The Ordovician–Silurian boundary on Manitoulin Island, Ontario, Canada

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Synopsis

The Ordovician–Silurian boundary in southern Ontario is reviewed. Sections on Manitoulin Island have been regarded by earlier workers as representing continuous sedimentation in a shallow carbonate platform environment on the north-east flank of the Michigan Basin. The best section across the boundary, exposed in the Kagawong West Quarry, is described and illustrated. Lithological studies have demonstrated a minor karst development near the systemic boundary. Conodont and macrofossil data demonstrate that the Kagawong Member, Georgian Bay Formation and the lower 15 cm of the overlying Manitoulin Formation are of Richmondian age (Ordovician, Cincinnatian Series). The remainder of the Manitoulin Formation is of Rhuddanian age (Silurian, Llandovery (Anticostian) Series). A hiatus is shown to occur 15 cm above the base of the Manitoulin Formation that represents the Gamachian Stage, Cincinnatian Series and possibly also the latest Richmondian Stage and earliest Rhuddanian Stage. Although the section on Manitoulin Island possesses many of the prerequisites of a boundary stratotype, the hiatus at the systemic boundary ruled it out of consideration as the formal stratotype. It is, however, one of many similar sections in the North American Midcontinent with a hiatus of this proportion at this level which is interpreted as reflecting the eustatic sea level drop in the latest Ordovician related to the north African continental glaciation.

Regional setting

In southern Ontario, undeformed, gently-dipping Ordovician and Silurian carbonates form the eastern margin of the Michigan Basin, affected slightly by the Algonquin Arch (Fig. 1). Over much of this area, the boundary between Ordovician and Silurian strata is a disconformity, but to the north, on Manitoulin Island (Fig. 1), several previous workers have considered it to be conformable with continuous sedimentation. More recent palaeontological and sedimentological work has revealed a paraconformable relationship.

South of the Algonquin Arch (Fig. 1) exposures of the systemic boundary near the base of the Niagara Escarpment reveal a sharp disconformable contact between the Queenston and Whirlpool formations. The Queenston red shales have been generally regarded as continental deposits of the 'Queenston Delta complex' with their widespread distribution being attributed to lowered sea-level caused by the Late Ordovician glaciation (Dennison 1976). A few limestone interbeds low in the Queenston Formation have yielded a marine fauna, including conodonts, brachiopods, and bryozoans with at least the former indicating a littoral community (Barnes *et al.* 1978) and suggesting a Richmondian (Late Ordovician) age. The overlying Whirlpool Formation is a white, cross-bedded sandstone barren of diagnostic fossils, but overlying shales within the Medina Group yield Llandovery fossils. The classic reference section for this area is that of the Niagara Falls gorge.

North of the Algonquin Arch (Fig. 1), the red shales are replaced progressively by shallow water limestone with minor grey shale of the Kagawong Member (30 m) of the Georgian Bay Formation (130 m). On Manitoulin Island the red shales are absent and these Late Ordovician carbonates are overlain by carbonates of the Manitoulin Formation (20 m), regarded as approximately equivalent to the sandstone of the Whirlpool Formation of the Niagara region. These regional stratigraphical relationships are illustrated in Fig. 1.

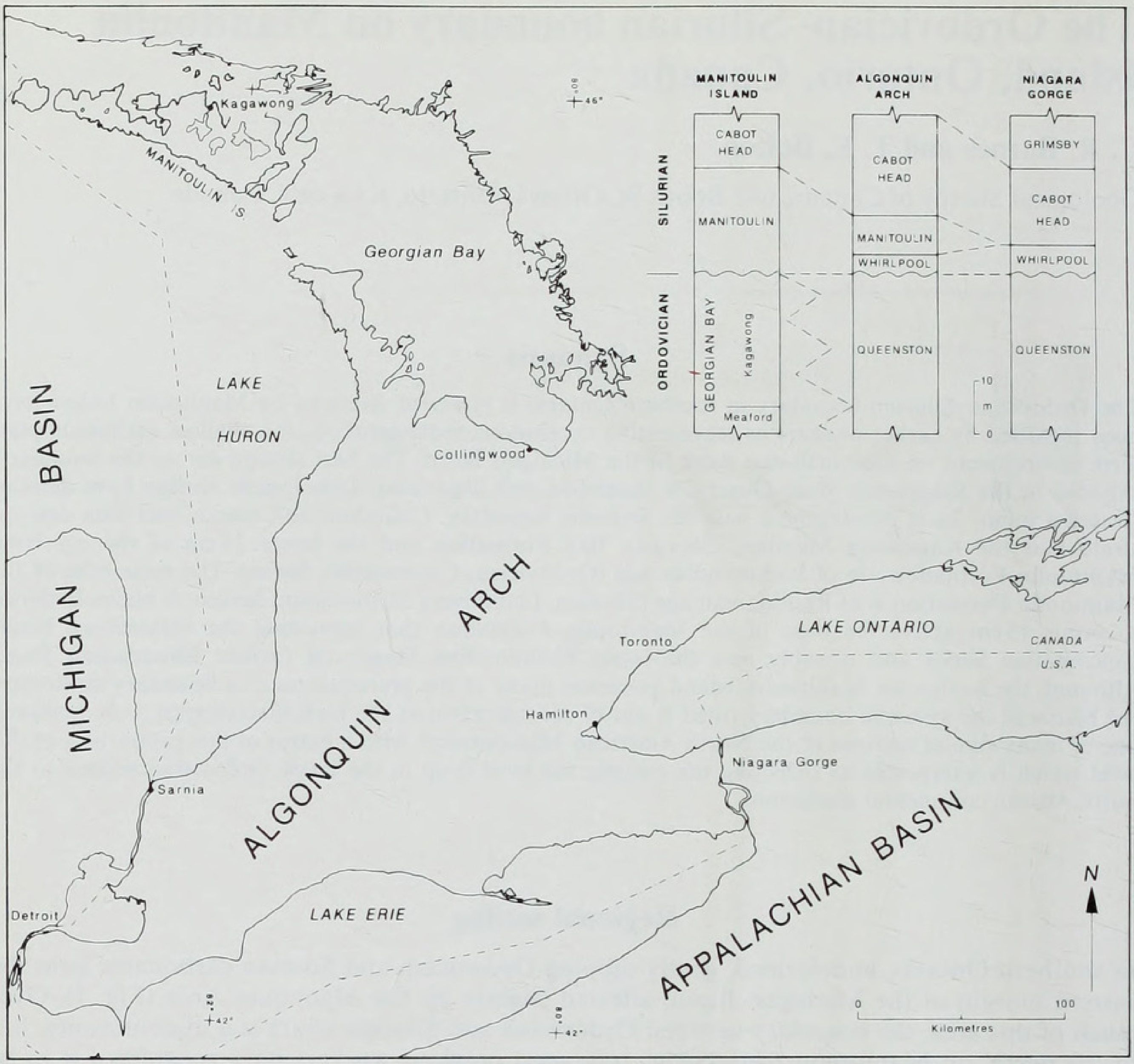

Fig. 1 Map of southern Ontario showing Manitoulin Island, main tectonic elements, and generalized stratigraphical successions across the Ordovician–Silurian boundary for Manitoulin Island, Algonquin Arch, and Niagara gorge.

Detailed stratigraphy

On Manitoulin Island, the systemic boundary is best exposed and most accessible at the small, disused Kagawong West Quarry (Figs 2, 3) on Highway 540, 3 km west of Kagawong (Alguire & Liberty 1968, Stop 2; Sanford & Mosher 1978, Stop 10; Telford *et al.* 1981, Stop 14; Kobluk & Brookfield 1982, Stop 6.3). The adjacent roadcut exposes additional strata of the Kagawong Member and the Manitoulin Formation. The following sequence is exposed:

Manitoulin Formation:

6·5 m Dolostone, massive to thick bedded at base, weathering into thin beds separated by irregular shale partings; medium to light brown with grey patches, weathering to a buff colour; medium crystalline; minor vugs in basal 15 cm; abundant fossil debris, especially brachiopods and rugose corals; minor silicification.

0·15 m Dolostone, thin bedded to laminated, argillaceous; medium brown, weathering to a very light brown colour; finely crystalline; beds separated by even shale partings; sharp upper and lower contacts; recessive unit.

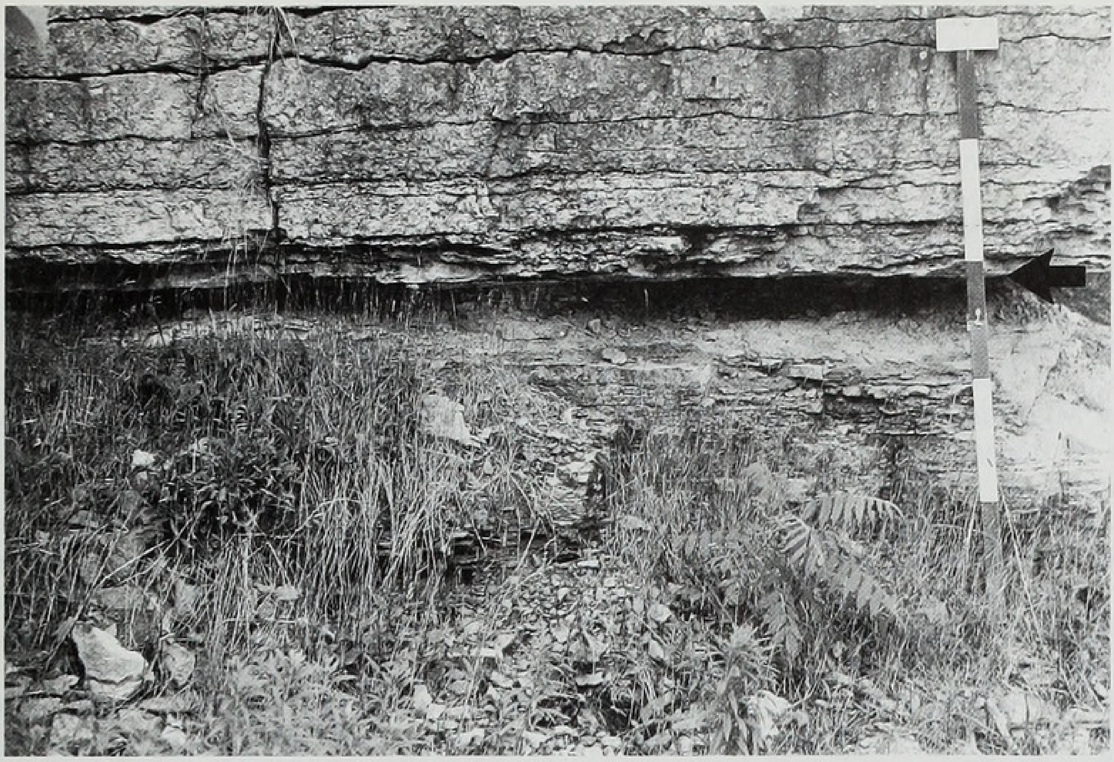

Fig. 2 Kagawong West Quarry showing Kagawong Member, Georgian Bay Formation and Manitoulin Formation. Ordovician–Silurian boundary is drawn (black arrow) at top of 15 cm recessive argillaceous dolostone unit.

Georgian Bay Formation, Kagawong Member:

1·7 m Dolomitic limestone, medium bedded weathering to thin beds; medium grey brown, weathering to blue grey; finely crystalline; poorly fossiliferous, bryozoans and stromatoporoids.

Liberty (1954: 13) and Bolton & Liberty (1954: 28) placed the systemic boundary at the top of the shaly recessive unit, including it within the Kagawong Member. Later Alguire & Liberty (1968: 8) included it in the Manitoulin Formation and considered this sequence to represent continuous sedimentation with no disconformity. Sanford & Mosher (1978: 13) and Sanford *et al.* (1978: 99) from lithological and geochemical evidence placed the systemic boundary 11 cm above the top of the shaly recessive unit, the unconformity probably developing under submarine rather than subaerial conditions. Kobluk (1984) defined two paleokarst surfaces—erosional disconformities below the base and 10 cm above the top of the recessive shaly unit. The lower paleokarst was regarded as at, or very close to, the systemic boundary. Johnson & Telford (1985), however, noted that the disconformable contact between the Manitoulin and Georgian Bay Formations is devoid of scour, rill or other features indicative of extended periods of erosion.

Palaeontology

Conodonts. Eight samples from this section, with particular emphasis on the Georgian Bay–Manitoulin formational contact, yielded nearly 1000 conodonts (Fig. 3). This fauna formed part of earlier studies by Tarrant (1977) and Barnes *et al.* (1978). The fauna of the Kagawong Member of the Georgian Bay Formation was listed by Barnes *et al.* (1978: fig. 3) and includes *Aphelognathus grandis* (Kohut & Sweet), *A. pyramidalis* (Branson, Mehl & Branson), *Oulodus ulrichi* (Stone & Furnish), *Panderodus staufferi* (Branson & Mehl), *Pseudobelodina vulgaris* Sweet, *Rhipidognathus symmetricus* Branson, Mehl & Branson. The last species dominates the fauna in the uppermost bed, indicating a littoral environment (e.g. *Rhipiodognathus* community of Barnes & Fåhraeus 1975). The progressive decrease in diversity upwards in the member also suggests upward shallowing. Most taxa are of late Maysvillian to Richmondian age. In the Composite Standard Section for the Middle and Upper Ordovician rocks of the Midcontinent Province, Sweet (1984, Appendix) reports *A. pyramidalis* and *P. staufferi* as restricted to the Richmondian interval. The Kagawong West fauna is herein assigned to the Richmondian *Aphelognathus divergens* Zone. Although several of the taxa range into Gamachian strata on Anticosti Island (McCracken & Barnes 1981: fig. 12), the presence on Manitoulin of *Plectodina tenuis*, *A. grandis* rather than *A.* sp. cf. *A. grandis*, *P. staufferi* rather than *P.* sp. cf. *P. staufferi*, and the absence of *Gamachignathus* spp., suggests a Richmondian rather than a Gamachian age. The fauna may be generally correlative with other Richmondian units such as the Bull Fork and Drakes formations, Cincinnati area (Sweet 1979*a*), the Noix Limestone, Edgewood Group of Missouri (McCracken & Barnes 1982) and the Vauréal Formation of Anticosti Island (Nowlan & Barnes 1981), but biofacies differences between these faunas make precise correlation difficult.

The thin shaly recessive bed, at the base of the Manitoulin Formation, contains a similar fauna with *Rhipidognathus* (Fig. 3). Only *P. gracilis* and possibly *O.* sp. are known to range into Silurian strata elsewhere; no characteristic early Silurian taxa are present. The shaly recessive unit is therefore considered to be of Ordovician (Richmondian) age.

The dolostones of the Manitoulin Formation yielded a conodont fauna (Fig. 3) that includes *Icriodella discreta* Pollock, Rexroad & Nicoll, *Spathognathodus comptus* Pollock, Rexroad & Nicoll s.f., and *Ozarkodina hassi* Pollock, Rexroad & Nicoll. The conodont fauna from the Lower Silurian of southern Ontario, including Manitoulin Island, and northern Michigan was described by Pollock *et al.* (1970), with other documentation by Barnes *et al.* (1978). The lower, but not lowest, part of the Manitoulin Formation thus includes forms indicative of the *Icriodina irregularis* Zone of Pollock *et al.* (1970), who also noted (p. 746) that in some sections 'the oldest parts of the Manitoulin ... seems to correspond with the pre-*Icriodina irregularis* Zone in the Midwest ... and with the lower part of Walliser's (1964) Bereich I.' *I. discreta* and *O. hassi* are known from earliest Silurian strata, Menierian Stage of Barnes (in press), in the Anticosti Island sections that are continuous across the Ordovician–Silurian boundary although *S. comptus* is absent (McCracken & Barnes 1981: fig. 12; Barnes, this volume). Herein, the Manitoulin Formation is assigned to the *Icriodella discreta–I. deflecta* Zone of Aldridge (1972). In the Manitoulin section, there is therefore no evidence of the latest Ordovician conodont Fauna 13 characteristic of the Gamachian Stage as described by McCracken & Barnes (1981) from Anticosti Island. Other sections in the Midcontinent in North America also lack this interval, e.g. the Cincinnati area (Sweet 1979*a*; Sweet *et al.* 1971; Sweet 1984), the Noix Limestone and Bowling Green Dolomite of the Edgewood Group, Missouri (McCracken & Barnes 1982), and elsewhere in the western Midcontinent (Sweet 1979*b*), and the Hudson Bay region (LeFèvre *et al.* 1975). McCracken & Barnes (1981) attributed this pattern to the latest Ordovician (Gamachian) regression, induced by the north African glaciation, which restricted areas of continuous sedimentation to subsiding marginal cratonic basins or non-eroding oceanic basins.

Macrofossils. The general fauna of the Kagawong Member, Georgian Bay Formation, as detailed by Caley (1936), suggests the inclusion of these carbonates within the standard North American Richmondian Stage. Within the upper 5 m, only *Stromatocerium*, *Tetradium* and poorly preserved undiagnostic bryozoans, bivalves and gastropods have been identified. According to Copper (1982: 680), 'the post-Richmondian Ellis Bay *Spirigerina–Hindella* faunas of Anticosti Island are absent, suggesting an interval of erosion or non-deposition'.

The fauna of the overlying Lower Silurian Manitoulin Formation is scattered throughout with concentrations confined to the uppermost beds (Bolton 1966, 1968). Characteristic forms include the corals *Paleofavosites asper* (d'Orbigny), *Palaeophyllum williamsi* Chadwick, cystoid *Brockocystis tecumseth* (Billings), brachiopods *Resserella eugeniensis* (Williams), *Mendacella* sp., '*Orthorhynchula*' *bidwellensis* Bolton, *Zygospiraella planoconvexa* (Hall), *Sypharatrypa* (?) *laticorrugata* (Foerste), *Eospirigerina parksi* (Williams), and *Dolerorthis* sp. An early Llandovery (Anticostian) pre-C_3 age, within the '*Coelospira*' *planoconvexa*–'*Atrypa*' *laticorrugata* Zone of

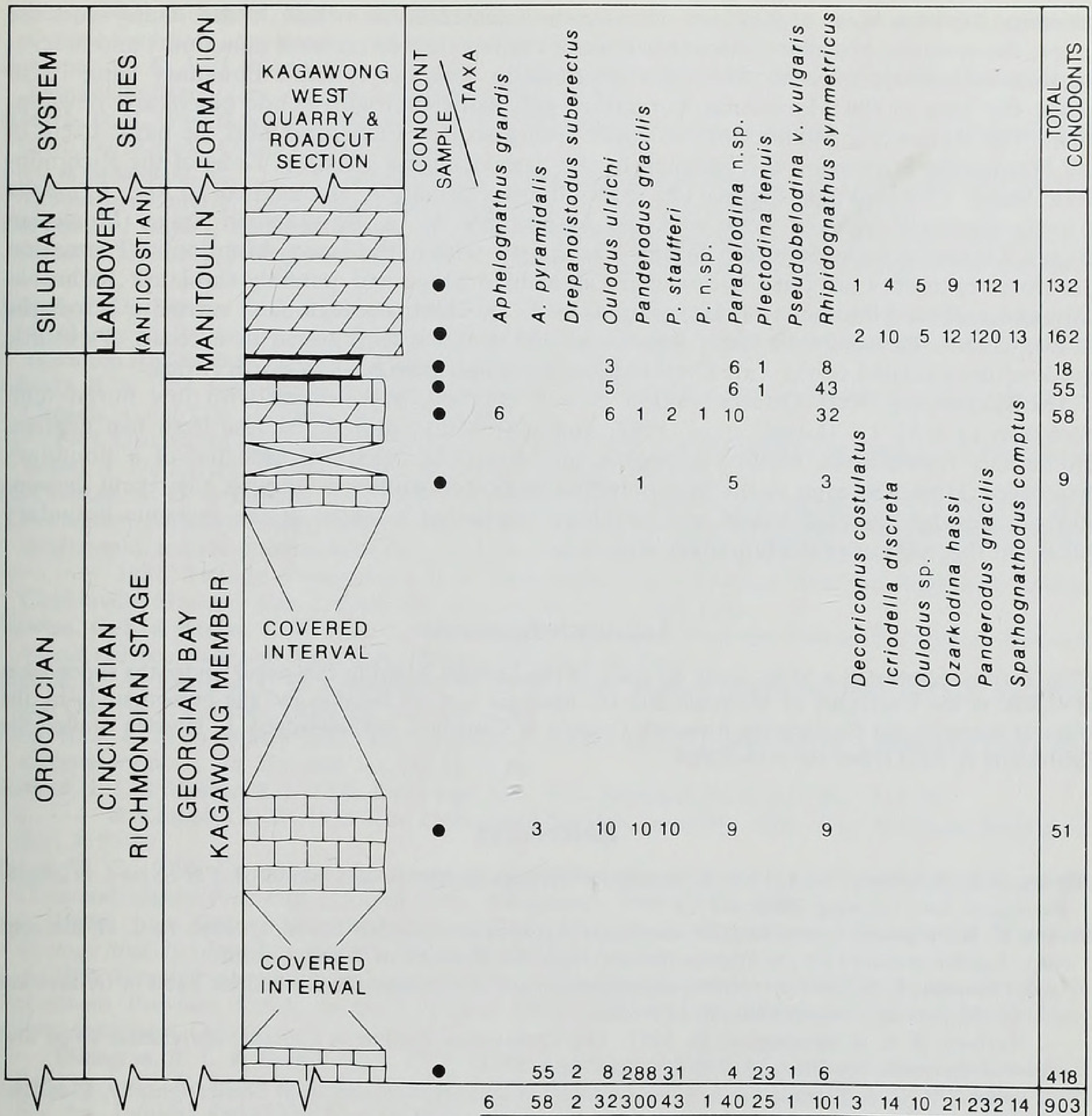

Fig. 3 Section at Kagawong West Quarry showing distribution of conodont species in upper Kagawong Member, Georgian Bay Formation and in lower Manitoulin Formation, across the Ordovician–Silurian boundary.

Ehlers & Kesling (1962: 7), is assigned to the Manitoulin Formation. In the Kagawong West Quarry, proper *Brockocystis tecumseth* was discovered near the base of the Manitoulin Formation and the first brachiopod concentration was located 1 m above the base. Copper (1978: 51) reported 'the atrypoid *Zygospiraella*, an index genus from earliest Llandoverian (A) strata on the Siberian platform and in the Baltic area is common' from the basal few centimetres of the Manitoulin Formation (above the recessive shaly dolostone bed). A Llandovery A age is also assigned to the Manitoulin and overlying Cabot Head formations by Johnson (1981).

Summary

In the classic Niagara gorge section of southern Ontario there is an undisputed disconformity between late Ordovician and early Silurian strata. To the north, on Manitoulin Island, several previous workers have argued for continuous sedimentation within a carbonate sequence across the systemic boundary. Recent studies of the last decade on both conodonts and macrofossils now indicate a paraconformable relationship with the systemic boundary lying 15 cm above the base of the Manitoulin Formation and associated with subtle paleokarst development. The Kagawong Member of the upper Georgian Bay Formation and the basal 15 cm of the Manitoulin Formation are assigned to the *Aphelognathus divergens* Zone of the Richmondian Stage, Cincinnatian Series. The Manitoulin Formation is assigned to the *Icriodella discreta–Icriodella deflecta* Zone and the Llandovery A, i.e. Rhuddanian Stage (Menierian Stage), Llandovery (Anticostian) Series. The hiatus within the lower Manitoulin Formation therefore represents the Late Ordovician Gamachian Stage and possibly the latest Richmondian and earliest Rhuddanian (Menierian) as well. This hiatus is regionally extensive across the Midcontinent (Barnes *et al.* 1981; Ross *et al.* 1982) and is interpreted as a result of eustatic sea-level drop related to the Late Ordovician continental glaciation in north Africa.

The Kagawong West Quarry section is well exposed, undeformed with low burial temperatures of CAI 1·5 (Legall *et al.* 1982) and with strata dipping at less than five degrees, moderately fossiliferous, readily accessible, and has other qualities expected of a boundary stratotype. However, even as the best potential section in southern Ontario, the recent demonstration through detailed faunal and lithologic studies of a hiatus at the systemic boundary ruled out this section as the boundary stratotype.

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