TRIP A3 (2)

TRACES FOSSILS AND STRATIGRAPHY IN THE POTSDAM AND THERESA FORMATIONS OF THE ST. LAWRENCE LOWLAND, NEW YORK

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INTRODUCTION

Our field examination will focus primarily upon two composite exposures of clastic sediments that make up the Potsdam and Theresa Formations as they are recognized in the St. Lawrence Lowland (Figures 1 and 2). Other outcrops will present some interesting features of the Potsdam Sandstone.

Stratigraphy in the region is occasionally problematical as a result of discontinuous outcrop, Paleozoic deposition upon an undulating Precambrian surface, and possible post-depositional structural deformation in some portions of the outcrop belt. We will concentrate on two sections lying at, or close to, the Precambrian/Paleozoic unconformity on the east flank of the Frontenac Axis (Figure 1). The sections pass upward through the siliceous Potsdam Sandstone into muddy, carbonate-cemented sandstones of the Theresa Formation. It is in these transitions between lithologies, and the depositional environments which they imply, that we shall find distinctions in bioturbation style and ichnofaunal content. Depositional environments have been summarized by Selleck (1978, 1984) and will not be the focus of this trip.

Reasons for becoming familiar with the trace fossils and lithologic characteristics of the Potsdam - Theresa interval are more than academic. They have much to do with making continued progress in our understanding of the stratigraphic history of this margin of the Canadian Shield during the Precambrian - Paleozoic transition. The Potsdam Formation, described by Emmons (1838), is the oldest recognized stratigraphic name in the American geologic literature, yet the rocks in the type area contain facies that are discontinuous, are

Figure 1: Regional map of the Adirondacks showing the St. Lawrence Lowlands and adjacent Precambrian Grenville terrane. Arrows show summarized vector means of moving averages for paleocurrent directions in the Thousand Island area after Lewis (1963).

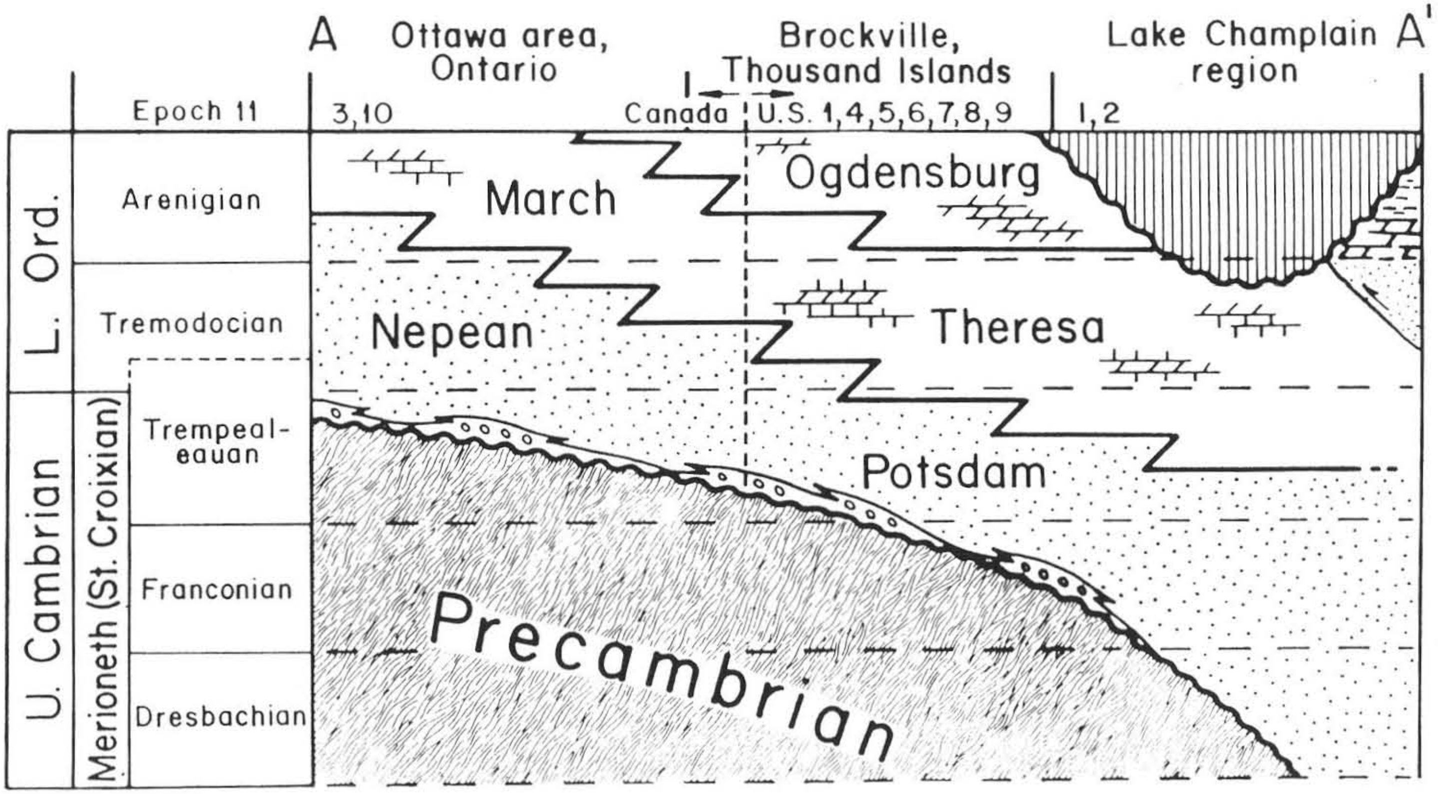

Figure 2: Lithostratigraphic and chronostratigraphic relationships for Cambrian-Ordovician rocks in the northern Adirondack region along line A-A' in Figure 1.

terrestrial in depositional origin (Chadwick, 1920), and may be Precambrian in age. They are notable for the absence of both body fossils and biogenic structures.

The Potsdam - Theresa interval in St. Lawrence County contains an assortment of facies and a number of formally named subdivisions, as well as a substantial list of locally-used names that make interpretation of the historical literature historical challenging. Readers are referred to Kirchgasser and Theokritoff (1971), Selleck (1984), and Kerans (1977) for discussions of the regional stratigraphic detail in the United States and to Greggs and Bond, (1971) for insights into the Canadian terminology.

Appearance of the first fossils, whether traces or shelled invertebrates, in this record is noteworthy as they offer the potential for correlation both locally and regionally, however tenuous those correlations may be. Fossils are reported from many outcrops in restricted numbers, and varying qualities of preservation. They only offer tantalizing pieces of biostratigraphic data for a puzzle that is complicated by presence of one, or more, disconformities among this suite of shallow water facies. Inarticulate brachiopods (*Lingulepis* sp.), flat-coiled gastropods, stromatolites, scarce conodonts, and the dendroid graptolite *Dictyonema potsdamense* which is known from only one locality, are the poor faunal elements we have to work with. Therefore, trace fossils have begun to attract more attention. Studying the appearance and development of the regional ichnofauna may add to our ability to recognize stratigraphic relationships.

POTSDAM SANDSTONE ALONG ROUTE 12

The Potsdam Sandstone in the region of Chippewa Bay and Oak Point (Figure 3) is a white, clean, medium- to poorly-sorted, fine- to coarse- grained, occasionally conglomeratic, cross-stratified or laminated, medium-bedded sandstone, generally having siliceous cement. Dolomitic cements occur upwards in some sections. Effects of high-energy depositional regimes are evidenced by presence of storm-generated conglomerate units interstratified with fine-grained sandstones. Intertidal lithotopes are suggested by herringbone cross-strata, current ripples and by mudcracks in interlayered Theresa facies. I reiterate that these Potsdam facies are significantly different from the "type Potsdam" as seen in Potsdam, N.Y. They are the Heuvelton Sandstone of Cushing (1916) or the "white Potsdam" of Chadwick (1920) which thicken southeastward from Chippewa Bay. They are at least in part Early Ordovician in age and locally there may be no Cambrian present.

The absence of Cambrian rocks is a "stretch" idea. It is suggested by the absence of the trace fossil *Climacticnites wilsoni* from the rocks here along the central St. Lawrence Lowland east of the Frontenac Axis. Yochelson and Fedonkin (1993) made a thorough study of this unusual trackway that occurs on tidal flat sandstone beds in Dresbachian formations from Missouri to the Champlain Valley. It is not an easy trace to miss and has been described from Perth, Ontario to the north and from Wellsley Island west of the Axis, yet it has not been recorded from a crescentic region flanking the Adirondacks from Chippewa Bay

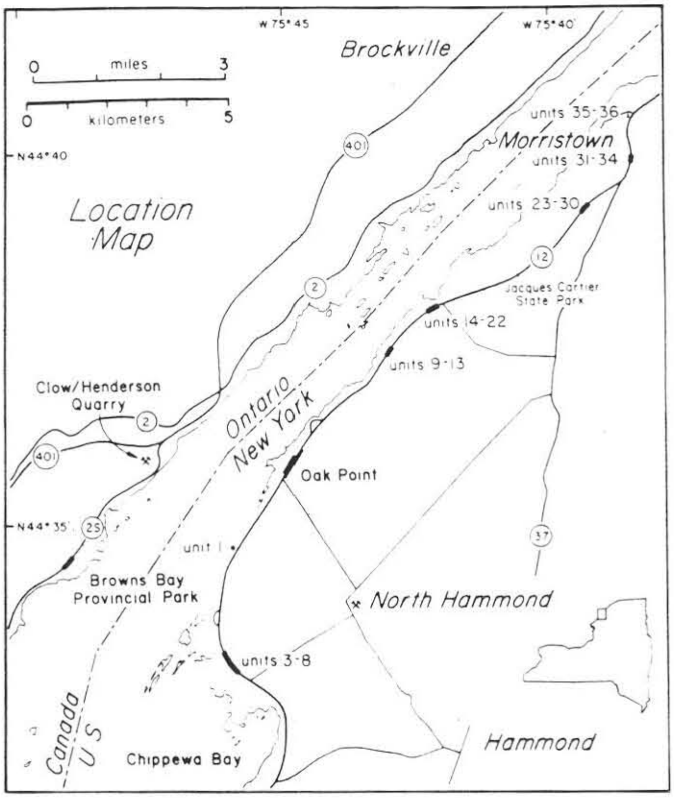

Figure 3: Detailed location map showing outcrops (by unit number) used to construct the composite section of the Potsdam and Theresa Formations along New York State Rt. 12 (Fig. 9). A Canadian reference section for the Nepean and March Formations in Ontario is along Rt. 2S in Browns Bay Provincial Park, and the Clow/Henderson quarry for the lower March Formation.

the Potsdam. Interbedded with this typical Theresa lithofacies are recurrent thin and medium beds of clean, white, cross-stratified siliceous sandstone recognizable as "Potsdam" lithofacies. The entire Theresa becomes thinner and undergoes a facies change to dominantly cross-stratified clean sandstone southeastward against the Adirondack Highlands (Selleck, 1984).

The Theresa thus contains mixed carbonate clastic lithologies in a shoaling-upward sequence. Conglomerates of Precambrian quartzite in the Theresa show that Precambrian topography continued to influence Theresa deposition (Selleck, 1984). The contact between the Potsdam and Theresa is well exposed at Chippewa Bay and Oak Point where grey, medium- to thick-bedded, calcareous and dolomitic, fine-grained sandstone overlies the Potsdam.

The lower 10 m of the Theresa is extremely bioturbated, and individual depositional events can be seen in decimeter-thick, scour-based, horizontally-laminated sandstones with burrowed tops. Most Theresa trace fossils figured herein were collected from these lower beds. Highly bioturbated lithologies in the lower Theresa represent protected, subtidal facies. Selleck (1984) noted that this facies is not everywhere preserved and occurs in areas of low Precambrian relief, indicating this facies filled topographic lows.

THERESA FORMATION

The Theresa Formation is a gray to bluish-gray, brown weathering, fine- to medium-grained, moderately-sorted thin- to thick-bedded, quartz sandstone often having calcitic or dolomitic cement and showing a greater amount of matrix residue after acid treatment than would the Potsdam. Interbedded with this typical Theresa lithofacies are recurrent thin and medium beds of clean, white, cross-stratified siliceous sandstone recognizable as "Potsdam" lithofacies. The entire Theresa becomes thinner and undergoes a facies change to dominantly cross-stratified clean sandstone southeastward against the Adirondack Highlands (Selleck, 1984).

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The middle and upper Theresa contain two sharply-defined lithofacies that alternate in vertical sequence. The first consists of grey, thick-bedded to massive, poorly sorted, medium- to coarse-grained, calcareous to dolomitic sandstone. This lithofacies is intensely bioturbated. Interbedded with grey sandstone is white, meter-thick, thin- to medium-bedded, fine- to medium-grained, siliceous to calcareous, planar and herringbone cross-bedded sandstone. This interbedding of distinct lithofacies does not occur in the lower Theresa. Upsection, the bioturbated sandstones are displaced by thicker, coarser, cross-bedded sandstones. Selleck (1984) reported increased dolomite content, mudcracks, intraformational conglomerates, and vuggy cryptalgal laminates in the upper Theresa.

The vertical alternation of lithologies described for the middle and upper Theresa resulted from migration of low intertidal sand flats. These were shoal-water areas that protected extensively burrowed interflat areas. The coarser, channeled, dolomitic sandstones in the upper Theresa represent high intertidal channel and overbank facies. The overlying Ogdensburg Dolostone contains stromatolites (Kerans, 1977; Selleck, 1987) and preserves supratidal facies.

ICHNOFACIES

The intertidal habitats preserved in the upper Potsdam Formation contain a *Skolithos* ichnofacies of low-level suspension-feeders dominated by *Diplocraterion. D. parallelum* is abundant, whereas *D. helmerseni* is rare. Escape burrows resembling *Monocraterion* (Hallam and Swett, 1966) are very common in one thick "white" Potsdam bed. Shallow *Skolithos* and *Monocraterion* burrows (3 to 6 cm) occur at most locations exposing the "white" Potsdam in the Thousand Island region, but *Skolithos* generally does not occur with *Diplocraterion*.

The principle of competitive exclusion (Dodd and Stanton, 1981) states that single-species dominated trophic groups are more common than not (Walker, 1972). The mutual exclusion of *Skolithos* and *Diplocraterion* in Cambrian tidal facies has been noted by many authors (in Cornish, 1987, p. 484). High population densities of *D. parallelum* in single thick-bedded sandstones are exposed at the "unit 1" location (Fig. 3). These beds approach "pipe-rock" density (Hallam and Swett, 1966; Swett et al., 1971), and indicate periods of relative substrate immobility, and probable diastems.

Bjerstedt and Erickson (1989) regard energy from tidal currents, rather than wave energy, as the predominant environmental parameter that was especially favorable for the trace-maker of *D. parallelum* in the upper Potsdam. The *D. parallelum* trace-maker was a tidalphile, and especially favored clean sands frequently mobilized by swift tidal currents on extensive low intertidal sand flats.

In the Potsdam, water motion due to swift tidal currents between, or on the margins of, Precambrian bedrock ridges (Selleck, 1984) provided an optimum habitat for *D. parallelum*. The Chippewa Bay outcrop exposes facies deposited in proximity to unusual relief on the Precambrian surface. The occurrence of abundant *D. parallelum* in the region appears ultimately due to anomalous Precambrian paleotopography in the Thousand Islands region.

The ichnofauna representing each component of the mixed ichnofacies occurs in a characteristic lithology. The distribution of trace fossils in the Theresa is attributable mainly to physical energy variation and persistence that is reflected in the grain-size and sorting of two distinct lithofacies. Grain-size and sorting is a reflection of the magnitude of environmental "energy levels", and also the degree of energy level persistence.

Paleodepth, *sensu stricto,* played no part in the distribution of the ichnofauna. Potsdam-Theresa facies were deposited entirely in peritidal to shallow subtidal facies where gross environmental energy levels, and the persistence of that energy, controlled the availability and type of trophic resources. Lithologic and textural criteria are important supporting evidence for interpretation of mixed trace-fossil assemblages. Otherwise, *a priori* assumptions may form the basis of recognizing ichnofacies when ichnotaxa assumed to be indicative of a particular ichnofacies are comingled.

The parameter of energy level persistence, rather than magnitude, represents the most important factor in the composition of the Theresa mixed *Skolithos-Cruziana* ichnofacies.

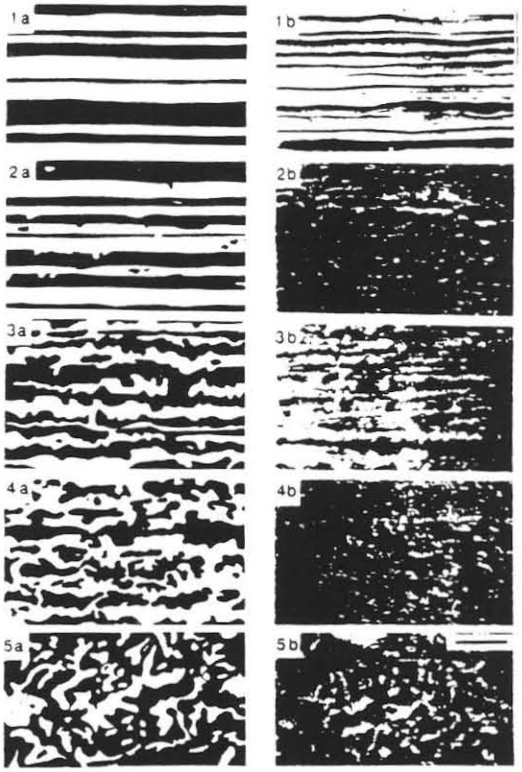

Figure 4: Schematic diagrams of ichnofabric indexes 1 through 5 with representative examples: schematic on the left; actual petrographic samples on the right. Scale bar is 10 cm. (From Drosser and Bottjer 1986, by permission)

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A characteristic ichnofauna occurs in each lithofacies. A *Cruziana* ichnofacies dominated by deposit-feeding burrows predominate in grey bioturbated sandstones. Among these deposit-

D. parallelum, *D. habichi, Skolithos*, and *Monocraterion* generally occur in horizontally-laminated, fine-grained, medium -bedded sandstone layers and lenses that occur in the lower 3 m of the Theresa. These beds represent sand splays washed into protected facies in Precambrian lows.

The *Skolithos* ichnofacies, dominated by suspension-feeders, is represented by shallow vertical tubes (3-6 cm) of *Monocraterion* and *Skolithos* in meter-thick, clean, cross-bedded sandstones. These sandstones record intertidal sand shoals or flats that successively migrated across bioturbated, low inter-flat facies.

ICHNOFABRIC CLASSIFICATION

In our studies we have used the concept of ichnofabric classification as developed by Drosser and Bottjer (1986, p. 558 & 559). The technique involves visual comparison of outcrops with a set of flashcards upon which a scaled area of bioturbation is portrayed. We have reproduced the illustration and description from their work for use in the field (see Figure 4).

Alternation of burrowed grey sandstones and white cross-bedded sandstones characterizes the Theresa from the middle to the top of the formation. The log of ichnofabric index for the Theresa in Figure 5 shows that in 43 m of total thickness, 24.8 m constitute grey, bioturbated sandstone, and 18.2 m constitute white, cross-bedded sandstone. For the grey sandstones, 100% of this thickness is Ichnofabric Index 4. For the white sandstones, 10.6 m (58%) are index 3, and 7.6 m (42%) are index 2. Thickness relationships among Bioturbation Units (BU's) are shown in Figure 6 (Bjerstedt and Erickson, 1989). A verbal descripttion of the Index of Droser and Bottjer (1986) is given below:

1) No bioturbation recorded; all original sedimentary structures preserved.
2) Discrete, isolated trace fossils; up to 10% of original bedding disturbed.
3) Approximately 10 to 40% of original bedding disturbed. Burrows are generally isolated, but locally overlap.
4) Last vestiges of bedding discernable; approximately 40 to 60% disturbed. Burrows overlap and are not always well defined.
5) Bedding is completely disturbed, but burrows are still discrete in places and the fabric is not mixed.
6) Bedding is nearly or totally homogenized.

(From Drosser and Bottjer, 1986)

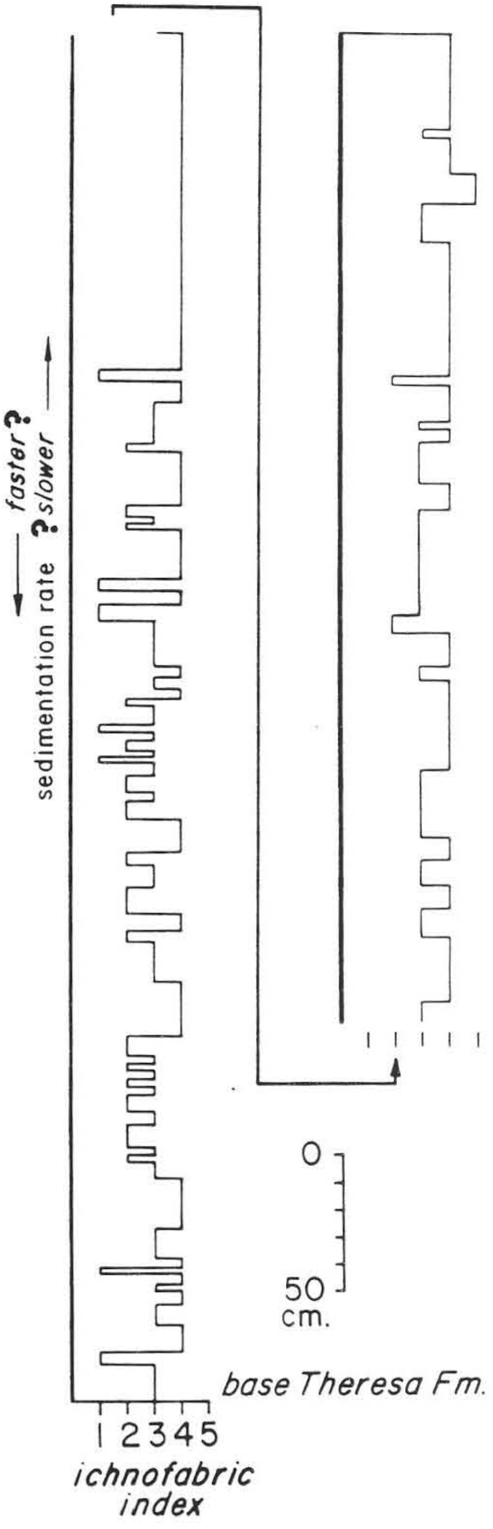

Figure 5: Detailed strip log showing bioturbation units defined by changes in ichnofabric index in unit 7 of the lower Theresa Formation at Chippewa Bay (Fig. 9). The relationship of ichnofabric to sedimentation rate is discussed in the text.

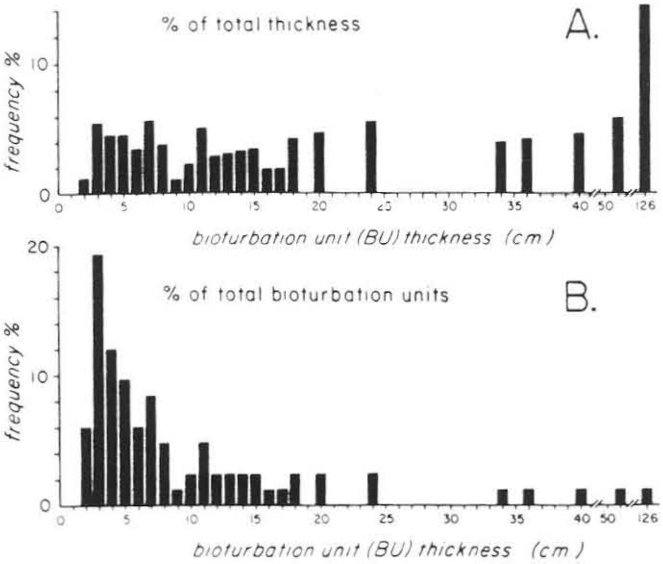

Figure 6: Thickness frequency of bioturbation units (BUs) from unit 7 of the Theresa Formation. **A**) Graph of BU cumulative thickness. **B**) Graph of BU thickness frequency. Endobenthic burrowing depth from -3 to -5 cm in shallow, protected subtidal facies is suggested by the BU thickness frequency cluster about 3-5 cm.

feeders are, *Fustiglyphus*?, *Gyrochorte*?, *Neonereites uniseralis*?, *Phycodes flabellum*, *Planolites beverlyensis*, *Rosselia socialis*, and *Teichichnus*. Suspension-feeders include *Diplocraterion habichi*, *D. parallelum*, *Monocraterion*, shallow-burrowing *Skolithos*, and possibly *Palaeophycus tubularis* (Pemberton and Frey, 1982). *Cruziana*? furrows are attributed to inferred scavenging or deposit-feeding trilobites.

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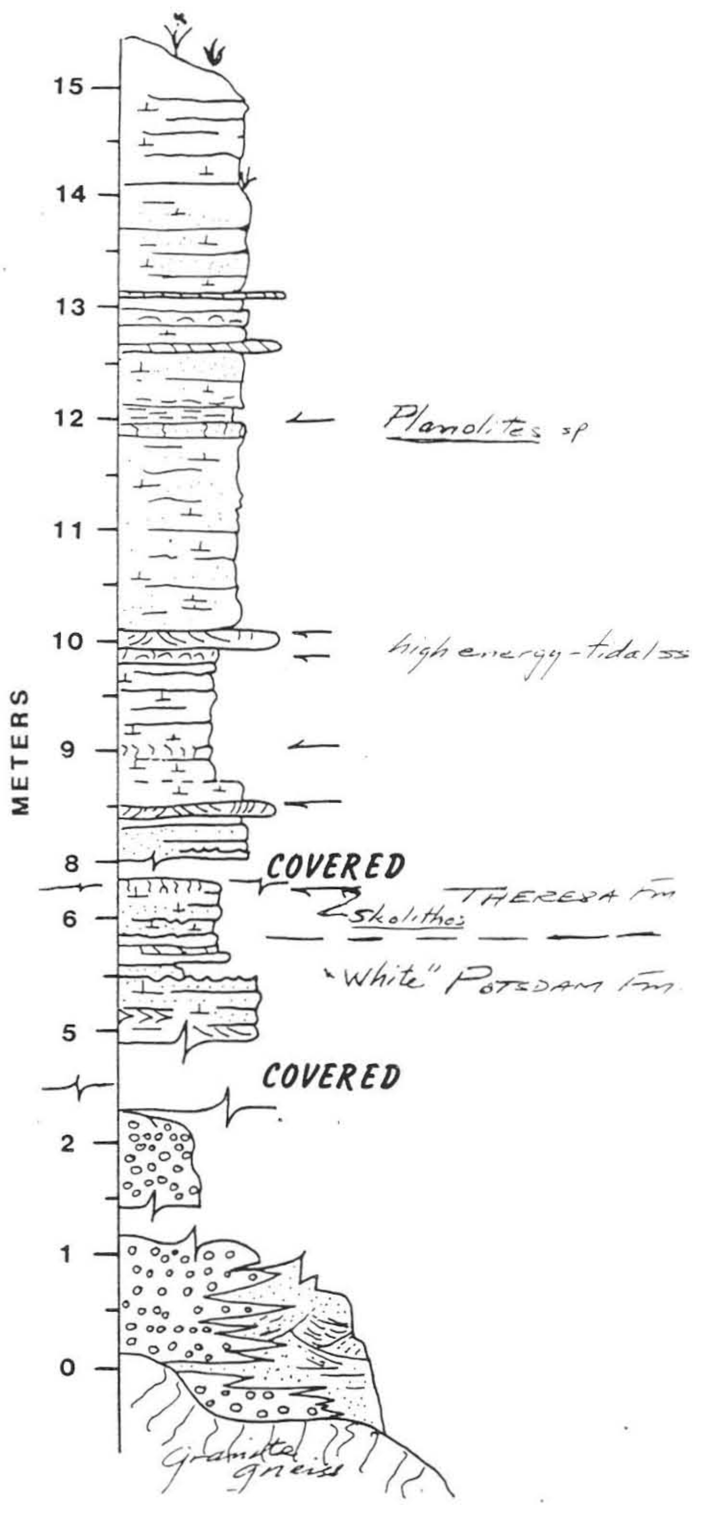

Figure 7: Stratigraphic column at Oak Point drawn to emphasize high energy "white Potsdam" sandstones that might have been a source for *Protichnites* (?) sp.

minimum burrow depths of *D. parallelum* were made through the upper Potsdam at this section. Data taken from Bjerstedt and Erickson (1989) are presented here in Figure 10.

SECTION AT OAK POINT

Although we will repeatedly see exposures of Theresa Formation along highway 12 there are few places where one can get a feeling for the stratigraphic relationships of the section without trespassing extensively on private property. The rocks at Oak Point provides a good opportunity to view much of the section without undue encroachment on private land. Please exercise care to stay on the roadway unless given the OK to explore, however.

At Oak Point more than 15.4 meters (50 feet) of strata are available for study, presenting most of the Potsdam-Theresa interval. The Potsdam lithologies at this locality are not fossiliferous in the lower portion and there may be some indications from the conglomerates and the magnitudes and types of cross-stratification that the Potsdam here is not marine in its base. A composite stratigraphic column made up the Oak Point Road is given in Figure 7.

The Potsdam-Theresa contact can be placed at this locality by the first occurrence of significantly-bioturbated, calcareous, grey sandstones. Potsdam lithologies re-enter the section at several positions in the adjoining outcrops, and most show some evidence of marine traces. Contrasting conditions of burrowing are easily seen in the upper half of this section.

When this outcrop was first created, approximately 25 years ago, St. Lawrence students collected from the outcrop debris the well preserved trackway of a large organism. This was illustrated by Bjerstedt and Erickson (1989) in Figure 15G but was not assigned. As we visit Oak Point it is appropriate to discuss the implications of the specimen further. The specimen (Figure 11A, 11B) is a meter-long slab of thin-bedded, dolomitic sandstone that reveals a trackway of evenly-spaced (evenly-paced) digit impressions from a multi-legged, bilaterally symmetrical, elongate organism that probably dragged a substantial posterior body element through the wet sand of a Theresa tidal flat. Width of the trackway is 23 cm, but width of the organism's body is not defineable from the trackway.

At least six legs are defineable from the pattern of impressions. One of these had trifid digitation (Figure 12A) and alternated with a bifid blade-like appendage in the walking sequence. Shorter, more centrally-located monodactylous walking legs (at least one pair) were shorter and were carried more centrally. These left much fainter impressions best seen on the whitened specimen (Figure 11B) and on a plaster cast made directly from the specimen (Figure 12B).

It seems certain that the trackway was the work of an arthropod moving at a steady gate through almost saturated sand. The identity of the organism is not recognizeable from the specimen. Assignment to an ichnogenus also would be premature in as much as the literature of Paleozoic arthropod trackways presently is confused and somewhat contradictory.

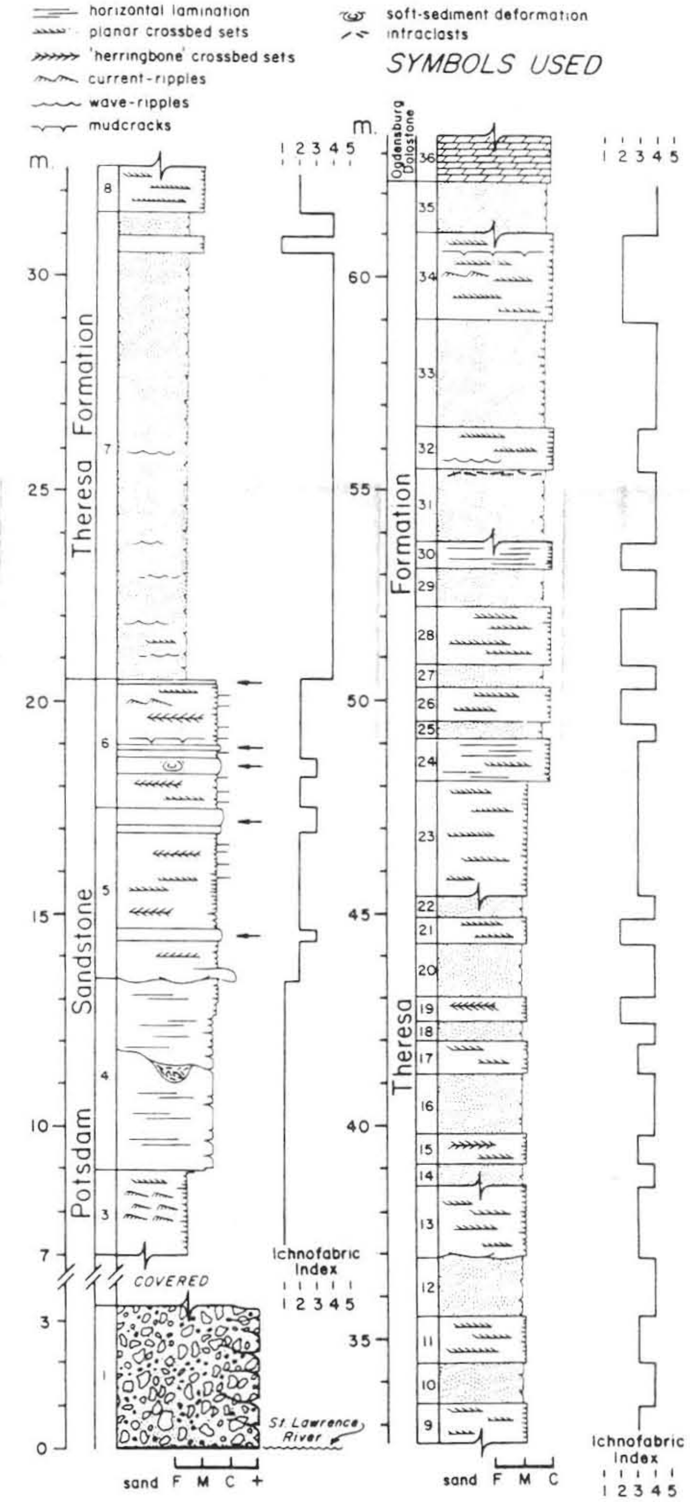

Figure 8: Composite section of the Potsdam and Theresa Formations in the Thousand Islands region showing bioturbation intensity based on ichnofabric indicies (Droser and Bottjer, 1988a). Arrows show medium- to thick-bedded sandstones containing *Diplocraterion* sp. in the "whit " Potsdam.

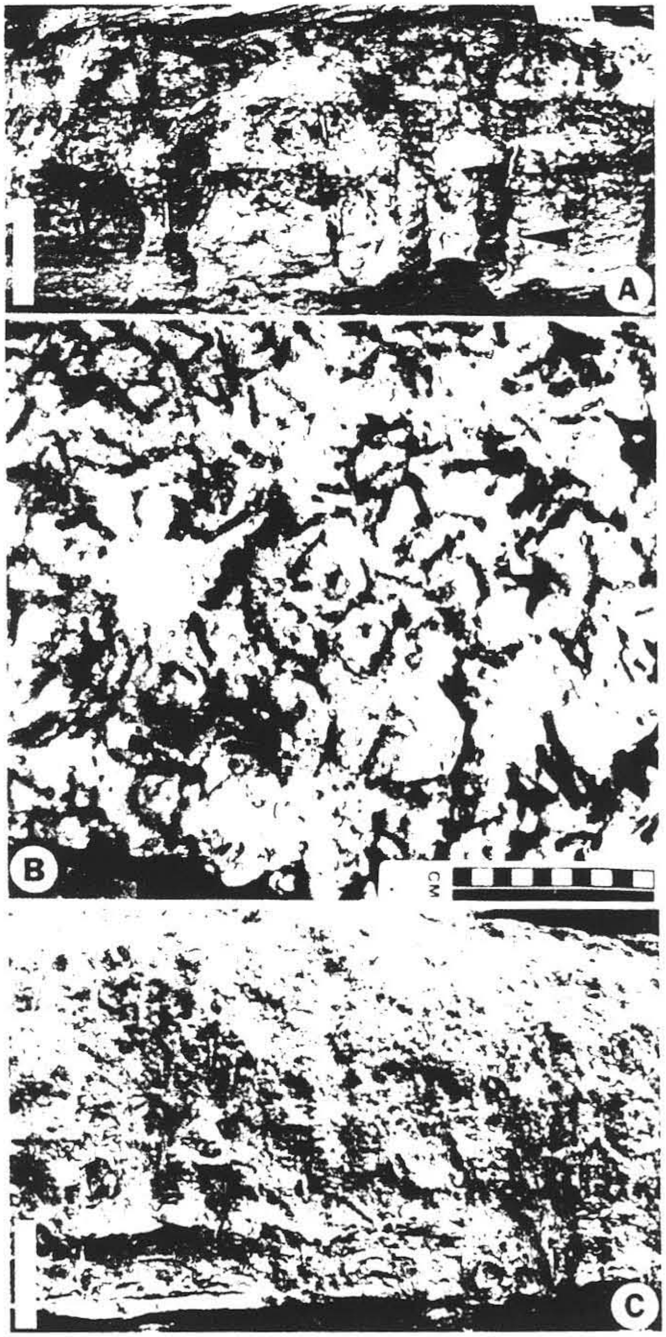

Figure 9: *Diplocraterion* sp. in the "white" Potsdam; bar scales = 10 cm. **A**) Clean sandstones containing *D. parallelum* at Chippewa Bay. Protrusive specimen at arrow may be escape shaft. **B**) Concave epireliefs on bedding plane exposure at unit 1 location. **C**) Thoroughly bioturbated sandstone bed in the "white" Potsdam at Chippewa Bay showing amalgamated *Diplocraterion* sp. tubes and escape burrows, some resembling nested funnels of *Monocraterion* sp.

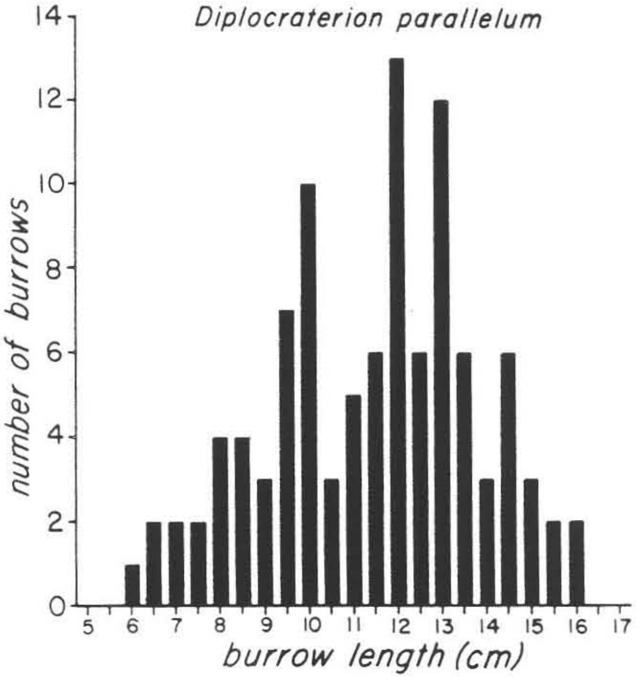

Figure 10: Histogram of minimum burrow depth for protrusive *Diplocraterion parallelum* from the "white" Potsdam Formation at Chippewa Bay, N = 102.

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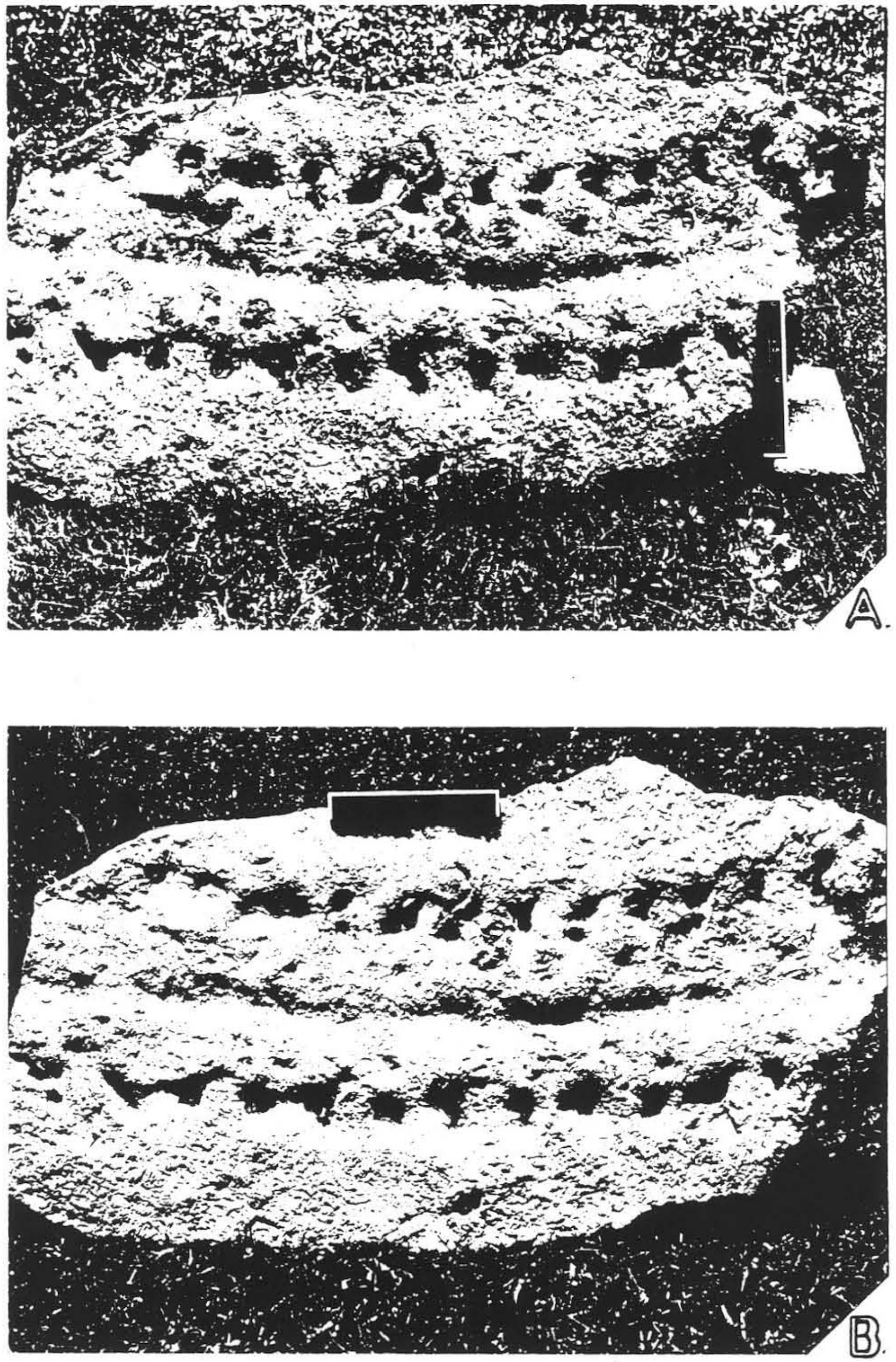

Figure 11: Slab of white sandstone from Oak Point showing trackway of *Protichnites*(?)-like ichnofossil. Scale bar = 15 cm. **A**) Specimen unwhitened. **B**) Specimen whitened to accentuate the depressions of short walking legs adjacent to groove.

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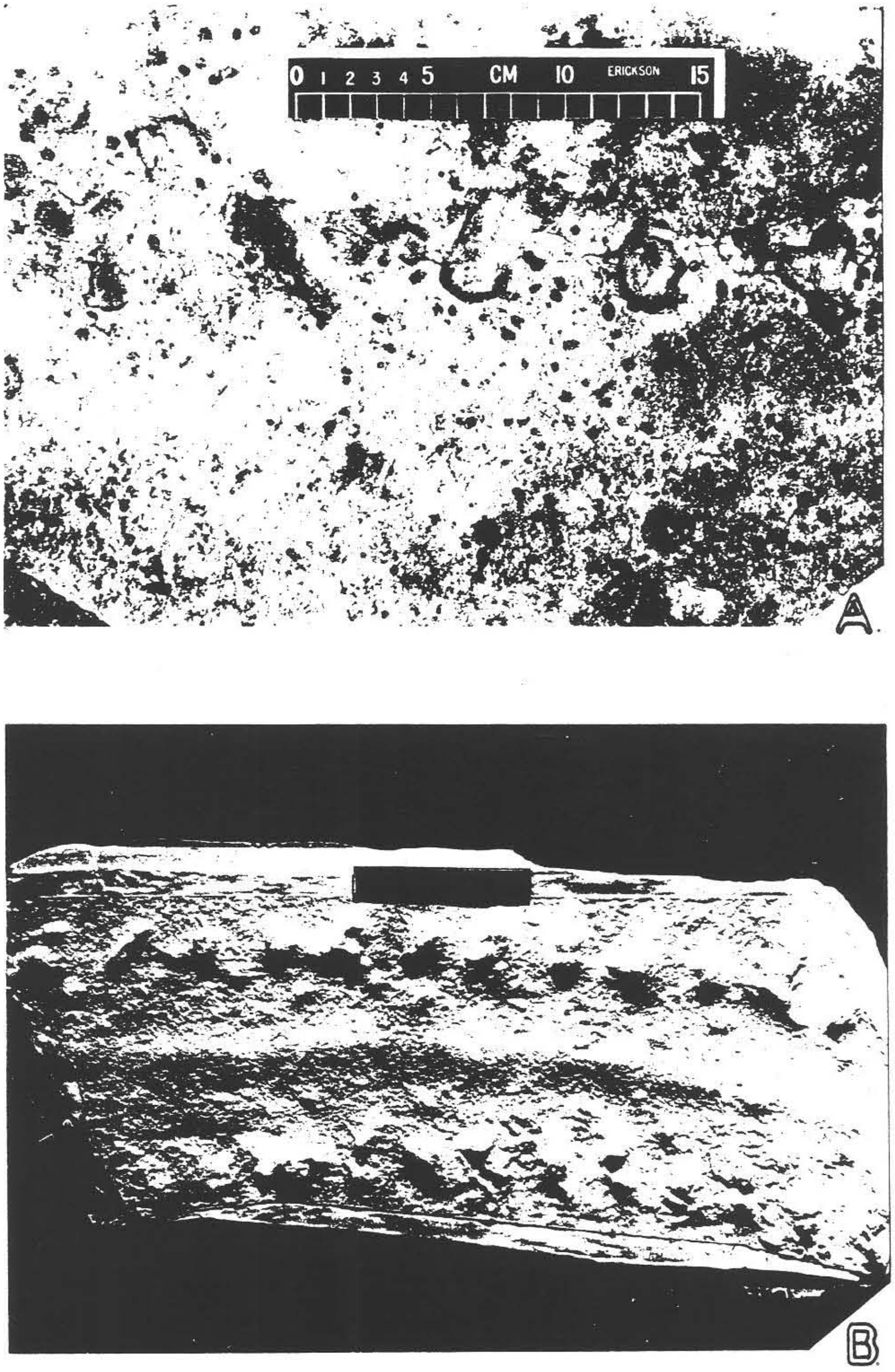

Figure 12: *Protichnites*(?)-like ichnofossil. **A)** Note the trifid impressions alternatng with bladeed bifid impressions on this region seen just below scale bar in 12B. **B)** Plaster cast of the tracks presenting them in epirielf as if on the base of the bed above. Scale bar is 15 cm.

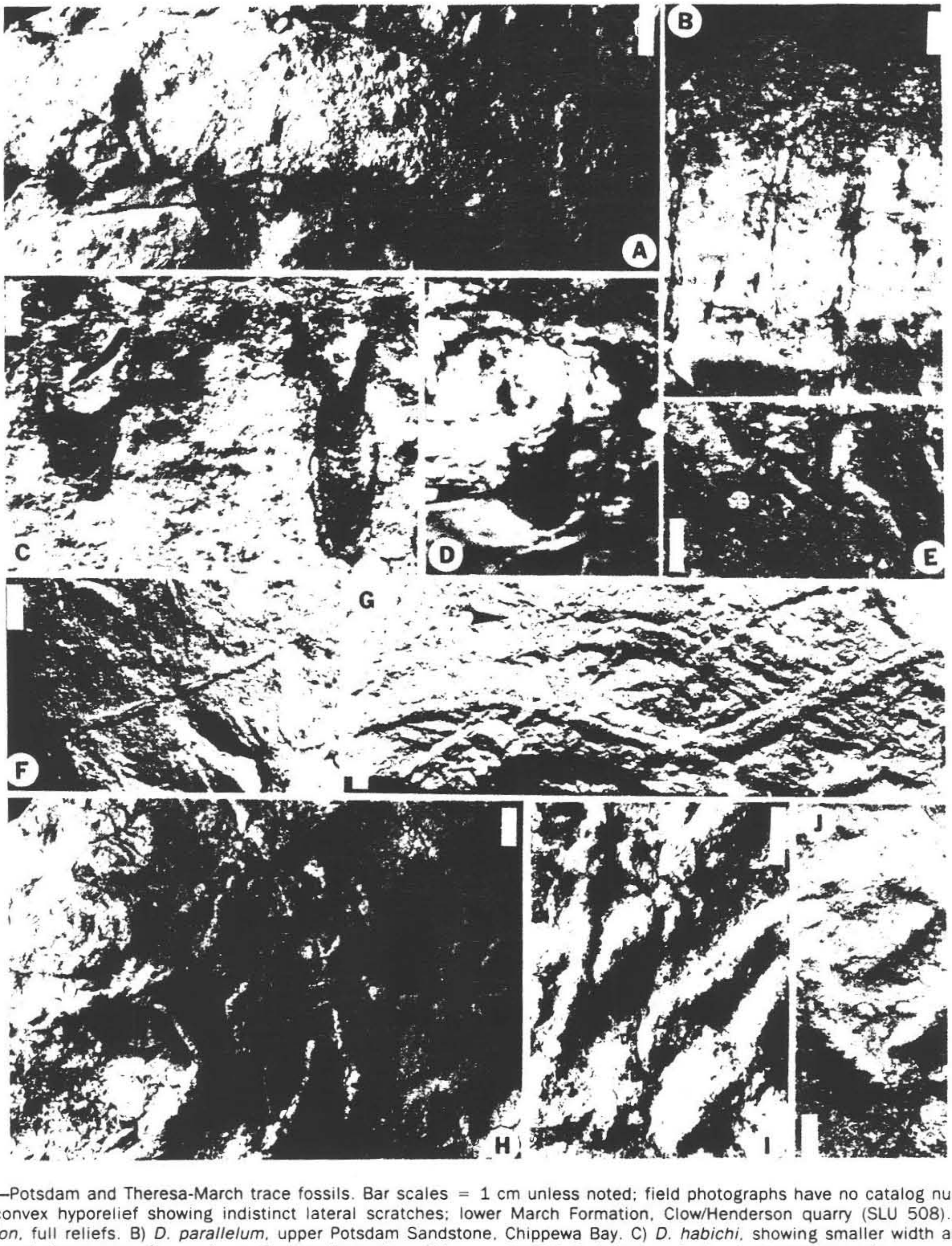

FIGURE 13—Potsdam and Theresa-March trace fossils. Bar scales = 1 cm unless noted; field photographs have no catalog numbers. **A)** *Cruziana*? convex hyporelief showing indistinct lateral scratches; lower March Formation, Clow/Henderson quarry (SLU 508). **B, C, D)** *Diplocraterion*, full reliefs. B) *D. parallelum*, upper Potsdam Sandstone, Chippewa Bay. C) *D. habichi*, showing smaller width and inward pinching/upward divergence of arms; lower Theresa Formation, Chippewa Bay. D) *D. helmerseni*, showing basal expansion; upper Potsdam Sandstone, Chippewa Bay. **E)** *Fustiglyphus*?, full relief in float block, black arrow shows single swelling, Theresa Formation, Oak Point. **F, G)** *Gyrochorte*?, convex epireliefs. F) Small specimen showing no plait structure, lower Theresa Formation, Chippewa Bay (SLU 509). G) Large specimen showing subtle plait structure, black arrow shows *Monocraterion*; lower Theresa Formation, North Hammond quarry (SLU 510). **H, I, J)** *Neonereites uniserialis*?, convex hyporeliefs, lower March Formation, Clow/Henderson quarry. H) (SLU 511), black arrow shows *Teichichnus*. I) (SLU 512). J) (SLU 513).

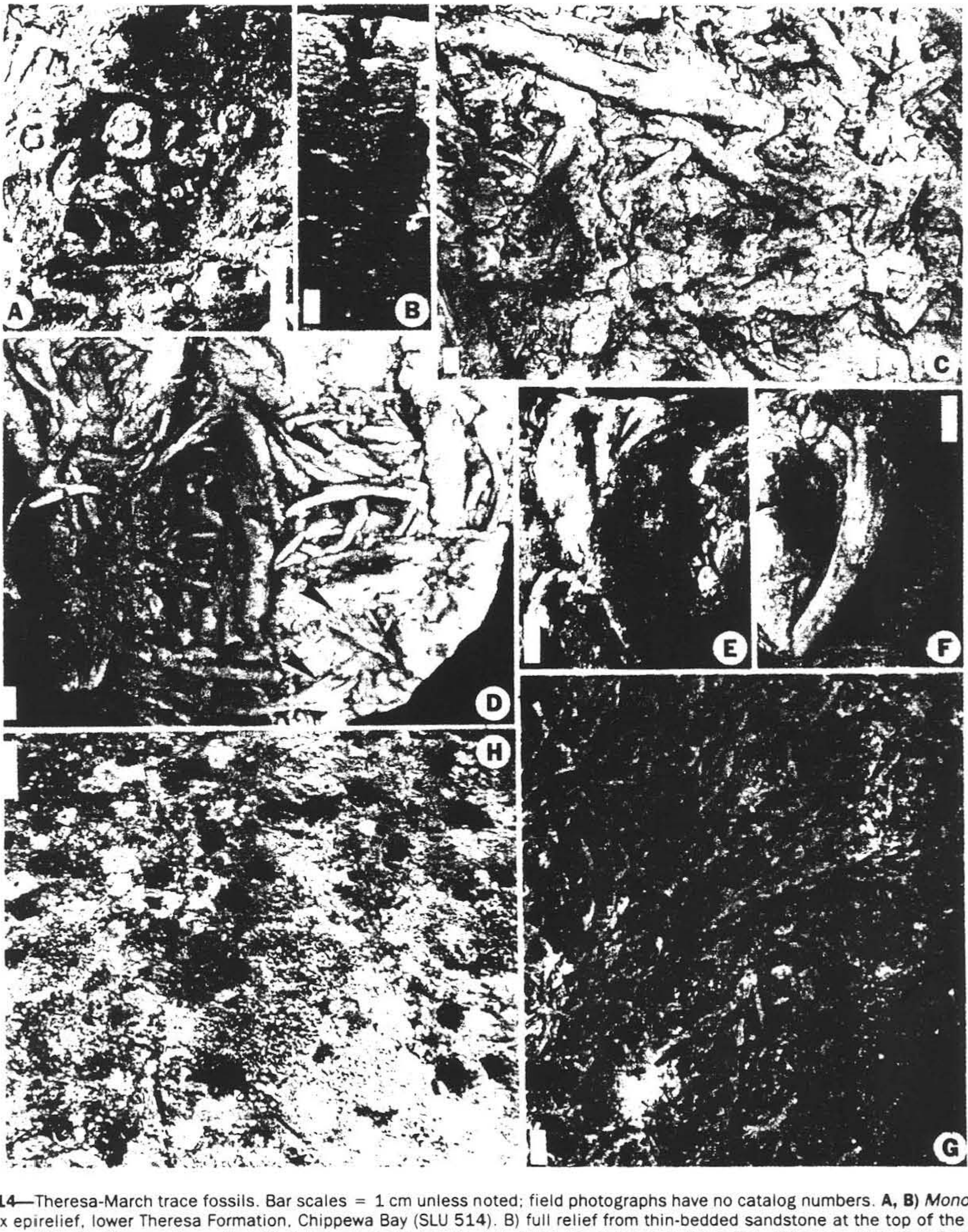

FIGURE 14—Theresa-March trace fossils. Bar scales = 1 cm unless noted; field photographs have no catalog numbers. **A, B)** *Monocraterion.* A) convex epirelief, lower Theresa Formation, Chippewa Bay (SLU 514). B) full relief from thin-bedded sandstone at the top of the Chippewa Bay outcrop (Fig. 5), Theresa Formation. **C)** *Palaeophycus tubularis,* full relief, lower Theresa Formation, Chippewa Bay (SLU 515). **D, E, F)** *Phycodes flabellum,* convex hyporeliefs, lower March Formation, Clow/Henderson quarry D) Slab with branching *P. flabellum* (black arrows), and abundant unbranched *Teichichnus,* (SLU 516). E) (SLU 517). F) (SLU 518). **G)** *Planolites beverlyensis,* convex hyporelief, lower Theresa Formation, North Hammond quarry (SLU 519). **H)** *Rosselia socialis,* concave epireliefs on a lichen-covered bench surface, bar scale = 5 cm, lower Theresa Formation, North Hammond quarry.

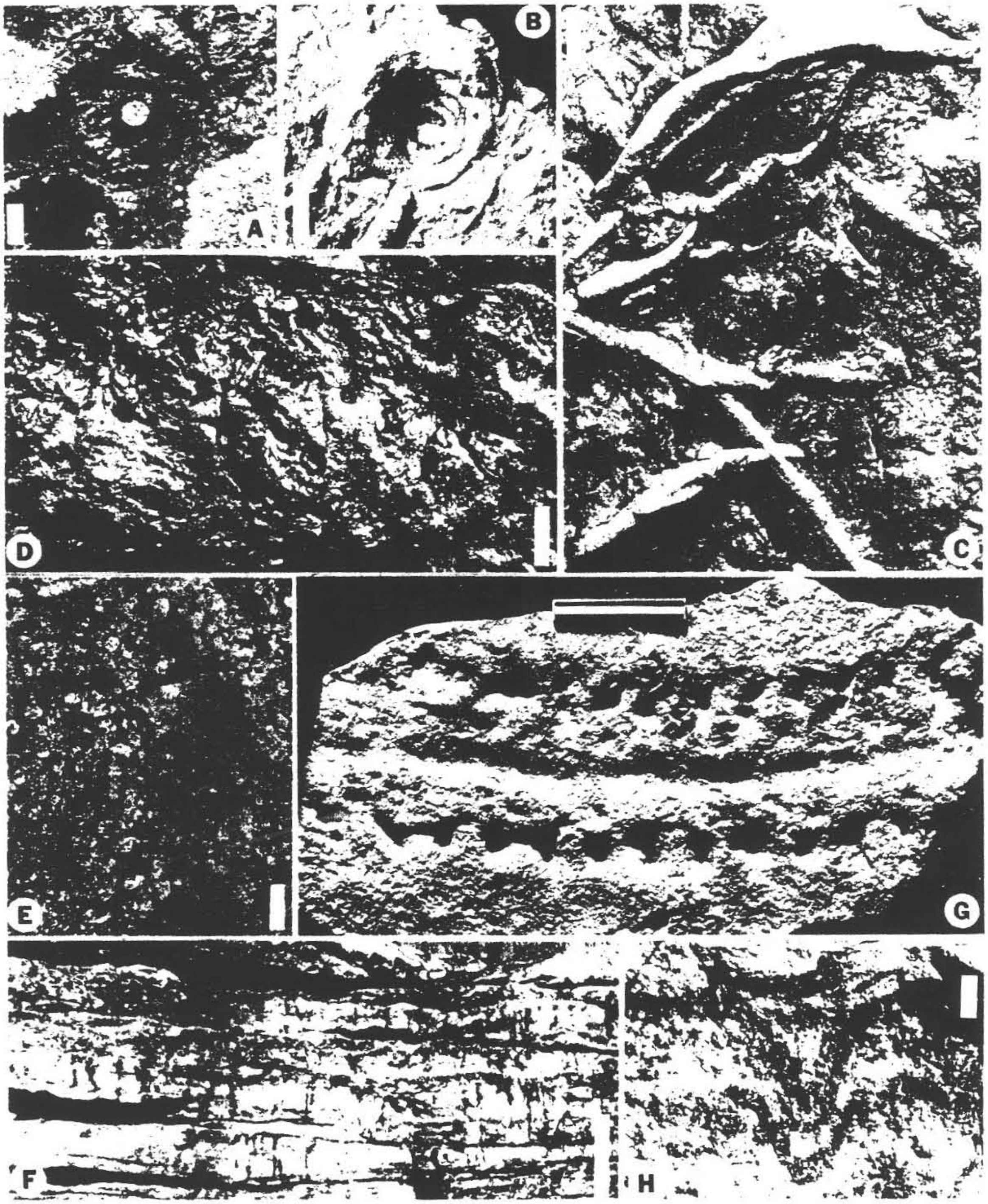

FIGURE 15—Theresa-March trace fossils. Bar scales = 1 cm unless noted; field photographs have no catalog numbers. **A, B)** *Rosselia socialis*. A) Concave epirelief showing basal tube on same bench surface in Fig. 14H, lower Theresa Formation, North Hammond quarry. B) Concave epirelief, lower Theresa Formation, Chippewa Bay (SLU 521). **C, D)** *Teichichnus*. C) convex hyporeliefs of discrete burrows, lower March Formation, Clow/Henderson quarry (SLU 524). D) weathered full reliefs on outcrop showing spreite, lower Theresa Formation, Chippewa Bay **E, F)** *Skolithos*. E) Epireliefs of sediment filled vertical tubes, lower Theresa Formation, Chippewa Bay (SLU 522). F) Shallow vertical burrows in meter-thick, thin-bedded sandstone at the top of the Chippewa Bay outcrop (Fig. 5), Theresa Formation, bar scale = 15 cm. **G)** Arthropod trail, concave epirelief from meter-thick, thin-bedded sandstone in the lower-middle Theresa Formation, Oak Point, bar scale = 15 cm (SLU 520). **H)** Escape burrow showing down-bent laminae, upper Theresa Formation, (unit 34; Figs. 3, 4).

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