ROADLOG AND STOP DESCRIPTIONS FOR NIAGARA COUNTY LOCATIONS

1 Road cut on Jackson St. below Somerset Railroad viaduct

2A Outwater Park (extra stop, not mentioned in guidebook)

2B Transit Rd., overview of Erie Canal locks from Route 78 bridge (extra stop)

3A Lockport Junction road cut (lower) optional

3B Lockport Junction road cut (upper) optional

4 Pekin Hill road cut (brief stop)

5 Niagara Escarpment and mouth of Niagara Gorge (*see also* Stop 0 in guidebook)

6 South Haul Road to Robert Moses Power Plant + Devil's Hole State Park

7 Robert Moses Power Plant access road and Forebay (stromatolites)

8 Whirlpool State Park

9 Niagara Falls from Goat Island

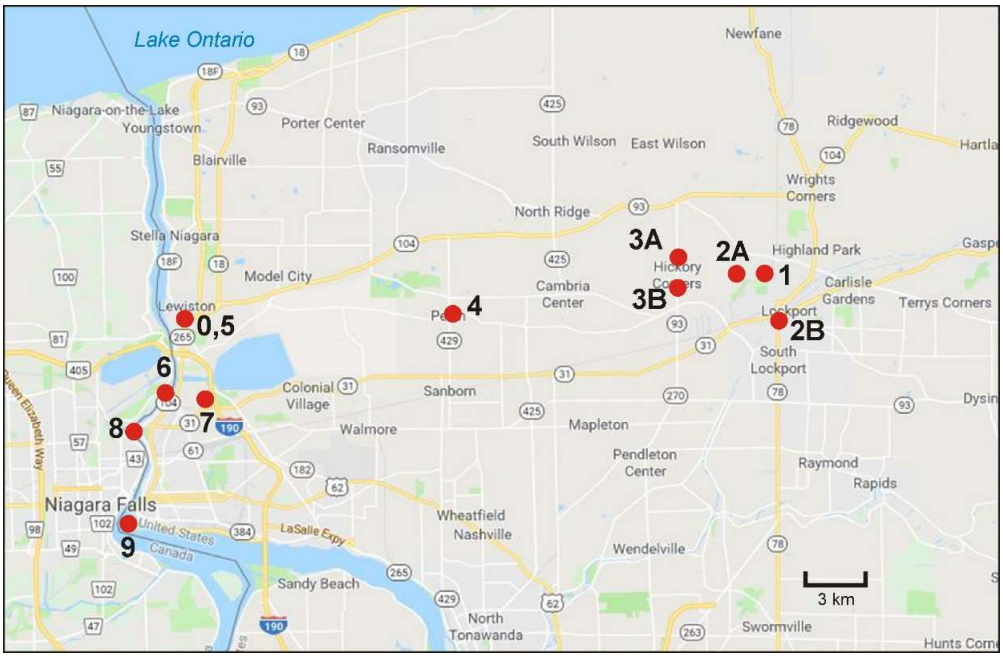

Figure 26. Stop and Optional Stop Locations

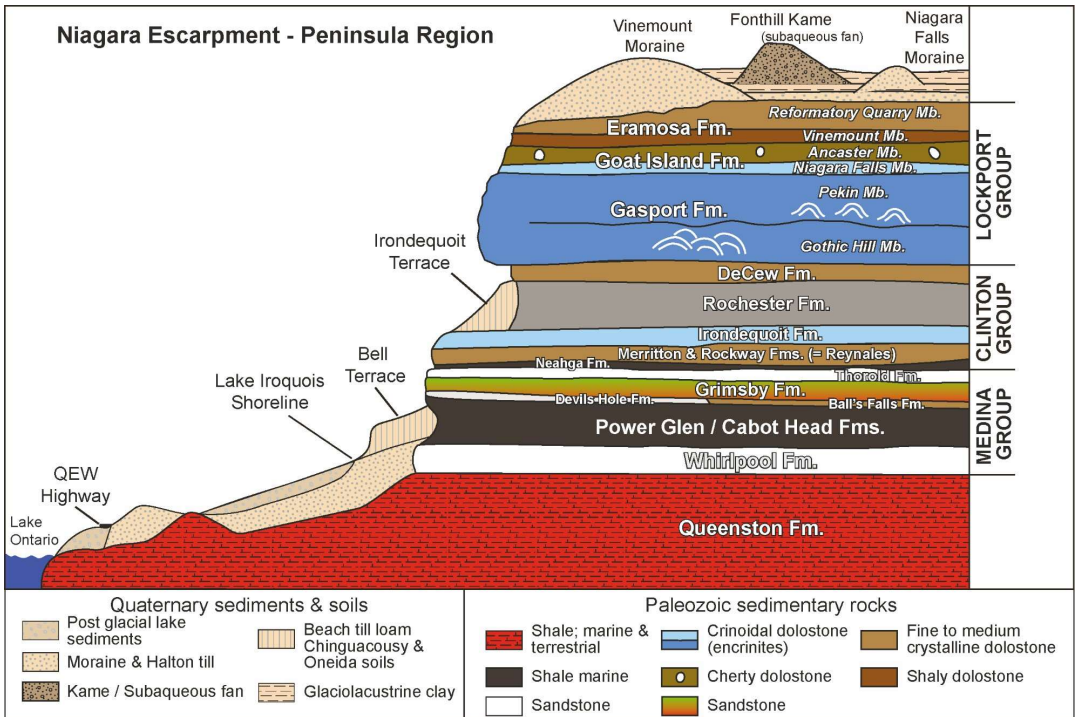

Figure 27. Paleozoic stratigraphy and simplified Quaternary geology of the Niagara Escarpment in southwestern Ontario, reflecting the region extending from Hamilton to Niagara Falls (Niagara Peninsula–Frontier region). Recent changes in the position of the Ordovician–Silurian boundary and significance of the Devils Hole Fm. (sandstone) and Ball's Falls fm. (dolostone is an informal unit) Eramosa Fm. (Reformatory Quarry Mb.) to Guelph Fm.? Figure is modified from Haynes (2000) courtesy of Frank Brunton.

(NOTE: Roadlog starts at junction of West Jackson Street and Plank Road, Niagara County, NY (see Figs. 26, 27 for stratigraphy and map of route)

STOP 1: ROAD CUT ON WEST JACKSON STREET BELOW SOMERSET RAILROAD VIADUCT (QUEENSTON SHALE - MEDINA GROUP)

Location: Road cut West Jackson Street near junction of Plank Road at Niagara Sewage Treatment Plant, and just beneath and east of viaduct for Somerset Railroad; Lockport, NY (lat./long. coordinateS:43.1839, -78.7029).

Quaternary Setting: Two spillway channels of Lake Tonawanda (and earlier glacial lakes) converge in an embayment cut back into the Lockport Escarpment (Kindle and Taylor, 1913; D'Agostino, 1958; Calkin and Brett, 1978). The embayment is filled by a red diamicton (probably till) overlain by glaciolacustrine sand, silt, and clay as well as gravel and sand beds presumed to be related to glacial outflow via the spill ways. A woody marl extending two meters above an upper (outflow?) gravel and sand in the Lockport spillway axis contains wood dated from 10,920 ± 160 B.P. at the base and 10,290 ± 200, 9,520 ± 110, and 9,145 ± 110 in the two successively overlying meters (Calkin and Brett 1978; Miller and Morgan,

1982). This woody marl contains a lower floral zone dominated by boreal forest taxa with abundant spruce. An upper zone is characterized by a restricted modern distribution of taxa (about 9,700 to 9,100 yr. B. P.) according to Miller and Morgan (1982). The earliest age of 10,920 B. P. appears to limit the use of the spillway (Gulf) by more recent outflows from Lake Tonawanda and the suggestion by Tinkler and others (1992) that glacial Lake Agassiz waters flowed through the Lake Tonawanda basin at about the same time on their way to the sea.

Bedrock: This outcrop has been described previously in considerable detail (see Friedman, 1982; Duke et al., 1987). It provides an outstanding exposure of the basal Silurian Cherokee Unconformity and a good opportunity to study the lower units of the Medina Group as well as the uppermost beds of the Queenston Shale. About 6m (20') of upper Queenston red mudstone and siltstone is exposed here. The Queenston has been interpreted as shallow, marginal marine to non-marine red beds. The Cherokee unconformity in this area is the basal surface of Whirlpool Sandstone, which is nearly planar. It is also a megasequence boundary separating the early or Creek phase of Sloss's Tippecanoe "megasequence" from the later Tutelo phase (see Dennison and Head, 1975). The Medina Group (Sequence I of the Silurian System) consists of a latest Ordovician- Early Silurian (early Llandovery, Al-B), siliciclastic wedge derived from tectonic source areas to the southeast (Figs. 5, 28). The lowest unit, Whirlpool Sandstone is about 3.5 m (11.5') thick at this location. The age of the Whirlpool has been debated but recent study at this locality has yielded chitinozoans and scolecodonts of apparent Ordovician age from thin shale seams (Schröer et al., 2012). While some may be reworked, others appear to represent genuine Hirnantian forms. Moreover, the laterally-equivalent lower Manitoulin Formation shows a ~+2‰ positive $\delta^{13}C_{carb}$ excursion interpreted as the final phase of the HICE (Hirnantian isotopic excursion) and indicating a Hirnantian age based (Bergstrom et al., 2011; Farnam and Brett, in review). Basal beds of the Whirlpool Sandstone are quartz arenites with northwest dipping cross strata, interpreted as non-marine, braided stream deposits (Middleton et al., 1987).

Large-scale channel-like structures occur in the lower sandstone at this locality. Shale drapes within such channels at Lockport have yielded marine acritarchs (M. Miller, unpublished data) indicating that the channels were backfilled by very shallow marine sands and minor muds during a lowstand/initial rise of sea level. Hence the irregular channeled surface that separates lower Whirlpool braided fluvial facies from upper Whirlpool hummocky cross-stratified, sparsely fossiliferous beds is a transgressive surface.

The Whirlpool Sandstone thus is interpreted to contain both a lowstand systems tract and an upper transgressive deposit (Figs. 5, 28). A thin bed containing small phosphatic pebbles and fossil fragments (mostly crinoid columnals) occurs the Whirlpool- Power Glen contact. This phosphatic pebble bed may mark a marine flooding surface, or surface of maximum starvation associated with relatively increased rates of sea level rise. This surface marks the change from shallow shelf sands of the upper Whirlpool into deeper shelf muds and storm sands of the upper Whirlpool into deeper shelf muds and storm sands of the Power Glen Formation, herein interpreted as relative highstand deposits (subsequence II; Fig. 28). Farnam and Brett (submitted) suggest that this represents the earliest Silurian glacioeustatic sea highstand.

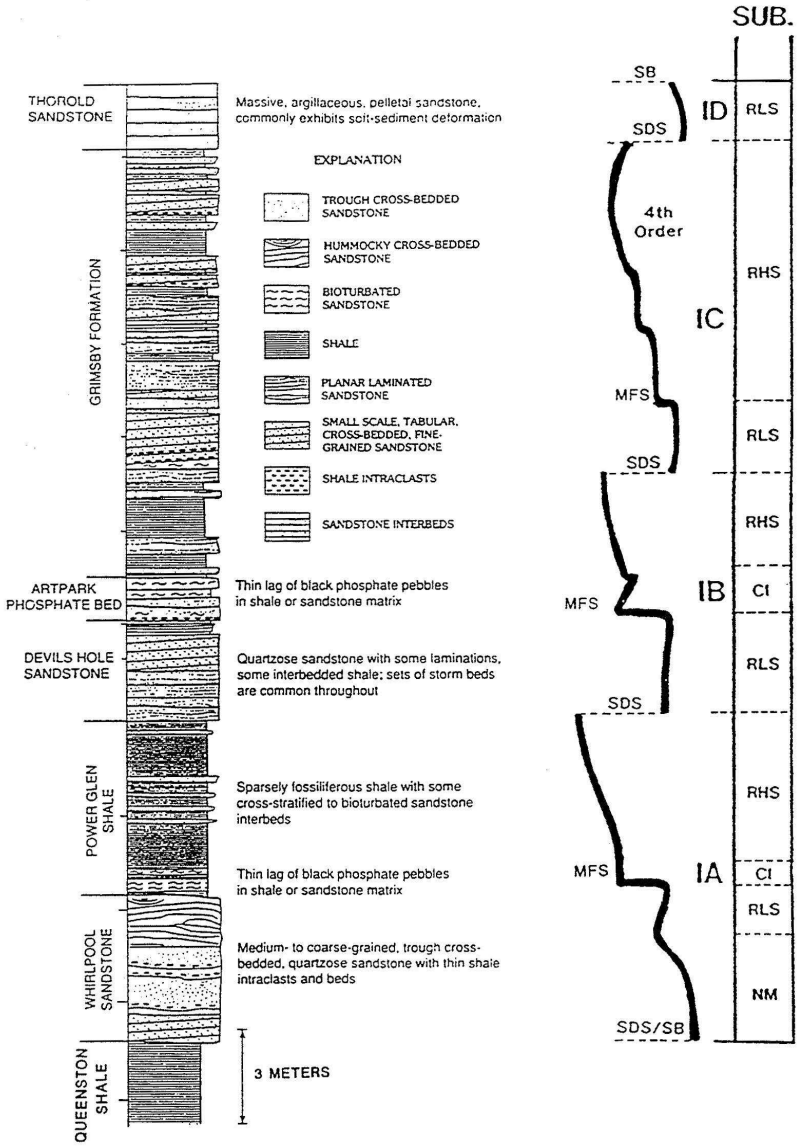

Figure 28. Lithostratigraphy, relative sea level curve, and sequence terminology for Medina Group (Sequence S-1) in Niagara County. RLS-A= relative sea-level curve for lower-order cycles. RLS-B= relative sea-level curve for large scale (fourth-order, ~0.5 myr) cycles; generally asymmetrical cycles. Bars on right side of figure indicate subdivisions of small scale sequences (SS: left bar) and for systems tracts; abbreviations: CI: condensed interval; NM: non-marine lowstand sands. RHS: relative highstand (highstand to falling stage), RLS: relative lowstand (lowstand to transgressive systems tract)

This outcrop is one of the easternmost exposures of the Power Glen Shale (Fig.5). At this locality, the Power Glen Shale comprises about 5 m (16') of greenish gray shale with thin tempestitic siltstone and sandstone beds. The basal meter-thick transitional zone consists of thin (2-10 cm) muddy sandstones with interbedded sandy shales. Sandstones in the Power Glen Shale feature small-scale hummocky lamination and gutter casts suggestive of shallow, storm influenced shelf deposition. Small burrows (*Planolites*) are common, but body fossils are rare. A distinct ball-and-pillow deformed zone occurs about midway through the unit.

Greenish sandy shales and sandstones occur near the top of the Power Glen suggesting a minor upward shallowing trend. However, the top of the unit (as defined herein) is sharply demarcated at the base of a massive white to pink mottled sublitharenitic sandstone about 2.5 meters (7.7') thick Devils Hole Sandstone of Brett et al. (1995). The basal and upper beds of the sandstone contain lingulid brachiopods and probable *Lingula* burrows.

The white sandstone appears to record a relative sea-level drop during which sands were distributed widely into the basin (Castle, 1998). The unit has some characteristics in common with the upper member of the Whirlpool Sandstone and, by analogy, is considered to be a lowstand to transgressive deposit (Fig. 28). Thin, spastolithic (oolitic) hematite stringers occur near the top of the unnamed sandstone and probably reflect reworking of sediments in shallow marine environments during an interval of sediment starvation. Hence, these shell-rich ferruginous sediments represent a condensed interval at the base of the Grimsby highstand deposits.

The Devils Hole Sandstone, in turn, is overlain by about 2.0 meters of brick red shales and interbedded sandstones assignable to the lower Grimsby Formation. These beds are ferruginous and exceedingly rich in fragments of lingulids with rare nautiloids and bryozoans. The reddish marine shales near the base of the Grimsby Formation pass upward into red and white- mottled sandstones and thin sandy shales. These beds are exposed high in the cut and are not readily accessible. This upper interval will be seen to better advantage at Niagara Gorge (Stops 5, 6).

Mileage		**(Niagara County Roadlog Begins Here)**
Cumulative	**Incremental**	
0.0	0.0	Continue east on West Jackson Street
1.0	1.0	Junction of Glenwood Avenue; take a sharp right turn on Glenwood
1.9	0.9	Junction of Craine Street (**turn left**)
2.1	0.2	Junction Trowbridge/Michigan Street (**turn left**)
2.2	0.1	Junction of Outwater Drive. Pull off and park near overlook off the Niagara Escarpment; restrooms are available nearby in the park. If time permits, we may take a brief hike into nearby Crain Street pit to view reefal limestones of the Gasport Fm. **Arrive Stop 2**

STOP 2: OUTWATER PARK

This stop at a small overlook along a loop of Trowbridge Street (coordinates: 43.1405, - 79.7081) provides a brief overview of the Niagara Escarpment near the late Pleistocene Lockport outlet of Lake Tonawanda. On clear days this provides views northward to Lake Ontario. A small quarry north of Craine Street (Craine Street quarry; 43.1799, -79.7107) in the adjacent private lot may permit observation of cross sections through small patch reefs in the Gasport Formation. A glacially polished surface shows excellent cross sections of stromatoporoids and corals.

Restroom building south of Outwater Drive (coordinates: 43.1795, -78.7059) is made of crinoidal grainstones of the Gasport Formation. Weathered surfaces show crinoid-cystoid columnals and small corals.

Cumulative	Incremental	
2.4	0.2	Junction of Michigan Street (**turn left**)
2.9	0.5	Junction of Niagara Street (**turn right**)
6.3	3.4	Overpass over Lockport Junction (Town Line) Road
6.6	0.3	Access road to Lockport Junction Road (Route 93) on left; **turn left onto road**.
6.65	0.05	For optional stop**, pull off along berm** on left side of road and park. Proceed on foot directly down embankment along Route 93 to roadcut. **Arrive Stop 3A**

OPTIONAL STOP 3A: HICKORY CORNERS (UPPER MEDINA AND LOWER CLINTON GROUPS)

Locality: Small cuts along both sides of NY Rte. 93, Lockport Junction Road, beneath and just north and south of the overpass of Lower Mountain Road over Route 93, Hickory Corners, Niagara County, NY (coordinates:43.1843, -78.7541 at southwest end)

Bedrock: This noted roadcut exposes a section of the upper Medina and lower Clinton Groups (sequences S-I and S-II). The basal units seen here are red shales near the top of the Grimsby Formation. These shales are overlain by a 1.0 to 1.2- meter thick, blocky, pinkish gray sandstone that displays color mottling due to bioturbation of *Daedalus* occur sporadically near the top of the sandstone ledge. Detailed regional correlation by Duke and Fawcett (1987) indicates that this unit is the equivalent of the Thorold Sandstone at the Niagara Gorge (Fig. 5).

The Thorold, in turn, is overlain by ~1.8 m of dominantly red silty shale with small burrows and leperditians in upper greenish gray layers of the (Cambria Member; type locality) uppermost Medina Group.

Here, the top of the Medina Sandstone is an erosion surface overlain by a thin (3 to 5 centimeter) dark gray, phosphatic sandy limestone (Densmore Creek Bed) with prolific *Hyattadina* brachiopod valves. A thin· laminated siltstone rests on the bed at the contact with the greenish gray Neahga Shale, which at this locality is about 1.0 meter thick (Fig. 7).

At the base of the overlying Hickory Corners Limestone (type section), Reynales Formation, is a thin (3 to 5 cm) pyritic, sandy limestone packed with black phosphatic pebbles and shell fragments (Budd Road phosphatic Bed); this bed has yielded conodonts of the tenuis Zone (lower Aeronian It is overlain by about 40 centimeters of alternating greenish gray shales and thin limestones capped by a 60-centimeter thick ledge of nodular crinoidal pack- and wackestone at the top of the roadcut. These beds contain a prolific fauna including corals, brachiopods (*Hyattidina. Daleiina, Platystrophia*) and pentameric crinoid stems belonging to the inadunate crinoid *Haptocrinus* (Eckert and Brett, 2001) and a prolific bryozoan fauna including several new species (Ernst et al., 2019).

Cumulative	Incremental	
6.8	0.1	Lockport Junction (Town Line) Road (Rt. 93) **turn right (south)** and rise up escarpment
7.1	0.3	lower end of roadcuts on both sides **Arrive Stop 3B**

STOP 3B: LOCKPORT JUNCTION ROADCUT (UPPER) (ROCHESTER, DECEW, GASPORT FORMATIONS)

Locality: Roadcut on both sides of State Route 93 or Lockport-Cambria (Junction)/Town Line Road,
Niagara County, NY (coordinates: 43.1787, -78.7543 at north end of cut)

Bedrock: This large roadcut displays the upper part of the Rochester Formation (about 5 meters), DeCew Dolostone (2.5 meters), and Gasport Limestone (over 7 meters). A subsequence boundary occurs between the dolomitic calcisiltites and shales of the upper Rochester Shale and the overlying DeCew Dolostone (Figs. 10, 13). The latter is a buff-weathering, silty dolostone with thin layers of intraclasts and contorted bedding. The basal contact is sharp and locally channeled.
The sharp and undulatory upper contact of the DeCew Dolostone with the Gasport Formation forms the boundary between the Clinton and Lockport groups and is interpreted as a sequence bounding unconformity (between sequences S-V and VI; Fig. 10). The surface represents an abrupt lowering of relative sea-level and beveling of older strata. The basal Gasport bed is a greenish gray brachiopod-rich, crinoidal grainstone with dolostone clasts eroded from the DeCew. A small bioherm composed of algal and bryozoan boundstone (micrite) occurs within the Gothic Hill Member. The overlying units will be examined at the next stop.

Continue south along Route 93.

Cumulative	Incremental	
7.9	0.2	Upper end of roadcut.
8.2	0.3	Junction Upper Mountain Road (Rt. 270/93); **turn right (west)** on Upper Mountain Road
8.9	0.7	Junction Thrall Road on right. Exposures of fossiliferous Rochester Shale occur along Thrall Road
13.1	4.2	Junction Rt. 425
15.1	0.2	Junction Old Pekin Road (one way). **Turn right and proceed downhill**
15.3	2.0	Park on shoulder before stop sign at junction with Rte. 429 and walk to outcrop along Rte. 429 **Arrive Stop 4**

STOP 4: PEKIN HILL: GASPORT-GOAT ISLAND FORMATIONS

Locality: Townline Road (Route 429) road cut at underpass below Upper Mountain Road, Pekin, NY (coordinates: 43.1687, -78.8853)

Bedrock: This classic exposure, detailed by Crowley and Poore (1974), displays biohermal structures characteristic of the lower Lockport Group. Although the exposure is becoming overgrown, it remains an important reference section.

In the northernmost end of the outcrop (east side of road) a crinoidal grainstone marks the top of the Gothic Hill Member of Gasport Formation (seen at the last stop). The crinoidal grainstone is overlain on the east side of the road cut by 4 to 5 meters of thin-bedded, bioturbated argillaceous dolostone which Brett et al. (1995) refer to as the Pekin Member of the Gasport Formation (see Figs. 10, 13).

Of particular importance is the sharp, channeled upper contact of the Pekin Member with pink, fine-grained crinoidal and cladoporid coral-bearing dolomitic grainstones of the basal (Niagara Falls Member) of Goat Island Formation on the east side of the road.

On the west side of the road, the main mass of lower bioherm described by Crowley and Poore (1974) can be seen. It is evidently a continuation of the biohermal mass seen near the bridge footing on the east side. This bioherm appears to occur above the sharp and distinctly irregular contact of the Goat Island Formation. Again, this contact is channelized into the argillaceous dolostones of the underlying Pekin Member. Hence the so-called "Gasport bioherm" at this locality appears to be a channel fill within the lower Goat Island Formation.

The bioherm consists of dolomicrite containing very abundant, large stromatoporoid heads, many of which are re-orientated or overturned and hence, are not preserved *in situ*. Overall, we interpret the bioherm here as a possible band of algally bound micrite and stromatoporoids (and a few tabulates) that lined a lowstand channel cut into the muddy carbonates of the Pekin Member.

Return to vehicles and drive to intersection with Rte. 429. Turn left and proceed up through the cut.

Mileage		
Cumulative	**Incremental**	
15.5	0.2	Upper end of road cut.
15.7	0.2	Junction Grove Street; access to Mountain Road; **turn right** and follow around curve to junction at Pekin stone church
15.9	0.2	Junction Upper Mountain Road; **turn left (west).**
16.4	0.5	Bridgeman Road.
16.8	0.4	Meyers Hill Road. Continue on Upper Mountain.
17.3	0.5	View of Ontario Lowland Plain to right. On clear days, this affords a view of Lake Ontario
17.5	0.2	Eastern boundary of Tuscarora Indian Reservation.
18.3	0.8	Black Nose Spring Road; continue on Upper Mountain Road.
18.9	0.6	Walmore Road
21.3	2.4	Y-intersection with Model City Road. **Bear left (cautiously),** staying on Upper Mountain Road. View to the right of Ontario Lowland Plain.
21.9	0.6	Western boundary of Tuscarora Reservation.
22.2	0.3	Reservoir for Robert Moses Hydroelectric Plant appears as bank on left
23.9	1.7	Upper Mountain Road ends at junction with Military Road (Rt. 265); stoplight. **Turn right onto Military Road**

24.7	0.8	Junction NY 104 in Lewiston Heights; **turn right (north)** onto Rt. 104
24.8	0.1	Brink of Niagara Escarpment near Lewiston Heights Country Club on the Barre Moraine cuts on right side of Rt.104 are in Goat Island Dolostone (Lockport Group). On clear days this vantage point provides an excellent view of the lower Niagara River and Lake Ontario
25.2	0.4	Proceed downhill (north) toward Lewiston; **stay to right**.
25.9	0.7	**Exit for NY 104** in Lewiston; **take exit and bear right** around curve
26.1	0.2	Junction NY 104, **turn right** (turns into Center St. Lewiston, NY
26.3	0.2	Junction S 9th Street, **turn left**
26.5	0.2	Junction Seneca Street, **turn right**
26.5	0.05	Junction Portage Road extension, **turn left** at Entrance to Earl Brydges Artpark
27.5	0.9	**Pull off and park** at Artpark Trail Trailhead; fisherman's access parking area **Arrive Stop 5**

STOP 5A: NIAGARA ESCARPMENT AND THE MOUTH OF NIAGARA GORGE.

Location: We will have a brief orientation and overview stop at the north end of Niagara Gorge at the Artpark Trailhead to review broad themes of Paleozoic and Quaternary history of the Niagara region and also the geomorphology of the Niagara Escarpment and Gorge (coordinates: 43.1619, -79.0445).

This site affords a spectacular view of the north end of the Niagara Gorge and the lower Niagara River; note the Brock Monument, a 56 m (185') tower on the brow of the escarpment at Queenston Heights, Ontario on the opposite side of the Niagara River, the monument commemorates. Sir Isaac Brock, a fallen Canadian hero in the War of 1812, who died on October 13, 1812, at the Battle of Queenston Heights.

Quaternary Setting: The north-facing cuesta (Niagara Escarpment; Fig. 29), which is overlain here by the Barre Moraine, forms an abrupt terminus of the Niagara gorge and stands 250 ft (76 m) above the adjacent Lake Ontario plain. The southern shore of glacial Lake Iroquois stood just north of the escarpment and its beach ridge is represented on the New York side by Ridge Road (US Rte. 104) at 312 ft (95 m) above sea level. The town of Lewiston lies partly within the original Cataract Basin, a plunge pool formed by the first falls (or rapids) into Lake Iroquois. Niagara Falls started here, with river flowing over the escarpment into Lake Iroquois about 12,300 years BP. At that time, there were several spillways over the Niagara Escarpment, this was westernmost; at this time there were also spillways at Lockport Medina and Holly. The Niagara Gorge has been cut southward by headward erosion from here about 7 miles in 12,000 years. The straight gorge section behind it was initiated during the
Lake Tonawanda phase; this is now heavily modified by the power plants and the Lewiston-Queenston bridge

Bedrock: Exposures of the Upper Ordovician upper Queenston Shale and its unconformable contact with the Whirlpool Sandstone are visible along a short path, adjacent to the river, commencing from fisherman's parking area immediately south of the Artpark theater; pillars for an old suspension bridge rest on top of a small plateau on the Whirlpool Sandstone. Note here the sharply undercut erosional contact and local channeling and medium-scale cross stratification within the massive, pale gray Whirlpool Sandstone; green shale clasts eroded from the Queenston occur near the base of the sandstone (see guide cover for stratigraphic section).

STOP. 5B Outcrops of the Silurian stratigraphic units above the Whirlpool Sandstone are accessible along an old haul road (old railroad grade modified during construction of the power plants) that leads southward from the Artpark Visitor Center into the gorge beginning at a pass between the main gorge wall and a small remnant butte of bedrock (at about 43.1611, -79.0441). The path continues south for about 0.9 mi (1.5 km) to the footings of the Lewiston-Queenston Bridge (43.1529, -79.0424). The complete Medina to lower Lockport succession is continuously exposed (although largely inaccessible) in 150 ft. high (45 m) gorge walls from Lewiston southward for nearly a mile; this sequence is particularly well displayed in a small tributary gully (Fish Creek) about 600 ft (175 m) south of the gorge entrance. At the entrance to the gorge (edge of Niagara Escarpment) an isolated "butte" of Lower Silurian (Power Glen–Devils Hole–lower Grimsby) bedrock between the path and the river, represents a remnant of a promontory in the gorge wall that was breached during excavation for the power plant (remains of an old railroad tunnel through the promontory are still visible in gorge wall opposite the butte). Both the butte and the main gorge wall south to the bridge provide access to the Power Glen-Grimsby sequence. Abundant fallen debris also provides an excellent look at the lithologies of the Medina, Clinton, and Lockport groups. Caution is required because rock falls are common.

The Power Glen Formation at 1B consists of greenish-gray clay shale (locally strained red from the overlying Grimsby), with a few thin, pale gray quartz arenite beds.It is well exposed in the small side gully of Fish Creek (coordinates:43.1590,-79.0437). Shales are generally barren of macrofossils, but sandstones contain

nauti1oids, bivalves, bryozoans, and a cluster of articulated crinoids (*Ptychocrinus medinensis)* was found in a thin sandstone lens about midway through the Power Glen (Brett, 1978) demonstrating normal marine, albeit normally dysoxic mud bottom conditions.

As at Lockport, the Power Glen shale is overlain sharply by calcareous Devils Hole Sandstones. A thin interval (5 ft; 1.5 m) of sandy dolostone with abundant small bryozoans and brachiopods and numerous small black phosphatic nodules, termed Artpark Bed occurs immediately above the sandstone (see Fig. 5).

The Grimsby Formation consists of green and red shales and siltstones, with mottled pale red arid white blocky sandstones; greenish-white reduction spots and fine Leisegang banding are common in the sandstones. Exposures in the gorge walls display cyclic alterations of red shales and fining-upward, lenticular, cross-laminated sandstones and siltstones. Note abundant shale pebble conglomerates at bases of lenticular (channelized) sandstone units, and thin, sandy coquinites containing *Lingula* fragments, bivalves, and rare bryozoans. Fallen blocks of Grimsby sandstone display a variety of sedimentary structures including oscillation and interference ripples, cross lamination (including HCS), rill marks, load casts, syneresis and rare desiccation cracks, and burrows (e.g., *Arthrophycus).* A 1.5- to 2 ft thick (0.4 to 0.6 m) layer of mottled sandstone with prominent ball-and-pillow structures, about 18 ft (5.5 m) above the base of the Grimsby, is well exposed in the cliffs about 600 to 2,000 ft (200 to 700 m) north of the Lewiston-Queenston Bridge (see Fig. 18).

STOP 5C: Units of the Silurian sequence above the Thorold Sandstone are inaccessible in the gorge cliffs north of the Lewiston-Queenston Bridge but may be examined in fallen debris; for example, very large blocks of the Irondequoit crinoidal limestone occur in a large rockslide about 850 ft (260 m) south of the gorge entrance.

The upper units are only accessible in outcrop by hiking up a short, rough trail that ascends a slope immediately south of the footings for the Lewiston-Queenston Bridge. About 1,300 ft (400 m) south of the Queenston Bridge, in and near a small stream (caution: contaminated water), are exposures of the upper Thorold, and overlying soft, greenish gray Neahga Shale (about 8 ft: 2.5 m thick); this shale is overlain, in tum, by about a meter of rubbly-weathering, bryozoan-rich, wacke- and packstone of the Hickory Corners (Reynales) Formation (Fig. 8). The top of this thin unit is demarcated by 4 in. thick (10 cm) greenish shale bed, containing abundant black phosphatic nodules; this unit marks the major mid-Clinton (Llandovery C-6) unconformity, and underlies the Rockway Dolostone, overlain by massive Irondequoit Limestone. A small rock shelter along the trail (coordinates: 43.1516, -79.0419) affords a good look at these beds. The talus of the overlying Rochester Shale yields excellent lose fossils.

Total walking distance in the gorge from Artpark parking area to this site is approximately 1.5 mi (2.5 km).

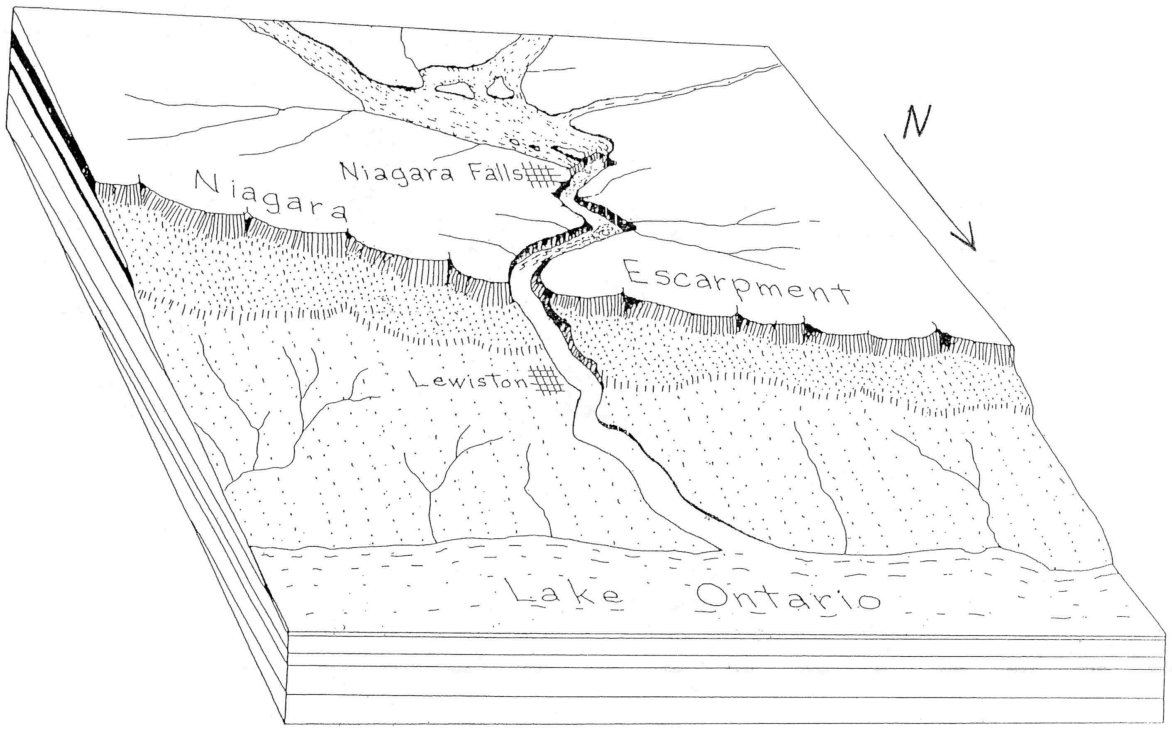

Figure 29

Bird's-eye view of Niagara Falls, looking south from the northern shore of Lake Ontario. Notice that the layers of the bedrock, which are of Ordovician and Silurian age, dip south. Notice particularly the Lockport Dolostone (upper dark-colored layer), which forms the Niagara Escarpment and the caprock of Niagara Falls. The Lockport Dolostone resists erosion and lies on top of easily eroded shales. The Niagara River began to flow along its present course about 12,000 years ago, when the Pleistocene ice sheet melted north from the Niagara Escarpment. Since that time, the Niagara River has cut a gorge 11 km long, and erosion of the caprock continues daily. From the lip of the falls, the Niagara River plunges vertically 53 m. It descends another 22 m in the gorge before reaching the Niagara Escarpment. From there to Lake Ontario, a distance of 9 km, the river falls less than 1 m

Return to vehicles at Artpark and retrace route to Center Street by South Ninth St.

Cumulative	Incremental	
27.5	1.4	Junction Center St and 9th Street**; turn right**
28.9	0.1	Junction entrance to NY Rt. 104 west and Robert Moses; **turn right**
29.0	0.1	**Stay left**, take left fork of NY 104 and Robert Moses Parkway, staying on Rt. 104 (west; actually, south).
29.1	1.0	Brow of Niagara Escarpment. Note hummocky topography of Barre-Vinemount Moraine (Fig. C2).
30.1	1.0	Underpass under I-190 access to Lewiston-Queenston International Bridge.
30.8	0.7	Stoplight at Old Lewiston Road; (a pull-off to left here provides parking to access southern part of Niagara Gorge). Pass by forebay area at tops of conduits for water inflow to generator turbines Robert Moses Power Vista.
31.4	0.3	Junction Hyde Park Blvd. (Rt. 61) at entrance to Niagara University. Turn left off Route 104 onto Rt. 61
31.7	0.3	Junction Robert Moses Power Plant South Access Rd. **Arrive Stop 6A**

STOP 6A: SOUTH HAUL ACCESS ROAD TO ROBERT MOSES POWER PLANT

Location: Large roadcuts in east wall of Niagara Gorge along South Haul access road for Robert Moses Power Plant and ascending for about 1 km north to a tunnel beneath Niagara Scenic Parkway. Parking is available in a fisherman's access parking lot just west of Rt. 62 (Hyde Park Boulevard) immediately south (uphill) from the tunnel. Lewiston, Niagara County, New York (USGS Lewiston 7.5' Quadrangle). **Note:** Access to the Haul Road exposure is strictly controlled by the Robert Moses Power Project and **requires advance permission.** This outstanding outcrop, arguably the most completely exposed Silurian section in New York State, provides an opportunity to summarize and review the stratigraphy (at base of road/power plant entrance: 43.1401, -79.0413; upper roadcut on west side and head of Devils Hole trail: 43.1349, -79.0444).

Bedrock: The section begins near the Power Plant with about 8 m of the Upper Ordovician:

Queenston Shale in sharp contact with the overlying Whirlpool Sandstone is the Cherokee Unconformity (Silurian Sequence I boundary, but probably of Hirnantian age). The units of the Medina succession are described in ascending order, as follows:

Medina Group (Figs. 4,5,6, 28).

Whirlpool Sandstone: (4.5 m) White, trough cross bedded, quartz arenite facies which record a non-marine to marine transition. Excellent profiles of channels are visible.

Power Glen Shale: (~ 8 m) Dark gray, friable shale, with very minor sandstone interbeds

Devils Hole Sandstone: (2 m) Pale gray, massive, quartz arenite with a distinctive, meter-thick phosphatic, sandy dolostone, Artpark Phosphate Bed near the top **(Cl).**

Grimsby Formation: (15 m) Greenish gray to maroon shales and mudstones with bundles of thin reddish and white mottled sandstones

Thorold Sandstone: (2 m) White, cross-bedded quartz arenite. The Thorold has a sharp, erosive base which marks the base of the next Medina subsequence (IC). A thin (2-10 cm), sandy phosphatic bed, the Densmore Creek Bed (Brett et al. 1995) rests sharply on the Thorold (and on a Cambria Shale remnant north of the Power Plant), marking the base of the Neahga Shale.

Clinton Group (Cover photo and Figs. 4, 6, 7)

Neahga Shale: (2 m)- Dark greenish gray, very friable shale (base sharp (S-II SB).

Reynales Formation (Hickory Corners Member): (~50 cm)- Medium gray, nodular,burrowed, bryozoan-rich wacke- to packstone. Conodonts indicate an early Aeronian age for the Reynales (see Waid and Over, 2016) this unit represents an erosional remnant of the Reynales.

Rockway Formation: (3 m)- Buff-weathering, argillaceous dolostone with thin dolomitic shales shows prominent rhythmic bands (10-50 cm) of sparsely fossiliferous argillaceous dolostone interbedded with thin gray shales. The Rockway shows a sharp upper contact (S-IV-V SB**).**

Irondequoit Formation: (2.5 m)- Massive, pinkish-gray, crinoidal pack-and grainstone. Clasts of fine-grained dolostone, derived from the underlying Rockway occur in the basal thin bed of the Irondequoit. Its sharp upper contact (MFS) is marked by a 30 cm thick shell bed. (Figs.4, 9,10)

Rochester Shale: (18 m)- Medium dark gray mudstone with thin calcisiltites and lenticular fossil rich limestones; 1.5 m of bryozoan-rich limestone beds underlie the sharp top (MFS) of the Lewiston Member. The upper Rochester (Burleigh Hill Member) also displays a sharp contact (SSB) with the enterolithic DeCew Dolostone beds.

DeCew Formation: (3m) -Dark gray, buff weathering, laminated dolostone (calcisiltite). Here and, especially in weathered exposures in the adjacent Devils Hole Park section, the DeCew displays spectacular soft-sediment deformation with isoclinally folded beds (seismite?).

Lockport Group (Cover; Figs. 10, 12-13): The sequence V-Vl boundary at the DeCew-Gasport contact is well exposed near the entrance to the "tunnel" beneath the Robert

Moses Parkway at the top of the cut; basal Gasport shows rip-up clasts of DeCew Dolostone (Figs. 19).

Gasport Formation: (5 m)-Pinkish gray thin bedded to massive dolostone. divided into a lower pinkish gray dolomitic crinoidal grainstone (Gothic Hill Member) and a 2.5 m upper argillaceous, bioturbated dolostone (Pekin Member) Weathered surfaces of the Gothic Hill grainstones display probable bipolar cross-stratification. The sharp upper contact is a subsequence boundary.

Goat Island Formation: (~ 10 m)- Buff weathering dolomitic, crinoidal grainstones, buff, thin bedded dolsotone with white chert, and dark brownish gray, argillaceous, banded dolostone; the basal unit (Niagara Falls Member) is massive crinoidal grainstone with scattered *Cladopora* corals and stromatoporoids; abundant vugs appear to be solution cavities in a stromatoporoid-rich zone.

The Ancaster Member is poorly developed here, thin (-2.5 m) and only sparingly cherty. Argillaceous and bituminous gray dolostones of the Vinemount Member form the uppermost unit on the access road. This member is much less shaly than at its type area near Hamilton.

OPTIONAL STOP 6B: DEVIL'S HOLE

Location: This small cave is accessible from a dirt trail leading along cliff to the river level in Devil's Hole State Park, accessible from the power plant haul road (43.1345, -79.0457).
(Alternatively, one may enter from a free parking lot at (clearly marked) along the Robert Moses Parkway, 3. 7 mi (5.2 km) south of the Lewiston exit and 4.3 mi (7 km) north of Niagara Falls

Quaternary setting: Devil's Hole lies at the lower end of the Niagara Glen Section (Fig, C3) and is a small reentrant in the east wall, marking the mouth of a former channel of the Niagara River. This channel, which is now occupied by Bloody Run Creek, existed for a short time after the Falls had receded south of this point (perhaps-10,000 B.P.) and before discharge was terminated by a drop in the level of Lake Tonawanda. The stairway and path leading into the gorge provide access to weathered exposures of the Lockport Formation and the DeCew Dolostone. At the head of the stairs, the major joint system of the area, with directions of N70° to 80°E and N to N38°E, is particularly well expressed in an exposed Lockport dolostone surface. Solution localized along the main set (N70° to 80°E) has produced a small cave (4 ft high and 30 ft deep; 1.2 m by 9 m) in the DeCew Dolostone about 60 ft (18 m) below this point.
The DeCew Dolostone displays spectacular soft-sediment deformation. Layers of intraformational conglomerate that are contoured into overturned isoclinal folds here may have been produced by slumping of fluidized sediment on a gentle paleoslope (see McLaughlin and Brett, 2004, 2006; Fig. 19). The overlying Gasport Formation of the Lockport Group (5 m) shows outstanding examples of cross bedding including bimodal (herring bone) bedding suggesting that the sediments accumulated in a high energy tidally influenced shoal (Fig.12). The basal contact of the Gasport Formation displays rip-up clasts of dolomicrite, derived from the underlying DeCew (Fig. 12). Overlying Lockport units (Goat

Island and Eramosa members) are inaccessible. This is also a historical site. Devil's Hole was the site of "America's first labor dispute": the Devil's Hole Massacre. On September 14, 1763, 300 warriors of the local Seneca tribe, angry French and Indian War. The natives threw soldiers and wagons over the edge of the gorge. The Senecas had formerly been hired by French colonists to portage goods between Fort Niagara at the mouth of Niagara River on Lake Ontario, around the Niagara Falls barrier, and Lake Erie.

Reboard vehicles and retrace route to Hyde Park Boulevard

Cumulative	Incremental	
32.3	0.05	Junction Hyde Park Blvd. **Go straight across** on Power Authority Service Road and access to Niagara University.
32.8	0.5	Junction Campus Parkway; **bear right** on main Service Road.
33.0	0.2	Junction service road to Robert Moses Plant on left at curve in road onto Detroit Avenue, **turn left and follow Service Road to end.**
33.5	0.5	Junction with Campus Drive opposite forebay area. **Turn right.**
33.5	0.1	**Pull off along roadside** at roadcuts just before overpass of I-190 over road. **Arrive Stop 7**

OPTIONAL STOP 7: CAMPUS DRIVE/POWER VISTA ROAD AND FOREBAY (UPPER LOCKPORT/SALINA GROUP)

Location: Higher units of the Lockport Group are visible along the fore bay and cuts along Campus Drive/Power Vista Road, just west of overpass of I-190 and 0.2 mi west of Military Road and 0.9 miles north of Route 31 (coordinates: 43.1353, -79.02108).

Bedrock: Here we will briefly examine, from a distance, exposures in the forebay canal of the upper Eramosa (new usage in New York) and lower Guelph Formations. Note the large algal bioherms, which characterize the uppermost units of the Lockport Group in Niagara County (seen at Stop 4). The highest units in the forebay canal are more or less tabular stromatolitic dolostone which are, at present, assigned to the Guelph Formation. Exposures in the small road cut at the underpass of the access road beneath the lanes of I-190 display exceptionally large stromatolites (Fig. 14). These strata represent a very distinctive marker horizon in the basal Salina Group beds in western New York. The stromatolite heads are approximately 2 meters across; superimposed on these are small digitate upward growths of stromatolitic boundstone. The stromatolitic horizon is thought to be traceable at least to Hamilton where it comprises the basal transition bed between the Guelph Dolostone and Salina Group.

Reboard vehicles and proceed straight ahead

Mileage Cumulative	Incremental	
33.6	0.1	Junction of Military Road **turn left (north.)**
34.0.	0.4	Pass by forebay area (on left) and Robert Moses Pump Generating Station (on right).
34.8	0.8	Junction Upper Mountain Road (right) and entrance road to Route I-190, Route 104, and Robert Moses Parkway (left). **Turn 1eft onto entrance road.**
34.9	0.1	Exit for Route I-190 north onto Lewiston Queenston International Bridge (don't take!).
35.0	0.1	Exit for Route I-190 south (don't take!).
35.1	0.1	Exit for NY 104 west and Niagara Scenic Parkway south; **keep left at fork** for Scenic Parkway **south**; follow signs toward Niagara Falls.
35.8	0.7	Merge onto Niagara Svenic Parkway; panoramic view of Niagara Gorge between Lewiston-Queenston Bridge and Robert Moses Power Vista; the large concrete edifice of Ontario Hydro's Adam Beck Power Station is directly opposite on west (Canadian) side of gorge.
36.6	0.8	Pedestrian overpass for Niagara Scenic Power Vista over the parkway. Power Vista provides working models of the power plant and basic information on gorge history and geology for tourists.
36.9	0.3	Overpass of parkway over South Haul Road; immediately below are exposures.
37.1	0.2	Exit for Devil's Hole State Park.
38.0	0.9	Views of Narrows section of-Niagara Gorge. **Arrive Stop 8**

STOP 8. WHIRLPOOL STATE PARK, NEW YORK.

Locality: From the parking lot, walk through the park shelter and follow the sidewalk to the overlook above Whirlpool Point (43.1206, -79.0661)

Quaternary Setting: Whirlpool State Park provides an overview of the Eddy Basin. Whirlpool, and exposure of the drift-filled, interglacial St. David's Gorge. Niagara River water rushing northward from the Eddy Basin immediately to the south, is funneled through a narrow constriction before entering the broad Whirlpool basin. Sudden change in velocity results in a large gyre that normally rotates in a counterclockwise direction. However, during times of low flow, the rotation in the Whirlpool reverses (see Krajewski and Terasmae, 1981).

The Whirlpool basin resulted from a chance intersection or the modern Niagara River with, and erosion of, the drift from the buried St. Davids Gorge, visible directly opposite the Whirlpool overlook. Tinkler and others (1994) provide evidence from downstream at the Niagara Glen that this intersection occurred about 4500 B. P., well after the discharge from the upper Great Lakes had started to return partial flow to Lake Erie from the exit at North Bay (~5500 B. P.).

The buried portion of the St. Davids Gorge in Ontario has been recognized as an ancient path of the Niagara since the time of James Hall and Charles Lyell (1845). From the escarpment, it extends north to Lake Ontario with distributaries to the lower Niagara River (Hobson and Terasmae, 1969; Flint and Lalcama, 1986). The St. Davids Gorge is nearly as deep and wide as the Upper Great Gorge, and its bottom pools and shallows like those of the re-excavated section, and of the Upper Great Gorge (Philbrick, 1970). A radiocarbon age of 22,800 ±_450 B. P. (GSC-816) was obtained on wood of interstadial swamp deposits occurring between drift sequences within this buried gorge north of the Whirlpool (Karrow and Terasmae, 1970). This, coupled with other studies, suggests that cutting occurred during, or more probably before Middle Wisconsin time under nonglacial conditions when base levels were similar to those of the present (e.g., Sangamon interglaciation; see also Flint and Lalcama, 1986).

The riverbed at this locality is the type section of Lower Silurian Whirlpool Sandstone, which forms the rapids and constriction just above the Whirlpool and is exposed as ledge or platform along its eastern margin. The overlying bedrock section, particularly the Irondequoit throughout the Lockport interval, is clearly visible but inaccessible beneath the landings for the aerocar on either side of the St. Davids Gorge in Canada opposite Whirlpool Point. Glacial sediments that fill the ancient Niagara River channel, including red till and overlying stratified drift, are exposed, but not accessible above the Lockport Formation at the gorge margin just below the park overlook (Fig.). Channel sand and gravel of the high, early stages of the Niagara River overlie this drift. Gastropods and bivalves from this deposit yielded the 9,800 B. P. radiocarbon age (Calkin and Brett, 1978; Brett, 1981a; see Tinkler and others, 1994).

Reboard vehicles and proceed straight ahead

Mileage Cumulative	Incremental	
44.2	0.7	Overpass of parkway over entrance to Whirlpool Bridge. Note: double decked railroad bridge and auto bridges; exposures of Rochester Shale and Lockport Dolostone visible to south of bridges at Niagara Sewage Pumping Station are some of the southernmost outcrops in the Niagara Gorge; they show substantial differences in facies from exposures of the same units further north in the gorge (see Brett, 1982 for further discussion).
45.8	1.6	Signs to Niagara Falls and Goat Island.
46.1	0.3	Pass by Shopping Mall on the left.
46.2	0.1	Stoplight at access road for Goat Island; turn right and proceed across bridge to Goat Island.
46.3	0.1	Note rapids above American Falls.
47.7	1.4	Goat Island; follow perimeter road around to parking lot near Terrapin Point and the Horseshoe Falls. Arrive **Stop 9**

STOP 9: NIAGARA FALLS FROM GOAT ISLAND, NIAGARA FALLS, NEW YORK

Goat Island is perhaps the most widely known US tourist overlook and it provides access to both Horseshoe and American Falls. From the parking lots we will walk first to the stairs and viewing area from Luna Island, passing by a statue of the great inventor Nikolai Tesla.

A small bridge takes you to Luna Island (coordinates: 43.0837, -79.0705) providing an excellent view of the American Falls at the brink and the small Bridal Veil Falls. From Luna Island we will ascend the Goat Island stairs passing by a wall on a bank that was excavated in 1974 to reveal a section of Quaternary sediments including river shells (Calkin and Brett, 1978; Fig. 31). At the top we will turn right and walk along the sidewalk along front edge of Goat Island, facing northwest toward the Canadian side of the gorge. We will pass by the Cave of the Winds access building (elevator to bottom of gorge and hike along platforms at base of American Falls

We will descend steps to the viewing area for the Horseshoe (Canadian) Falls at Niagara Falls viewing area (coordinates: 43.0800, -79.0745). This falls carries nearly 90% of the Niagara River flow; note the stable horizontal arch shape of the present falls. Erosion of the falls is substantially lowered as result of diversion of water by power plants on both sides. This is a classic picture stop for the Horseshoe Falls on the US side.

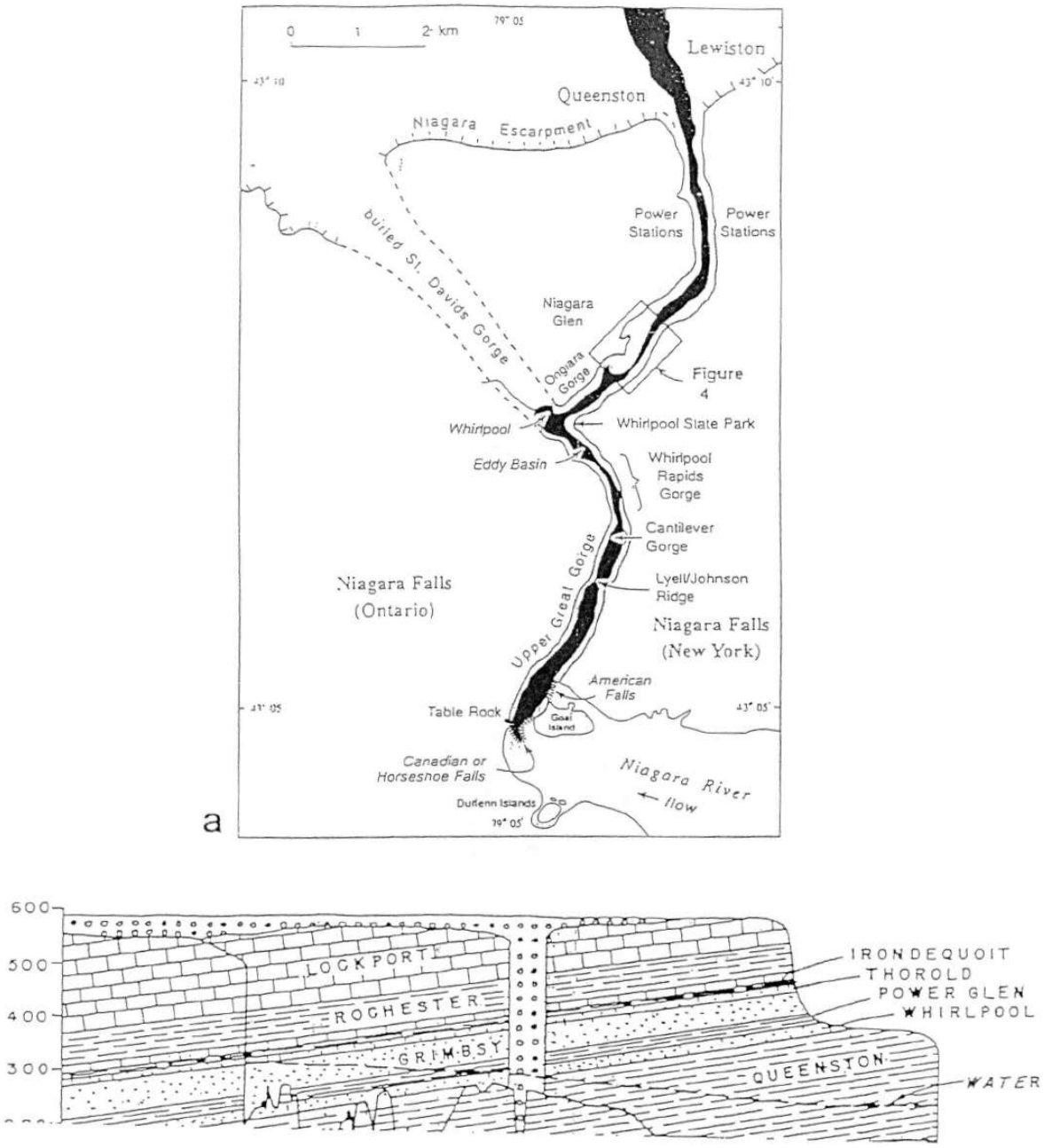

Figure 30. Niagara Gorge. a) Map of Niagara Gorge showing location of Wintergreen Flat and Whirlpool; b) cross section of the gorge showing topography of the river bottom, with local plunge pools. Modified from American Falls International Board, 1974.

Quaternary Geology: Detailed engineering geological data on the American Falls area are available in American Falls International Board (1974; see also Calkin and Wilkinson, 1982). Views westward across the gorge to Canada from between the two falls reveal the steep, cut-slope of the Niagara Falls Moraine. This moraine reaches 164 ft (50 m) above a narrow bedrock shelf along the gorge margin that is occupied by Queen Victoria Provincial Park in Ontario. The drift was swept from this area by the Niagara as it was deflected northward by the moraine at an earlier, high phase.

Goat Island itself consists of ancient channel fill of latest Wisconsin drift, which is topped by postglacial Niagara River gravels (Fig. 31); sections of these sediments are only accessible during excavations on the island, as took place in 1974.

The underlying, northwest-sloping Lockport bedrock surface may be the eastern bank of an ancient south-trending Falls-Chippawa channel of Spencer (1907), or part of the north-trending St. Davids Gorge system (see Flint and Lalcama, 1986).

Mollusks within the river gravels have yielded radiocarbon ages of 9,100 B.P. This suggests that Goat Island was abandoned as part of the Niagara River bottom about that time, or that more recent river scouring has removed any younger gravel material. A mastodon tooth was removed by James Hall and Charles Lyell from river gravels at a locality near Prospect Point, across the American Falls from Goat Island; cuttings for a retaining wall along the stairway in (Calkin and Brett, 1978).

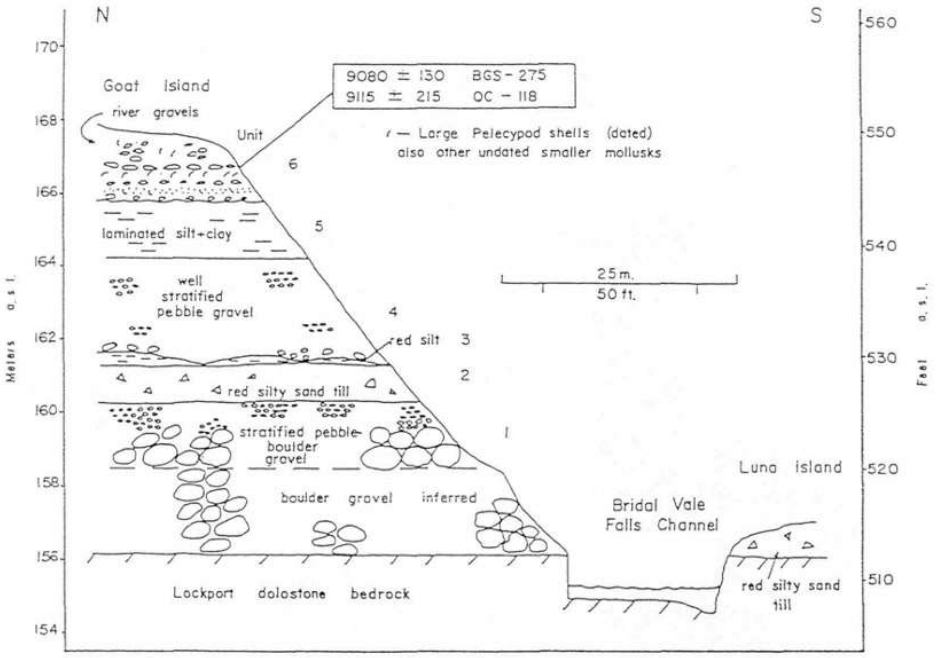

Figure 31. Stratigraphic section through surficial deposits of Goat Island, Niagara Falls. The American Falls is just to the right. The strata exposed above the Lockport Dolostone at Whirlpool Park are similar to this stratigraphy from the red till upward, From Calkin and Brett (1978) and Brett and Calkin (1987).