackestone; 3) slightly argillaceous laminated dolomudstones (locally lime mudstones); and 4) the Coronach anhydrite (Kendall, 1976). The basin-centred anhydrite unit is thinner and less widespread than the Lake Alma anhydrite, extending north only to Township 11 in south-central Saskatchewan.

Redvers Unit

The Redvers unit is composed of a basal argillaceous dolomudstone bed and an upper laminated dolomudstone or lime mudstone. This unit is mapped with confidence only where an argillaceous marker bed separates it from the overlying Stony Mountain carbonates on geophysical logs.

Stony Mountain Formation

Ethington and Furnish (1960) recovered Richmondian conodonts from two Stony Mountain samples in the type area north of Winnipeg, Manitoba. A more detailed assessment of conodonts from equivalent strata in the United States has been provided by Sweet (1979).

In all but the extreme western and northwestern parts of the study area, where it is undifferentiated, the Stony Mountain Formation is subdivided into (O-Y): 1) the Hartaven Member of slightly argillaceous to argillaceous fossiliferous lime mudstones and wackestones; 2) the Gunn Member of fossiliferous very argillaceous limestones with interbeds of variably dolomitized lime mudstones; and 3) the Gunton Member of primarily nodular, commonly unfossiliferous, dolomudstones, overlain by laminated dolomudstones and a capping anhydrite.

3. Conodont Biostratigraphy and Paleoecology

The distribution of conodont species in each of the wells is discussed below. A reference for the biostratigraphic subdivisions mentioned in the text is shown as Figure 2. Tables 1 to 4 show the numerical distribution of species in samples from the wells and Figures 3 to 5 show relative abundance curves for genera in each of the wells, except Imperial Pangman for which there is little data. Selected specimens of most of the species reported in Tables 1 to 4 are illustrated in Figures 6 and 7.

Imperial Pangman 3-14-8-20W2

From Imperial Pangman 3-14-8-20W2, four samples were taken from the lowest 16 ft (4.9 m) of the

Table 1 - Numerical distribution of conodont species by sample depth in feet and GSC locality number in the Pangman well.

Imperial Pangman 3-14-8-20W2

	Yeoman				
	8470.1(C-257739)	8464.2 (C-257740)	8459.0 (C-257741)	8454.0 (C-257742)	
Belodina sp.	0	1	0	0	
Panderodus gibber	0	0	0	1	
Panderodus gracilis	0	17	0	8	
Pseudobelodina? dispansa	0	0	0	1	
Pseudobelodina vulgaris vulgaris	0	1	0	0	
Total:	**0**	**19**	**0**	**10**	**29**
Mass (grams):	300	393	300	285	1278

Yeoman Formation. No rock suitable for acid digestion was found in the Winnipeg Formation. The distribution of conodonts recovered is shown in Table 1. The 29 specimens are mainly assignable to species of the widespread and long-ranging genus *Panderodus*. One specimen of *Pseudobelodina vulgaris vulgaris* at 8464.2 ft (2579.9 m) indicates a Late Ordovician, mid-Edenian or younger age for the lower part of the Yeoman Formation. This interpretation is based on the range of this species as defined primarily by Sweet (1979, 1984).

Cal-Stan Holdfast 14-12-23-26W2

From Cal-Stan Holdfast 14-12-23-26W2 16 samples from 130 ft (39.6 m) of the Yeoman Formation and six from the lower 44 ft (13.4 m) of the Herald Formation were analyzed (Figure 3).

Biostratigraphy

The distribution of conodonts is shown in Table 2. Samples from the lower part of the core in the Yeoman Formation (below the 5759.1 ft; 1755.4 m) level, GSC loc. C-322670) yielded few conodonts and thus no biostratigraphic interpretations are made for the interval 5759.1 ft. to 5805.4 ft (1755.4 m to1769.5 m).

The first appearance of *Culumbodina penna* Sweet, which is indicative of Middle Edenian to Middle Maysvillian age, occurs at 5743.6 ft (1750.6 m) (GSC loc. C-322668) and additional specimens occur up to 5714.0 ft (1741.6 m) (GSC loc. C-322664), well within the upper part of the Yeoman.

The upper samples in the well are dominated by specimens of *Aphelognathus* aff. *A. divergens* Sweet. This species is similar to specimens described by Sweet (1979) as *A. divergens* but also shares some characteristics with the older species *A. shoshonensis* Sweet. Although Sweet (1979) indicated that these species did not have overlapping ranges, he suggested that they may be part of a lineage. The faunas in this interval and those of a similar interval in the Oungre well (upper Yeoman–lower Herald) appear to be transitional between the two species, or their ranges overlap. Although the age of upper Yeoman to lower Herald remains uncertain, it is at least Middle Maysvillian, as indicated by *Culumbodina penna* lower in the section, or possibly younger.

This *Aphelognathus* species is associated with an abundance of simple cones lacking biostratigraphic significance, but two species, *Parabelodina denticulata* Sweet and *Parabelodina* cf. *P. adenticulata*, seem to occur within the upper Yeoman–lower Herald interval and may have future biostratigraphic utility. Such specimens were identified as *Parabelodina denticulata* at 10,019.0 ft (3053.8 m) (GSC loc. C-257708) in the Lake Alma Member of the Herald Formation in the Oungre 15-9-2-14W2 well. In the Holdfast well, they occur at 5661.8 ft (1725.7 m) and 5682.5 ft (1732.0 m) (GSC locs. C-322658 and C-322660) in beds of the upper Yeoman and the middle of the Lake Alma Member (Table 2 and Figure 3).

Paleoecology

The fact that the distribution of Ordovician conodont genera and species are affected by facies distribution was first recognized by Seddon and Sweet (1971). They attributed the patterns they had recognized to a pelagic habit in conodonts. This was challenged by Barnes and Fåhraeus (1975) who suggested that most Ordovician conodont genera were benthic or nektobenthic, living at or near the bottom of the water column. In both studies the distribution of conodont genera was related to facies distribution.

A study specific to Upper Ordovician biofacies was completed by Sweet and Bergström (1984) in which they recognized six conodont biofacies for the Edenian-Maysvillian of North America.

Their biofacies are modified herein to reflect local faunas and other biofacies work on the Late Ordovician by Nowlan and Barnes (1981). The biofacies for the Late Ordovician, in order from shallowest to deepest, are based on conodont genera believed to be benthic or nektobenthic:
1) *Rhipidognathus* biofacies, 2) *Oulodus-Aphelognathus* biofacies, 3) *Plectodina* biofacies, 4) *Phragmodus* biofacies, and 5) *Amorphognathus* biofacies. The genera *Panderodus* and *Drepanoistodus* and many of the other simple cone genera such as *Belodina* and *Pseudobelodina* are believed to be pelagic.

The relative abundance of significant genera from the Holdfast well is summarized in Figure 3. Although all samples are reported, the value of those with only a few specimens should be discounted. The lower part of this well (5767 to 5805.4 ft; 1757.8 to 1769.5 m) yields few conodonts and most are specimens of *Panderodus*. Thus, there are no paleoecological indicators except a

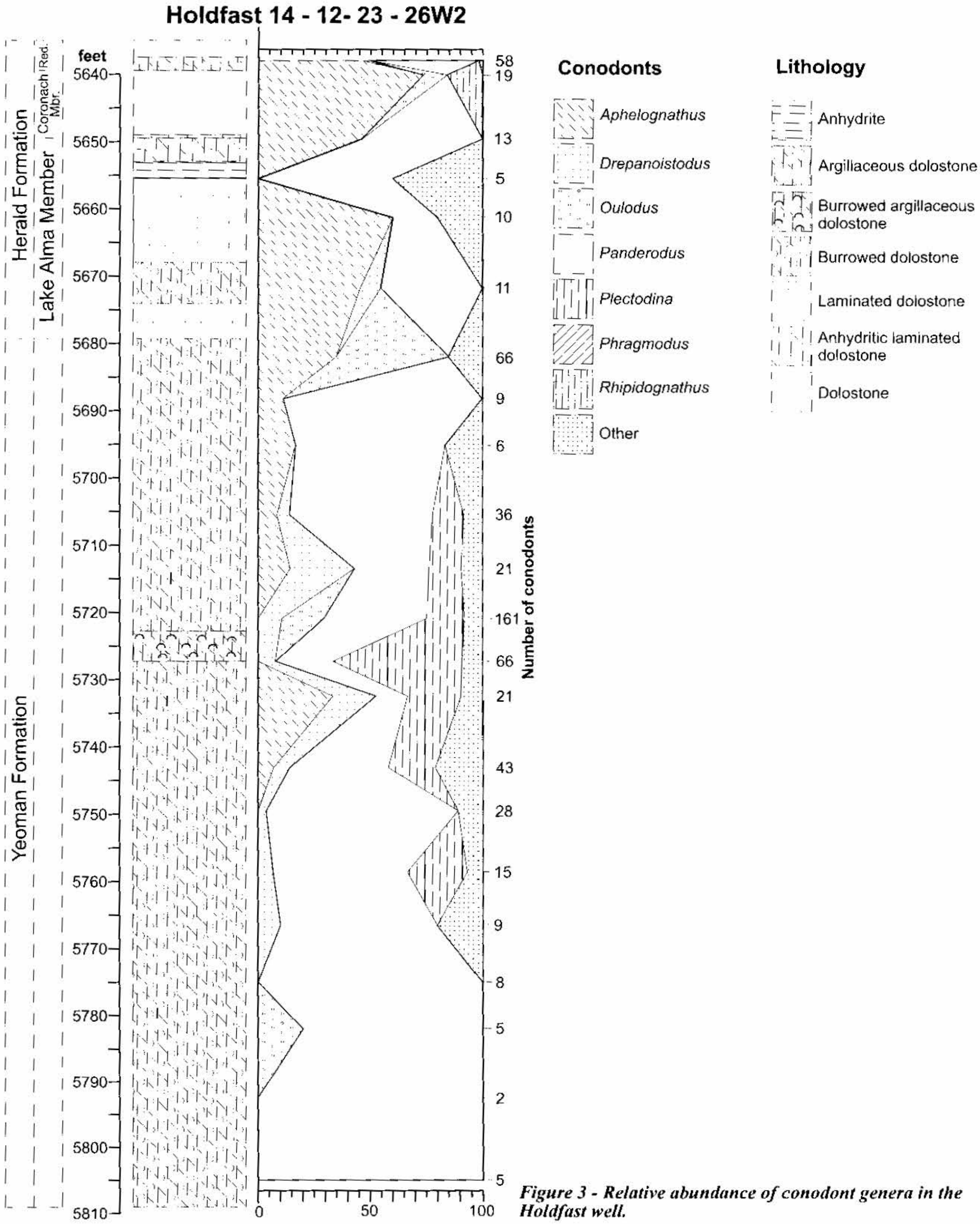


Figure 3 - Relative abundance of conodont genera in the Holdfast well.

Cal-Stan Holdfast 14-12-23-26W2

	Yeoman																Herald						
	5805.4 (C-322675)	5792.8 (C-322674)	5782.5 (C-322673)	5775.5 (C-322672)	5767.0 (C-322671)	5759.1 (C-322670)	5750.0 (C-322669)	5743.6 (C-322668)	5733.0 (C-322667)	5727.8 (C-322666)	5721.4 (C-322665)	5714.0 (C-322664)	5706.0 (C-322663)	5695.7 (C-322662)	5688.7 (C-322661)	5682.5 (C-322660)	5672.3 (C-322659)	5661.8 (C-322658)	5656.0 (C-322657)	5650.1 (C-322656)	5640.6 (C-322655)	5638.5 (C-322654)	
Aphelognathus aff *A. divergens*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	5	6	0	6	14	27	
Aphelognathus sp.	0	0	0	0	0	0	0	3	7	0	0	3	3	1	1	0	0	0	0	0	0	0	
Belodina confluens	0	0	0	0	1	1	0	4	1	2	2	0	0	0	0	0	0	0	0	0	0	0	
Culumbodina occidentalis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Culumbodina penna	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
Drepanoistodus suberectus	0	0	0	0	1	1	1	3	4	5	17	6	2	0	0	0	1	0	0	0	0	2	
Oulodus ulrichi	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	
Oulodus? sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Panderodus bergstroemi	0	0	0	0	1	0	2	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
Panderodus cf. *P. bergstroemi*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	
Panderodus gibber	0	0	0	0	1	0	1	0	0	0	4	0	3	0	1	4	0	0	0	0	0	2	
Panderodus gracilis	5	2	4	8	5	9	21	17	2	17	70	6	20	4	6	29	5	2	3	0	2	22	
Panderodus panderi	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	4	
Panderodus serratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Parabelodina denticulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	
Parabelodina cf. *P. denticulata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	
Plegagnathus nelsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
Plectodina aculeatoides	0	0	0	0	0	0	0	9	5	38	27	0	0	0	0	0	0	0	0	0	0	0	
Plectodina florida	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	
Plectodina sp.	0	0	0	0	0	4	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
Pseudobelodina inclinata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	
Pseudobelodina vulgaris vulgaris	0	0	0	0	0	0	0	0	1	3	6	0	2	0	0	0	0	0	0	0	0	0	
Pseudobelodina? *dispansa*	0	0	0	0	0	0	2	1	0	1	4	1	0	0	0	0	0	0	2	0	0	0	
Pseudooneotodus mitratus	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Rhipidognathus symmetricus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	
Walliserodus sp.	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	
Total:	**5**	**2**	**5**	**8**	**9**	**15**	**28**	**43**	**21**	**66**	**161**	**21**	**36**	**6**	**9**	**66**	**11**	**10**	**5**	**13**	**19**	**58**	**617**
Mass (grams):	595	535	665	378	578	314	436	624	430	393	402	521	442	418	650	552	496	440	608	489	501	453	10920

Table 2 - Numerical distribution of conodont species by sample depth in feet and GSC locality number in the Holdfast well.

few specimens of the genus *Oulodus* indicating relatively shallow conditions.

Deepening of the basin is indicated by the appearance of *Plectodina* at 5759.1 ft (1755.4 m) and the genus is well represented through to the 5706 ft (1739.2 m) level. However, clear indications of sea-level oscillations are recognized by the presence of shallower water biofacies represented by *Aphelognathus* at 5733 ft (1747.4 m) and 5743.6 ft (1750.6 m). Abundant *Oulodus* mixed with *Plectodina* at 5721.4 ft (1743.9 m) may suggest an intermediate water depth. An argillaceous dolostone bed at 5727.8 ft (1745.8 m) produced the greatest abundance of *Plectodina*, suggesting an increase in water depth. Samples from adjacent beds are also abundant in conodonts.

The remainder of the section appears to represent shallower water deposition with *Aphelognathus* and *Oulodus* dominating the fauna throughout the 5638.5 to 5695.7 ft (1718.6 to 1736.0 m) interval. Abundance is low and specimens of *Aphelognathus* are excluded close to an evaporite unit within the Lake Alma Member. An extremely shallow episode is recorded by *Rhipidognathus* at 5640.6 ft (1719.3 m) within the uppermost part of the Coronach Member of the Herald Formation.

No indications of deep water biofacies were found in this well.

CDR Shell FPC Oungre 15-9-2-14W2

The core from CDR Shell FPC Oungre 15-9-2-14W2 brackets the upper Yeoman, Herald, and lowermost Stony Mountain formations. Nine samples were taken from the uppermost 63 ft (19.2 m) of the Yeoman Formation, ten samples from the Herald Formation (104 ft, 31.7 m thick) and three from the lower 13 ft (3.96 m) of the Stony Mountain Formation (Figure 4).

Biostratigraphy

The distribution of conodont species is shown in Table 3. The lowest six samples (10,040.5 to 10,089.0 ft; 3060.3 to 3075.1 m) yield specimens probably assignable to *Aphelognathus* but the specimens are so fragmentary or the preserved apparatuses are too incomplete for specific identification. These samples also include specimens of *Oulodus*? sp. and *Pseudobelodina vulgaris vulgaris*, the latter supplying a minimum age of mid-Edenian for the interval as at Pangman. Good specimens of *Plectodina aculeatoides*, a species that ranges from mid-Edenian to mid-Richmondian, were collected at 10,052.5 ft (3064.0 m) and 10,061.5 ft (3066.7 m).

A single specimen assignable to *Culumbodina* occurs at 10,040.5 ft (3060.3 m) which suggests an age no younger than mid-Maysvillian. This places an upper age limit on this lower part of the Yeoman at the Oungre well.

The next highest biostratigraphically significant form, *Aphelognathus* aff. *A. divergens*, occurs at 10,028.3 ft (3056.6 m) in the upper part of the Yeoman Formation. This form is most similar to *A. divergens* reported by Sweet (1979, 1984) to be restricted to the Richmondian Stage of the Upper Ordovician, but the M elements are more similar to those of *A. shoshonensis*, a somewhat older species. These specimens appear just a few feet above mid-Maysvillian conodonts, and thus may be transitional between Maysvillian *A. shonshonensis* and Richmondian *A. divergens* and suggest a Late Maysvillian age. This is similar to the situation noted at the Holdfast well.

Samples higher in the Yeoman Formation and from the lower part of the Herald Formation are conodont poor. Specimens of *Panderodus bergstroemi*, a mid-Maysvillian or younger species, occur at 10,019.0 ft (3053.8 m) but the interval from 9937.5 ft (3029.0 m) to 10,006.55 ft (3050.0 m) is virtually barren except for specimens of the long-ranging *Panderodus*.

Aphelognathus re-appears at 9927.5 ft (3025.9 m), together with a single specimen of *Rhipidognathus*, a paleoecologically significant form, representing extremely shallow conditions. Unfortunately the specimens of *Aphelognathus* are not particularly well preserved and cannot be firmly identified as *A. divergens* which is the species expected in the Herald Formation based on correlation with the Fort Garry Member in Manitoba. Additional collections are required to sort out the evolution of *Aphelognathus* in this part of Saskatchewan.

A diverse fauna appears at the base of the Harthaven Member of the Stony Mountain Formation. It includes the biostratigraphically diagnostic *Amorphognathus ordovicicus* known from late Maysvillian to Gamachian strata around the world, and abundant specimens of *Phragmodus undatus* and a variety of other taxa. Higher samples in the Stony Mountain Formation yield a markedly similar fauna.

Paleoecology

The numerically dominant taxon throughout the Yeoman and Herald formations is the probably pelagic, simple cone conodont *Panderodus*. The shallow water *Oulodus-Aphelognathus* biofacies (10,070.2 to 10,089.0 ft; 3069.4 to 3075.1 m) characterizes the lower part of the Yeoman Formation in the Oungre well. Slight deepening is indicated by the succeeding *Plectodina* biofacies (10,032.2 to 10,061.5 ft; 3057.8 to 3066.7 m) and a return to the shallower water in the uppermost Yeoman at 10,028.3 ft (3056.6 m) is coincident with a change from mottled dolostone to bioclastic dolostone.

Conodonts are generally rare in the Herald Formation; in part, this may reflect proximity of several samples to anhydrite beds. From the available evidence, the Herald appears to have been deposited in shallow water inhabited mainly by pelagic forms, but also periodically by the *Oulodus-Aphelognathus* biofacies.

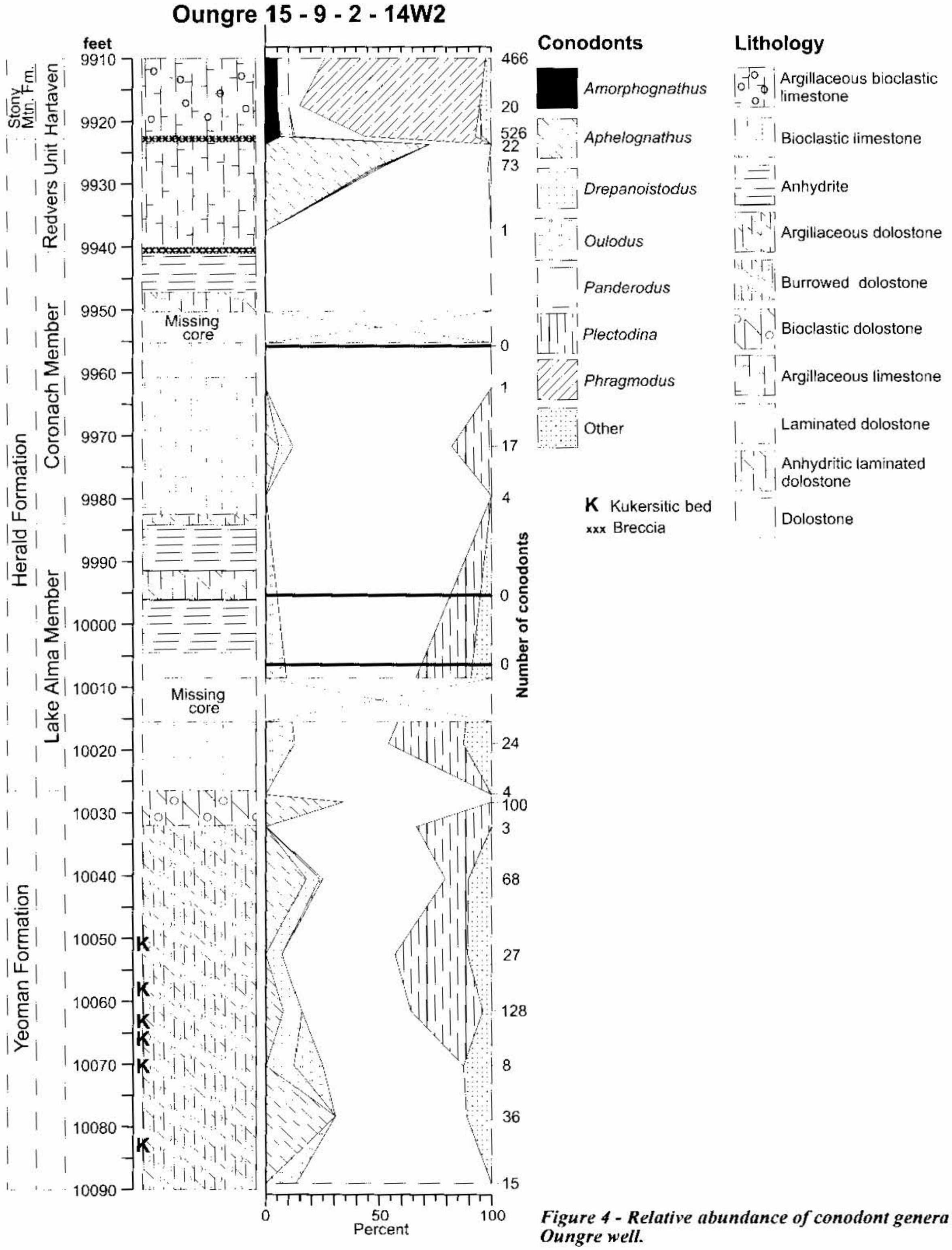


Figure 4 - Relative abundance of conodont genera in the Oungre well.

CDR Shell FPC Oungre 15-9-2-14W2

	Yeoman									Herald										Stony Mountain			
	10089.0 (C-257699)	10078.3 (C-257700)	10070.2 (C-257701)	10061.5 (C-257702)	10052.5 (C-257703)	10040.5 (C-257704)	10032.2 (C-257705)	10028.3 (C-257706)	10027.1 (C-257707)	10019.0 (C-257708)	10006.55 (C-257709)	9995.5.5 (C-257710)	9979.6 (C-257711)	9971.7 (C-257712)	9962.45 (C-257713)	9956.0 (C-257714)	9937.5 (C-257715)	9927.5 (C-257716)	9923.75 (C-257717)	9922.45 (C-257718)	9917.5 (C-257719)	9910.0 (C-257720)	
Amorphognathus ordovicicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	1	24	
Aphelognathus aff. *A. divergens*	0	0	0	0	0	0	0	34	0	0	0	0	0	0	0	0	0	35	16	0	0	0	
Aphelognathus sp.	0	11	0	10	0	12	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	
Belodina confluens	0	3	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	2	
Culumbodina occidentalis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Drepanoistodus suberectus	0	0	1	10	2	4	0	0	0	0	0	0	0	1	0	0	0	1	0	30	1	23	
Oulodus? sp.	2	0	1	0	0	1	0	0	0	3	0	0	0	0	0	0	0	1	0	4	0	0	
Panderodus bergstroemi	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	
Panderodus gibber	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	
Panderodus gracilis	13	17	5	60	14	35	2	66	3	3	0	0	4	12	1	0	1	35	6	157	1	75	
Panderodus panderi	0	4	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	
Parabelodina denticulata	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
Parabelodina cf. *P. denticulata*	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	
Paroistodus? nowlani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	
Phragmodus undatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	16	333	
Plectodina aculeatoides	0	0	0	41	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Plectodina florida	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	
Plectodina sp.	0	0	0	0	0	0	0	0	0	8	0	0	0	3	0	0	0	0	0	0	0	0	
Plegagnathus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	
Pseudobelodina vulgaris vulgaris	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	
Pseudobelodina? dispansa	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	
Pseudobelodina sp.	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Pseudooneotodus mitratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	
Rhipidognathus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	
Staufferella brevispinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	
Walliserodus sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	
Total	**15**	**36**	**8**	**128**	**27**	**68**	**3**	**100**	**4**	**24**	**0**	**0**	**4**	**17**	**1**	**0**	**1**	**73**	**22**	**526**	**20**	**466**	**1543**
Mass (grams):	400	456	400	468	400	522	400	334	400	623	400	242	200	197	300	333	400	498	300	297	250	218	8038

Table 3 - Numerical distribution of conodont species by sample depth in feet and GSC locality number in the Oungre well.

The recurrence of *Plectodina* sp. at 10,019.0 ft (3053.8 m) and at 9971.7 ft (3039.4 m) may be indicative of deeper water. A single specimen of *Rhipidognathus*, representative of extremely shallow water, occurs in the upper part of the Herald Formation at 9927.5 ft (3025.9 m).

The faunal change into the Stony Mountain Formation is made dramatic by the abundance of *Amorphognathus* and *Phragmodus* representative of deeper water biofacies and an implied major transgression.

Imperial Hartaven 2-11-10-9W2

Imperial Hartaven 2-11-10-9W2 contains core from the Herald and Stony Mountain formations from which five samples were taken from the uppermost 47 ft (14.3 m) of the Herald Formation including the Redvers unit and most of the Coronach Member, and thirteen samples from 91 ft (27.7 m) of Stony Mountain Formation, ranging through the Hartaven, Gunn, and Gunton members (Figure 5).

Biostratigraphy

The distribution of conodont species in the Hartaven well is shown in Table 4. Conodonts from the Coronach Member and Redvers unit of the Herald Formation are similar to those recovered from this interval in the Oungre 15-9-2-14W2 and Holdfast 14-12-23-26W2 wells. They are dominated by specimens of the simple cone genera *Panderodus* and *Drepanoistodus*. The most abundant denticulate form is referable to *Aphelognathus*. This species is referred to *A.* aff. *A. divergens.* This interval is undoubtedly Late Ordovician, but its precise location within the Maysvillian-Richmondian interval is uncertain. It is likely Late Maysvillian, but the relationship of the species of *Aphelognathus*, the only abundant denticulate genus, needs to be clarified to support this view (see comments above under the Oungre well).

The basal sample of the Stony Mountain Formation yields an abundant fauna that includes the internationally recognized zonal fossil *Amorphognathus ordovicicus*, which ranges from mid-Maysvillian through Richmondian and into the Gamachian, and an enormously abundant influx of *Phragmodus undatus*.

Specimens of *Oulodus rohneri* Ethington and Furnish, an indicator of Richmondian or younger Late Ordovician age, occur within the upper part of the Hartaven Member of the Stony Mountain Formation (GSC loc. C-257728, 7469.7 ft (2276.8 m). Also present is the first occurrence of the Richmondian *Staufferella brevispinata* Nowlan and Barnes. Specimens of *O. rohneri* also occur in the lower part of the Gunton Member (GSC loc. C-257733; 7429 ft; 2264.4 m).

The high abundance and diversity in the Hartaven and Gunn members drop off drastically in the Gunton Member. Abundance runs from an astonishing 4200 specimens per kilogram in the Hartaven Member, to five specimens per kilogram in the Gunton Member. No biostratigraphically diagnostic forms occur above 7418.5 ft (2261.2 m) in the Gunton Member.

Paleoecology

The yield from samples of the Coronach Member is generally too sparse to provide worthwhile information on biofacies; however, one sample (C-257723 at 7513.7 ft; 2290.2 m) is within the *Apehlognathus* biofacies. The Redvers unit reveals a shallow depositional episode by the dominance of specimens of *Aphelognathus,* and the sample at 7498.5 ft (2285.5 m) (GSC loc. C-257724) includes specimens of *Rhipidognathus,* indicating extremely shallow conditions. The topmost sample in the Redvers yielded only two specimens of *Panderodus*.

Dramatic deepening of the basin during Hartaven time is indicated by the abundance of the deep water forms *Phragmodus* and *Amorphognathus*. The relative abundance of *Phragmodus* is reduced at the base of the Gunn Member (GSC loc. C-257729; 7467.2 ft; 2276.0 m) and specimens of the shallower water genus *Oulodus* increase in abundance, although simple cones, especially *Panderodus,* dominate the faunas above this level. Slight deepening of the basin in the upper Gunn Member is signified by the reappearance of *Phragmodus* and *Plectodina*, but their number is greatly reduced. The base of the Gunton Member of the Stony Mountain Formation is still within the *Oulodus* biofacies, but immediately above, abundance and diversity completely drops off with simple cone genera being the only representatives. In the senior author's opinion, the cone genera represent pelagic conodont forms and that the entire Gunton succession may have been deposited in water too shallow to accommodate any benthic forms.

4. Discussion

The biostratigraphic data confirm an Edenian-Maysvillian age for the Yeoman Formation, especially as based on the presence of species of *Culumbodina*. Specimens of *Parabelodina denticulata* and a related form occur in the upper Yeoman and lower Herald formations and thereby suggest a Maysvillian age for this part of the section. The precise age of the upper part of the Herald remains in doubt because of the difficulty of identifying sparse specimens of *Aphelognathus*. However, recovery of *Parabelodina denticulata* and *Aphelognathus divergens,* an indicator of Richmondian age, from the correlative Fort Garry Member of the Red River Formation in Manitoba (Elias *et al.*, 1988) suggests that the upper Herald is Richmondian, but the presence of *Aphelognathus divergens* cannot be confirmed.

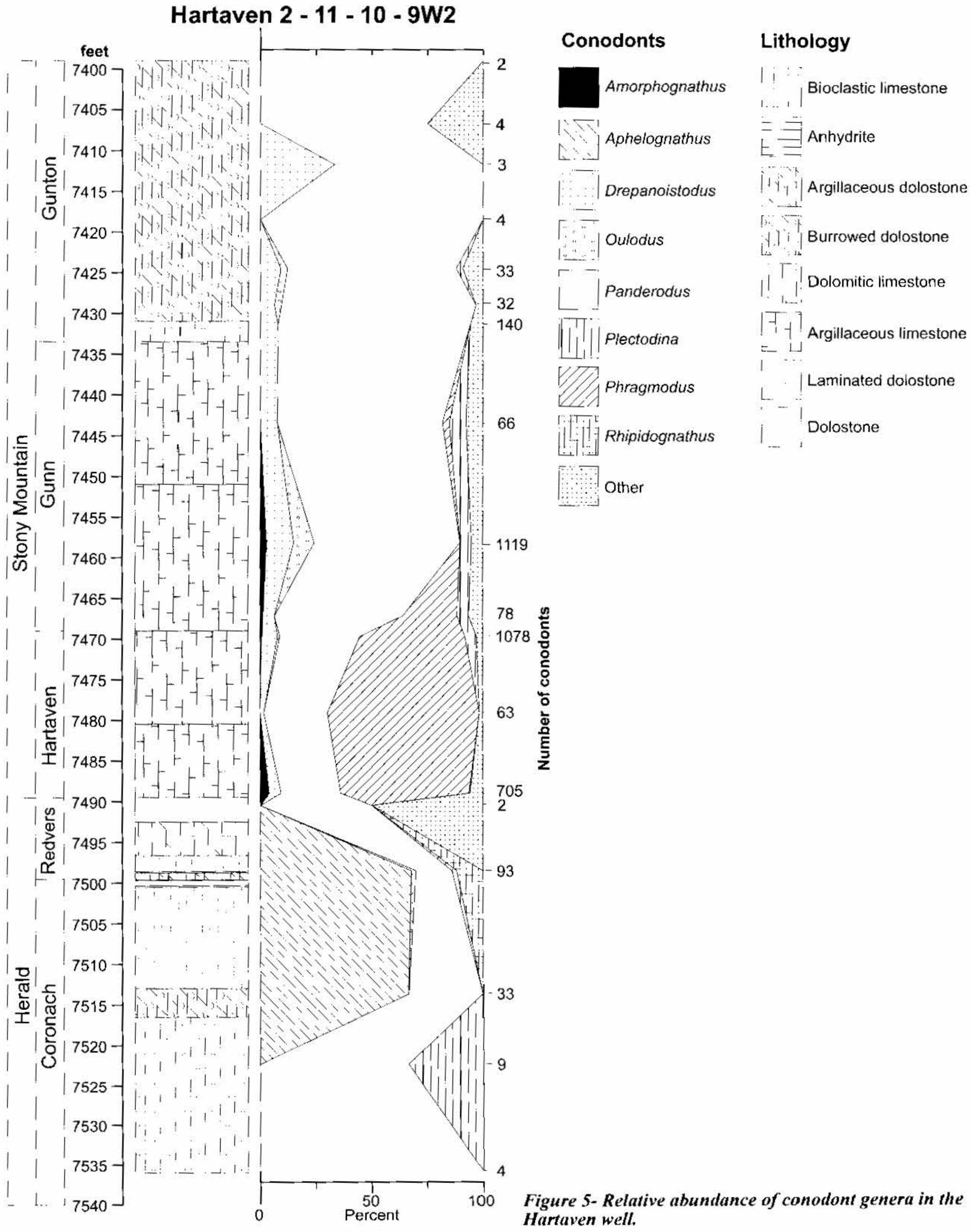


Figure 5- Relative abundance of conodont genera in the Hartaven well.

Imperial Hartaven 2-11-10-9W2

	Herald					Stony Mountain													
	7535.8 (C-257721)	7522.3 (C-257722)	7513.7 (C-257723)	7498.5 (C-257724)	7490.5 (C-257725)	7489.0 (C-257726)	7479.1 (C-257727)	7469.7 (C-257728)	7467.2 (C-257729)	7458.2 (C-257730)	7443.4 (C-257731)	7431.4 (C-257732)	7429.0 (C-257733)	7424.5 (C-257734)	7418.5 (C-257735)	7411.7 (C-257736)	7406.7 (C-257737)	7399.0 (C-257738)	
Amorphognathus ordovicicus	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	
Amorphognathus sp.	0	0	0	0	0	0	0	8	1	31	0	0	0	0	0	0	0	0	
Apelognathus aff. *A. divergens*	0	0	22	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Belodina confluens	0	0	0	0	0	0	0	0	0	12	0	0	0	2	0	0	0	0	
Belodina sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
Coelocerodontus trigonius	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	
Drepanoistodus suberectus	0	0	0	0	0	38	1	76	4	137	5	11	2	3	0	1	0	0	
Oulodus rohneri	0	0	0	0	0	0	0	11	0	0	0	0	1	0	0	0	0	0	
Oulodus ulrichi	0	0	0	0	0	0	0	0	0	103	0	0	0	0	0	0	0	0	
Oulodus sp.	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	
Padnerodus bergstroemi	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Panderodus gibber	0	0	0	2	0	4	0	10	1	39	0	5	0	0	0	0	0	0	
Panderodus gracilis	4	6	8	13	1	177	18	362	44	641	49	116	27	25	4	2	3	2	
Panderodus panderi	0	0	0	0	0	8	0	16	0	53	0	0	1	0	0	0	0	0	
Paroistodus? nowlani	0	0	0	0	0	9	0	0	0	3	0	0	0	0	0	0	0	0	
Phragmodus undatus	0	0	0	0	0	406	43	508	19	0	0	0	0	0	0	0	0	0	
Phragmodus? sp.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	
Plectodina florida	0	0	0	2	0	0	0	56	4	58	0	0	0	0	0	0	0	0	
Plectodina sp.	0	3	0	0	1	3	0	0	0	0	5	0	0	1	0	0	0	0	
Plegagnathus dartoni	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	
Plegagnathus nelsoni	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	
Plegagnathus sp.	0	0	0	0	0	3	0	0	0	0	1	0	1	1	0	0	0	0	
Pristognathus bighornensis	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	
Pseudobelodina vulgaris vulgaris	0	0	0	0	0	18	0	13	0	18	0	4	0	0	0	0	0	0	
Pseudobelodina? dispansa	0	0	0	0	0	11	0	1	4	7	2	3	0	0	0	0	1	0	
Rhipidognathus symmetricus	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Staufferella brevispinata	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	
Walliserodus amplissimus	0	0	0	0	0	0	0	5	0	2	0	0	0	0	0	0	0	0	
Total:	**4**	**9**	**33**	**93**	**2**	**705**	**63**	**1078**	**78**	**1119**	**66**	**140**	**32**	**33**	**4**	**3**	**4**	**2**	**3468**
Mass (grams):	300	305	300	357	350	499	400	415	300	265	300	596	350	345	350	409	400	449	6690

Table 4 - Numerical distribution of conodont species by sample depth in feet and GSC locality number in the Hartaven well.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

Figure 6 - Illustrations of conodonts from the Upper Ordovician of Saskatchewan (specimens arranged alphabetically by genus and species, A to P).

1 to 4) *Amorphognathus ordovicicus* ***Branson and Mehl. 1, Outer lateral view, Pb element, x71, GSC 120873; 2, outer lateral view, M element, x85, GSC 120874; 3, lateral view, Sd element, x97, GSC 120875; 4, oral view, broken Pa element, x91, GSC 120876. All specimens from the lower part of the Stony Mountain Formation in the Oungre well: 1 and 2 from GSC loc. C-257718, 3 and 4 from GSC loc. C-257720.***

5 to 15) *Aphelognathus* ***aff.*** *A. divergens* ***Sweet. 5, Inner lateral view, Sc element, x55, GSC 120877; 6, posterior view, Sb element, x51, GSC 120878; 7, posterior view, Sa element, x54, GSC 120879; 8, posterior view, Sb element, x49, GSC 120880; 9, inner lateral view, Sc element, x76, GSC 120881; 10, inner lateral view, M element, x60, GSC 120882; 11, inner lateral view, M element, x78, GSC 120883; 12, outer lateral view, Pb element, x31, GSC 120884; 13, lateral view, Pa element, x79, GSC 120885; 14, lateral view Pa element, x59, GSC 120886; 15, Pa element, x68, GSC 120887. Specimens 6, 7, 9, 11, 12, and 14 are from GSC loc. C-257706 in the Yeoman Formation in the Oungre well; specimens 5, 8, 10, and 13 are from GSC loc. C-257724 in the upper part of the Herald Formation, Hartaven well; specimen 15 is from GSC loc. C-322654 in the Herald Formation, Holdfast well.***

16 and 17) *Belodina confluens* ***Sweet. 16, Lateral view, compressiform element, x67, GSC 120888; 17, lateral view, grandiform element, x61, GSC 120889. Both specimens from GSC loc. C-322668 in the Yeoman Formation, Holdfast well.***

18) *Coelocerodontus trigonius* ***Ethington. Lateral view, x75, GSC 120890, from the Stony Mountain Formation in GSC loc. C-257729, Hartaven well.***

19) *Culumbodina occidentalis* ***Sweet. Lateral view, x43, GSC 120891, from the Yeoman Formation, GSC loc. C-322668, Holdfast well.***

20) *Culumbodina penna* ***Sweet. Lateral view, x92, GSC 120892, from the Yeoman Formation, GSC loc. C-322668, Holdfast well.***

21 and 22) *Drepanoistodus suberectus* ***(Branson and Mehl). 21, Lateral view, oistodontiform r element, x84, GSC 120893; 22, lateral view, q element, x80, GSC 120894. Both specimens from the basal Stony Mountain Formation in GSC loc. C-257718, Oungre well.***

23, 25, 26, and 31) *Oulodus ulrichi* ***(Stone and Furnish). 23, Lateral view, Sc element, x52, GSC 120895; 25, inner lateral view, Pb element, x60, GSC 120896; 26, inner lateral view, M element, x80, GSC 120897; 31, posterior view, laterally broken Pa element, x70, GSC 120898. All specimens from the Stony Mountain Formation, GSC loc. C-257730, Hartaven well.***

24) *Oulodus rohneri* ***Ethington and Furnish. Posterior view, Pa element, x85, GSC 120899, from the Stony Mountain Formation, GSC loc. C-257733, Hartaven well.***

27) *Panderodus gibber* ***Nowlan and Barnes. Lateral view, x80, GSC 120900, from basal Stony Mountain Formation, GSC loc. C-257726, Hartaven well.***

28) *Panderodus panderi* ***(Stauffer). Lateral view, x65, GSC 120901, from the basal Stony Mountain Formation, GSC loc. C-257726, Hartaven well.***

29) *Panderodus gracilis* ***(Branson and Mehl). Lateral view, x75, GSC 120902, from the basal Stony Mountain Formation, GSC loc. C-257726, Hartaven well.***

30) *Parabelodina denticulata* ***Sweet. Lateral view, x100, GSC 120903, from the Herald Formation, GSC loc. C-322660, Holdfast well.***

32 and 34) *Parabelodina* ***cf.*** *P. denticulata* ***Sweet. 32. Lateral view, x131, GSC 120904; 34, lateral view, x120, GSC 120905. Specimen 32 from the Herald Formation, GSC loc. C-322658, Holdfast well and specimen 34 from the Herald Formation, GSC loc. C-257708, Oungre well.***

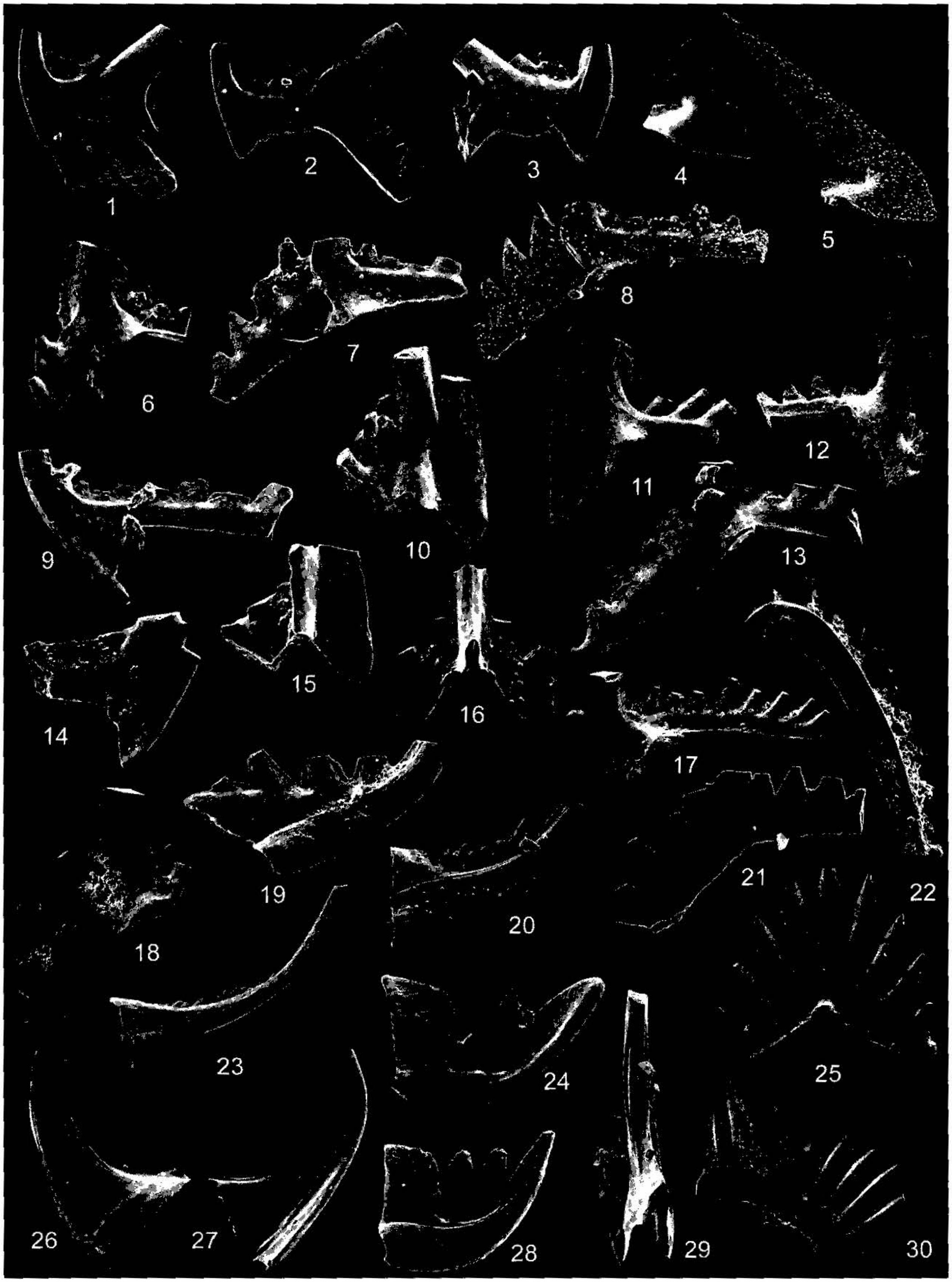
33) *Paroistodus? nowlani* ***Zhen, Webby and Barnes. Inner lateral view, oistodontiform element, x137, GSC 120906, from the basal Stony Mountain Formation, GSC loc. C-257726, Hartaven well.***

A striking turnover in the conodont fauna occurs at the base of the Stony Mountain Formation. *Amorphognathus ordovicicus*, the worldwide index for Middle Maysvillian and younger Late Ordovician strata, is found together with extremely abundant *Phragmodus undatus*. Specimens of *Oulodus rohneri* in the lower part of the Stony Mountain Formation confirm a Richmondian age for the unit. Conodont abundance decreases drastically in the upper part of the Stony Mountain Formation and diagnostic forms are absent. Previous work (Norford *et al.*, 1998; Nowlan and Haidl, 1999) has shown that the remainder of the Stony Mountain and the lower part of the Stonewall are Richmondian and that the Ordovician-Silurian boundary occurs within the Stonewall Formation.

Conodont biofacies, expressed in terms of relative abundance curves for genera, show marked changes in depositional environment from the base of the Yeoman, through the Herald, and into the Stony Mountain Formation. Yields from the basal part of the Yeoman are sparse, but the forms present (e.g. *Oulodus*) are suggestive of shallow water deposition. General deepening followed, as indicated by the increase in species of *Plectodina* throughout much of the middle and upper part of the Yeoman Formation (Figures 3 and 4). Within this interval, increases in the relative abundance of *Aphelognathus* suggest distinct shallowing episodes.

One such shallowing episode is reflected by higher energy fabrics in the "transitional" unit at the top of the Yeoman in several wells (including Oungre) (Pratt *et al.*, 1996; Canter, 1998; Kreis and Kent, 2000), and in sub-aerially exposed surfaces in the lower portion of the laminated carbonate unit of the Lake Alma Member (Kent and Kissling, 1998; Kreis and Kent, 2000). The recurrence of *Plectodina* within Lake Alma laminated carbonates in the Oungre well may reflect a deepening event associated with deposition of the upper portion of this laminated unit. In the Holdfast well, the presence of burrowed fossiliferous dolostone between beds of Lake Alma laminated strata also suggests a deepening event. The relative abundance of *Aphelognathus* in this fossiliferous unit and the overlying laminated unit suggests shallower conditions than in the middle part of the Yeoman. However, paleoecological interpretation of the Lake Alma sequence based on conodonts is limited in this well because the lower laminated bed was not sampled. Further detailed sampling in this and other cores is required to determine whether or not a sequence boundary separates lower Lake Alma laminated strata from overlying carbonates and basin-centred, subaqueously deposited Lake Alma evaporites as suggested by Canter (1998).

Specimens of *Rhipidognathus* are present in the upper part of the Herald Formation in both the Holdfast and Hartaven wells (Figures 3 and 5). This suggests an extreme shallowing episode and a possible period of emergence. Lithological evidence for sub-aerial exposure in this part of the stratigraphic section is reported by Kreis and Kent (2000).


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

The striking concentration of deep and possibly cooler water conodonts *Amorphognathus* and *Phragmodus* at the base of the Stony Mountain Formation indicates a major transgression and a rise in sea level or the introduction of a cooler water mass. Based on evidence from the Hartaven well, this deep water episode persists through the Hartaven Member and into the lower part of the Gunn Member. While specimens of *Phragmodus* continue to be present in upper samples from the Gunn, they are much less abundant and the proportionate decrease in number of *Plectodina* suggest shallowing (Figure 5). The Gunton Member of the Stony Mountain Formation produces few conodonts suitable for biofacies analysis.

Figure 7 - Illustrations of conodonts from the Upper Ordovician of Saskatchewan (specimens arranged alphabetically by genus and species, P to W).
1 to 8)** Phragmodus undatus **Branson and Mehl. 1, Lateral view, Sc element, x77, GSC 120907; 2, lateral view, Sc element, x93, GSC 120908; 3, lateral view, Sd element, x75, GSC 120909; 4, inner lateral view, M element, x55, GSC 120910; 5, inner lateral view, M element, x86, GSC 120911; 6, inner lateral view, Pb element, x74, GSC 120912; 7, outer lateral view, Pa element, x75, GSC 120913; 8, outer lateral view, Pa element, x81, GSC 120914. Specimens 1, 3, 4, 6, and 7 from basal Stony Mountain Formation in GSC loc. C-257718, Oungre well; specimens 2, 5, and 8 from basal Stony Mountain Formation in GSC loc. C-257726, Hartaven well.
9 to 13)** Plectodina aculeatoides **Sweet. 9, Inner lateral view, Sc element, x90, GSC 120915; 10, posterior view, Sb element, x107, GSC 120916; 11, inner lateral view, M element, x95, GSC 120917; 12, inner lateral view, Pb element, x62, GSC 120918; 13, lateral view, Pa element, x92, GSC 120919. All specimens from Yeoman Formation, GSC loc. C-257702, Oungre well.
14 to 18 and 21)** Plectodina florida **Sweet. 14, Inner lateral view, Sc element, x98, GSC 120920; 15, posterior view, Sb element, x98, GSC 120921; 16, posterior view, Sc element, x116, GSC 120922; 17, inner lateral view, M element, x74, GSC 120923; 18, inner lateral view, Pb element, x77, GSC 120924; 21, lateral view, Pa element, x111, GSC 120925. All specimens from Stony Mountain Formation in the Hartaven well: 14, 15, 16, 18, and 21 from GSC loc. C-257730 and 17 from C-257729.
19)** Plegagnathus nelsoni **Ethington and Furnish. Lateral view, x98, GSC 120926, from the Herald Formation, GSC loc. C-322654, Holdfast well.
20 and 23)** Pseudobelodina? dispansa **(Glenister). 20, Lateral view, broad element, x80, GSC 120927; 23, lateral view, slender element, x69, GSC 120928. Specimen 20 from basal Stony Mountain Formation, GSC loc. C-257726, Hartaven well and specimen 23 from Yeoman Formation, GSC loc. C-322665, Holdfast well.
22)** Pristognathus bighornensis **Stone and Furnish. Posterior view, Pa element, x70, GSC 120929, from Stony Mountain Formation, GSC loc. C-257731, Hartaven well.
24 and 28)** Pseudobelodina vulgaris vulgaris **Sweet. 24, Inner lateral view, x64, GSC 120930; 28, lateral view, x100, GSC 120931. Specimen 24 from Yeoman Formation, GSC loc. C-322665, Holdfast well and specimen 28 from Yeoman Formation, GSC loc. C-257740, Pangman well.
25 and 30)** Rhipidognathus symmetricus **Branson, Mehl and Branson. 25, Posterior view, symmetrical element, x45, GSC 120932; 30, posterior view, asymmetrical element, x33, GSC 120933. Both specimens from upper part of Herald Formation, GSC loc. C-257724, Hartaven well.
26, 27, and 29)** Walliserodus amplissimus **(Serpagli). 26, Inner lateral view, Sc element, x91, GSC 120934; 27, lateral view, Sa element, x92, GSC 120935; 29, posterior view, Sa element, x100, GSC 120936. All specimens from the lower part of the Stony Mountain Formation, GSC loc. C-257728, Hartaven well.

5. Future Work

More detailed sampling combined with lithologic studies are required to facilitate sequence stratigraphic interpretation of Upper Ordovician strata. The data presented here are integrated with geochemical data on the neodymium isotopes and samarium-neodymium ratios of conodont and rock samples from many of the same samples (Fanton *et al.*, in review). The combination of biostratigraphic and paleoecological data with these geochemical tools provides insight into the submergence history of the craton in the Williston Basin area. Integration of these types of lithological, geochemical, and paleontological data is planned for correlative sections of Manitoba and Saskatchewan, probably in the Weyburn-Midale area and over the Ordovician-Silurian boundary interval in Saskatchewan and Manitoba.

6. References

Amsden, T.W. and Miller, A.K. (1942): Ordovician conodonts from the Bighorn Mountains of Wyoming; J. Paleont., v16, p301-306.

Barnes, C.R. and Fåhraeus, L.E. (1975): Provinces, communities, and the proposed nektobenthic habit of Ordovician conodontophorids; Lethaia, v8, p133-149.

Brindle, J.E. (1960): The faunas of the Lower Paleozoic carbonate rocks in the subsurface of Saskatchewan; Sask. Dep. Miner. Resour., Rep. 52, 45p.

Canter K.L. (1998): Facies, cyclostratigraphic, and secondary diagenetic controls on reservoir distribution, Ordovician Red River Formation, Midale Field, southern Saskatchewan; Eighth International Williston Basin Symposium, Core Workshop Volume, Regina, October 1998, Saskatchewan, North Dakota and Montana Geol. Soc., p41-65.

Carlson, C.C. (1960): Stratigraphy of the Winnipeg and Deadwood formations in North Dakota; N. Dakota Geol. Surv., Bull. 35, 149p.

Elias, R.J., Nowlan G.S., and Bolton, T.E. (1988): Paleontology of the type section of the Fort Garry Member, Red River Formation (Upper Ordovician), southern Manitoba; New Mexico Bureau Mines Miner. Resour., Mem. 44, p341-359.

Ethington, R.L. and Furnish, W.M. (1960): Upper Ordovician conodonts from southern Manitoba; J. Paleont., v34, p265-274.

Fanton, K.C., Holmden, C., Nowlan, G.S., and Haidl, F.M. (in review): $^{143}Nd/^{144}Nd$ and Sm/Nd stratigraphy of Late Ordovician epeiric sea carbonates; Geochim. Cosmochim. Acta.

Furnish, W.M., Barragy, E.J., and Miller, A.K. (1936): Ordovician fossils from the uppermost part of the type section of the Deadwood Formation, South Dakota; Amer. Assoc. Petrol. Geol. Bull., v20, p1329-1341.

Haidl, F.M., Longman, M.W., Pratt, B.R., and Bernstein, L.M. (1997): Variations in lithofacies in Upper Ordovician Herald and Yeoman formations (Red River), North Dakota and southeastern Saskatchewan; *in* Wood, J. and Martindale, B. (comp.), Can. Soc. Petrol. Geol.–Soc. Econ. Paleont. Mineral., Core Conference, Calgary, p5-39.

Kendall, A.C. (1976): The Ordovician carbonate succession (Bighorn Group) of southeastern Saskatchewan; Dep. Miner. Resour., Rep. 180, 185p.

__________ (1977): Origin of dolomite mottling in Ordovician limestones from Saskatchewan and Manitoba; Bull. Can. Petrol. Geol., v25, p480-504.

Kent, D.M. (1960): The evaporites of the Upper Ordovician strata in the northern part of the Williston Basin; Sask. Dep. Min. Resour., Rep. 46, 46p.

Kent, D.M. and Haidl, F.M. (1999): Geology of Ordovician Winnipeg and Red River rocks, southeast Saskatchewan; Depositional environments and reservoir potential of Lower and Middle Paleozoic rocks in Saskatchewan, Can. Soc. Petrol. Geol., Calgary, CSPG Short Course G-4, unpubl. notes, p1-37.

Kent, D.M. and Kissling, D.L. (1998): Covert facies of the Red River C Laminated Member, northern Williston Basin; *in* Christopher, J.E., Gilboy, C.F., Paterson, D.F., and Bend, S.L. (eds.), Eighth International Williston Basin Symposium, Sask. Geol. Soc., Spec. Publ. No. 13, p24.

Kessler, L.G. (1991): Subsidence controlled stratigraphic sequences and the origin of shelf sand ridges, Winnipeg Group (Middle Ordovician) Manitoba, Saskatchewan and North Dakota; *in* Christopher, J.E. and Haidl, F.M. (eds.), Sixth International Williston Basin Symposium, Sask. Geol. Soc., Spec. Publ. No. 11, p1-13.

Kissling, D.L. (1997): Rethinking the configurations of Red River reservoirs; Fifth International Williston Basin Horizontal Well Workshop; Sask. Energy and Mines and North Dakota Geol. Survey.

__________ (1999): Life and death roles of Red River Thalassinoides; Abstracts, Rocky Mtn. Sect., Amer. Assoc. Petrol. Geol. Bull., v83, p1184.

Kreis, L.K. (2000): Geology of the Middle Ordovician Winnipeg Formation in Saskatchewan, Lower Paleozoic Map Series, Sask. Energy Mines, Open File Rep. 2000-2, Sheet 3 of 8.

Kreis, L.K. and Kent, D.M. (2000): Basement controls on Red River sedimentation and hydrocarbon production in southeastern Saskatchewan; *in* Summary of Investigations 2000, Volume 1, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 2000-4.1, p21-42.

Longman, M.W. and Haidl, F.M. (1996): Cyclic deposition and development of porous dolomites in the Upper Ordovician Red River Formation, Williston Basin; *in* Longman, M.W. and Sonnenfeld, M.D. (eds.), Paleozoic Systems of the Rocky Mountain Region, Rocky Mtn. Sec., Soc. Econ. Paleont. Mineral., p29-46.

Norford, B.S., Nowlan, G.S., Haidl, F.M., and Bezys, R.K. (1998): The Ordovician-Silurian boundary interval in Saskatchewan and Manitoba; *in* Christopher, J.E., Gilboy, C.F., Paterson, D.F., and Bend, S.L., (eds.), Eighth International Williston Basin Symposium, Sask. Geol. Soc., Spec. Publ. No. 13, p27-45.

Norford, B.S., Haidl, F.M., Bezys, R.K., Cecile, M.P., McCabe, H.R., and Paterson, D.F. (1994): Middle Ordovician to Lower Devonian strata of the Western Canada Sedimentary Basin; *in* Mossop, G.D. and Shetsen, I. (comp.), Geological Atlas of the Western Canada Sedimentary Basin; Can. Soc. Petrol. Geol./Alta. Resear. Counc., p109-127.

Nowlan, G.S. (in review): Stratigraphy and conodont biostratigraphy of Upper Ordovician strata in the subsurface of Alberta, Canada; Palaeont.

Nowlan, G.S. and Barnes, C.R. (1981): Late Ordovician conodonts from the Vaureal Formation, Anticosti Island, Quebec; Geol. Surv. Can., Bull. 329, p1-49.

Nowlan, G.S. and Haidl, F.M. (1999): New conodont data from the Ordovician-Silurian boundary interval in southeastern Saskatchewan; *in* Summary of Investigations 1999, Volume 1, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 99-4.1, p12-16.

Oberg, R. (1966): Winnipeg conodonts from Manitoba; J. Paleont., v40, p130-137.

Pratt, B.R., Bernstein, L.M., Kendall, A.K., and Haidl, F.M. (1996): Occurrence of reefal facies in Red River strata (Upper Ordovician), subsurface Saskatchewan; *in* Summary of Investigations 1996, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 96-4, p147-152.

Seddon, G. and Sweet, W. C. (1971): An ecologic model for conodonts; J. Paleont., v45, p869-880.

Stasiuk, L.D (1991): Organic petrology and petroleum formation in Paleozoic rocks of northern Williston Basin, Canada; unpubl. Ph.D. thesis, Univ. Regina, 312p

Stasiuk, L.D., Kybett, B.D., and Bend, S.L. (1993): Reflected light microscopy and micro-FTIR of Upper Ordovician Gloeocapsomorpha prisca alginite in relation to paleoenvironment and petroleum generation, Saskatchewan, Canada; Org. Geochem., v20, p707-719.

Stone, G.L. and Furnish, W.M. (1959): Bighorn conodonts from Wyoming; J. Paleont., v33, p211-228.

Sweet, W.C. (1979): Late Ordovician conodonts and biostratigraphy of the western Midcontinent Province; Brigham Young University, Geology Studies, v26, p45-86.

_________ (1982): Conodonts from the Winnipeg Formation (Middle Ordovician) of the northern Black Hills, South Dakota; J. Paleont., v56, p1029-1049.

_________ (1984): Graphic correlation of upper Middle and Upper Ordovician rocks, North American Midcontinent Province, U.S.A.; *in* Bruton, D.L. (ed.), Aspects of the Ordovician System, Palaeont. Contrib. Univ. Oslo, No. 295, p23-35.

Sweet W.C. and Bergström, S.M. (1984): Conodont provinces and biofacies of the Late Ordovician; *in* Clark, D.L. (ed.) Conodont Biofacies and Provincialism, Geol. Soc. Amer., Spec. Pap. 196, p69-87.