# Trip F-1

## STROMATOLITES AND ASSOCIATED BIOGENIC STRUCTURES IN CAMBRIAN AND ORDOVICIAN STRATA IN AND NEAR OTTAWA, ONTARIO

**J. Allan Donaldson**
Department of Earth Sciences, Carleton University, Ottawa, Ontario, Canada K1S 5B6

**Jeffrey R. Chiarenzelli**
Department of Geology, State University of New York, Potsdam, New York 13676
chiarejr@potsdam.edu

## INTRODUCTION

This trip will provide an overview of some interesting sedimentary and biosedimentary structures in Cambrian and Ordovician strata of the National Capital Region (Figure 1); stratigraphic relationships (Brand and Rust, 1977; Williams, 1991; Wilson, 1946) will receive only cursory attention (Figures 2 and 3). The main thrust of the trip is to bring attention to the abundance and variety of shallow water environments throughout early Paleozoic time in this part of eastern Canada. Most outcrops to be visited are within the fault-controlled Ottawa-Bonnechere Graben.

During the drives between several stops, the uplifted northern block of the Gatineau Hills is clearly visible. While driving along Carp Road, we will be following a parallel fault along which Precambrian basement of the Carp Ridge has been uplifted relative to the Paleozoic strata to the south. Most of the rich farmland underlain by Paleozoic strata was inundated by the Champlain Sea, which receded from the region less than 12,000 years ago Some of these clay-rich areas (including substantial volumes of the landslide-prone Leda clay), were buried by sand and gravel initially deposited as outwash during deglaciation, and subsequently by the paleo-Ottawa River.

Although several outcrops containing fossils will be visited, the unusual abundance of stromatolites in strata of eastern Ontario will be emphasized. In places these stromatolites are so abundant that they provide views reminiscent of large tracts of Proterozoic terranes in northern Canada with which both trip leaders are familiar. Such abundance of biofilm-mediated structures, in strata deposited well after the time during which many browsers and grazers had evolved, seems paradoxical. Yet environments suitable for abundant biofilm growth essentially free of predators exist in several parts of the world today. Where such active ecoscapes currently exist, hypersalinity sufficiently high to inhibit proliferation of browsers and grazers is the primary environmental condition that allows biofilm structures to grow in abundance. Such environments are postulated for growth of most of the stromatolitic units to be viewed in Paleozoic strata during this excursion. Although commonly abundant in beds above and below, shelly and trace fossils are essentially absent from the stromatolitic strata; another line of evidence is the common occurrence of associated evaporite pseudomorphs.

A highlight of the trip will be visits to two occurrences of stromatolites and associated biofilm structures in quartz arenite beds. Similar biosedimentary structures have been observed on the other side of the Frontenac Axis (Dalrymple, pers. com.), and we have seen similar biosedimentary structures in a few localities in New York State. Because such structures can be readily mistaken for dewatering structures when seen in vertical section, re-examination of well-know localities elsewhere is warranted. Because of the prevailing view that stromatolites occur only in carbonate strata, quartz-sand stromatolites may well have been overlooked in other areas of correlative strata (especially in unmetamorphosed Precambrian siliciclastic strata, where such biosedimentary structures should have been abundant under conditions of normal as well as elevated salinity).

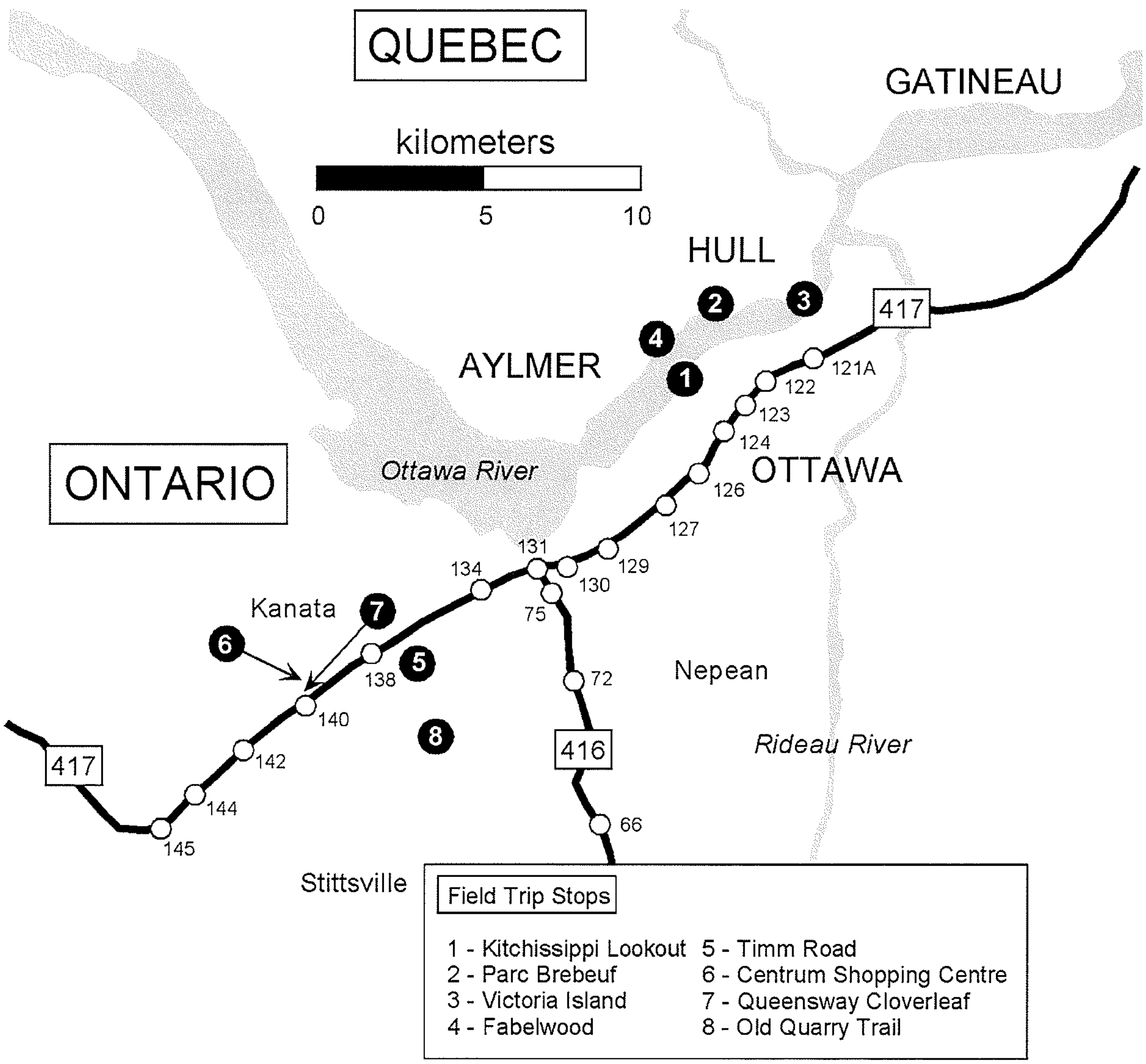


Figure 1. Field trip stop locations. Exit numbers on Highways 417 and 416 are shown for reference. See road log for detailed locations.

| Period | Series | Stage | SOUTHEASTERN ONTARIO | | | | | NORTHERN NY | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Williams &Teleford (1986) | | | Wilson (1946) | | Fisher (1977); Cameron & Mangion (1977) | |
| | | | Group | Formation | Member | Formation | Faunal Zone | Group | Formation |
| ORDOVICIAN | Cincinnatian | Richmond | Queenston | | | Queenston | | No equivalents | |
| | | | Carlsbad | | | Russell | | | |
| | | Maysville | | | | Carlsbad | | | |
| | | Eden | Billings | | | Billings | | | |
| | | | | Lindsay | Upper | Eastview | | | |
| | | | | | Lower | Ottawa | Coburg | Trenton | Hillier |
| | | | | | | | | | Steuben |
| | | | | | | | | | Denley |
| | Champlainian | Sherman | | Verulam | | | Sherman Fall | | Sugar River |
| | | Kirkfield | | Bobcaygeon | Upper | | Hull | | Kings Falls |
| | | Rockland | | | Middle | | | | Napanne |
| | | Black River | | | Lower | | Rockland | Black River | Selby |
| | | | | | | | Leray | | Watertown |
| | | | | Gull River | Upper | | Lowville | | Lowville |
| | | | | | Lower | | Pamelia | | Pamelia |
| | | | | Shadow Lake | | | | | |
| | | Chazy | | Rockcliffe | Upper | St. Martin | | Chazy | St. Martin |
| | | | | | Lower | Rockcliffe | | | Rockcliffe |
| | CANADIAN | | Beekmantown | Oxford | | Oxford | | Beekmantown | Ogdensburg |
| | | | | March | | March | | | Theresa |
| CAMBRIAN | | | Potsdam | Nepean | | Nepean | | Potsdam | Keeseville |
| | | | | Covey Hill | | | | | Ausable |

Figure 2. Stratigraphic correlation of Cambro-Ordovician units in the Ottawa area (Southeastern Ontario) with adjacent parts of northern New York (after Willams et al. 1992.)

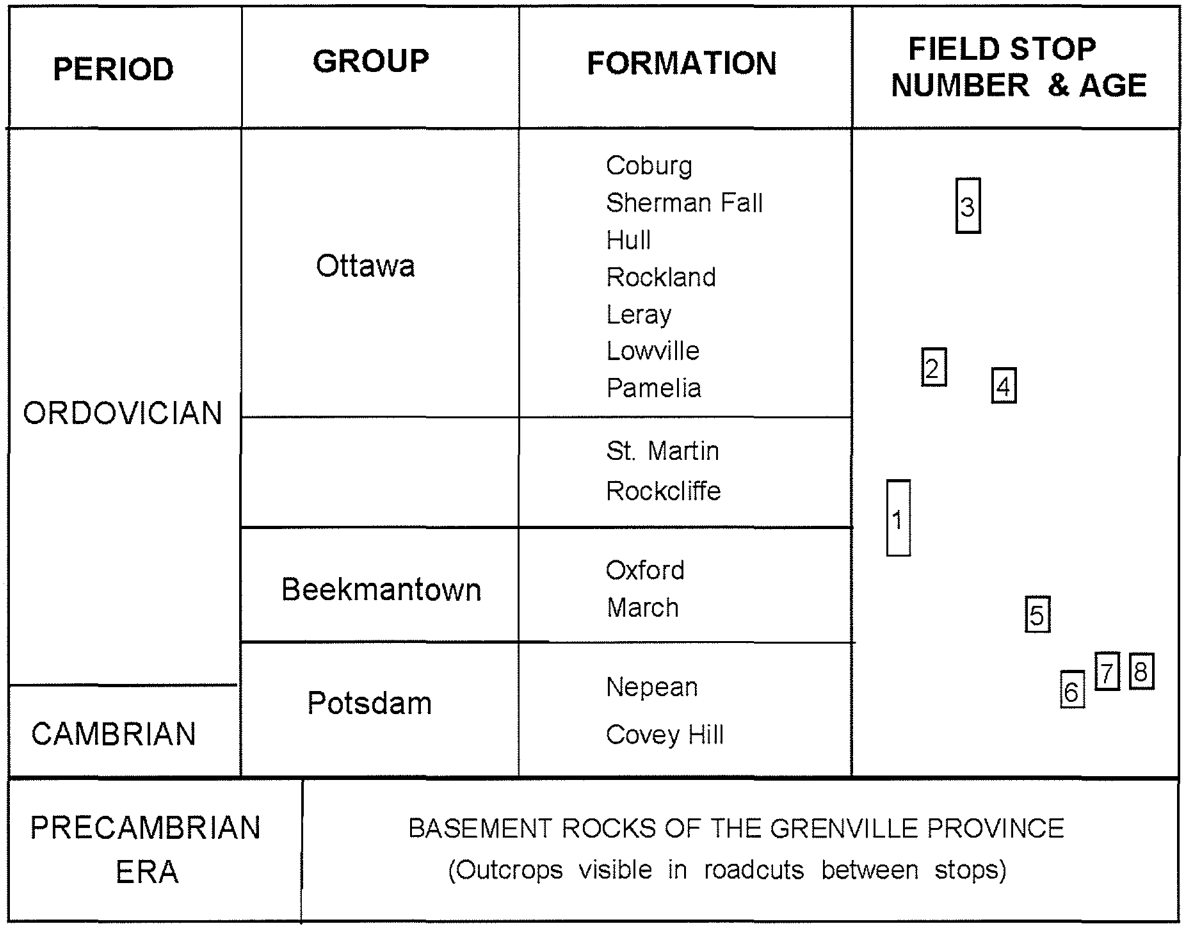


Figure 3. Relative stratigraphic position of units exposed at each of the field trip localities.

## ROAD LOG AND STOP DESCRIPTIONS FOR TRIP F-1

Meet at 9:30 am in the Kitchissippi Lookout parking lot, Ottawa.

NOTE 1. Allow at least 1.5 hours to drive from the junction of Hwy. 401 and Hwy. 416 to our rendezvous point (Kitchissippi Lookout parking lot, Ottawa).

NOTE 2. Field Trip F-1 will end around 4 pm, on Eagleson Road south of Kanata. This will allow ample time to return to Potsdam for the NYSGA Registration and Welcoming Reception (6:00-9:00 pm) in Thatcher Hall, SUNY Potsdam.

NOTE 3. Please be sure to have some type of photographic identification at the border. A passport is preferred, especially upon reentry to the U.S..

NOTE 4. Because of the urban setting, this trip will involve some complex driving including entering cul-de-sacs, and frequent turns to reverse direction and obey traffic laws. Thus it is very important to reset your odometer at each locality prior to leaving for the next.

**How to get to the starting point from the USA-Canada border:**

Follow Hwy 401 to Highway 416; take Hwy 416 north for 75 km to Hwy 417 (known as 'The Queensway' within Ottawa). Keep in the lane to enter Queensway East, and drive 3.8 km eastward (past the Richmond Road and Greenbank-Pinecrest exits). Take the next exit at Woodroffe, exiting right on a cloverleaf, and turn left at the stoplights (4.2 km from Hwy 416) to go north over the Queensway just exited. At 5.2 km, Woodroffe takes a 1-block jog to the east on Carling (after turning right on Carling, move quickly into one of the two left two lanes, to be able to turn left in less than 200 m to continue north on Woodroffe; this turn is at the stoplights, just before a shopping centre with a large Sears store). Continue straight, crossing Richmond Road at 6.4 km, proceeding downhill (over a paleo-Ottawa River shoreline) to the point (6.8 km) where Woodroffe merges eastward with the Ottawa River Parkway. Follow the Parkway eastward for 2.5 km, and turn left at the faded black sign (on the far left) marking Kitchissippi Lookout. Be careful not to miss this turn, which lacks stoplights or stop signs; it comes immediately beyond a pedestrian underpass to the same destination. Drive to the west end of the Kitchissippi parking lot, and meet at the kiosk armoured with display panels that provide information about the natural and cultural history of the Ottawa River (Note to subsequent users of this guidebook: on Sundays during the summer months, parts of this parkway, as well as other NCC Parkways in Ottawa, are restricted to use by cyclists and pedestrians only).

## STOP 1. LIMESTONE, OTTAWA GROUP (ORDOVICIAN) AT KITCHISSIPPI LOOKOUT, OTTAWA

(Caution: cyclists and skateboarders use the paved path near the river, and patches of poison ivy occur sporadically along the shore beyond it).

The top of a two-metre cliff section along this part of the shore reveals a 20 cm bed of limestone containing laterally linked domal stromatolites with a synoptic relief of 10 cm. The recessively weathered underlying flaggy to slabby beds of limestone contain rare shale interlayers, and are sporadically rich in fossils, including orthocone cephalopods, brachiopods and bryozoa. Some bedding surfaces display desiccation cracks and ripple marks.

| CUMULATIVE MILEAGE KM (MILES) | KM (MILES) FROM LAST POINT | ROUTE DESCRIPTION |
|---|---|---|
| 0.0 (0.0) | | Leave Kitchissippi Lookout (**STOP 1**), cross Parkway and turn left traveling east on the Ottawa River Parkway. |
| 0.9 (0.6) | 0.9 (0.6) | Turn left (north) on Island Park Drive and cross the Ottawa River into Quebec via the Champlain Bridge. |
| 2.5 (1.6) | 1.6 (1.0) | Turn right at first stop light past bridge onto Rue Lucerne. |
| 4.3 (2.7) | 1.8 (1.1) | Drive east one block past Parc Moussette turning right on Rue Bégin. |
| 4.4 (2.8) | 0.1 (0.1) | **STOP 2**. Park near the intersection of Rue Bourget and Rue Maricourt and; avoid sides of the street with no parking; meet at Brébeuf statue. |

**STOP 2. LIMESTONE, OTTAWA GROUP (ORDOVICIAN): PARC BRÉBEUF, GATINEAU, QUEBEC**

N45°25.067' W075°44.722'

Those arriving early at STOP 2 may wish to check out the tapered base of the Brébeuf statue, which contains at least 500 cobble stones representative of the many rock types within the Grenville Province, sampled during Pleistocene glaciation, and rounded during subglacial transport and fluvial transport during deglaciation (<12000 years ago) . Their clean polished surfaces, reflecting derivation from a gravel pit in Pleistocene outwash, provide an opportunity to study the mineralogy, textures and structures (foliation, lineation, intrusive contacts, folding) typical of Precambrian terrane to the north. Around the base of the statue, metre-square pavement panels have been inset with uniformly sized clasts -- some with well rounded equi-size pebbles of white limestone; others with angular fragments of black basalt.

From the base of the statue, walk directly to the shore of the Ottawa River where gently dipping bedrock platforms of limestone display a variety of fossils: corals, stromatoporoids, cephalopods, gastropods, mollusks, brachiopods, crinoids, bryozoa, trace fossils, and fragments of trilobites. The artistically arranged limestone blocks in the retaining walls display a wide range in grain size, as well as primary structures such as bedding, ripple marks and crossbedding. Secondary structures include joints and stylolites. Note how features are accentuated on weathered surfaces.

To the east, a large boulder of Precambrian gneiss marking the Voyageurs Portage shows excellent folded foliation in three-dimensions. Immediately north, Rue Bourget has a curb along the south side consisting of two rows of stone paving blocks. Most are Nepean sandstone (set both on edge and parallel to bedding), but a few are granite. Some of the sandstone blocks display Liesegang banding. From the east end of Rue Bourget, walk east along the bike path (look out for speeding cyclists and rollerbladers). In rounding the curve below the transformer station on the left, note the variety of bedding-surface structures in limestone slabs set in the sloping base of the fenced-in transformer area. At its northeast fenced corner, take the last gravel footpath to the east (just before the T- junction in the bike path) out to the south shore of an inlet on the Ottawa River. Excellent views of folds in limestone beds can be seen along the northeastern shore of this inlet.

| CUMULATIVE MILEAGE KM (MILES) | KM (MILES) FROM LAST POINT | ROUTE DESCRIPTION |
|---|---|---|
| | | RESET ODOMETER BEFORE LEAVING |
| 0.0 (0.0) | | Leave Parc Brébeuf (**STOP 2**) and drive north on Rue Bégin to Taché Blvd. |
| 0.4 (0.2) | 0.4 (0.2) | Turn right and follow Taché Blvd east to Rue Eddy. |
| 2.4 (1.5) | 2.0 (1.3) | Turn right at Rue Eddy and travel south on the Chaudieres Bridge |
| 3.1 (1.9) | 0.7 (0.4) | Drive part way across the bridge, passing three stoplights, and turn left on Middle Street at the black sign indicating access to Victoria Island |
| 3.4 (2.1) | 0.3 (0.2) | Drive past an old generating station, and park in a small raised gravel parking lot on the right side, just past the Ottawa-Hull Navy Association building. Walk downhill towards Cul-de-sac sign. **STOP 3.** |

## STOP 3. OTTAWA GROUP LIMESTONE (ORDOVICIAN), VICTORIA ISLAND, OTTAWA RIVER

N45°25.216' W075°42.855'

In this exposure of Ottawa Group limestone, megaripples are recurring bedforms topping coarse clastic flat-lying beds that are intercalated with carbonate mudstones containing abundant trace fossils both perpendicular & parallel to bedding. Fossils in the megarippled units include bryozoa, brachiopods, crinoids and orthocone cephalopods (cf. Wilson, 1956). A distinct alternation is evident between these calcarenite beds rich in shelly fossils (mainly fragmented) and the shaly calcilutite beds rich in trace fossils. This probably represents alternation between quiet-water conditions and episodic storms. This interpretation fits well with the abundance of fine-grained intraclasts in the coarse-grained interbeds. Rare carbonate mudstone surfaces displaying desiccation cracks, reflecting intermittent exposure. The symmetrical megaripples are superposed on crossbedded units, suggesting storm reactivation of originally asymmetric current-deposited subaqueous dunes.

| CUMULATIVE MILEAGE KM (MILES) | KM (MILES) FROM LAST POINT | ROUTE DESCRIPTION |
|---|---|---|
| | | RESET ODOMETER BEFORE LEAVING |
| 0.0 (0.0) | | Leave Victoria Island (**STOP 3**) by retracing your entry via Middle Street. |
| 0.3 (0.2) | 0.3 (0.2) | Turn left on Booth St. and drive south. Cross over intersection with the Ottawa River Parkway (no turns are allowed, due to construction). Keep right at the OC Transpo sign. |
| 1.0 (0.6) | 0.7 (0.4) | Turn right on Scott St. and head west. |
| 4.0 (2.5) | 3.0 (1.9) | Turn right (north) on Island Park Drive and re-cross the Champlain Bridge. |
| 6.3 (3.9) | 2.0 (1.4) | Turn left at Rue Lucerne (the first stop light after leaving the bridge). |
| 6.6 (4.1) | 0.3 (0.2) | Drive west about 200 m from these stoplights, and turn left again into Samuel de Champlain parking lot (6.6 km). Walk a few steps riverward to the bike path along the north shore of the Ottawa River. Turn left on this paved path and walk halfway back toward Champlain Bridge (Caution: speeding cyclists and skateboarders may suddenly appear around the curves, and patches of poison ivy commonly flank both sides of the paved path). The best exposures are in front of Fablewood, a historic yellow frame house with brown trim. **STOP 4**. |

## STOP 4. STROMATOLITES IN PAMELIA FORMATION (ORDOVICIAN), FABLEWOOD

N45°24.676' W075° 45.980'

Glaciation has cut a near bedding-parallel section (Figure 4) through a single bed less than 40 cm thick that contains a continuous display of closely packed domal stromatolites. Successive degraded biofilm sheets separated by storm-deposited fine-grained carbonate sediments are marked by concentric rings of carbonaceous matter. In some areas, freeze-thaw action has exhumed the original morphologies over many square metres of laterally linked, domal stromatolites. Mapping at 1:25 scale has revealed strong local north-south trends of elongation for the stromatolite heads (Donaldson et al., 2002). In many places two or more are coalesced in parallel , strings oriented in the same (north-south) direction. By analogy with modern stromatolites in Hamelin Pool, Shark Bay, Western Australia, these trends are readily attributed to the action of tides and onshore-wind-driven waves (Playford, pers. com.). Some small stromatolites are elongate perpendicular to the prominent north-south trend; because several inter-stromatolite patches of small-scale asymmetric ripples indicate easterly currents, elongation of the orthogonally oriented small stromatolites is attributed to longshore currents. Intermittent exposure is reflected by micro-desiccation patterns on the tops of a few large stromatolites. Also by analogy with the modern stromatolites of Shark Bay, a hypersaline environment in which biofilm predators (Garrett, 1970) could not survive is inferred. This is supported by the observation that, whereas the underlying stromatolite-free beds of carbonate are fossiliferous (with gastropods and vermiform trace fossils particularly abundant), the stromatolite unit is free of megafossils. Only conodonts have been observed, and those extracted from the stromatolite unit are compatible with a hypersaline environment (Von Bitter, pers. com.).

| CUMULATIVE MILEAGE KM (MILES) | KM (MILES) FROM LAST POINT | ROUTE DESCRIPTION |
|---|---|---|
| | | RESET ODOMETER BEFORE LEAVING |
| 0.0 (0.0) | | Leave (**STOP 4**) by retracing your entry via Samuel de Champlain parking lot drive. |
| 0.1 (0.1) | 0.1 (0.1) | Turn right on Rue Lucerne. |
| 0.3 (0.2) | 0.2 (0.1) | Turn right (south) at stop light re-crossing the Champlain Bridge. |
| 1.6 (1.0) | 1.3 (0.8) | Turn right on the Ottawa River Parkway and drive west. |
| 7.6 (4.7) | 6.0 (3.7) | At. 7.6 km keep right to exit heading west on the Queensway (HWY. 417). |
| 13.3 (8.2) | 5.7 (3.5) | Drive west and move right to access the Moodies Drive exit. |
| 13.5 (8.3) | 0.2 (0.1) | Turn left at Moodies Drive and proceed south. |
| 14.9 (9.2) | 1.4 (0.9) | Turn right at Timm Drive, just beyond the railway overpass and proceed west. |
| 18.1 (11.2) | 3.2 (2.0) | Drive 3.2 km west on Timm Drive. Park as far over on the crushed stone shoulder as possible. (Caution: some patches of poison ivy, mainly near the fence). **STOP 5.** |

Figure 4. Plan-view photograph of stromatolite exposures in Gatineau, Quebec (STOP 4).

## STOP 5. MARCH FORMATION: DOLOSTONE AND DOLOMITIC QUARTZ ARENITE (ORDOVICIAN), TIMM DRIVE

N45°24.676' W075°45.980'

This section is only a few metres above the top of the Nepean formation. The carbonate beds contain abundant burrows, including several varieties that are bedding-parallel. Despite the extensive bioturbation, wispy biofilm structures and a few possible dewatering structures can be seen at several stratigraphic levels. Both the siliciclastic and carbonate beds display abundant crossbedding, and carbonate intraclasts are evident in some of the siliciclastic beds. Scattered patches of white to pale pink calcite are inferred to be replacements after evaporite minerals. The strata exposed here are similar to some outcrops showing the Potsdam –Theresa transition in New York State, as described by Selleck (1984).

| CUMULATIVE MILEAGE KM (MILES) | KM (MILES) FROM LAST POINT | ROUTE DESCRIPTION |
|---|---|---|
| | | RESET ODOMETER BEFORE LEAVING |
| 0.0 (0.0) | | Leave (**STOP 5**) by continuing west on Timm Drive. |
| 0.4 (0.2) | 0.4 (0.2) | At 0.4 km Timm Drive crosses Eagleson Road at a stoplight and becomes Katimavik Road. Continue straight across. |
| 3.6 (2.2) | 3.2 (2.0) | At the intersection of Katimavik and Terry Fox Drive, turn right and head north on Terry Fox Drive. |
| 4.3 (2.7) | 0.7 (0.5) | Continue over the Queensway and turn right on Earl Grey Drive (Entrance to Centrum Shopping Plaza). |
| 4.8 (3.0) | 0.5 (0.3) | Follow this road for 0.3 km to Chapters bookstore. Turn right to pass the Wal-Mart store, and turn left into the parking area along the southeastern side of Wal-Mart (4.8 km). Gather at the vertical section of horizontally bedded strata behind this building. **STOP 6**. |
| NOTE | LUNCH HERE | Depending on time, we will have lunch before or after this stop -- lots of restaurants to choose from, most of them east of the Centrum entrance sign. |

## STOP 6. NEPEAN FORMATION QUARTZ ARENITE (CAMBRO-ORDOVICIAN; POTSDAM EQUIVALENT), CENTURM SHOPPING PLAZA

N45°18.669' W075°54.716'

This 3m section (Figure 5), recently studied in detail (Anderson, 2004; Anderson et al., 2004), has provided significant information about the complex history of cementation in relation to sea level changes for this uppermost part of the Nepean. Additional information for the study was obtained from a longer exposure of equivalent strata (Dobie, 2004), but unfortunately, much of her longer section to the south (subparallel to the Queensway, north side), has been significantly degraded by construction now underway (a reflection of the lack of respect/protection afforded significant geological features not only in Ontario, but in most parts of the world).

The strata exposed in this section have been divided into facies on the basis of bedding thickness and sedimentary structures such as crossbedding and inferred biofilm structures. The diversity of these interdigitated facies is considerably more complex than as described for the principal reference section (Greggs and Bond, 1972). The prominent thick-bedded dune facies consists mainly of subaqueous dune cross-stratified quartz arenite, in places infilling erosionally-based tidal channels. The thin-bedded laminated facies is characterized by biofilm-mediated crenulate laminations (cryptalgal laminations), heavy mineral streaks, cross-laminated asymmetric ripple marks and granule-rich single-grain layers suggestive of lag accumulation. Soft-sediment deformation (convolute lamination) is locally evident at the top of the section, locally capped by a thin layer of domal quartz-sand stromatolites.

Frameworks grains consist almost entirely of fine- to very coarse-grained quartz; minor components are microcline, plagioclase and chert. Extremely well-rounded zircon, tourmaline and opaque iron oxides form the heavy mineral streaks, but some opaque patches are of post-depositional origin, having clearly been deposited interstitially. Biofilms, now degraded, are inferred to have played a role in accumulation of these trace components (rare semi-opaque brownish-stained patches visible in thin section may be degraded pyrobitumen). Interstitial clay minerals occur as thin discontinuous films around some framework grains in the least-cemented zones. Quartz alone is the cement for well-indurated beds up to 3 cm thick in all facies, and for most crossbedded sandstones in the dune facies; a few beds that stand out as glassy markers display abrupt truncations (Figure 6), suggesting that they may have been penecontemporaneously cemented, and then locally disrupted by erosional undercutting of unconsolidated substrate, localized upward pressure associated with dewatering, or dissolution of patchy zones of intercalated evaporites. Subspherical clusters of quartz sand (almost exclusive to the dune facies) show a distinctive blade-like external morphology comparable to modern desert rose structures, suggesting that they are pseudomorphs after evaporite-cemented rosettes which grew interstitially within the quartz sand before cementation by silica. Some of these subspherical structures, locally coalesced in clusters (as are modern 'desert roses' of gypsum), contain cores of calcite-cemented quartz sand.

Different cementation styles in the dune facies compared to the bounding thin-bedded facies are attributed to contrasts in permeability and differences in the flux of silica-bearing solutions related to water-table variations. Rosettes in the dune facies probably grew soon after emergence above sea level of the highly permeable dune facies; subsequent precipitation of quartz cement in pore spaces between framework components of this facies resulted in widespread preservation of original grains within overgrowths. Having escaped this early cementation, the beds above and below were more subject to grain-contact solution during subsequent burial compaction, leading to the development of pervasive mosaic textures and abundant stylolites. Grenville basement rocks form a hill a few hundred m to the northeast, immediately beyond Castlefrank Road, (just past the top of the section). Such Precambrian highs may have been islands adjacent to, and ultimately over which, the Paleozoic strata were deposited. If time permits, an extra stop will be made at segments of outcrop not yet covered by concrete along the vertical section south of Earl Grey Drive, parallel to the east side of Terry Fox Drive (marking the western boundary of the Centrum Shopping Centre). Impressive cross-sections of metre-deep channels (Figure 7) filled with dune facies sandstone are exposed behind the Texas Chop House (at N45 18.476' W075 54.255'). Crossbed inclinations indicate that these represent tidal channels.

| CUMULATIVE MILEAGE KM (MILES) | KM (MILES) FROM LAST POINT | ROUTE DESCRIPTION |
|---|---|---|
| | | RESET ODOMETER AT INTERSECTION OF EARL GREY WITH TERRY FOX DRIVE |
| 0.0 (0.0) | | Leave (**STOP 6**) by turning left on Terry Fox Drive. |
| 0.9 (0.6) | 0.9 (0.6) | Cross over the Queensway and turn left on Katimavik (0.9 km). |
| 1.3 (0.8) | 0.4 (0.2) | Take the next left on Davis (1.3 km) |
| 2.3 (1.4) | 1.0 (0.6) | Left on McGibbon, left at the second intersection with Rowe (2.1 km), and right on Davis (2.2 km). This complex operation has allowed us to return to Katimavik (2.3 km). Turn right on Katimavik and head west. |
| 2.7 (1.6) | 0.4 (0.2) | Turn right on Terry Fox Drive and head north. |
| 3.3 (2.0) | 0.6 (0.4) | Cross over the Queensway again, but this time take the cloverleaf road marked 417 West ('To Arnprior'). |
| 3.5 (2.2) | 0.2 (0.1) | Before merging with the Queensway, pull well off on the wide gravel shoulder (3.5 km), far enough back from the merge point to avoid blocking visibility for other motorists entering Hwy 417 West. Proceed to flat glacially polished outcrop to your right. Use the utmost caution leaving and returning to the vehicles because of the high-speed traffic. **STOP 7**. |

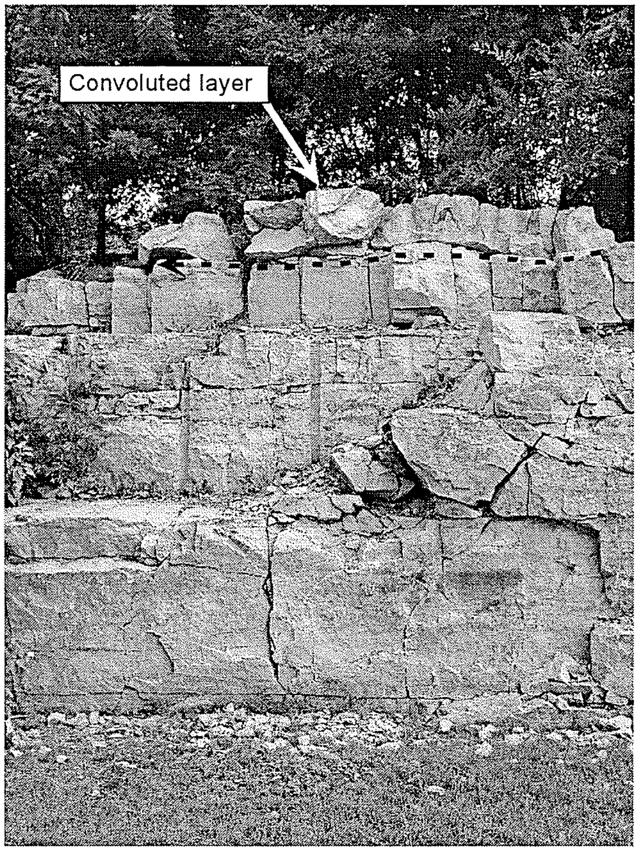


Figure 5. Three-meter-thick exposure of Nepean sandstone behind the Wal-mart in Kanata, Ontario (STOP 6). Note convoluted layer at the top of the outcrop.

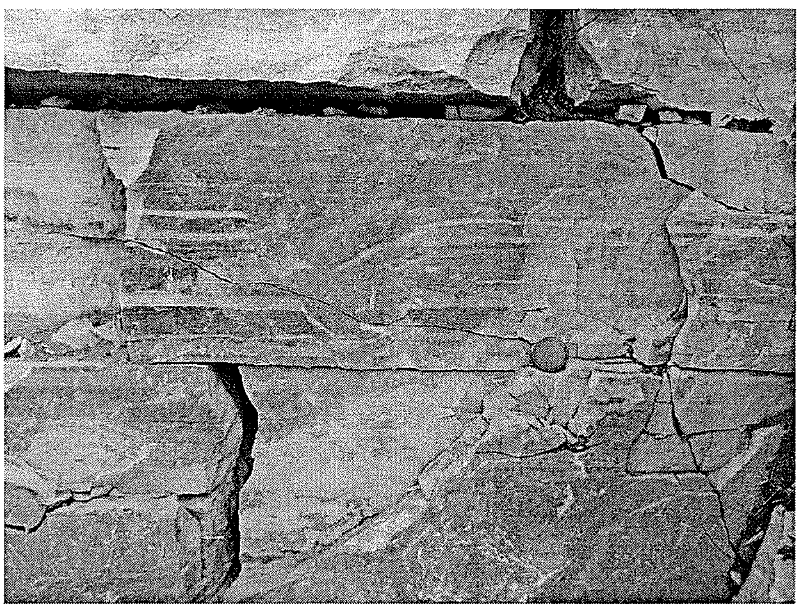

Figure 6. Truncated and silificied layer in the Nepean Sandstone behind the Wal-mart in Kanata, Ontario (STOP 6).

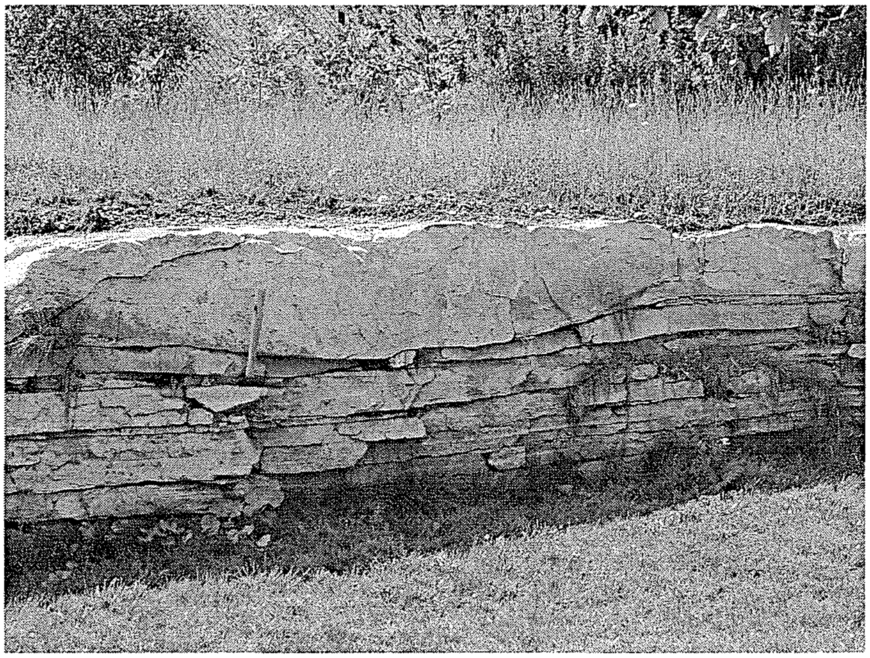

Figure 7. Tidal channels in the Nepean Sandstone, Kanata, Ontario (STOP 6).

## STOP 7. NEPEAN FORMATION QUARTZ ARENITE (CAMBRO-ORDOVICIAN), QUEENSWAY CLOVERLEAF

N45°18.410' W075°54.675'

In the top 30 cm of this 2-m section, and in correlative outcrops on the south side of the Queensway, plus the median strip between them, various aspects of distinctive domal stromatolites in quartz arenite are remarkably well displayed. Since their discovery a few years ago, more have been recognized in other Nepean and Potsdam outcrops, but none to compare with these. This locality has been designated as an Ontario ANSI (Area of Natural Scientific Interest) Site, which is supposed to afford protection for significant geoscientific features. The fact that currently planned expansion of the Queensway will mean destruction of a good part of this world-class site clearly indicates the low priority allotted to significant geofeatures in relation highway construction and commercial development.

The glacially polished top of this outcrop of quartz arenite provides numerous cross sections through distinctly laminated domal stromatolites, many showing elaborate crenulate to colloform ornamentation of their laminae (Donaldson et al., 2000). To account for the random tilted arrangement of stromatolites displayed so well here in a flat-lying succession, the model proposed requires early cementation of the stromatolite unit above a still-unlithified substrate of water-charged sand. As a result of a seismic disturbance, the rigid unit of laterally linked silica-cemented stromatolites snapped apart along the thin inter-stromatolite links, allowing the now-separated heads to rotate and founder in random directions into the overpressured sand. Subsequent burial and completion of cementation of the entire unit allowed preservation of the distinctive array that has been so well displayed as a result of fortuitous bedding-parallel slicing through this stromatolite unit during Wisconsinan glaciation.

Local patches displaying overturning of thin sandstone laminae are attributed to synsedimentary rupture of flexible sand-charged biofilm sheets that were subsequently flipped or rolled back (Figure 8) by waves and/or currents (cf. Donaldson, 1967). Dubiofossils described from Potsdam sandstone of New York State (Erickson, 1993) may have had a similar biofilm-mediated origin. The section east of the entry cloverleaf road displays a distinct channel cut into biofilm laminated strata. Thin recessively weathered chips in the lower part of this massive channel-fill unit are inferred to be flakes torn from the truncated biofilm sheets. The base of the channel shows a few load-like protuberances, suggesting rapid deposition, perhaps as a result of bank collapse.

A few small bedding-surface exposures display intact horizontal layers of small, low-amplitude domal stromatolites, some superposed on, or laterally grading to, asymmetric ripple marks. Other bedding surfaces display very small-scale wrinkle patterns capping laminae of quartz sand, similar to interference ripple marks, but significantly under-scaled relative to grain size. These appear to be analogous to small-scale ripples mediated by thin biofilm coatings on siliciclastic tidal flats in modern peritidal sediments (De Boer, 1981; Gerdes et al., 2000; Noffke, 2000.), as well as in other ancient siliciclastic deposits (Hagadorn and Bottjer, 2002; Noffke et al., 2002; Schieber, 1999). In well-sorted layers of silica-cemented sandstone, hemispherical hollows are inferred to represent the molds of gypsum rosettes. Although no evaporite minerals have yet been directly detected, blade-like impressions in the hemispherical cavities suggest early silica cementation of the enclosing sands, followed by subsequent dissolution of the evaporites responsible for the 'sand rose' morphology (Figure 9). In addition, some stromatolites display upward pointed crystal pseudomorphs of probable evaporite minerals (Figure 10). This suggestion of hypersalinity provides an explanation for this rare occurrence of stromatolites in a Phanerozioic setting (Donaldson and Hilowle, 2002) -- just as for the earlier observed lack of gastropods in stromatolite-rich Ordovician carbonates. Probable stromatolites in the Potsdam sandstone on the southwestern side of the Frontenac Axis have also been noted by Dalrymple (pers. com.).

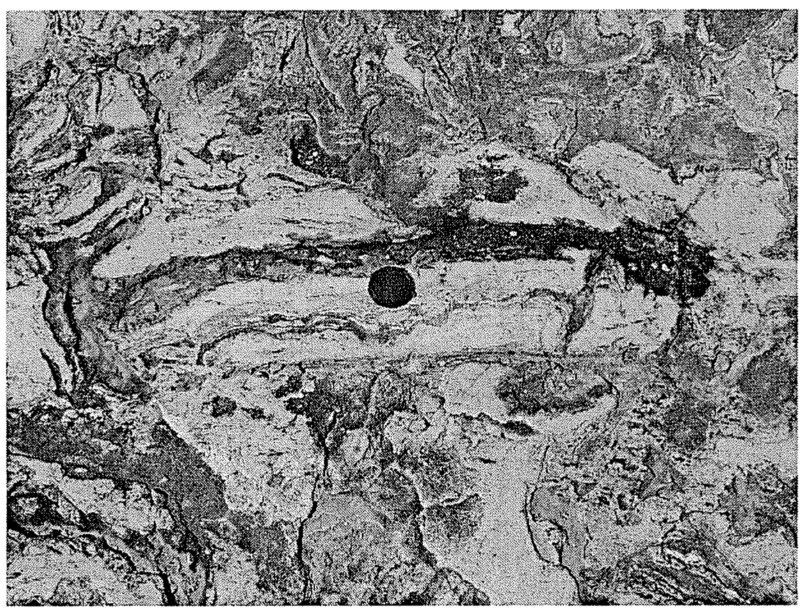

Figure 8. Glacially polished disrupted quartz arenites of the Nepean Sandstone with wrinkly, silificied biofilm layers (STOP 7).


Figure 9. Recessively weathering pockets within the Nepean Sandstone. Note the blade-like morphology in the hemispherical molds, probably produced by the replacement of evaporite rosettes (STOP 7).

Figure 10. Close up of disrupted quartz arenites showing fine detail of layers and possible evaporite pseudomorphs (right of lens cap) in the Nepean Sandstone (STOP 7).

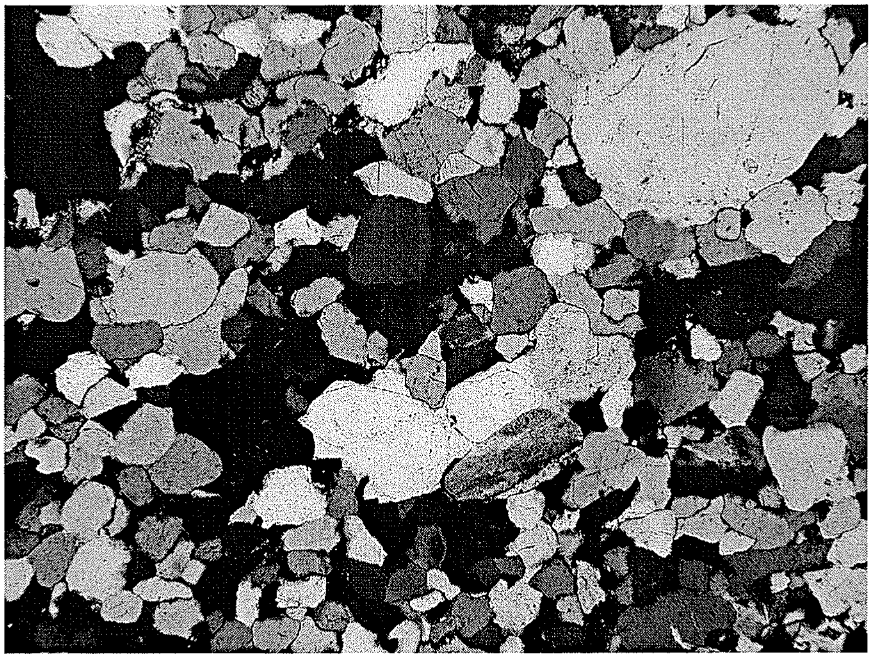

Figure 11. Photomicrograph of the Nepean sandstone from STOP 7. The quartz-rich composition and rounded of quartz grains is apparent. (Cross nicols, field of view 5 cm).

Thin-section and geochemical analysis (Table 1) indicate that the rock composed predominantly of quartz framework grains cemented by silica overgrowths (Figure 11). Geochemical analyses form this location indicate the rock is composed of >98% silica (Table 1) and relatively little else. Locally copper oxide and yellow carnotite(?) staining is evident. Some zones weather recessively indicating carbonate cement. The relative abundance of zirconium indicates that zircon is likely the dominant heavy mineral.

Table 1. Whole rock ICP-MS analysis of the Nepean Sandstone at Stop 7. Concentrations of major and select trace elements are given.

| **Major Element** | **Percentage** | **Trace Element** | Parts per **million** |
|---|---|---|---|
| $SiO_2$ | 98.29 | As | 0.5 |
| $Al_2O_3$ | 0.40 | Ba | 11 |
| $Fe_2O_3$ | 0.36 | Cd | <0.1 |
| MgO | 0.15 | Co | 0.6 |
| CaO | 0.09 | Cu | 13.8 |
| $Na_2O$ | 0.03 | Hf | 4.4 |
| $K_2O$ | 0.04 | Hg | <0.01 |
| $TiO_2$ | 0.08 | Ni | 3.2 |
| $P_2O_5$ | <0.01 | Rb | 1.5 |
| MnO | 0.01 | Pb | 2.1 |
| $Cr_2O_3$ | <0.001 | Sr | 9.4 |
| LOI | 0.5 | U | 0.1 |
| Total C | 0.02 | V | <5 |
| Total S | 0.02 | Zn | 4 |
| **Sum** | **99.95** | Zr | 203.8 |

| CUMULATIVE MILEAGE KM (MILES) | KM (MILES) FROM LAST POINT | ROUTE DESCRIPTION |
|---|---|---|
| | | RESET ODOMETER |
| 0.0 (0.0) | | Leave (**STOP 7**) by merging onto Queensway and drive west. |
| 2.0 (1.2) | 2.0 (1.2) | Exit Queensway at Palladium Drive (Exit 142). Keep in the left lane to turn left to pass over the highway. |
| 2.9 (1.8) | 0.9 (0.6) | Move right to enter the cloverleaf entrance to return eastward on Hwy 417. |
| 8.5 (5.3) | 5.6 (3.5) | Exit at Eagleson Road, turning right to drive south. |
| 10.4 (6.4) | 1.9 (1.2) | Cross Robertson-Hazeldean Road. Keep left after this intersection, to allow a left turn, at the blue $OP_5$ sign less than 200 m beyond, into the Old Quarry Trail parking lot. |
| ON | FOOT | From the southeast corner of this lot, follow the crushed-stone footpath southeast for 200 m. Just beneath the power line, walk 10 m to the right through the grass to a flat outcrop with two vertical joint faces that intersect at right angles. **STOP 8.** |
| END OF TRIP | RETURN DIRECTIONS | Retrace your entry into the parking lot and head north on Eagleson Road. Enter the Queensway and head east. Exit at the exit for Hwy. 416 and drive south towards the Prescott-Ogdensburg Bridge and Potsdam. |

## STOP 8. NEPEAN FORMATION (CAMBRO-ORDOVICIAN), OLD QUARRY TRAIL

N45°12.103' W075°52.482'

This siliciclastic outcrop is correlative with the outcrop at STOP 7. Convolute folds in a 1 m-thick unit below a thin unit of foundered 'half-moons and bananas' formed by disruption of an early-cemented layer of stromatolites above still-unconsolidated sand. Overpressure by interstitial water due to closer packing of well-rounded framework grains, aided by an almost complete lack of matrix, resulted in the creation of convolute folds (note lack of deformation in the underlying quartz arenite beds, and progressive attenuation in the upper limbs of antiforms in the metre-thick unit showing convolute lamination ). Side views show several foundered 'half-moon' stromatolites within the synformal cores (Figure 12). The three-dimensional morphology of the apparent 'folds' is envisioned as linked bowls (somewhat like half an egg carton, with the egg-pocket openings facing concave-up). Subparallel alignment of the foundered and rotated stromatolites, as seen on the upper surface, suggests possible slope control, with probable condensation of the discrete stromatolite 'clasts' due to downslope sliding. Areas in the Nepean/Potsdam succession elsewhere showing evidence of synsedimentary brecciation (e.g. Selleck, 1978), suggesting that such areas warrant re-examination for evidence of early cementation of beachrock-like carapaces developed over unconsolidated sand layers due to biofilm mediation -- an association likely to rupture easily during seismic disturbances.

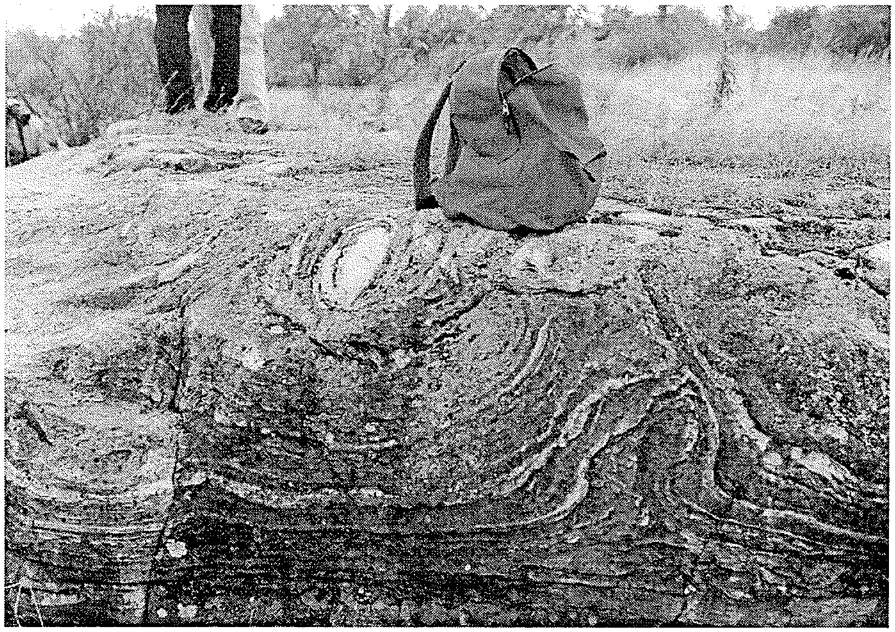

Figure 12. Convoluted layer in Nepean Sandstone at STOP 8. Note the banana-shaped clast next to the backpack and broad synformal warps between a tight antiform.

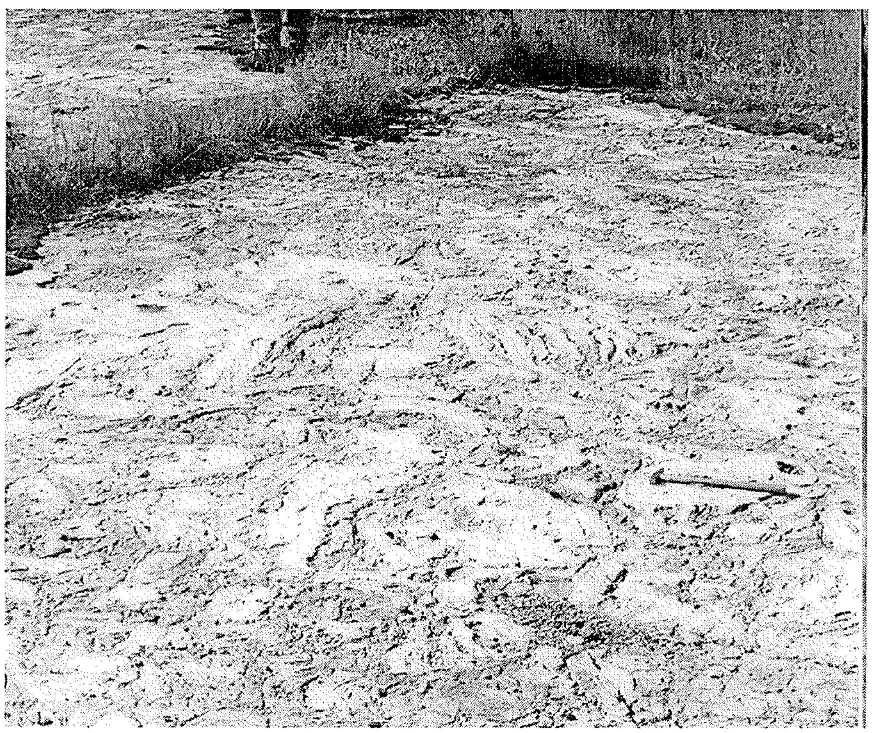

Figure 13. Plane view of Nepean Sandstone outcrop at STOP 8. Note the elongate cross-sectional shapes formed by foundering of domal structures.

## REFERENCES CITED


Anderson, K., 2004, Facies description and cementation history of the Cambro-Ordovician Nepean Formation. B.Sc. Thesis, Integrated Sciences, Carleton University, Ottawa.

Anderson, K., Dobie, N., J. A. Donaldson, and W. Arnott, R. W. C., 2004, Complex cementation history of a laterally extensive section within the Cambro-Ordovician Nepean Formation, Ottawa, Ontario. Geological Association of Canada, Annual Meeting, 2004, Program with Abstracts, 29.

Brand, U., and Rust, B. R., 1977, The age and upper boundary of the Nepean Formation in its type section near Ottawa, Ontario. Canadian Journal of Earth Sciences, v. 14, p. 2002-2006.

De Boer, P. L., 1981, Mechanical effects of micro-organisms on intertidal bedform migration. Sedimentology, v. 28, p. 129-132.

Dobie, Natalie, 2004, Depositional interpretation and sequence stratigraphic framework of the Nepean Formation, Kanata, Ontario. B.Sc. thesis, University of Ottawa.

Donaldson, J. A., 1967, Precambrian vermiform structures: a new interpretation. Canadian Journal of Earth Sciences, v. 4, p. 1273-1276.

Donaldson, J. A., Munro, I., and Hilowle, M. A., 2002, Biofilm structures, trace fossils and stromatolites in Early Paleozoic quartz arenites and carbonates of the Ottawa region, Ontario. Twelfth Canadian Paleontology Conference (CPC-2002), Program and Abstracts, 12.

Donaldson, J. A., Hilowle, M. A., and Arnott, R. W. C., 2000, Biofilm-mediated structures in quartz arenites of the Cambro-Ordovician Nepean Formation. GeoCanada 2000 - The Millenium Geoscience Summit, Conference CD-ROM, Abst. 868.

Donaldson, J. A., and Hilowle, M. A., 2002, Organic mats, evaporite pseudomorphs and soft-sediment deformation in quartz arenites of the Cambro-Ordovician Nepean Formation. GAC/MAC Program with Abstracts, 27.

Erickson, J. M. 1993, A preliminary evaluation of dubiofossils from the Potsdam Sandstone. New York State Geological Association, Field Trip Guide Book, 65th Meeting, St. Lawrence, Trip A-3, 121-130.

Garrett, P. 1970, Phanerozoic stromatolites: noncompetitive ecologic restriction by grazing and burrowing animals. Science, v. 169, p. 171-173.

Gerdes, G., Noffke, N., Klenke, Th. & Krumbein, W. E., 2000, Microbial signatures in peritidal sediments a catalogue. Sedimentology, v. 47,p. 279-308.

Greggs, R. G., and Bond, I. J., 1972, A principal reference section proposed for the Nepean Formation of probable Tremadocian age near Ottawa, Ontario. Canadian Journal of Earth Sciences, v. 9, p. 933-941.

Hagadorn, J. W., and Bottjer, D. J., 2002, Restriction of a Late Neoproterozoic biotope: suspect microbial structures and trace fossils at the Vendian-Cambrian transition. Palaios, v. 17, p. 73-85.

Noffke, N., 2000, Extensive microbial mats and their influences on the erosional and depositional dynamics of a siliciclastic cold water environment (Lower Arenigian, Montagne Noire, France). Sedimentary Geology, v. 136, p. 207-215.

Noffke, N., Knoll, A. H. & Grotzinger, J. 2002, Sedimentary controls on the formation and preservation of microbial mats in siliciclastic deposits: a case study from the Upper Neoproterozoic Nama Group, Namibia. Palaios, v. 17, p. 1-12.

Selleck, B. W., 1978, Syndepositional brecciation in the Potsdam Sandstone of northern New York State. Journal of Sedimentary Petrology, v. 48, p. 1177-1184.

Selleck, B. W., 1984, Stratigraphy and sedimentology of the Theresa Formation (Cambro-Ordovician) in northeastern New York State. Northeastern Geology, v. 6, p. 118-129.

Schieber, J., 1999, Microbial mats in terriginous clastics: the challenge of identification in the rock record. Palios, v. 14, p. 3-12.

Williams, D. A., 1991, Paleozoic geology of the Ottawa-St. Lawrence Lowland, southern Ontario. Ontario Geological Survey, Open File Report 5770.

Williams, D. A., Telford, P. G., McCracken, A. D., and Brunton, F. R., 1992, Cambiran-Ordovician geology of the Ottawa Region: Canadian Paleontology Conference Field Trip Guidebook No.2, Geological Association of Canada - Paleontology Division, 51 p.

Wilson, A. E., 1946, Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec. Geological Survey of Canada, Memoir 241, 66p.

Wilson, A. E., 1956, A Guide to the geology of the Ottawa District. The Canadian Field-Naturalist, 70, No. 1, pp. 1-68.