New Conodont Data from the Ordovician-Silurian Boundary Interval in Southeastern Saskatchewan

G.S. Nowlan [1] *and F.M. Haidl*

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1. Introduction

Previously published conodont data from drill holes and outcrops in Manitoba and Saskatchewan indicate that the Ordovician-Silurian boundary occurs in the upper one-third of the Stonewall Formation in the Williston Basin area (Norford *et al.*, 1998). New data suggest that the boundary is in a similar position in the Imperial Herald 1-31-1-20W2 well which is located closer to the centre of the Williston Basin than previously sampled locations (Figure 1).

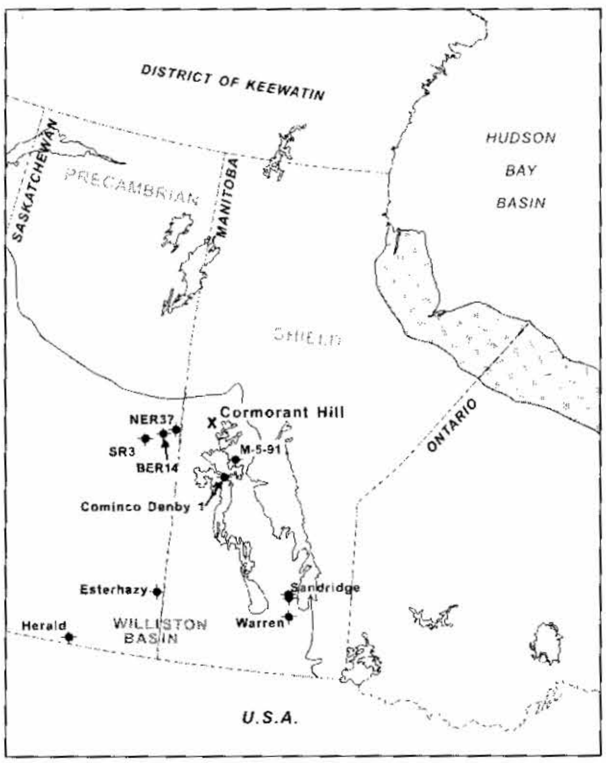

Figure 1 - Location in the Williston Basin area of selected cores and outcrops of the upper one-third of the Stonewall Formation. Conodont data are available for the Herald (this paper), Esterhazy, Sandridge, Warren, and Cormorant Hill (Norford et al., 1998) sections.

2. Stratigraphic Setting

Warm shallow seas covered much of the North American craton during the Late Ordovician and Early Silurian. Rocks from this time are characterized, in general, by repetition of the following lithologies: 1) argillaceous dolomudstone and dolomitic shale marker beds with varying proportions of quartzose sand; 2) fossiliferous, commonly burrowed, dolomudstone/wackestone; 3) skeletal, lithoclastic, peloidal dolowacke/pack/grainstone; 4) dolomudstone (commonly laminated); and 5) anhydrite in the central portion of the basin. The sequences are interpreted as representing brining- or shallowing-upward cycles, or cycles that reflect both processes (e.g. Roehl, 1967; Kendall, 1976; Johnson and Lescinsky, 1986; Pratt *et al.*, 1996). A recently published interpretation of the oldest of these repetitive sequences in the Yeoman and lower Herald formations (Red River) suggests that deposition of the evaporites represents a deepening event which followed deposition of shallow water carbonates, some of which show evidence of subaerial exposure (Canter, 1998; Kent and Kissling, 1998). Detailed sedimentological studies are required to determine if this interpretation has relevance to the sequences in the Stonewall Formation.

Correlation of lithologic units in the Imperial Herald well to those in Esterhazy 16-26-20-33W1, another well that has been extensively sampled for conodonts, is shown in Figure 2. Anhydrite deposits are present at the top of the Stony Mountain and in the lower Stonewall in the Herald well; they do not extend to the Esterhazy well which is farther from the basin centre. Overall, strata between the lower Stonewall marker and the lower t-marker are much more fossiliferous in the Esterhazy core than in the one from Herald. A 2.5 m unit of dolowackestone containing abundant specimens of the brachiopod *Oepikina stonewallensis* (Brindle, 1960; Kendall, 1976) is present in the Herald core at the same stratigraphic level as a coral-stromatoporoid doloboundstone unit in the Esterhazy well.

In both wells, the interval associated with the Ordovician-Silurian boundary has two closely spaced beds designated as the lower and upper t-markers which are separated by a dolowacke/mudstone unit. On geophysical logs, the lower t-marker in the Herald well is 107 cm thick (2850.49 to 2851.56 m; 9352 to

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

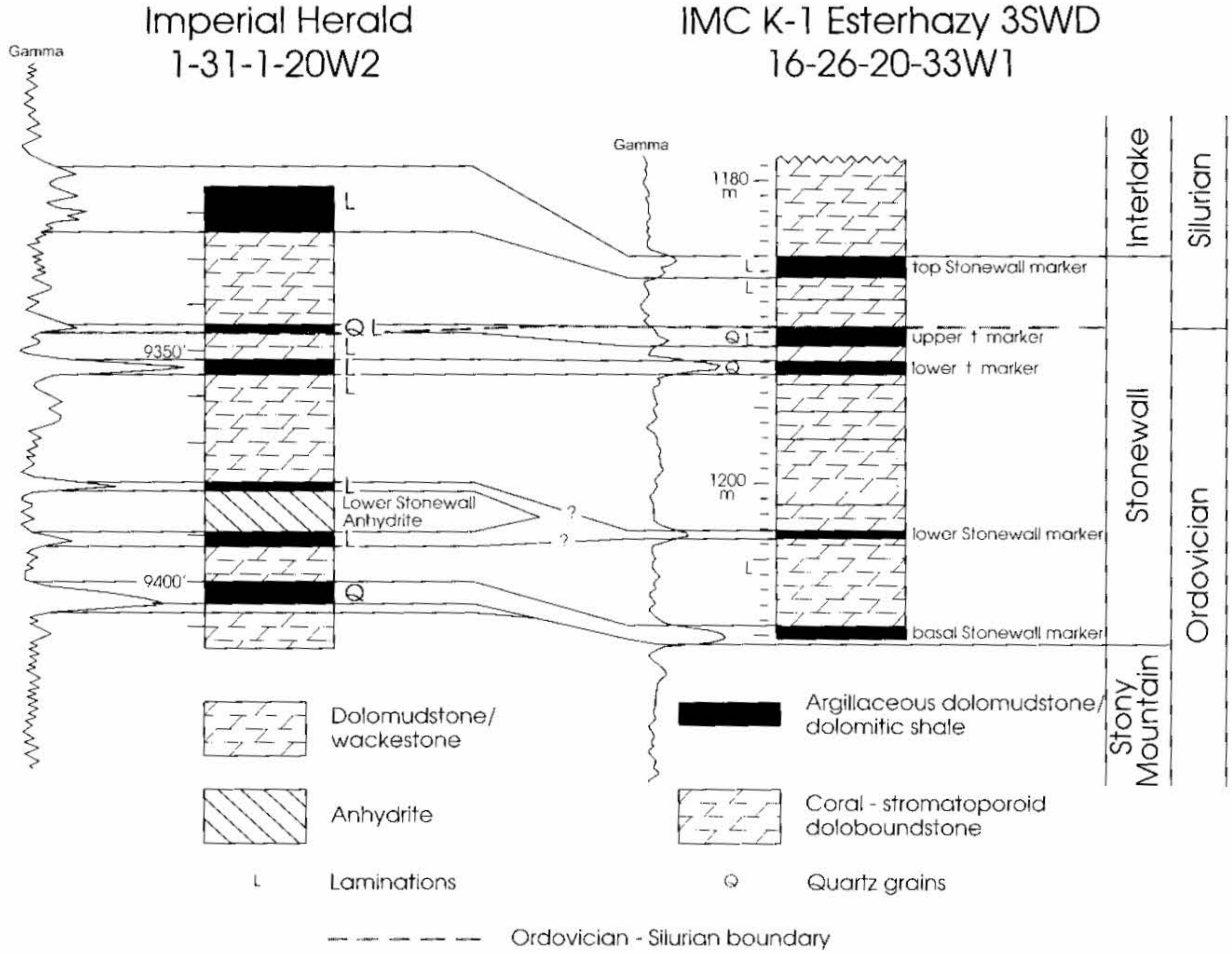

Figure 2 - Correlation of gamma-ray logs and lithologic units in the Imperial Herald 1-31-1-20W2 and IMC K-1 Esterhazy 3SWD 16-26-20-33W1 wells. The Ordovician-Silurian boundary, as determined from conodont data, is illustrated by a dashed line. In the Herald well, Silurian conodonts were identified in an interval from 9345.5 to 9346.0 ft and Ordovician conodonts in a sample from 9347.0 to 9347.5 ft. In the Esterhazy well, Silurian conodonts are present in a sample from 1189.59 to 1189.80 m and Ordovician conodonts in an interval from 1189.88 to 1190.01 m (Norford et al., 1998).

9355.5 ft), only 50 cm of which is preserved in core. This unit is composed of dark grey, laminated, dolomitic shale and argillaceous dolomudstone; it is bioturbated at the top. A fossiliferous dolowackestone with abundant corals, bryozoans, and echinoderms grades upward to a dolomudstone that is laminated in its upper part, just below the upper t-marker. At Esterhazy the lower t-marker is 80 cm thick (1192.0 to 1192.8 m). Sand grains are abundant in shale laminations within the dolomudstone at the base of the lower t-marker and in the overlying dolomitic shale/argillaceous dolomudstone (60 cm) which is reddish brown with yellow mottling. Overlying the bioturbated top of the lower t-marker is a mottled dolostone with scattered large vugs, some of which resemble fossil molds. This is overlain by a nodular dolomudstone which becomes increasingly brecciated upwards to where it grades into the upper t-marker.

The upper t-marker is identified by a gamma-ray response that is higher than the adjacent carbonates but lower than the lower t-marker (Figure 2). In the Herald well, the upper t-marker is composed of bluish-grey mottled, dolomudstone with abundant laminae and scattered grains of quartzose sand (Figure 3). In the Esterhazy core, the upper t-marker is a grey and buff mottled dolomudstone with a "chaotic" texture. It contains minor irregular laminae of greenish-grey clay-filled fractures or cracks, in which anhydrite is also common and lenses and scattered grains of quartzose sand are abundant in the upper 25 cm (see Figure 5, Norford, *et al.*, 1998). For details of the t-markers in other wells and outcrops in Saskatchewan and Manitoba see Norford *et al.* (1998).

Strata between the upper t-marker and the top of the Stonewall Formation comprise: 1) a basal dolomudstone, commonly fossiliferous with laminated interbeds; 2) interbeds of peloidal-skeletal-lithoclastic dolowackestone; 3) a laminated dolomudstone; and 4) a laminated argillaceous, dolomudstone marker bed at the top (top Stonewall marker, Figure 2).

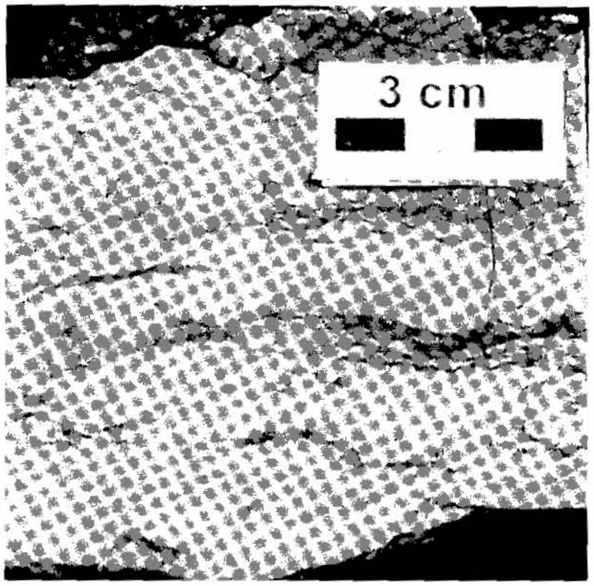

Figure 3 - Imperial Herald 1-31-1-20W2, 2848.6 m (9345.8 ft), upper t-marker. Abundant quartzose sand grains scattered throughout and concentrated in wispy laminae. Silurian conodonts were recovered from sample interval 9345.5 to 9346 ft.

The brachiopod *Virgiana decussata* (Whiteaves), indicative of a late Rhuddanian (early Llandovery) age is common near the base of the Interlake Formation in Manitoba and has been identified in several Saskatchewan cores, including that from the Esterhazy well (Jin *et al.*, this volume; Jin *et al.*, 1994). The Stony Mountain Formation which underlies the Stonewall is dated as Richmondian (see discussion in Elias *et al.*, 1988).

3. Conodont Data

Eight samples from the Herald well have been processed for conodonts; all of the samples have yielded some specimens, nearly 300 in total (Table 1), although recovery of biostratigraphically diagnostic forms is generally sparse. Before analyzing the data presented, it is important to note how the Ordovician-Silurian boundary is defined for the purposes of this study. Although Melchin *et al.* (1991) have shown that conodonts of Silurian aspect occur together with Late Ordovician forms in a thin transitional boundary interval in complete sections in the Arctic Islands, the boundary is taken here at the first appearance of forms of Silurian aspect because of the likely absence of Gamachian strata and at least some of the early Rhuddanian (for a more complete discussion of this question, see Norford *et al.*, 1998, p33).

With this definition, the data show that the Ordovician-Silurian boundary lies between 9346 and 9347 ft. Below 9347 ft, the fauna is of Late Ordovician (Richmondian to ?Gamachian) age based on the presence of specimens of: 1) *Oulodus rohneri* Ethington and Furnish (a Richmondian to Gamachian indicator; see Nowlan and Barnes, 1981; McCracken and Barnes, 1981; Sweet, 1984); 2) and specimens of *Pseudobelodina vulgaris* Sweet that resemble the latest Richmondian indicator subspecies *P. v. ultima* Sweet, but are too rare and fragmentary to be identified with certainty; and 3) *Aphelognathus* sp., most similar to *A. divergens* Sweet, a Richmondian species, but they are also too rare and fragmentary to be identified positively. The numerically dominant component of these Late Ordovician assemblages are specimens assignable to the simple cone genus *Panderodus*, which has a long range from Middle Ordovician to Middle Devonian, and to *Drepanoistodus suberectus* (Branson and Mehl), a long ranging species restricted

Table 1- Numerical distribution of conodont specimens identified within samples in the Imperial Herald 1-31-1-20W2 well.

	Measurements in feet (below KB)								
Specimens Identified	9340.0-9340.5	9344.0-9344.5	9345.5-9346.0	9347.0-9347.5	9350.4-9350.7	9351.5-9352.0	9355.75-9356.25	9359.25-9359.8	**Total**
Aphelognathus sp.				5	1	6	5		**17**
Drepanoistodus suberectus (Branson & Mehl)				17	10	27			**54**
Oulodus rohneri Ethington & Furnish						6			**6**
Panderodus gibber Nowlan & Barnes						2			**2**
Panderodus panderi (Stauffer)				7	2	11			**20**
Plectodina? sp.								5	**5**
Plegagnathus sp.					1				**1**
Pseudobelodina inclinata (Branson & Mehl)					1	5			**6**
Pseudobelodina vulgaris Sweet				2		1			**3**
Panderodus gracilis (Branson & Mehl)	1	1	3	32	32	65		3	**137**
denticulate fragments		1					15	4	**20**
Kockelella manitoulinensis (Pollock *et al.*)	3								**3**
Oulodus? sp.	6								**6**
Ozarkodina hassi (Pollock *et al.*)			2						**2**
Ozarkodina oldhamensis (Rexroad)			1						**1**
TOTAL	**10**	**2**	**6**	**63**	**47**	**123**	**20**	**12**	**283**

to the Ordovician. As expected, the fauna is typical of the Midcontinent Faunal Region, and similar to faunas recovered from elsewhere in Saskatchewan and Manitoba at this level (Norford *et al.*, 1998).

The lowest Early Silurian conodont specimens occur in the sample at 9345.5 to 9346.0 ft (Table 1). The fauna represents a typical Early Silurian (probably Rhuddanian) mid-continent fauna comprising specimens of *Ozarkodina hassi, O. oldhamensis,* and *Kockelella manitoulinensis.* This type of fauna is well known from earliest Silurian strata in North America, especially in the intracratonic basins: Michigan Basin (Pollock *et al.*, 1970) and Hudson Bay Basin and Williston Basin (Norford *et al.*, 1998). Similar faunas also occur in areas marginal to the Laurentian Platform such as the Arctic (Melchin *et al.*, 1991), Gaspé Peninsula (Nowlan, 1983), Anticosti Basin (Nowlan and Barnes, 1981; McCracken and Barnes, 1981), and western Canada (Nowlan *et al.*, 1988; Over and Chatterton, 1987).

4. Discussion

One of the curious aspects of the Ordovician-Silurian boundary sections examined in Saskatchewan and Manitoba to date (Norford *et al.*, 1998; Elias *et al.*, in press) is that there does not appear to be any reworking of Ordovician conodonts into Silurian deposits. This is also true for the Herald well (data from this paper). The assumed gap in time between the deposition of the uppermost Ordovician unit and the earliest Silurian unit is equivalent to the duration of the Gamachian Stage of the latest Ordovician and at least the early part of the Rhuddanian stage of the earliest Silurian, an interval of three to five million years (see data cited in Okulitch, 1995). Denticulate conodonts from the two periods are so distinctive that it would be easy to tell re-worked Ordovician material, but none has been identified so far. On the other hand, it would not be possible to tell if specimens of the abundant simple cone genus *Panderodus* had been reworked because Ordovician and Silurian forms are indistinguishable. Since the chances of reworking of both types of element are the same, it is assumed that no re-working has occurred. It is difficult to envisage how the Silurian transgression could have proceeded without eroding at least some of the underlying Upper Ordovician strata which we know to have been rich in conodonts. The lack of re-working implies that no strong river systems developed during the hiatus and that transgression was slow and gentle, with no major storms and thus minimal erosion of Upper Ordovician strata, at least in the areas studied to date.

In the Herald well, the Ordovician-Silurian boundary lies within, or at the base of, the upper t-marker; whereas, in the Esterhazy well, earliest Silurian faunas appear just above the upper t-marker (Norford *et al.*, 1998). This raises the possibility that the upper t-marker is slightly diachronous between the two wells. The origins of the marker beds that characterize Stonewall and Interlake strata are not well understood. Johnson and Lescinsky (1986) interpreted them as regressive units. Kendall (1976), on the other hand, interpreted them as transgressive deposits. Given that a gap of three to five million years is interpreted between strata with latest Ordovician conodonts and those with earliest Silurian conodonts (see above), the occurrence in the Esterhazy core of Ordovician conodonts 4 cm below the top of the upper t-marker and Silurian conodonts 4 cm above supports an interpretation of this bed as a regressive unit. One possible explanation for the different ages of conodonts in the upper t-marker in the Esterhazy and Herald wells may be that the upper t-marker in Herald represents a transgressive event associated with migration of the first Silurian faunas into the Williston Basin, whereas, in the Esterhazy well, this marker bed is a regressive deposit that records subaerial exposure in the area prior to that Silurian transgression. A difference in sedimentary and diagenetic textures in the upper t-marker beds in these wells also suggests that the two marker beds may have a different history. In Esterhazy, this unit has a brecciated "chaotic" texture, whereas in the Herald core it is characterized by interbedding of mottled and laminated strata (cf. Figure 3, this paper and Figure 5, Norford *et al.*, 1998).

5. Further Work

Of primary importance is more detailed sampling in the Herald core in order to narrow down the boundary interval and establish with greater certainty the possible diachronous nature of the upper t-marker bed. Further detailed sampling should also be completed on core from the Sandridge area of Manitoba. To date, two wells have been examined in this area where it was shown that the t-marker interval may contain Silurian conodonts (Norford *et al.*, 1998, Figure 10). More detailed sampling will assist in establishing the degree of diachronism of the t-marker interval across a wider region. In addition, it would be worth sampling cores from drill holes in Cumberland–Namew Lake area (e.g. SR3, BER14, NER37, Figure 1) in which the t-marker interval is poorly developed, in order to ascertain the position of the Ordovician-Silurian boundary and to facilitate correlation of stratigraphic units in this area to those in Manitoba and southern Saskatchewan.

It is also crucial that sedimentological studies be initiated in order to determine environments of deposition in the Stonewall Formation and to elucidate the origin of the marker beds. A longer term goal is the integration of paleontological, stable isotopic, and sedimentological data to address impact of sea-level changes and basin subsidence on sequences in the Williston and Hudson Bay basins and the interconnection between the two. Some initial work has begun to address this important potential contribution to the understanding of the development of two adjacent intracratonic basins (Fanton *et al.*, 1998; Norford *et al.*, 1998; Jin *et al.*, this volume).

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