GEOTOUR
OF
FRONTENAC
ARCH BIOSPHERE RESERVE

Sunday
October 5, 2008

Canada

LEEDS COUNTY STEWARDSHIP COUNCIL

GRENVILLE LAND STEWARDSHIP COUNCIL

Frontenac Arch
BIOSPHERE RESERVE
Building Sustainable Communities

GEOLOGICAL NOTES
PREPARED BY
ALLAN DONALDSON
&
CHRIS FINDLAY,
FRIENDS OF CANADIAN GEOHERITAGE

DEPARTURE: 9:00 AM
CONCLUSION: 5:00 PM

FIELD TRIP LOGISTICS
ARRANGED BY
JACK HENRY, STEWARDSHIP COORDINATOR
GRENVILLE LAND STEWARDSHIP COUNCIL

On behalf of the Grenville Land Stewardship Council, the Leeds County Stewardship Council, the Frontenac Arch Biosphere and Parks Canada, we would like to acknowledge Al Donaldson, Chris Findlay, and Elaine Beggs for the endless hours that they have contributed to this tour guide. This guide illustrates the important geological history of the Frontenac Arch Biosphere and will continue to be an excellent resource of the area for years to come.

Box Lunch & Refreshments Included

Transport:

Coach – Howard Bus Services
(56-seater with amenities)

Tour Bus will be available for boarding
at 8:45 am in the "Food Basics" Supermarket parking lot
on Jefferson Drive, Brockville
Park all vehicles in the NE corner of the supermarket parking lot
(between Tim Horton's & Food Basics)

INDEX

Official 1000 Islands Authentic Map

Drive - From Hwy 401, take Exit 696 north on Stewart Blvd. Turn left at the intersection Jefferson Drive, and left again into the parking lot with the green entrance sign.

A BRIEF GEOLOGICAL HISTORY OF THE FRONTENAC ARCH REGION

The geological story of the Frontenac Arch region began more than one billion years ago along the southeastern margin of an ancient continent called *Laurentia,* which then lay near the equator. This land mass would eventually become the core of the North American continent. Between about 1.3 billion years and 1 billion years ago, a second large continental mass moved northwesterly against Laurentia, like a giant vice to crush its southern margins. As a result of the collision, the ancient Precambrian rocks (1.8 to 2.5 billion years old) that formed the southern part of Laurentia were shoved down beneath the crust, deformed by heat and pressure, and then thrust up to form the northeasterly-trending *Laurentian Mountain Belt.* The roots of this former mountain belt, known geologically as the *Grenville Province*, now extend from the coast of Labrador, across Quebec, Ontario and northern New York and then disappear beneath younger rocks of central U.S.A. The *Frontenac Arch* is a northwest-trending relic of this belt that connects Grenville rocks of the Algonquin Highlands in Ontario with similar rocks of the Adirondack Highlands in New York State (Figure 1).

A long period of erosion reduced the rugged mountain topography of the Laurentian Mountain Belt to a relatively uniform Precambrian plain with maximum relief generally less than 100 metres. Beginning about 540 million years ago, the Cambrian and Ordovician sedimentary rocks (sandstone, limestone, dolostone and minor shale) that form the cover over the Precambrian rocks came into existence through the lithification of fragmental and chemical sediments deposited in shallow seas that flooded the region. Whether these rocks originally covered the Arch itself and were later stripped away by erosion and ice or whether the Arch was a positive feature at that time (i.e. stood above water level) and did not receive sediments is an open question, although the evidence seems to favour the latter. At any rate, the older Grenville rocks (granite, granite gneiss, schist, quartzite, marble) were relatively resistant to erosion and commonly form prominent knolls where the original cover of younger sediments was either stripped away or never deposited. The present-day St. Lawrence River, flowing over the Precambrian basement (modified locally by the scouring and polishing of glacial ice), has given rise to the topography of the Thousand Islands.

About 20,000 years ago, much of eastern Canada and northeast U.S.A. was covered by the great *Laurentide Ice Sheet*. The eastern part of this ice sheet, known as the *Labrador lobe*, flowed southerly from its center in Ungava. In the Frontenac Arch region, ice moved southwesterly, roughly parallel to the geological “grain” of the Grenville rocks. Between about 17,000 and 14,000 years BP (before present) the ice began to melt back to the north. By about 12,500 years BP, a large glacial lake called *Lake Iroquois*, the forerunner of the present-day smaller *Lake Ontario,* had formed to the west of the Arch. A few hundred years later, the ice had melted back sufficiently to allow seawater of the *Champlain Sea* to flood most of the area of the present Gulf of St. Lawrence, the St. Lawrence and lower Ottawa river valleys and Lake Champlain.

During this time, marine clays and silts of the Champlain Sea were deposited on top of earlier glacial sediments. As the sea retreated, these deposits (glacial sediments and marine clays) were reworked by wave action in shallow waters, resulting in a complex mixture of deposits whose ancestry is locally problematic. By about 9,000 years BP the Champlain Sea had disappeared, and by about 6,000 years BP, the present Great Lakes and Ottawa and St. Lawrence River drainage patterns had been established.

GEOLOGICAL OVERVIEW OF THE GEOTOUR

This trip has been designed to provide an overview of geodiversity within the Frontenac Arch Biosphere Reserve and to demonstrate earth-science principles to those with little or no previous geological training. The varied landscapes within this region are dictated by the three basic components of the underlying geology noted above (Geological History). Formed during parts of three Eras (late Precambrian, early Paleozoic and late Cenozoic), the oldest is the Frontenac Arch, an extension of the Canadian Shield that extends southward to link with the Adirondacks of New York State (Figure 1). Rocks within the Arch comprise metamorphic and intrusive igneous rocks of the Precambrian *Grenville Series,* more than one billion years old. The second component includes all of the overlying unmetamorphosed and predominantly flat-lying sedimentary rocks (sandstone, shale, limestone and dolostone beds) that range in age from 400 to 500 million years. These were deposited during Cambrian and Ordovician time (the two lowermost Periods of the Paleozoic Era). The third component includes the unconsolidated cover deposits lying on the Precambrian and Paleozoic bedrock. Glacial till, an unsorted mix of particles ranging from clay to giant boulders, was deposited during Wisconsinan advance of a continental blanket of ice up to 3 km thick during the Pleistocene Ice Age (late Cenozoic).

Although some Wisconsinan glacial deposits in eastern Ontario, the latest of four major episodes of Pleistocene glaciation, are no more than 17,000 years old, the oldest advance, as recorded in several places elsewhere in North America, began almost 2 million years ago. During the melting of the last ice sheet, vast volumes of sand and gravel were deposited as outwash in front of the retreating ice. Melt-back of the ice also allowed the Atlantic Ocean to invade low areas, creating the Champlain Sea within which thick accumulations of clay, silt and sand were deposited 13,000 to 9,000 years ago.

We will visit nine areas that collectively illustrate the major geological components of the region (Figure 2): metamorphosed Grenville rocks of the Precambrian Shield; unmetamorphosed quartz sandstones at the base of the overlying Paleozoic strata; and unconsolidated Late Cenozoic deposits of Pleistocene glacial till, sand and gravel that intermittently blanket the older consolidated rocks. At each stop we will discuss the rock types present, stressing significant geological features (especially contact relationships between different rock types) that serve to reveal the geological history.

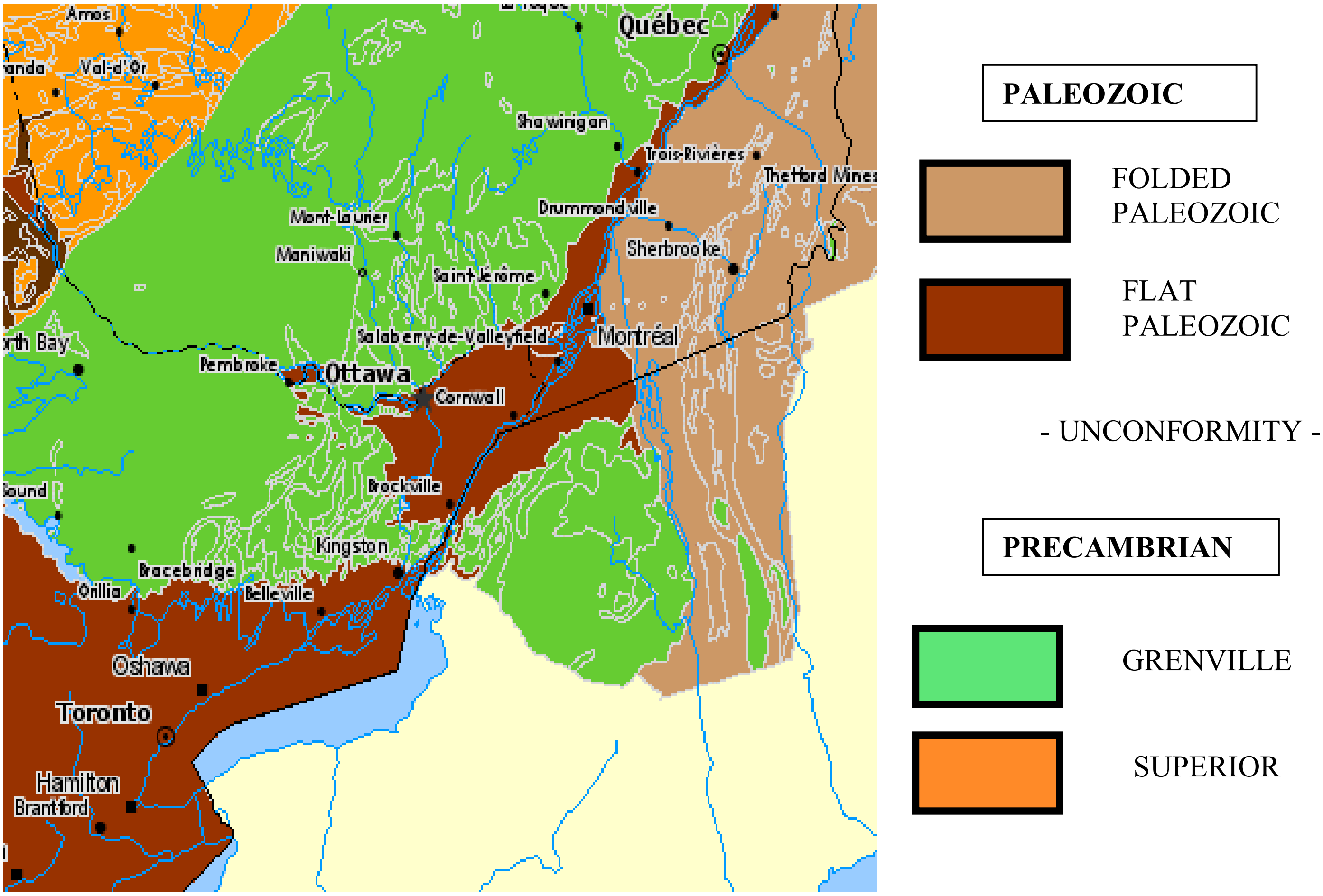
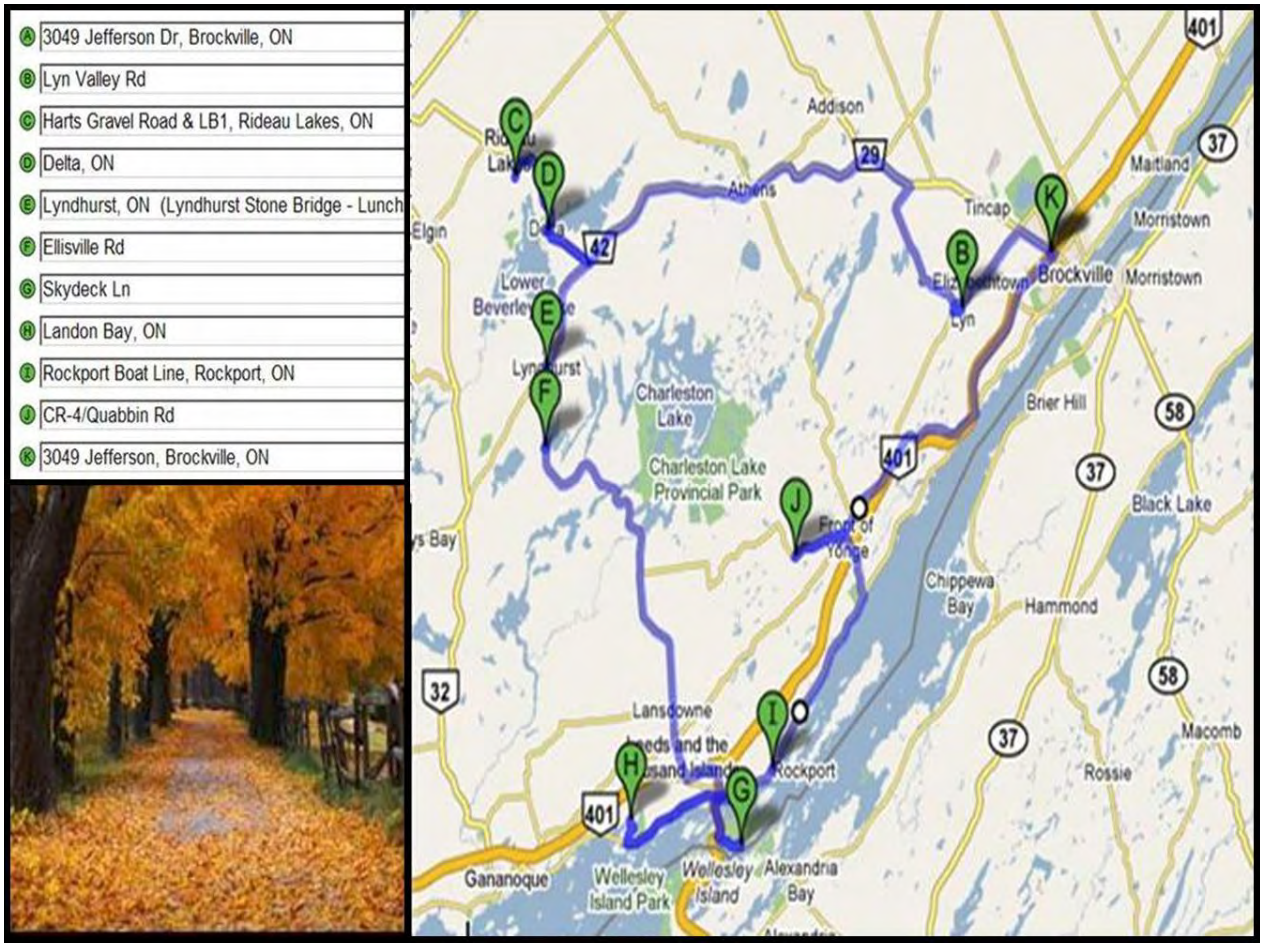


Fig. 1 Simplified regional geological map of Frontenac Arch. Adapted from Atlas of Canada (http://atlas.nrcan.gc.ca)



Ⓐ 3049 Jefferson Dr, Brockville, ON
Ⓑ Lyn Valley Rd
Ⓒ Harts Gravel Road & LB1, Rideau Lakes, ON
Ⓓ Delta, ON
Ⓔ Lyndhurst, ON (Lyndhurst Stone Bridge - Lunch
Ⓕ Ellisville Rd
Ⓖ Skydeck Ln
Ⓗ Landon Bay, ON
Ⓘ Rockport Boat Line, Rockport, ON
Ⓙ CR-4/Quabbin Rd
Ⓚ 3049 Jefferson, Brockville, ON

Fig. 2 Route map for Grenville-Leeds Geotour, Sunday, October 5, 2008.
"Note that the alphabetically labelled Stops B to J correspond in ascending sequence to Stops 1 to 9 in the text; K marks both start and final stop for the excursion."

GEOLOGICAL COLUMN		
ERA		**TIME BP**
CENOZOIC		
	--------	65 MY
MESOZOIC		
	--------	225 MY
PALEOZOIC		
	--------	540 MY
PRECAMBRIAN		

Table 1 - Subdivisions of geological time. No rocks of Mesozoic age are preserved in the Frontenac Biosphere Preserve. Although the Precambrian rocks in this region, which belong to the Grenville Structural Province, are more than 1 billion years old, they are but one-quarter the age of the oldest rocks in the world (Acasta Gneiss, Northwest Territories). Only the two lowermost time units of the six in the Paleozoic are represented (Cambrian and Ordovician), and only the uppermost time unit of the Cenozoic (Quaternary, which comprises Pleistocene glacial deposits and overlying present-day Holocene deposits).

CONCEPTS AND TERMS RELEVANT TO THIS EXCURSION

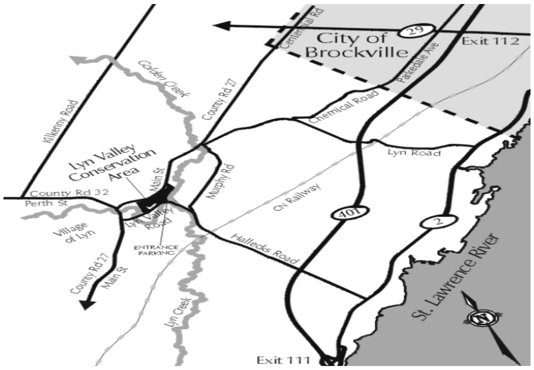
- Geological time scale
- Actualism, Steno’s principles
- Age relationships, truncations
- Unconformity
- Crystalline texture of igneous and metamorphic rocks; clastic texture of sedimentary rocks
- Minerals: feldspar, quartz, mica, amphibole, pyroxene, calcite, dolomite, sulphides, iron oxides
- Structure, joint, fault, fold, fold axis, anticline, syncline
- Foliation, lineation, gneissosity, schistosity, cleavage
- Gneiss, schist, amhibolite, marble, basalt, diorite
- Intrusions: pluton, dyke, vein, pegmatite, aplite, xenolith
- Alteration, reaction rims
- Mechanical weathering, chemical weathering, regolith, paleosol
- Clastic and chemical sediments
- Block, boulder, cobble, pebble, sand, silt, clay
- Roundness, sphericity
- Primary structures, secondary structures
- Strata, stratigraphy, depositional environment
- Lithification, cement, matrix
- Bedding, lamination, crossbedding, angle of repose
- Ripple mark (symmetric, asymmetric), interference ripple mark, stylolite
- Fossil, trace fossil, biogenic structure, biofilm, stromatolite
- Continental glaciation, deglaciation
- Glacial striae, chatter marks, hydraulic scouring, glacial erratic
- Glacial till, outwash, roche moutonee

Drive - West on Jefferson; turn right on Kent Blvd, left on Parkedale, for 3.5 km to junction with Lyn Rd. Right on Lyn Rd. to Junction with County Rd. 27; left on 27 to Lyn Village. In village, turn left on Lyn Valley Conservation Area Rd.

GEOTOUR ITINERARY

STOP 1 - Lyn Valley Conservation Park, Lyn (Km 0)

Vertical cliff of Potsdam sandstone with pebble interbeds (clasts are all quartz sandstone). The stratification (bedding) in the sandstone is nearly horizontal, indicating that the region has not been subjected to folding since the original beds of sand and gravel were deposited more than 500 million years ago. Ripple marks, low-angle crossbedding and gravel interbeds indicate deposition in water rather than by wind (Large-scale steeply inclined crossbedding elsewhere in outcrops of pebble-free Potsdam sandstone reflect transport by wind and deposition in terrestrial dunes). Trace fossils plus a wide range of directions of crossbed inclination indicate a shallow-water marine environment; curled biofilm structures plus desiccation cracks reflect occasional subaerial exposure. Some distinctive biofilm structures are apparent (Figure 3), and surface patches of gravel and sand cemented to the outcrop surface, marking paces where crossbedded Pleistocene outwash was once in contact with this Paleozoic cliff, reflect the rapid rate at which unconsolidated deposits can be transformed to rock.



At the entrance to the park, small outcrops of Grenville gneiss represent the Precambrian “basement”, more than 1 billion years old, upon which were deposited the quartz sands and quartzite-pebble gravels that subsequently lithified to form the now solid Potsdam strata. Whereas well-rounded sand grains can readily be seen in the unmetamorphosed Potsdam beds, mineral grains in all Grenville rocks display an interlocking texture indicative of recrystallization due to high temperature and pressure as a result of deep burial (10 to 20 km). The close spaced lines in this rock represent parallel planes of mineral alignment (foliation) that here are oriented almost vertically. It is because of this metamorphic layering that this rock is classified as “gneiss”. Crosscutting dykes of granite pegmatite lack foliation, so must have been injected after the deformation that created the foliation.

Examine the variety of boulders along the front of the park. These were extracted from local outwash deposits, so provide a fine array of samples derived by glacial erosion of bedrock to the north: mainly Precambrian rocks from the Canadian Shield. The interlocking textures characteristic of both igneous and metamorphic rocks is well shown by boulders containing pegmatite dykes, which in turn exemplify crosscutting relationships that allow the recognition of successive events, as do inclusions and offsets along faults. The difference between igneous and metamorphic rocks also can be demonstrated here: foliation (layering in metamorphic rocks) can be understood by examining boulders of gneiss in comparison to boulders of massive (unlayered) igneous rocks. Finally the difference between joints (fractures with no offset) and faults (fractures along which offset has occurred) can be observed in some three dimensions.

Although the contact is not exposed here, we can infer that the small Grenville outcrops represent the older Precambrian “basement” upon which the Potsdam sand and gravel beds were deposited. As opposed to the lines that represent the three-dimensional foliation, faint parallel lines on the surface of the outcrop are glacial striae, scratches caused by movement of the continental ice sheet over the region during the Pleistocene Ice Age (the last few million years of Earth history). The pattern of continental ice movement has been reconstructed by measuring the orientation of such striae during systematic mapping across all of Canada.

Fig. 3 Horizontally bedded quartz sandstone in the lower part of the Potsdam Group, exposed in a cliff north of the entrance gate to the Lyn Conservation Area. Note the prominent wavy biofilm structures above and below the toonie. These distinctive roll-up structures record the curling of sheets of sand grains bound by tenacious films of cyanobacteria in response to desiccation. Although the sands were deposited in water, the presence of such structures indicates intermittent episodes of subaerial exposure. Elsewhere in eastern Ontario and in northern New York State, similar organic mats have trapped quartz sand to form distinctive domal stromatolites.

Drive - From Conservation Area to Lyn Village. Right through Village to County Rd 46. Follow Hwy. 46 to Hwy. 29. Left on 29 to Forthton (9.9 km), and then Hwy. 42 through Athens and Delta. Just before reaching Philipsville, turn left on Harts Gravel Rd, Rideau Lakes.

STOP 2 – Harts Gravel Rd., Rideau Lakes (Km 37.2)

Another vertical cliff of Potsdam sandstone. The lowermost beds contain ripple marks, crossbedding and abundant trace fossils. Glacial outwash of unconsolidated sand, gravel and cobbles shows excellent crossbedding, some of very large scale. As was seen at the previous stop, patches of this post-glacial detritus adheres to the vertical face of the Potsdam outcrop (Figure 4), reflecting incipient cementation since this outwash was deposited less than 8000 years ago. Most of these unconsolidated deposits were extracted from here for road building, but the cemented patches have persisted, in spite of rain and spring runoff.

Fig. 4 Patches of poorly cemented glacial outwash gravel plastered on a vertical cliff exposure of Potsdam sandstone with thin shaly interbeds. The white sandstone beds contain trace fossils identical to those to be seen in building stone at the next stop. Note large-scale crossbedding in the outwash gravel, indicating strong currents during deposition of the gravels. The leftward inclination of these crossbeds indicates the direction of water flow.

Drive - South on Hwy. 42 to Delta to the Heritage Mill.

STOP 3 - Heritage Mill, Delta (Km 41.1)

The walls of this historic mill display the best array of Potsdam trace fossils available anywhere. They have been accentuated by weathering of iron-oxide minerals to rusty coloured iron hydroxides that clearly outline the living chambers of worm-like creatures. These are not true fossils, but the tubular paths of the organisms are clearly preserved – hence the acceptance of these structures as trace fossils. The generic names *Skolithus* and *Diplocraterion* are assigned to these distinctive verical tubes and U-shaped burrows, respectively (Figure 5). Note that many of the blocks are upside down with respect to original orientation when these structures were created by living critters in sandy beach environments half a billion years ago. Did the stonemasons place these blocks randomly, or did they purposefully create an exercise in observation for future geotourists?

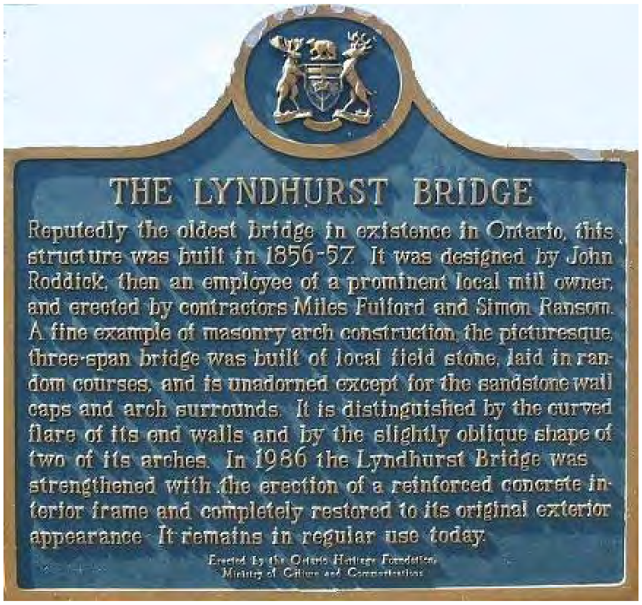
Fig. 5 Typical building stone in walls of the Old Stone Mill at Delta, built in 1810. This block, like most others in the outer walls of the mill, displays two varieties of distinctive trace fossils. Colour contrasts outline abundant vertical tubular burrows of *Skolithus* and several U-shaped burrows of *Diplocraterion*.

Drive - Continue South on Hwy. 42 to Lyndhurst Rd. (Hwy. 33) (Km 49). Right on Lyndhurst Rd to Lyndhurst Village and Heritage Bridge.

STOP 4 - Park below Lyndhurst Bridge, Lyndhurst (Lunch) (Km 55.4)

Built in 1856-57 (Figure 6), this triple-arch stone structure is the oldest bridge in Ontario. The stonework consists of Potsdam sandstone showing a variety of primary structures, plus a few blocks and split cobblestones of granite and massive mafic rocks. Where lime has leached out of the mortar, crenulate surface coatings of calcium carbonate simulate deposits formed in a similar fashion on the walls of caves by the precipitation of lime dissolved by groundwater percolating through limestone.

Fig. 6 Lyndhurst Bridge, built in 1856-57. The stone is mainly Potsdam sandstone, but some fieldstone boulders and cobbles of granite, gneiss and gabbro have been incorporated.



THE LYNDHURST BRIDGE

Reputedly the oldest bridge in existence in Ontario, this structure was built in 1856-57. It was designed by John Roddick, then an employee of a prominent local mill owner, and erected by contractors Miles Fulford and Simon Ransom. A fine example of masonry arch construction, the picturesque, three-span bridge was built of local field stone, laid in random courses, and is unadorned except for the sandstone wall caps and arch surrounds. It is distinguished by the curved flare of its end walls and by the slightly oblique shape of two of its arches. In 1986 the Lyndhurst Bridge was strengthened with the erection of a reinforced concrete interior frame and completely restored to its original exterior appearance. It remains in regular use today.

Erected by the Ontario Heritage Foundation,
Ministry of Culture and Communications

Drive – West on Hwy. 33 to Junction with County Rd. 3. Drive South on Hwy. 3 for about 7.5 km, watch for green sign on right "Ellisville Rd"; pull into Ellisville Rd to unload. WARNING – HEAVY TRAFFIC, PARTICIPANTS SHOULD EXERCISE CAUTION AT THIS STOP. PLEASE STAY ON THE SHOULDER OF THE WEST SIDE OF HWY. 33).

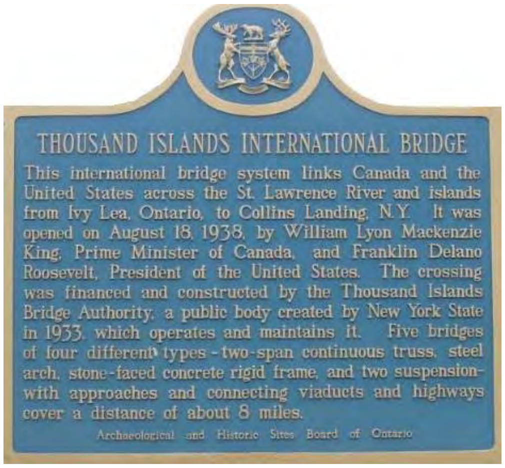
STOP 5 – Ellisville Rd, Leeds & 1000 Islands (Km 67.2)

((WARNING - EXERCISE CAUTION AT THIS STOP. PLEASE STAY ON WEST SIDE OF ROAD))

This road-cut outcrop is a good example of Precambrian Grenville crystalline limestone (marble). It shows Internal features such as layering, Inclusions, lineation, folding and plastic deformation (Figure 7). It is one of the most common rock types In the Grenville series in this area, but because of its relatively soft and crumbly nature, it erodes more easily than the harder quartzite and gneiss with which it is interlayered, and therefore tends to occur in valleys and low-lying areas.

Fig. 7 Highway rock-cut showing granularity and intricate folding typical of typical Grenville gneiss. During metamorphism at a depth of more than 10 km, the rock behaved plastically, resulting in folding, contortion and truncation of bedding in the original limestone, and enlargement in the solid state of the original grains of the mineral calcite, the essential mineral in limestone. The field of view is 1m wide.

Drive - Continue South on County Rd. 3 through Lansdowne to Thousand Islands Parkway (The Biosphere Reserve Office is at this intersection). Left on Parkway, and then only a few hundred metres beyond this turn, bear left to take the Thousand Islands Bridge exit (Route 137 South to Interstate 81). Go through the tollgate and across the first bridge section to Hill Island. Continue to Skydeck Drive (left exit). Follow this road which becomes a winding to gravel road. Drive past Black Rat Snake Rd. and stop at the gate to gravel pit (National Park sign). Follow path a few hundred metres into the pit.



THOUSAND ISLANDS INTERNATIONAL BRIDGE

This international bridge system links Canada and the United States across the St. Lawrence River and islands from Ivy Lea, Ontario, to Collins Landing, N.Y. It was opened on August 18, 1938, by William Lyon Mackenzie King, Prime Minister of Canada, and Franklin Delano Roosevelt, President of the United States. The crossing was financed and constructed by the Thousand Islands Bridge Authority, a public body created by New York State in 1933, which operates and maintains it. Five bridges of four different types - two-span continuous truss, steel arch, stone-faced concrete rigid frame, and two suspension - with approaches and connecting viaducts and highways cover a distance of about 8 miles.

Archaeological and Historic Sites Board of Ontario

STOP 6 - Hill Island National Park (Km 103.5)

Glacial outwash at south end of an esker complex. Well-washed sand and cobbly gravel deposited during deglaciation (from 12000 to 8000 years ago). Several distinct terraces mark working levels created during excavation, but some appear to be natural, reflecting prolonged pauses in lowering of the water level (Figure 8). Outcrops of foliated Grenville gneiss, locally brecciated, have been crosscut by both pegmatite dykes and quartz veins. Note the glacial striae on some glacially polished outcrops.

Fig. 8 Sand and gravel pit on Hill Island. This large abandoned enterprise was the source of aggregate and fill during construction of the Parkway and St. Lawrence Seaway. Parts of this esker-delta complex are boulder-rich, whereas other parts consist of well-sorted sand and gravel. The clasts provide a good representation of rocks that compose the Grenville Province, plus a less prominent sampling of Paleozoic strata. Note the several levels of benches, most of which were created during extraction of sand and gravel.

Drive - Return North over bridge through tollgate. Take third exit to right - "1000 Islands Parkway West - Ivy Lea". On Parkway continue west about 7.5 km to Landon Bay Campground and Recreational Centre (North side of Parkway).

STOP 7 – Landon Bay (Km 114.7)

Take Lookout path at back of campgrounds to the crest of an outcrop of granite that overlooks Landon Bay and the St Lawrence River. The granite, intruded by a large quartz vein, and containing similar-appearing patches of quartzite, has been glacially abraded to form a roche moutonee (a rock landform that is gently curved and streamlined at the up-ice end, and angular at the down-ice end where blocks have been plucked away along joints). Its surface has been polished and striated as well as scoured and grooved by boulders frozen into the base of the continental ice sheet (this produced the linear grooves). It also has been sculpted by the hydraulic action of meltwater charged with sand; this produced the large sinuous grooves (Figure 9) and undercut channels guided by fractures. Chattermarks (distinctive nested sets of curved fractures) confirm the direction of ice advance.

Fig. 9 Hydraulic scouring and prominent joints on top of granite hill at end of Lookout path, Landon Bay. Note sinuous, bifurcated hydraulic scours.

Drive - Return East on the Thousand Islands Parkway, continuing past the Thousand Islands Bridge to Rockport. Pull into the Rockport Boat Line parking lot and park in the designated area. Walk east about 400 metres along the paved residential road to an outcrop on the north side, opposite the Howard Marine sign.

STOP 8 – Rockport Boat Line, Rockport (Km 128.8)

This outcrop displays lit-par-lit layers of pink to white granite pegmatite and aplite that were injected, in the fluid state, parallel to the foliation of fine-grained gray to black gneiss and schist. Similar magmatic fluids were injected along crosscutting fractures during several episodes that can be put in sequence by observing crosscutting relationships. The metamorphic foliation of the host rock for these intrusions may have developed along the bedding of an original clay-rich sedimentary rock, such as mudstone or siltstone. Although foliation is typically vertical or dips steeply in most exposures or Grenville metamorphic rocks, it here is almost horizontal, perhaps due to location along the hinge of a fold, or to low-angle thrust faulting. The pinch-and-swell nature of some lit-par-lit injections indicates lateral extension during a process termed “boudinage” (Figure 10). Note also the prominent hydraulic scouring similar to Stop 7 that forms benches along the outcrop.

Fig. 10 Grenville gneiss intruded by a pegmatite dyke that is semi-conformable to the near-horizontal foliation. An underlying parallel injection of pegmatite has been subjected to extension after injection, resulting in the creation of distinct boudinage. Note and hydraulic scouring and polishing. View looking southwest over St. Lawrence River.

Drive - Return to Parkway via lower Rockport Village Road. Right on Parkway and continue East about 10 km to Mallorytown Landing (St Lawrence Islands National Park HQ) and Junction with County Rd. 5. North on 5 to Village of Mallorytown and Junction with Hwy 2. Turn left at Junction, follow Hwy. 2 west about 1 km. Turn right at Quabbin Rd. (County Rd 4). Follow Quabbin Rd. through village and across railway tracks. Continue West about 4 km to where road climbs through a road cut just past Quabbin Hill Rd turnoff to the South.

STOP 9 - Quabbin Hill (Km 145.8)

The rock cut on the north side of the road on Quabbin Hill exposes the unconformity between Potsdam sandstone and underlying Grenville basement rock. The latter displays excellent spheroidal weathering of the basement (Figure 11), which here is a massive intrusive mafic rock. The Potsdam contains trace fossils perpendicular to bedding, just like those seen in our previous stops to view Potsdam sandstone, but the underside of one bed also displays a different variety of trace fossils: sinuous trails parallel to bedding (Figure 12). Of particular interest here are two independent indications of repeated subaerial exposure: bedding-parallel nodular zones within silty layers that probably represent tropical soil horizons, and desiccation patterns on several bedding surfaces. The unconformity surface marks a gap in the geological record of about half a billion years, either because the land was elevated so no rock record accumulated, or because erosion removed any strata that were deposited after Grenville rocks were formed, but before the start of Paleozoic sedimentation. Fortunately, such large gaps are filled by records in many other places around the world, allowing reconstruction of a nearly complete geological record extending back almost 4 billion years.

Fig. 11 Unconformity, north side of Quabbin Hill road cut. Note distinctive spheroidal weathering at top of the Precambrian Grenville-age basement, and basal Potsdam sandstone beds of the overlying Paleozoic succession. The surface of contact between these two units on the northeast side of the Frontenac Arch represents a gap in recorded geological history of half a billion years.

Fig. 12 Underside of a bed of Potsdam sandstone, south side of Quabbin Hill road cut, showing abundant sinuous trace fossils parallel to bedding.

Drive – Quabbin Rd South directly to 401, take Hwy 29 N Brockville, left at 2nd light onto Jefferson Drive to Food Basics Supermarket.

STOP 10 - RETURN TO BROCKVILLE BY 5:00 PM

ACKNOWLEDGEMENTS

We thank Jack Henry for making this trip possible, and for taking care of all of the logistics. Most of the itinerary was established on the basis of suggestions by Jack Henry and Cliff Rogers. Chris Bellemore provided additional advice and assistance for Stops 8 and 9. Skillfully working through several drafts, Elaine Beggs merged text and figures to produce this guidebook.

BIBLIOGRAPHY

The publications listed below provide a wide range of source material for those interested in expanding their knowledge about the geological underpinnings of not only the Frontenac Axis Biosphere Preserve, but of areas elsewhere in Canada and other countries. The book by Murray Gray is an excellent source of information about geodiversity–biodiversity interdependency; the books by Winchester, Bryson, and Fortey provide excellent non-technical insights into the wonders of geology, as well as some interesting historical observations about the progress of science.

- **Ambrose, J.W., 1964. Exhumed paleoplains of the Precambrian Shield of North America; Am. J. Sci., vol 262, pp. 817- 857.**

- **Bates, R. L. and J. A. Jackson, eds., 1984. Dictionary of Geological Terms, 3rd edition, Am. Geo. Institute, 571p.**

- **Bryson, Bill, 2004. A Short History of Nearly Everything. Random House Publishing, 687p.**

- **Davidson, A., 1998. An overview of Grenville Province geology, Canadian Shield; Chapter 3, in Geology of the Precambrian Superior and Grenville Provinces and Precambrian Fossils in North America, (co-ord.) S.B. Lucas and M.R. St-Onge; Geol. Surv. Can., Geology of Canada, no. 7, p. 205 - 270 (also Geol. Soc.Amer.,The Geology of North America, v. C-1).**

- **Donaldson, J. A., and Chiarenzelli, J.R., 2007. Disruption of mats by seismic events, In: J. Schrieber et al., Editors, Atlas of Microbial Mat Features Preserved within the Siliciclastic Record, Elsevier, Chapter 8b, pp. 245-247**

- **Douglas, R.J.W., 1970. (Sci. ed.) Geology and Economic Minerals of Canada: Geol. Surv. Can. Economic Geology Report No. 1, 838 p.**

- Easton, R.M., 1992. The Grenville Province and the Proterozoic History of Central and Southern Ontario; Chapter 19 of Geology of Ontario, edited by P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Scott; Ont.Geol. Surv. Special Volume 4, Part 2, pp 715 - 724.

- Eyles, Nick, 2002. Onario Rocks; Fitzhenry and Whiteside, 374p.

- Fortey, Richard, 2005: The Earth: An Intimate History; HarperCollins, 501p,

- Greggs, R.G. and Gorman, W.A. 1976 "Geology of the Thousand Islands"; Island Insights No. 2 Parks Canada, 53 p.

- Hunter & Associates. 1977. "A study of the Glacial Geomorphology and Sedimentology of the Hill Island Gravel Pit", for St Lawrence Islands National Park, Mallorytown Ont. Parks Canada File SLI 77/78-23.

- Johnson, M.D., Armstrong, D.K., Sanford, B.V., Telford, P.G. and M.A. Rutka., 1992. Paleozoic and Mesozoic Geology of Ontario; Chapter 20, pp. 907 -1008.

- Miall, Andrew, and Nick Eyles, 2007. Canada Rocks: The Geologic Journey; Fitzhenry and Whiteside, 512p.

- Owen, E.B., 1951. Pleistocene and Recent Deposits of the Cornwall - Cardinal Area, Stormont, Dundas and Grenville Counties, Ontario; Geol. Surv. Can. Paper 51-12, 24p.

- Prest, V.K., 1970. Quaternary Geology; Chapter XII in Geology and Economic Minerals of Canada; (Sci. ed.) R.J.W. Douglas; Geol. Surv. Can. Economic Geology Report No. 1, pp 675 - 764.

- Wilson, Alice E., 1964 (reprinted 1970). Geology of the Ottawa - St. Lawrence Lowland, Ontario and Quebec; Geol. Surv. Can., Memoir 241, 66 p.

- Winchester, Simon, 2001, The Map the Changed the World, Harper Collins

- Winchester, Simon, 2003, Krakatoa: The Day the World Exploded, August 27, 1883: Harper Collins, 416 p.

- Wynne-Edwards, H.R. 1967. Westport Map - Area, Ontario, With Special Emphasis on the Precambrian Rocks; Geol. Surv. Can. Memoir 346,142p.