7

Middle Ordovician of the Lake Simcoe Area of Ontario, Canada

CARLTON E. BRETT AND WENDY L. TAYLOR

Extraordinary occurrences of well-preserved crinoids and other echinoderms have long been known from the Middle Ordovician Trenton (or Simcoe) Group in the vicinity of Lake Simcoe in southern Ontario, Canada (Fig. 77). These rocks are exposed in several inactive and currently operating quarries; the most famous section can be found in the disused quarry just off the Trenton Canal locks west of Kirkfield, Ontario. Other excellent sections occur in the Carden Quarry near the town of Brechin, Ontario.

Pelmatozoan assemblages occur at several levels in the Middle Ordovician Trenton carbonates of the Lake Simcoe area, but two horizons may be singled out as particularly outstanding examples of exceptional preservation (Fig. 72):

Assemblages in the upper 3–4 m of the Bobcaygeon Formation (= Kirkfield Limestone of earlier workers) are associated with hardgrounds, resulting from interrupted sedimentation, on the tops of skeletal limestone beds.

One or more beds of *Cupulocrinus* are associated with crinoidal limestone in the lower 2–3 m of the Verulam Formation.

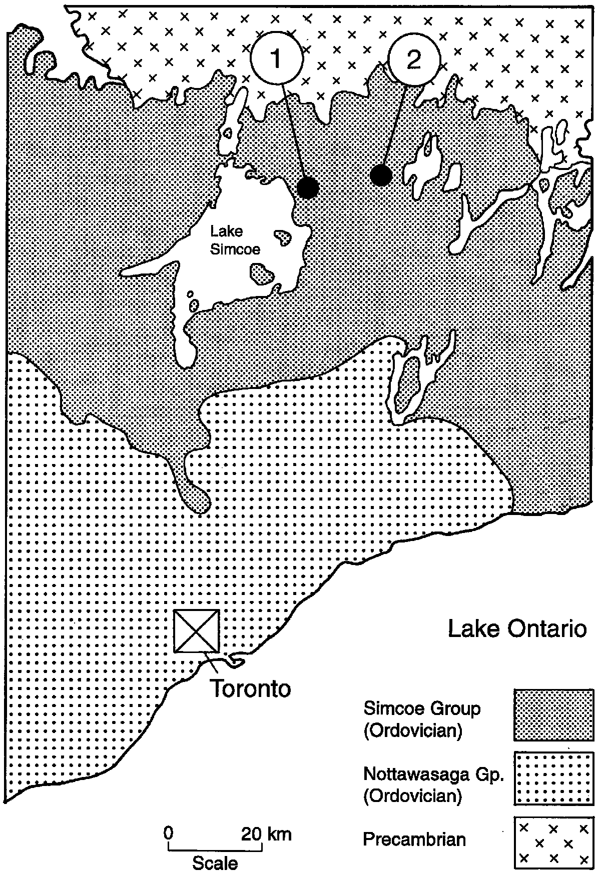

Fig. 77. Location map for crinoid localities near Lake Simcoe, Ontario. (1) Brechin; (2) Kirkfield. (Modified from Melchin *et al.* 1994.)

THE BOBCAYGEON HARDGROUNDS

The Upper Bobcaygeon (Kirkfield) Limestone consists of thin-to medium-bedded, commonly graded crinoidal

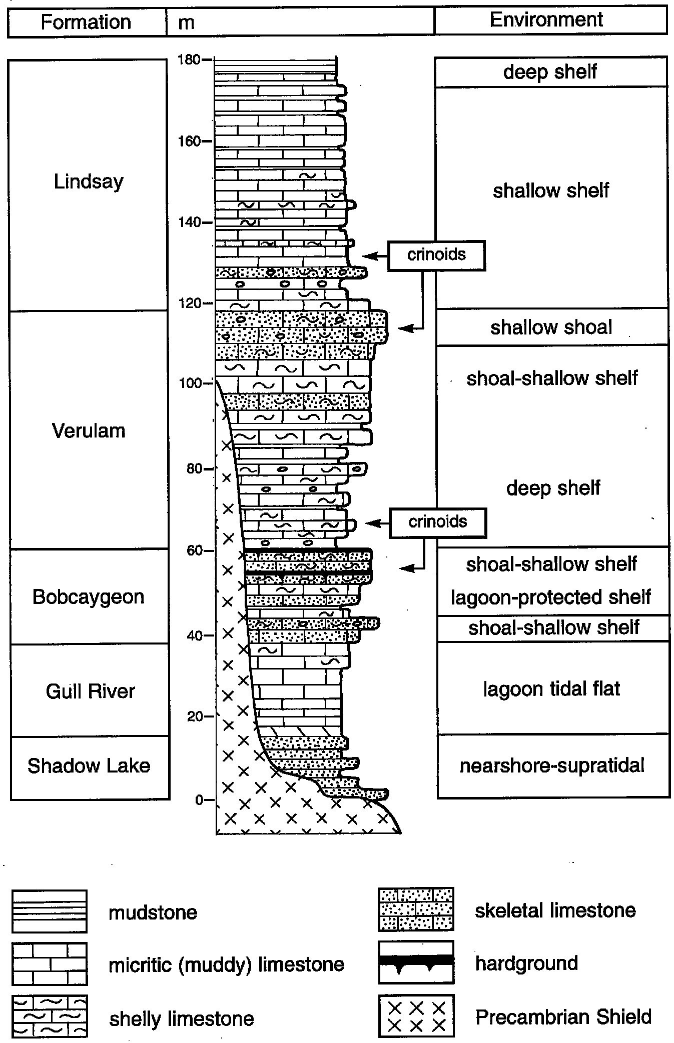

Fig. 78. Generalized stratigraphic section for Middle and Upper Ordovician rocks in the Lake Simcoe area of Ontario. (Modified from Brookfield & Brett 1988.)

limestones interbedded with medium grey calcareous shales and laminated calcareous silt beds. Horizons of intense burrowing are observed in some silty beds. Many beds display some evidence of normal grading from skeletal limestone upward into laminated calcareous siltstone. The tops of the skeletal-rich beds display irregular topographies representing burrowed hardground surfaces, especially noticeable on the tops of calcareous siltstones (Fig. 78).

Some bed tops are clearly hardgrounds. They display very sharply defined relief up to 5 cm with minor dark staining (phosphatic?) and abundant *Trypanites* borings. Some of these surfaces also show encrusting organisms, including patches of bryozoans, discoidal pelmatozoan holdfasts and, rarely, edrioasteroids (Fig. 83).

The echinoderm fauna associated with hardgrounds in the Middle Ordovician Bobcaygeon Formation is quite varied. The small hybocrinid *Hybocystites* is the most abundant crinoid (Fig. 79). The large camerate *Archaeocrinus* is present (Fig. 80), and various inadunates, including the newly described cladid *Illemocrinus amphiatus* (Fig. 81) and the disparid *Isotomocrinus typus* (Fig. 82). Much less common are the primitive calceocrinid *Cremacrinus* and the paracrinoid *Amygdalocystites*. Also found are cystoids, such as the rhombiferans *Cheirocrinus* and *Pleurocystites*, and edrioasteroids (*Edriophus levis*). These echinoderms are associated with abundant encrusting bryozoans (*Heterotrypa, Prasopora*) and the holdfasts of ptilodictyids. Brachiopods are uncommon in these assemblages but, locally, small *Platystrophia, Zyg-*

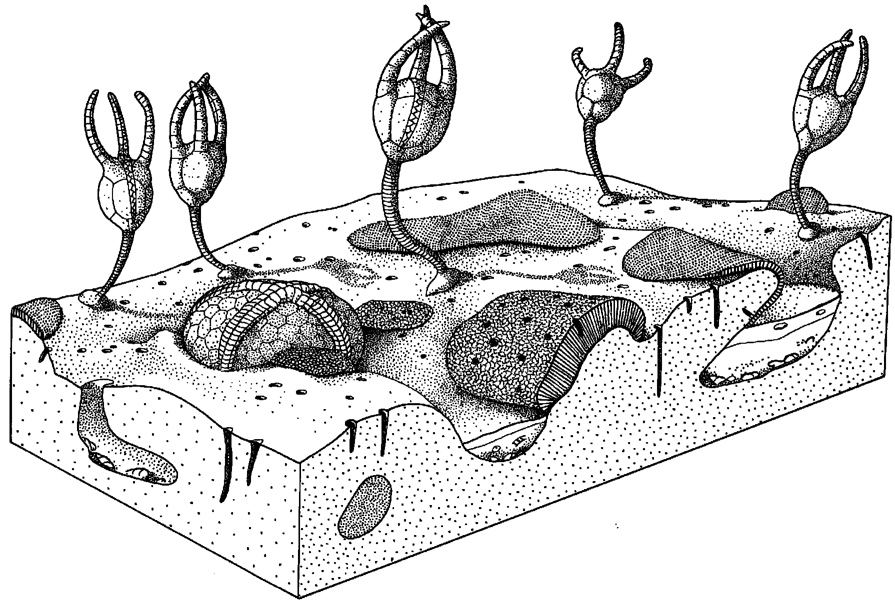

Fig. 79. Reconstruction of Middle Ordovician hardground community. Note irregular topography of hardground, abundant *Trypanites* borings and encrusting bryozoans. Echinoderms include the small, short-stemmed hybocrinid *Hybocystites eldonensis* and the edrioasteroid *Edrioaster bigsbyi* (left foreground). (After Brett & Liddell 1978.)

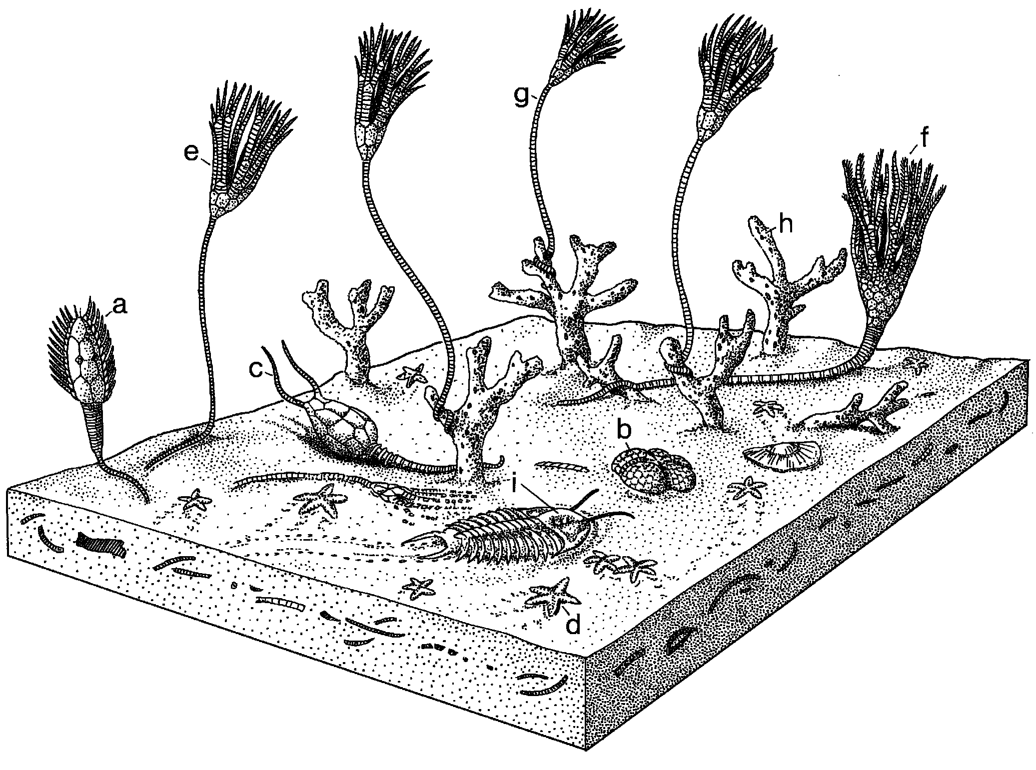

Fig. 80. Reconstruction of Verulam Formation community; area shown represents 0.1 m^2. (a) *Glyptocystites multiporus* (cystoid); (b) *Edrioaster bigsbyi*; (c) pleurocystid cystoid; (d) *Stenaster salteri* (asterozoan); (e) *Cupulocrinus jewetti*; (f) *Archaeocrinus pyriformis*; (g) *Ottawacrinus typus*; (h) *Batostoma* sp. (bryozoan); (i) *Ceraurus* sp. (trilobite). (After Liddell 1975a.)

Fig. 81. *Illemocrinus amphiatus*, a small, simple cladid from the Bobcaygeon Limestone near Brechin, Ontario. Note complete short, pentameric stem and small, cemented discoidal holdfast, also stout anal sac. (Royal Ontario Museum.) ×1.5. To view this figure in colour, see the colour plate section following page xv.

ospira and inarticulate brachiopods are found attached to or encrusting upon the hardgrounds. Borings assignable to *Trypanites* typically riddle the irregular knobby surfaces of the Bobcaygeon hardgrounds.

On certain hardgrounds, echinoderms are represented only by holdfasts or attachment structures of varied cementing forms. Particularly large volcano-like structures, up to 2 cm in diameter, merit attention. These apparently belong to *Cleiocrinus* (Fig. 54), a long-stemmed camerate otherwise preserved as disarticulated crowns in shale-filled pockets on the surface. Edrioasteroids may also be preserved on many of the surfaces that are covered by grey mudstone. However, a small number of hardground surfaces are overlain by smothered bottom assemblages of the longer-stemmed crinoids and cystoids. Among the more spectacular surfaces is a persistent hardground in the Kirkfield, Brechin, region with locally attached clusters of the small crinoid *Hybocystites*. The echinoderms are tethered by short stems, typically only 1.5 cm in length, and they tend to be crowded into small, shale-filled pockets or irregularities on the surfaces. They are buried by grey shales. Less commonly, specimens of *Cremacrinus* are also found attached with their holdfasts, as is the paracrinoid *Amygdalocystites*. The bottom-dwelling and possibly vagrant *Pleurocystites* is present on several hardground bedding planes. Thus, despite long intervals of exposure of the hardground surfaces with little or no sediment cover, as evidenced by their strong encrustation and boring by *Trypanites* (Fig. 79), at times these surfaces were buried rapidly by silty clays. These sediments were probably transported by storms as distal gradient flow deposits from the weathered Precambrian bedrock surfaces to the north and northwest.

The details of depositional environments of the crinoid-encrusted hardgrounds from Kirkfield, Ontario,

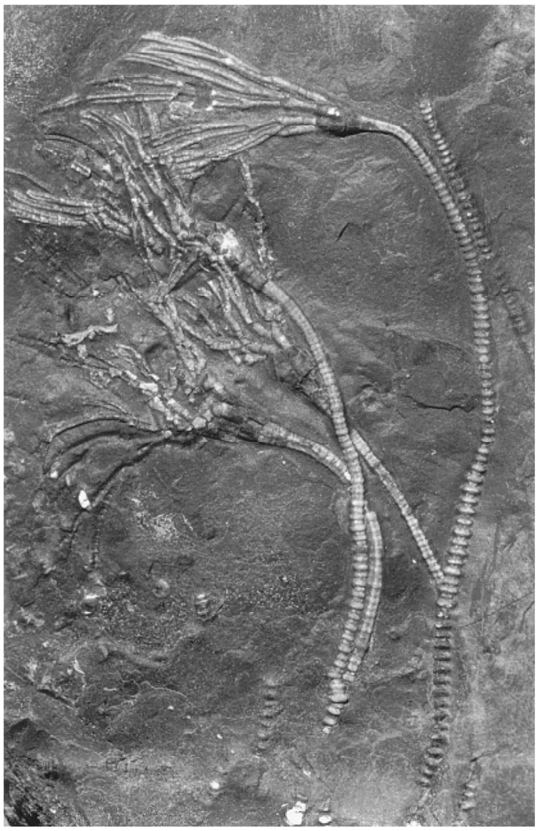

Fig. 82. *Isotomocrinus typus*, a small, slender disparid from the Bobcaygeon Limestone of the Carden Quarry, Brechin, Ontario. (Kevin Brett Collection.) ×1.3. To view this figure in colour, see the colour plate section following page xv.

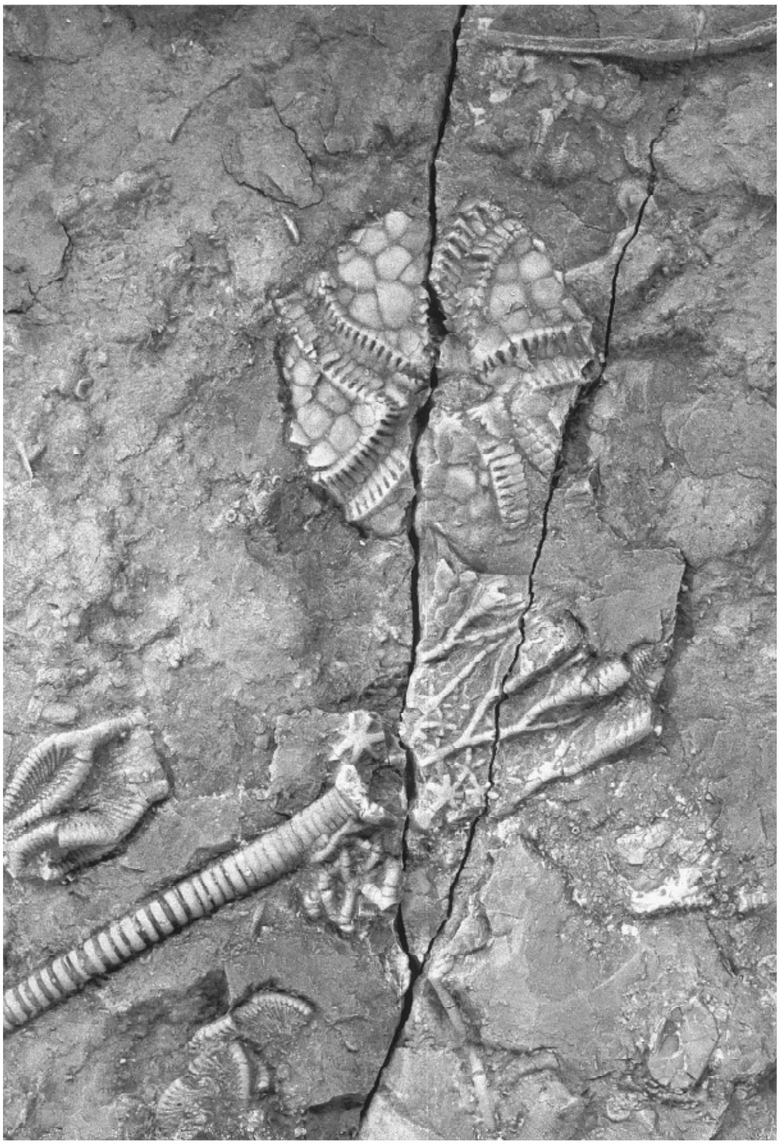

Fig. 83. Hardground assemblage from the upper part of the Bobcaygeon (Kirkfield) Limestone showing the large edrioasteroid *Edrioaster bigsbyi*, the camerate crinoid *Archaeocrinus* sp. and the pinnulate arms of another, unidentified camerate. Quarry south of Brechin, Ontario. (Collection of Paleontological Research Institution, Ithaca, NY; photograph W. L. Taylor.) ×1.5.

have been discussed at some length by Brett and Liddell (1978). The carbonate sediments that constitute the hardgrounds were typically deposited very rapidly as graded storm layers of skeletal limestone and laminated to cross-laminated lime mudstone. After episodes of rapid reworking and deposition of the carbonate sediments, long intervals of non-deposition led to incipient cementation of the carbonate storm layers. Typically, the hardgrounds display relict burrow structures that were evidently produced by organisms in relatively firm, semi-consolidated carbonate silts and muds. Erosive scour of superficial layers exposed the burrow-galleried limestone on the sea bottom, where they formed firm to hard pavements suitable for the colonization of pelmatozoans attached by discs. In some cases, there is evidence for multiple generations of encrusting and boring organisms of skeletal remains attached to the hardgrounds.

The general depositional environments of the Bobcaygeon Limestone ranged from somewhat protected inner lagoon settings to relatively higher-energy shoal margin facies, characterized by closely stacked or amalgamated and graded crinoidal limestones. The hardground facies discussed here must have developed under rather quiet conditions, but occurred in areas that were subject to occasional storms that cleared the nearby skeletal beds from mud. The siliciclastic muds that buried the organisms appear to have been derived from Precambrian (Grenville) basement rocks. These were exposed with no vegetation cover, and were therefore deeply weathered, on nearby islands of the Precambrian shield. Some of the muds may also have been transported into the shallow shelf area from the active Taconic Orogenic belt that lay some 300 km to the southeast. The mechanism of transport of these muds remains enigmatic. Clearly, they represent event deposits of a different kind than those produced by a typical storm wave winnowing and wash-over from skeletal shoals. Possibly they reflect flood wash-off events in which the suspended mud was deposited relatively rapidly because of flocculation upon mixing fresh and salt water. Although Brookfield (1988) has argued that the Ordovician carbonates in the Lake Simcoe area were deposited under cool temperate climates, most authors agree that this area lay in a shallow subtropical belt perhaps 15–20° south of the palaeoequator.

Crinoidal Limestones of the Verulam Formation

A second type of echinoderm assemblage occurs more commonly on certain of the skeletal limestones of the Upper Bobcaygeon and Verulam Formations. These echinoderms are typically associated with skeletal debris layers that are composed largely of remains of the crinoids themselves. The most common of the crinoids is the cladid *Cupulocrinus jewetti*, which occurs locally in clusters of many hundreds of individuals near the base of the Verulam Formation (Fig. 84). Such beds were exceptionally well exposed in the higher layers of the now-abandoned Kirkfield Quarry. A large number of nearly complete *Cupulocrinus* specimens were obtained from thin shale partings within the skeletal limestones at one particular level. These crinoids were closely associated with a large number of the asteroid *Stenaster* and a much smaller number of other echinoderms, particularly the cladids *Cincinnaticrinus*, *Plicodendrocrinus* and *Carabocrinus*, and camerates such as *Archaeocrinus*. Ramose bryozoans are relatively common, although not as abundant as the crinoids on certain of these layers. Brachiopods are relatively scarce and are represented primarily by *Platystrophia*. Trilobites (*Ceraurus*) are moderately common.

Fig. 84. Three crowns of *Cupulocrinus jewetti*. This cladid with arm morphology similar to that of early flexible crinoids is the dominant echinoderm from the Verulam Formation. Kirkfield Quarry, Kirkfield, Ontario. (Thomas Whiteley Collection.) ×1.7.

These crinoid assemblages occur as high-density clusters on bedding planes typically associated with broad, shale-filled low spots or pockets. The crinoids appear to have been rapidly uprooted, toppled over and buried by muds. The fact that partial crowns and other remains of *Cupulocrinus* occur in the underlying skeletal limestones suggests that they were indeed a major component of the background fauna of these areas. Periodically, they were destroyed in large numbers and occasionally, when accompanied by pulses of mud, were buried almost intact. However, a remaining problem with these assemblages is the nearly complete lack of holdfasts on any of the crinoids. Moreover, none of the crinoids possess cirri that might have aided in anchoring the stems to the substrate. Rather, they all appear to have distally tapering stems. Conceivably, the crinoids may have had some flexibility in the distal portions of the stems that allowed them to coil around other objects or around each other; or the distal part of the stems formed semi-recumbent runners that resisted uprooting. However, they were also clearly vulnerable to dislodgement. This fact makes it all the more enigmatic that these crinoids seem to be closely associated with the well-washed crinoidal limestones that we normally associate with near-wave-base, high-energy conditions. Nonetheless, similar associations, also typically dominated by *Cupulocrinus*, have been documented in a number of other high-energy crinoidal limestones. Obviously, the crinoids had the ability to cope with such environments much of the time. Nonetheless, the intermittent strong storms dislodged and killed a large number of individuals in short periods of time. The crinoid remains, once toppled, were rapidly covered either with crinoid fragments, as in the case of certain specimens found intact within crinoidal limestones, or by siliciclastic muds. The latter typically served as substrates for the colonization of later generations of horizontal, sediment-feeding burrowers. These burrows commonly occur in masses within the burial muds overlying the crinoids. The burrow fillings are typically accentuated by early diagenetic cementation.

IMPORTANT COLLECTIONS IN NORTH AMERICA

Museum of Paleontology, University of Michigan, Ann Arbor, Michigan, USA
Royal Ontario Museum, Toronto, Canada