QUATERNARY GEOLOGY AND LANDFORMS BETWEEN BUFFALO AND THE GENESEE VALLEY

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INTRODUCTION

The Quaternary geology and landforms in western New York State north of the southern Finger Lakes (Valley Heads moraine) formed during the final recession of the Late Wisconsin ice sheet from its terminal position (Figure 1). There are a few places where Middle Wisconsin drift is preserved, such as in the Genesee Valley (Young and Burr, 2006), that indicate there is a more complex, older glacial record yet to be explored. This field trip explores the dominant geomorphic features created by the final stages of ice recession across a scarp-dominated bedrock landscape from Batavia to the southern Lake Ontario shoreline.

The complex sequence of proglacial lakes that accompanied glacial recession across the Great Lakes region is well documented in the geologic literature of the last century, but some events continue to be subjects of detailed study and debate. For the purposes of this field trip, the creation of glacial Lake Whittlesey (Figure 2) at the time of the Port Huron advance (circa 13,000 ^{14}C yrs BP) is an appropriate place to begin a discussion of the major events in western New York that culminated in the formation of early Lake Ontario, Lake Tonawanda, and the development of Niagara Falls in the Niagara Gorge.

LATE WISCONSIN HISTORY

Glacial Lake Whittlesey, with its westward outlet through the Ubly channel, barely extended into western NY as a narrow embayment that ended 17 miles east-southeast of Buffalo near the Marilla moraine (Figures 2 and 3). Its shoreline elevations range from 850 feet above sea level (asl) near Cattaraugus Creek to 910 feet asl 12 miles north of Hamburg (Calkin, 1970). This phase of deglaciation was followed by a series of three Lake Warren stages, of which the last and lowest (Warren III) may have followed a brief drop to a lower Lake Wayne stage. The Lake Warren strands are 45 to 70 feet below the Whittlesey level in the region at elevations between 750 and 865 feet asl (Figure 10). The Lake Whittlesey strand transects the Hamburg moraine, but not the Marilla moraine (Figures 2 and 3). This indicates that the drop to the oldest Lake Warren I position occurred before significant ice retreat from the Marilla moraine (Muller and others, 2003).

Both the Hamburg and Marilla moraines are considered to be Port Huron in age. The ice subsequently retreated from its Port Huron position to form the Alden, Buffalo, and Niagara Falls moraines, all of which are transected by the lowest strand of Lake Warren III. The barriers controlling the spread of Lake Warren waters were a series of closely-spaced ice positions against the Onondaga Escarpment further east between Batavia and Hamilton, NY (Calkin, 1970; Calkin and Feenstra, 1985). The entire recession and accompanying 6 or more lake stages from the Marilla moraine to the Niagara (Lockport) Escarpment (19miles) may have taken as little as 400 to 600 years (Karrow and others, 1961). Minimum ages for the draining of Lake Whittlesey are between 12,610 and 12,730 ^{14}C yrs BP (Muller and Calkin, 1993). During the multiple Warren stages western glacial waters finally connected with co-existing central NY lakes through channels running eastward from the Genesee Valley to Syracuse. Lowest Lake Warren formed when ice readvanced to either the Batavia or the Alden moraine (Figure 3).

As the ice receeded north to the Barre moraine, Lake Tonawanda formed with the Barre moraine at its northern edge. During its early existence, Lake Tonawanda was a shallow extension of the upper Niagara River and early Lake Erie (Brett and Calkin, 1996). During its highest level (590ft) near Niagara Falls the lake was approximately 58 miles long and 30 feet deep. The flow from early Lake Erie probably fluctuated greatly, so the erratically flowing waters from Lake Tonawanda spilled into glacial Lake Iroquois, when the ice eventually retreated north of the Niagara (Lockport) Escarpment. Multiple Lake Tonawanda outlets eventually formed along the Niagara Escarpment in response to the highly fluctuating Lake Erie outflow into Lake Tonawanda (Figures 3, 16, 17 19). The outlets, from east to west, were near Holley, Medina, Gasport, Lockport, and at Lewiston (Niagara River). Greater isostatic rebound to the northeast gradually caused abandonment of the eastern outlets and shifted the main flow toward the Niagara River (Lewiston outlet). Radiocarbon ages on wood from the Lockport area indicates that the main discharge had shifted from Lockport to Lewiston by 10,920±160 ^{14}C yrs BP (Brett and Calkin, 1996). A more extensive discussion of the Lake Tonawanda history and the formation of Niagara Falls is contained in Brett and Calkin (1996).

It has been speculated that the catastrophic draining of glacial Lake Agassiz between 11,000 and 10,500 years BP caused major increases (3 to 10 times) in flows to Lake Tonawanda when Lake Agassiz discharged to Lake Superior and possibly through Lake Erie (Brett and Calkin, 1996). However, quiet-water marl deposits in the Lockport spillway (Figure 19) suggest that flow was limited during this inferred Lake Agassiz interval. Lake Tonawanda waters in the western part of the basin could have persisted until only a few hundred years ago, but the shift of full discharge of all the Great Lakes to the Niagara River is dated at 3780 years BP by a mollusk assemblage (Brett and Calkin, 1996).

Glacial Lake Iroquois, the final glacial feature visited on this trip, is probably the best known of the proglacial lake stages in the Ontario basin, because of its prominent relief and the location of the original Route 104, which follows the Lake Iroquois strand along much of the Ontario shore. Lake Iroquois formed around 12,200 ^{14}C yrs BP, and persisted for several hundred years, based on existing chronology and the strong development of its shoreline. Many of its features are as well developed as those seen along the modern shoreline of Lake Ontario. Early Lake Ontario was at a much lower level when the ice sheet finally retreated from the north flank of the Adirondacks (Covey Hill outlet) and allowed Lake Iroquois waters to escape to the Atlantic Ocean via the St. Lawrence Valley. Lake Ontario gradually has risen to its present elevation from this low stand, which was between 250 and 300 feet lower at Rochester, NY.

This trip will explore the landforms and field relationships seen from the Batavia moraine northward to the Lake Iroquois shoreline northwest of Lockport, NY. A major focus of the trip is the contrast between the bedrock and glacial relief. The route will permit comparison of the morphology of terrestrial and subaqueous moraines and the internal stratigraphy of sediments that may have been deposited by meltwater flowing into Lake Tonawanda immediately north of the Barre moraine. The influence of the Onondaga and Lockport Escarpments on the glacial history is closely linked to the evolution of the Niagara River and Niagara Falls.

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NYSGA 2006 – FIELD TRIP B6 – SUNDAY OCTOBER 8TH, 2006

QUATERNARY GEOLOGY AND LANDFORMS BETWEEN BUFFALO AND THE GENESEE VALLEY

Road Log (Follow route and numbered Stops on Figures 3-6)

0.0 Depart Adam's Mark hotel parking lot to the right onto Lower Terrace St (one-way street).

0.1 Left onto West Seneca St.

0.1 Left onto Franklin St.

0.3 Take a right onto Church St.

0.7 Turn left onto Elm St.

1.4 Take onramp to Hwy 33 East.

9.8 Turn right onto Genesee St. Pass Buffalo-Niagara airport on left.

12.0 Cross Transit Rd.

12.8 Cross Ellicott Creek.

16.6 Pull into driveway on left and park on one side (Figure 9). **STOP 1.**

The Buffalo/Niagara Falls moraine complex. Gravel quarries are cut into a large outwash fan [labeled Wisconsin outwash gravel (W_{og}) on Muller (1977)], which borders the Buffalo Moraine. Borings made for the study of the gravel aquifer in this area show two till units bracketing up to 40 ft. of sand and gravel, indicating that the outwash fan pre-dates a more recent ice advance. Thin red lake clay partings separate thick rippled sand units, indicating that the outwash sand/gravel was likely deposited subaqueously. The overlying till and sand/gravel unit shows evidence of flow and deformation. The till has been traced at least to the Alden Moraine (Figure 3), 8 km to the south.

20.9 Take a left at the stop sign onto Walden Ave – turns back into Genesee St. – still on Hwy 33.

23.1 Cross Crittenden Rd. and onto Lake Warren beach ridges (Figure 10).

Glacial Lakes of the Erie Basin. Because the Laurentide Ice Sheet (LIS) was sourced in the north (Figure 1), and Lake Erie drains north, large pro-glacial lakes were created as the LIS flowed into and out of the Lake Erie basin. The highest lake level recorded in the greater Buffalo region, termed Glacial Lake Whittlesey (Figure 2), created mainly an erosional escarpment between 850 and 900 ft. asl (260-274 m asl). Present Lake Erie elevation is 570 ft asl (174 m asl). As the LIS retreated to the Alden, Buffalo, Niagara Falls and Batavia moraines (Figure 3), the lake level dropped to a new level termed Glacial Lake Warren, which deposited beaches along the field trip route from 820 to 850 ft. asl (250-260 m asl) between 12,700 and 12,500 ^{14}C yr BP. Following Glacial Lake Warren, lower lakes termed Grassmere, Lundy, Algonquin and Dana existed; these lakes pre-date non-glacial Lake Tonawanda (see below), which existed from slightly before 12,000 ^{14}C yr BP up to ~9000 ^{14}C yr BP. See shoreline elevations and relative amounts of postglacial uplift on Figure 8.

Key chronological constraints on the glacial history of western New York (from Muller, 1977; Calkin, 1970).

22,800 ^{14}C yr BP	Uppermost organic materials in the buried St. David's gorge that pre-date the LGM
14,100 to 13,400	Valley Heads, Lake Escarpment, Gowanda Moraine deposits
13,000	Lake Whittlesey, Hamburg Moraine
12,700	Lake Warren (high stand), Alden Moraine
12,500	Lake Warren (low stand), Batavia Moraine, Niagara Falls Moraine
12,400 to 9,000	Existence of Lake Tonawanda
12,200 to 11,000	Lake Iroquois (main phase)

37.5 Take a left onto River St. – a small road that may not be marked.

38.3 Turn left onto Main St. just after crossing Tonawanda Creek.

38.4 Veer right onto Route 63 as it departs Route 5.

40.8 Turn left onto Galloway Rd. (Figure 11). This road closely follows the Batavia moraine.

The Batavia moraine. The Batavia moraine near Batavia has noticeably greater and more irregular relief than the moraines that will be visited to the north and west. This is due, in part, to the formation of some of the younger moraines at a submerged ice front (Figure 7). In this environment moraines are subject to being covered by lacustrine sediments and then to being winnowed and eroded by waves as lake levels fall. The west end of the Batavia moraine (930+ ft asl) projects above the elevations of Lake Warren, and thus it would have escaped wave erosion when an eastern finger of Lake Warren formed a narrow extension into the Genesee Valley with shorelines at current elevations close to 860 ft asl near Geneseo, NY. While driving along this Batavia moraine segment, note its dimensions and relief for comparison with the more subdued Barre moraine to be visited later (Figures 3, 5). According to Calkin (1970) the Batavia moraine is believed to have formed around the time of the lowest Lake Warren stage, which coincided with ice recession from that position (Figure 3). Lake Warren had three phases, Warren I and II are higher and older, Warren III is the lowest and youngest, and followed a short-lived drop to a "Lake Wayne" stage (Figure 8).

42.5 Turn right onto Downy Rd.

43.2 Turn left onto Batavia – Oakfield TNL Rd. At mileage 46.0 route crosses crest of Batavia moraine.

46.5 Turn right onto Maple Rd.

47.4 Traveling North, Maple Rd. drops off the Onondoga Escaprment. Old quarry and recycling center exposes Onondoga limestone (Middle Devonian). Note how, in general, the region's resistant bedrock units lead to relief (30-100 ft. escarpments, Figure 12) that dwarfs the glacial topography. **STOP 2.** Examine the nature of the resistant Onondaga Formation.

49.2 Turn left onto Ham Rd.

49.5 Turn right onto Knowlesville Rd.

50.3 Turn right onto Lewiston Rd.

51.0 Crossing Nichols Hill drumlin. Note height and trend of this prominent drumlin.

51.6 Drive straight through intersection as Lewiston Rd. veers right. You are now on Lockport Rd.

53.4 Turn left onto Albion Rd.

55.3 Begin ascent of drumlin along its axis.

55.7 Pullout on right side of road affords nice view of drumlin relief and inter-drumlin bog (Figure 13). The two drumlins here, trending WSW, show the direction of ice flow during the late stages of the last glaciation. **STOP 3.**

Tonawanda Lowland. This location is approximately one mile north of the southern edge of Lake Tonawanda (note surrounding wetlands), which was nearly 7 miles wide at this longitude. Lake Tonawanda's northern limit was determined by the rising dip slope of the Lockport Escarpment. The southern limit was formed, in part, by moraines (Figure 3) and by the gradual increase in elevation toward the Onondaga Escarpment (Figure 7). Lake Tonawanda formed following the lowering of Lake Warren toward the Lake Iroquois level, which is north of the Lockport Escarpment (Figure 3). Lake Tonawanda had several northerly outlets (Figure 3, Arrows), which are progressively older and higher toward the east. Lake Tonawanda waters flowed off the escarpment into Lake Iroquois, when it first formed. As shown on Figure 2, the easternmost outlet formed first and was succeeded in turn by the more westerly outlets as indicated by letters A through E on Figure 3. Current threshold elevations near the eastern (Holley outlet) are near 650 ft asl, whereas the threshold elevations near Gasport are closer to 600 ft asl. The westerly displacement of the outlets was dictated by the greater amount of postglacial rebound toward the northeast (Figure 8). Eventually the Lake drained completely after the outflow was shifted toward the modern position of the Niagara River.

56.1 Veer left as road descends northern drumlin flank.

58.1 Road now called Eagle Harbor Rd. Continue through intersection. Note stony till just south of intersection. Road crosses Barre moraine.

59.8 Turn left into Eagle Harbor Sand and Gravel quarry. Part of the Burma Woods esker and kame moraine complex. Dozens of small-scale quarries and this large one in this vicinity. **STOP 4**. Planned lunch stop. After visit, exit driveway and turn left.

Burma Woods Esker. This esker and outwash complex (seen in a modern excavation) may have formed during the earliest stage of Lake Tonawanda, when the ice had just retreated from the Barre moraine (Muller and others, 2003). Muller and others (2003) note that the position of this and similar eskers indicates early southward meltwater flow into Lake Tonawanda. Although the esker deposits are not currently visible in the modern pit, it is possible that the deformed sediments being excavated are contemporaneous with an ice position fronting on early Lake Tonawanda. The sediments visible in August 2006 at the working face (Figure 15) indicate that saturated sediments were deformed by intraformational slumping, and possibly by upward groundwater discharge immediately in front of the ice margin. This will be the longest stop on the trip (including lunch) and will allow time for discussion of how the currently exposed sedimentary structures may relate to the history of ice recession from the Barre moraine, or to the development of Lake Tonawanda.

60.3 Turn left onto Maple St. and pull off to the right at one tenth of a mile to see the roadcut through the Burma Woods esker. This esker is only several meters high, but contains well-rounded sand and cobbles with some boulders. **STOP 5.** Watch for traffic.

60.9 Turn left onto Pine Hill Rd.

62.3 Turn right onto Gray Rd.

63.0 Turn right onto Hemlock Ridge Rd. This road is built atop the Barre Moraine. Note how the Burma Woods esker trends perpendicularly to the Barre Moraine (Figures 3, 5).

65.3 Our route takes a quick jog. Turn left onto Shelby Rd, then immediately right onto Fletcher Chpl.

68.7 Cross S. Gravel Rd.

69.7 Turn left into the trailhead parking lot just after crossing the small creek. This little valley held one of the spillways of Lake Tonawanda. **STOP 6.** Depart parking lot turning left. Take an immediate left onto W. Shelby Rd.

Lake Tonawanda spillway. This is the location of one of the main spillways from Lake Tonawanda across the Lockport Escarpment south of Medina (see Figure 3 and discussion for Stop 3). At this location the lake outflow was able to cut down through the Barre Moraine, probably beginning at a low saddle in the moraine crest.

71.2 Cross Salt Rd.

74.1 Cross Griswold St.

75.1 Left at T-intersection onto Graham Rd.

75.6 Stay straight onto Route 77.

78.4 At junction of Rt. 77 and Gasport Road turn south.

79.3 Turn right on Lincoln Ave.

79.6 Cross Lake Tonawanda outlet channel.

80.9 Turn right on Hollenbeck.

82.5 Turn right on Rt. 77.

82.8 Turn left onto Mill Road (parallel to outlet).

84.2 Left back onto Gasport road.

84.5 Left into Victor Fitchlee Park for rest stop and short walk into Royalton Ravine (lake outlet at East branch of Eighteenmile Ck). **STOP 7**. This Park has restroom facilities and is located adjacent to a deep outlet channel passing through Gasport. A short walk down Royaltine Ravine leads to the broader Tonawanda channel, and the Ravine exposes shaley bedrock, which indicates how thin the glacial drift is at this location. Leave parking lot turning left back onto Gasport Rd.

84.7 Turn right onto Mountain Rd.

85.4 View to left off of Niagara Escarpment. Smoke stack in distance on shore of Lake Ontario, 12 miles away.

85.7 Turn left onto Bolton Rd. Road descends the Niagara Escarpment.

85.9 Cross Route 31.

86.1 Turn left onto Telegraph Rd., which follows the Erie Canal.

87.0 Turn right onto Main St.

87.5 Turn left onto Slayton-Settlement Rd.

92.5 Left onto Lake Ave.

93.8 Right onto Market St. at stop sign just after crossing the canal bridge. Note series of locks to get the Erie Canal across the Niagara Escarpment.

94.9 Right onto Main St.

95.3 Right onto N. Transit St.

96.0 Left onto Outwater Dr.

96.6 Outwater Park. Overlook to Lake Ontario from top of Niagara Escarpment. **STOP 8**. Proceed out exit of park onto residential street. Somewhere between here and Michigan St. park and walk to footpath 100 feet down Michigan St. from Craine St. – see Mi. 98.8. (Parking is difficult at this Stop and maybe impossible for a bus.)

96.7 Turn right onto Craine St.

97.0 Turn right onto Michigan St.

97.0 Hidden driveway on right leads to footpath to old quarry site where glacial drift has been stripped away revealing a striated fossiliferous surface of the Lockport Dolomite. **STOP 9.**

98.0 Turn left onto Gooding St.

98.7 Good exposure on left of Medina Group in Niagara Escarpment. Alternate **STOP 9**.

99.5 Turn left onto Old Niagara Rd.

102.3 Get onto Route 104 going west. Intersection is awkward; take a right at stop sign then a quick left onto Route 104. Route 104 follows the glacial Lake Iroquois beach.

Glacial lake Iroquois. Glacial Lake Iroquois is probably the best known of the proglacial lake stages in the Ontario basin, because of its prominent relief and the location of the original Route 104, which followed its course along much of the lake shore. The development of the Niagara Gorge and the retreat of Niagara Falls, and their relationship to Lake Tonawanda, are complex and interesting stories, described recently by Brett and Calkin (1996) in the guidebook for the Northeast Section Meeting of the Geological Society of America in Buffalo.

Lake Iroquois formed around 12,200 ^{14}C yrs BP, and persisted for several hundred years, based on existing chronology and the strong development of its shoreline. Many of its features are as well developed as those seen along the modern shoreline of Lake Ontario. It is not generally realized that Lake Ontario subsequently reached a much lower level when the ice sheet finally vacated the north flank of the Adirondacks (Covey Hill outlet) and Lake Iroquois waters escaped to the Atlantic Ocean (glacially lowered) via the St. Lawrence Valley. Since reaching this lower level, which was between 200 and 300 feet lower at Rochester, NY, the modern lake has been steadily rising to its present level. This is the result of postglacial tilting of the basin and uplift of the threshold that controls flow out through the St. Lawrence River. It was previously thought that Lake Ontario was a marine or brackish arm of the ocean for a short period (Champlain Sea), but modern studies have demonstrated that marine waters did not advance much west of Ogdensburg, NY, during that post-Iroquois, early Lake Ontario low stand. Further reading about the glacial history of the Ontario and Erie basins is contained in Geological Association of Canada Special Paper 30, *Quaternary Evolution of the Great Lakes* (Karrow and Calkins, 1985), and in Special Paper 35, *The Late Quaternary Development of the Champlain Sea Basin* (Gadd, 1988).

104.6 Turn right onto North Ridge Rd. Here, the road is still on a beach berm, but this beach is a spit-like feature that diverges westward from the main Iroquois beach strand.

104.9 Pull onto right shoulder. Stop to see sand and gravel of the Iroquois beach. **STOP 10.** Proceed westward on North Ridge Rd.

- IF TIME PERMITS, DRIVE TO LAKE ONTARIO -

106.0 Turn right onto Route 425. You immediately drive off Iroquois beach and onto flat Iroquois lake plain.

113.1 Turn left onto Route 18.

115.1 Turn right into Wilson Tuscarora State Park. Potential **STOP 11** (time permitting). Compare character of modern Ontario beach and its sediments with those most recently viewed at Stop 10.

END OF TRIP, Return by bus to Buffalo.

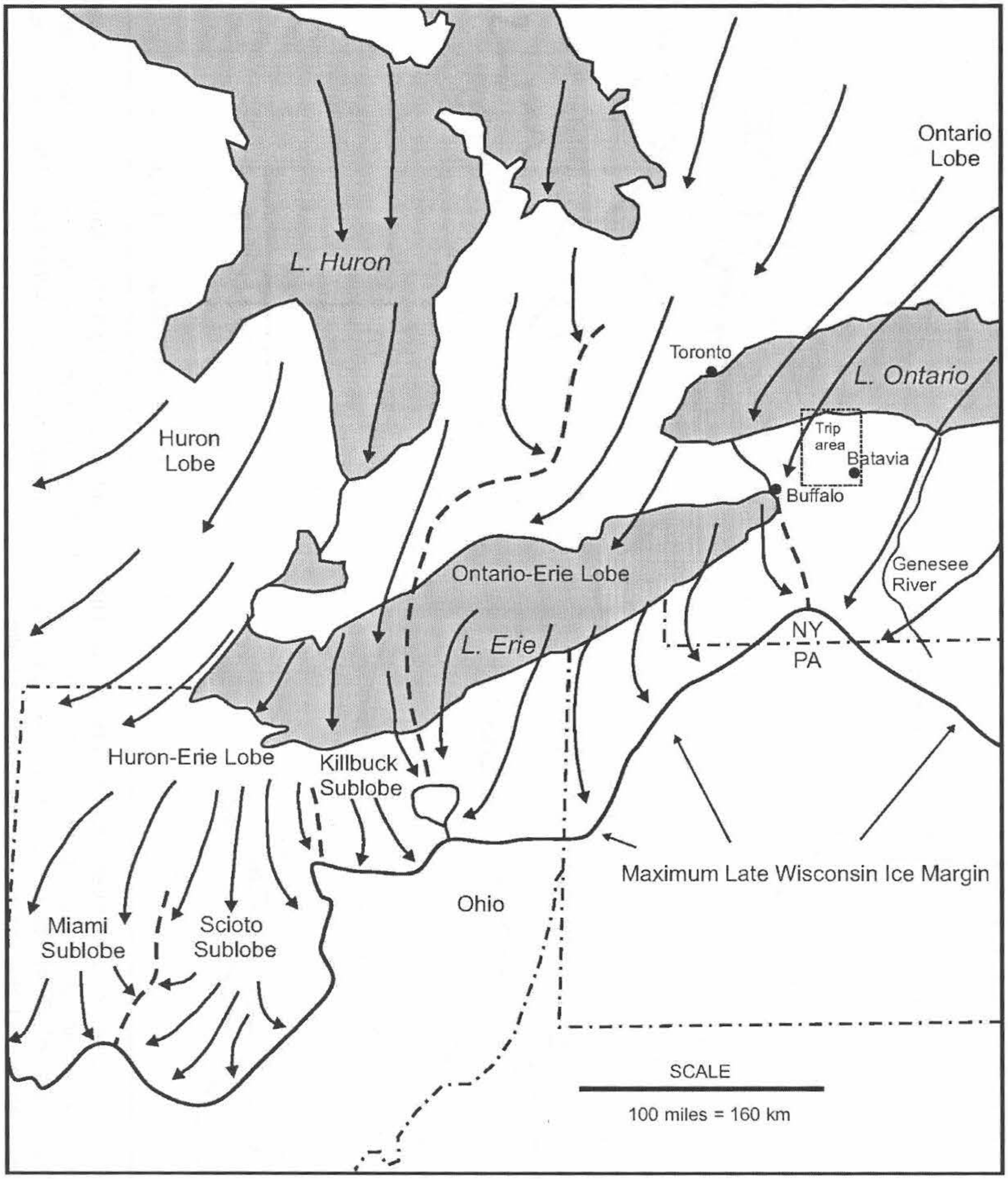


Figure 1. Position of Maximum Late Wisconsin ice margin in western Lake Ontario and Lake Erie basins. Large arrows show approximate flow lines in various sublobes. Trip area is outlined by box near Batavia, NY. See greater detail of trip area in Figures 2-6. Modified from Muller and others, 2003.

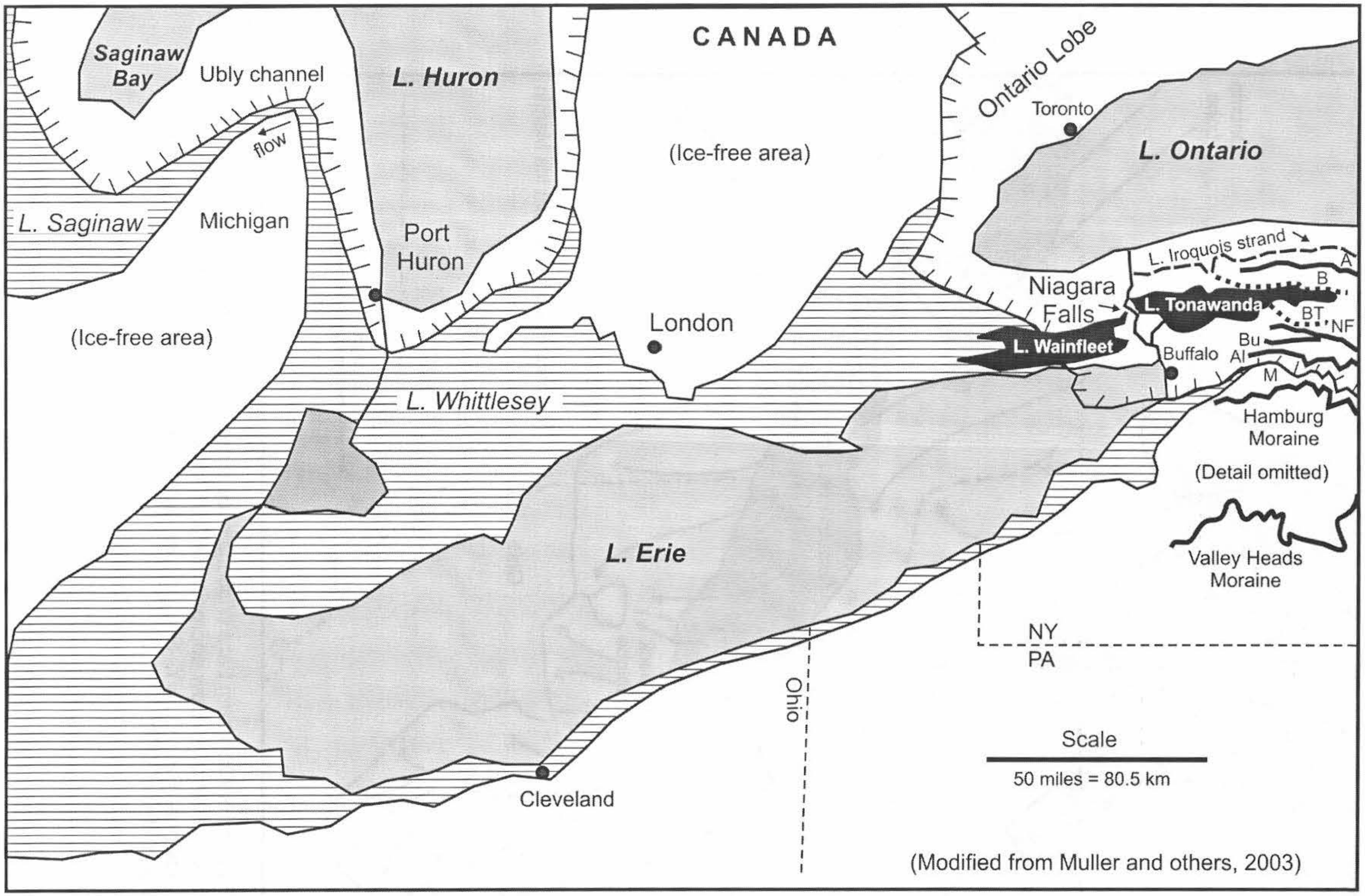


Figure 2. Ice position and selected geologic features near the end of Port Huron ice advance with extent of glacial Lake Whittlesey (13,000 to 12,700 ^{14}C years ago) ending at Marilla moraine. Lake Tonawanda-Wainfleet shown in black with positions of selected moraines [A=Albion, B=Barre (dotted), BT=Batavia (dotted), NF=Niagara Falls, Bu=Buffalo, Al=Alden, M=Marilla]. The conditions shown set the stage for the creation of Lake Tonawanda and Niagara Falls.

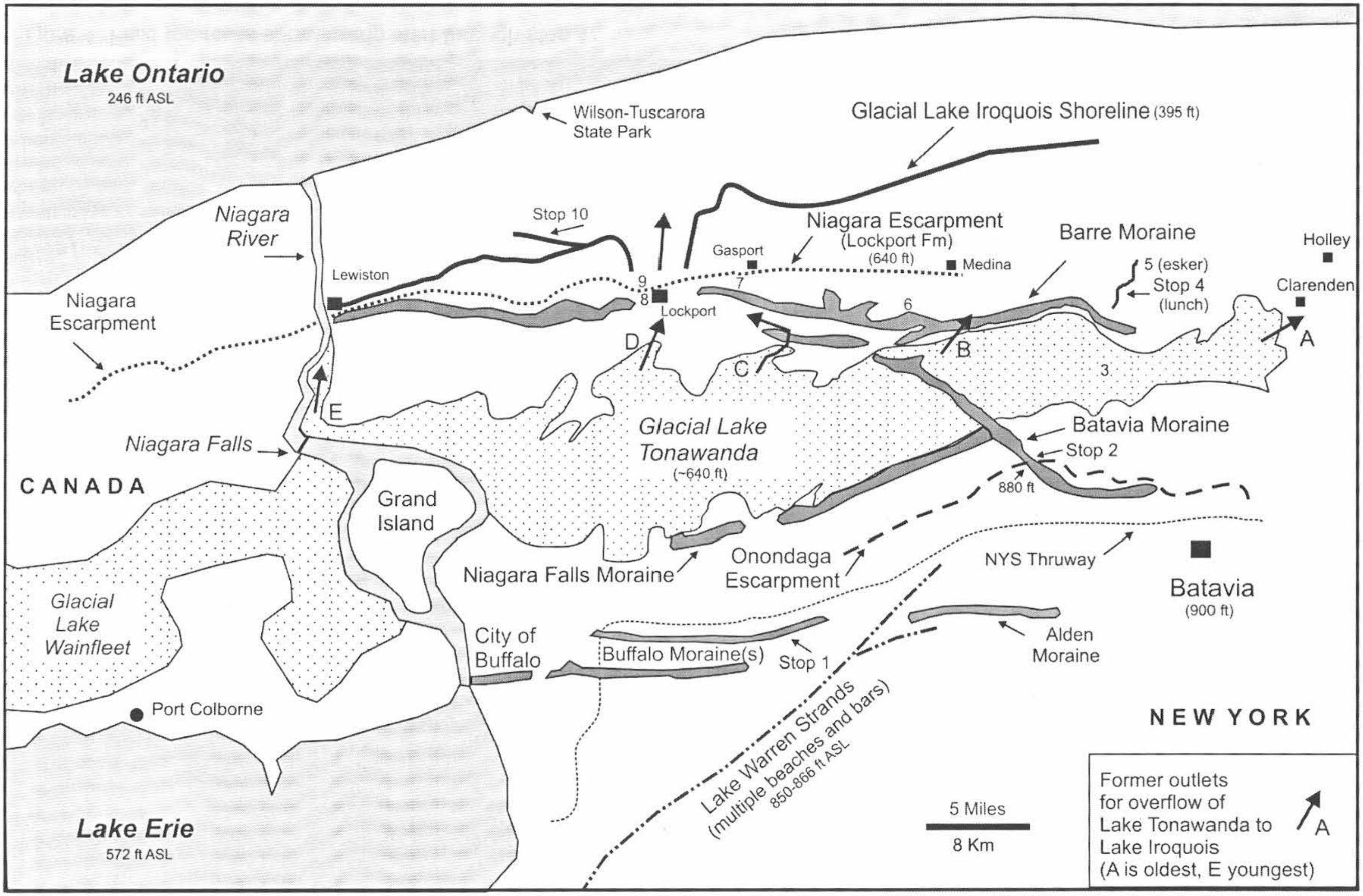


Figure 3. Geologic features to be visited and discussed on trip. Numbers 1-10 indicate locations of planned stops. Moraines, shorelines and other features compiled from map by Muller (1977) and figures in Muller and others (2003).

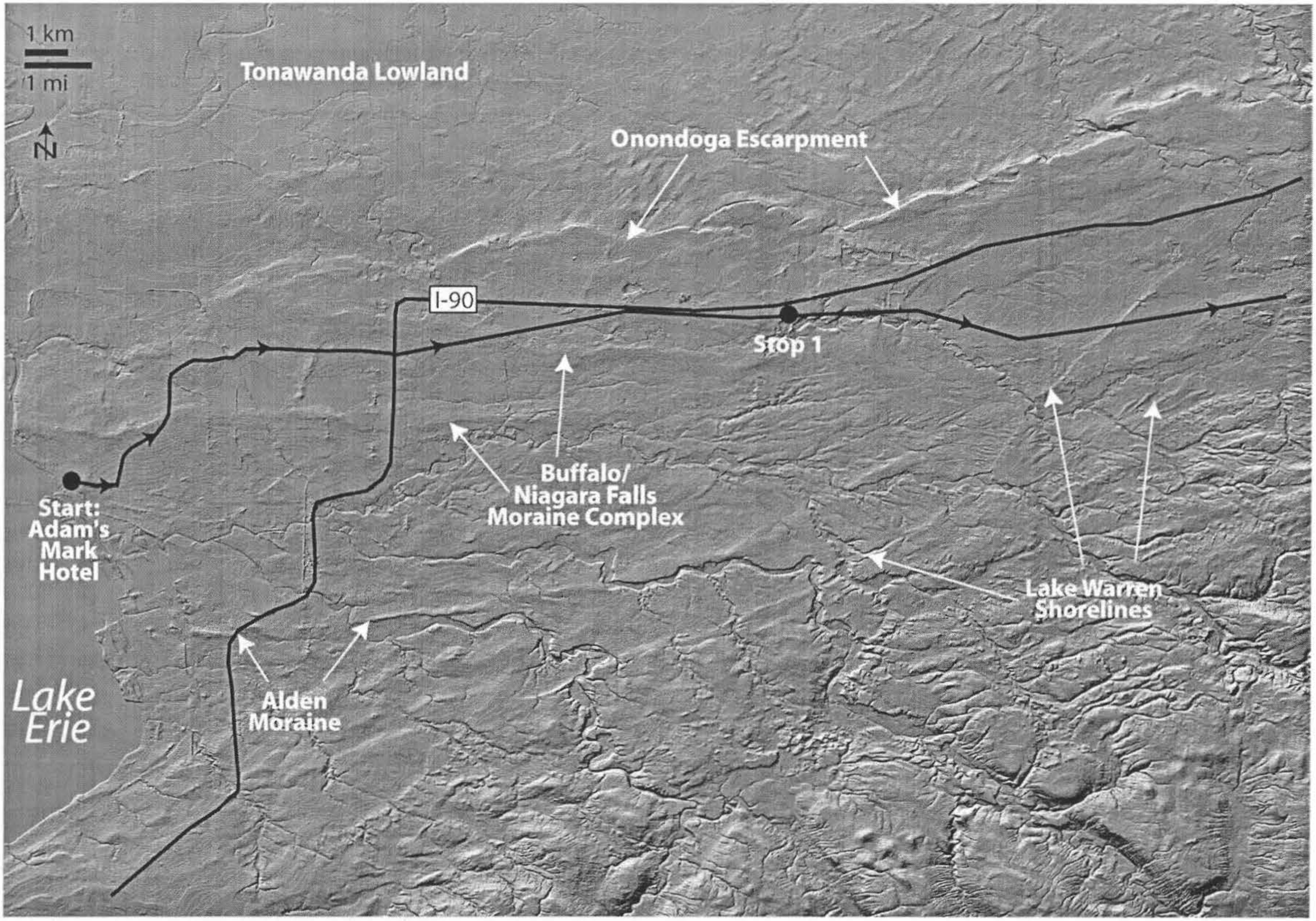


Figure 4. Field trip route showing trip start through stop 1.

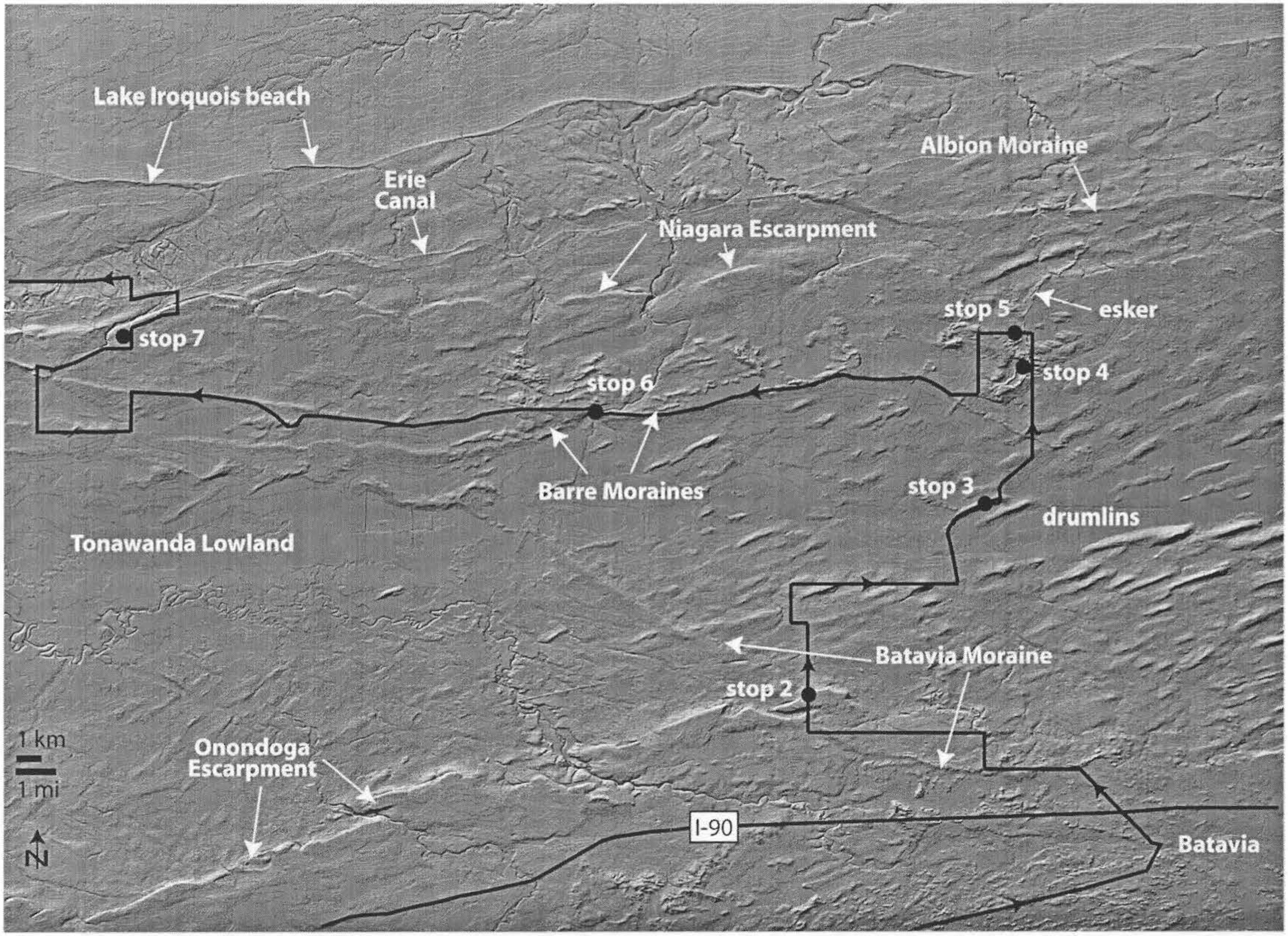


Figure 5. Field trip route showing stops 2 through 7.

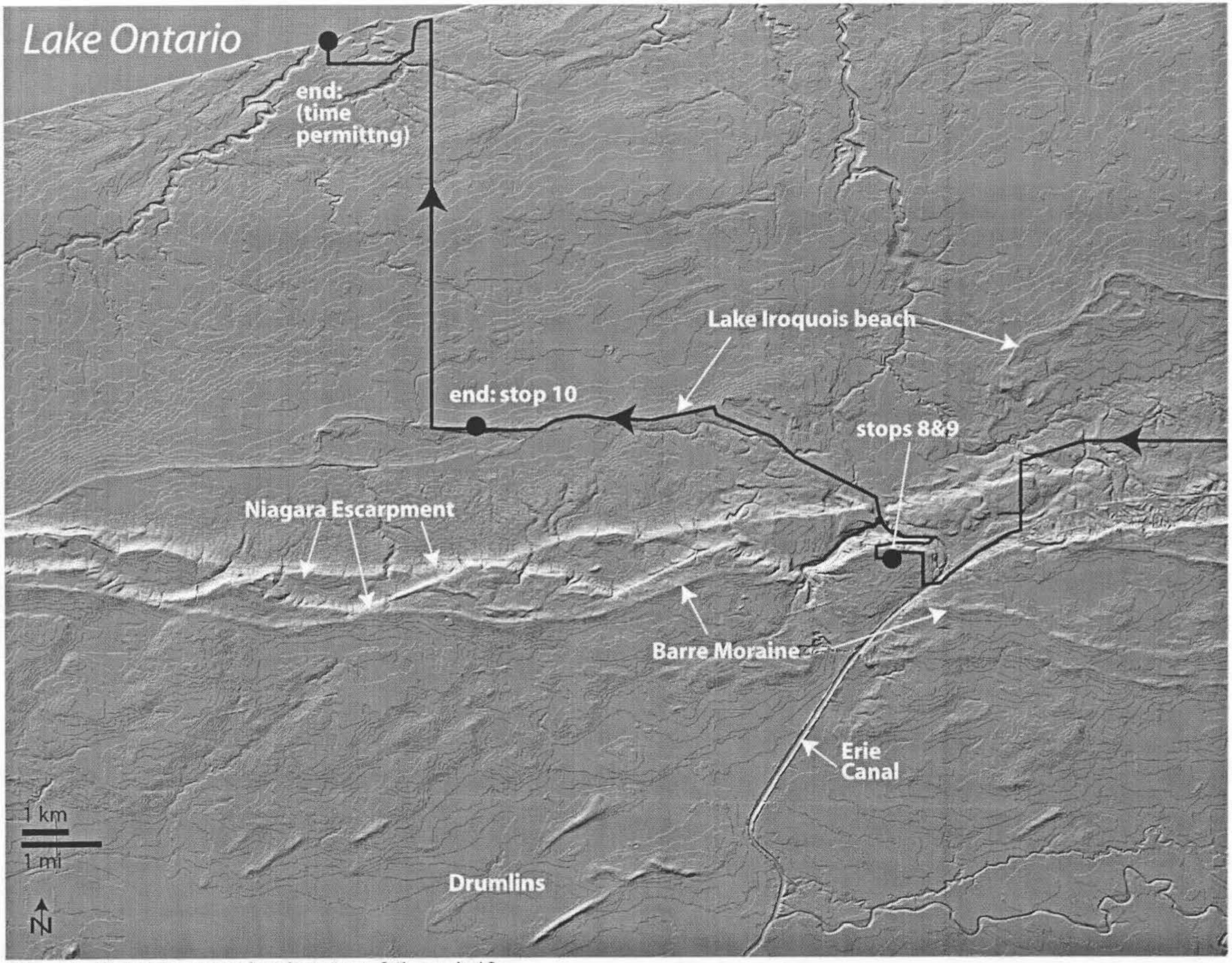


Figure 6. Field trip route showing stops 8 through 10.

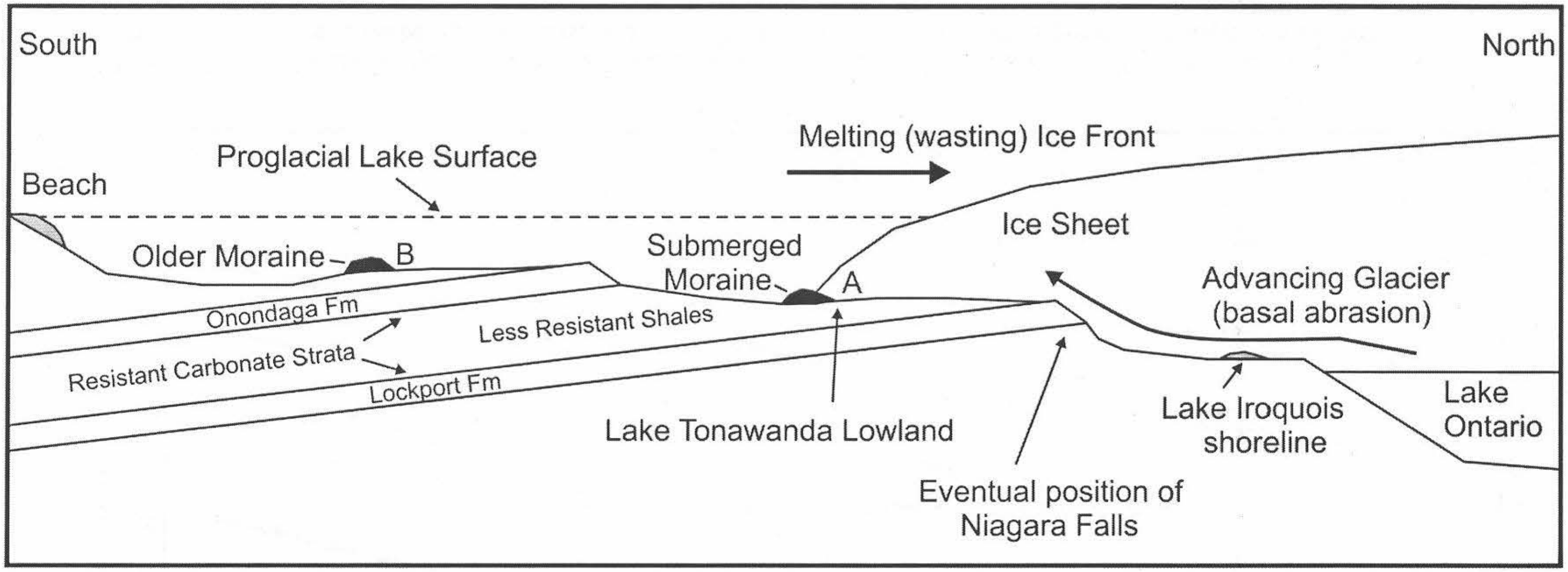


Figure 7. Schematic diagram of important topographic elements and resistant bedrock escarpments that controlled the development of existing geologic landforms as the Laurentide glacier retreated between 13,000 and 12,000 ^{14}C years ago. As the ice was melting back at the edge, the lower portion of the glacier was still advancing and eroding the bedrock. Beaches formed at the edges of glacial lakes also are referred to as "strandlines" or "strands". Some moraines formed under water in the shallow lakes (A), sometimes creating more subtle, low-relief landforms, also referred to as "morainal banks", "grounding-line wedges" or "DeGeer moraines". Some morainal deposits also were buried by fine sediments and then eroded by waves (B) as the lake surfaces were lowered to the next stage. This explains the subtle, smooth relief of some moraines. The ultimate level of modern Lake Ontario is shown and is still rising from a lower stand as a result of the postglacial tilting of the basin. Differential tilt of the Ontario basin is ongoing at about 1 ft/100 years from northeast (Ogdensburg) to southwest (Buffalo).

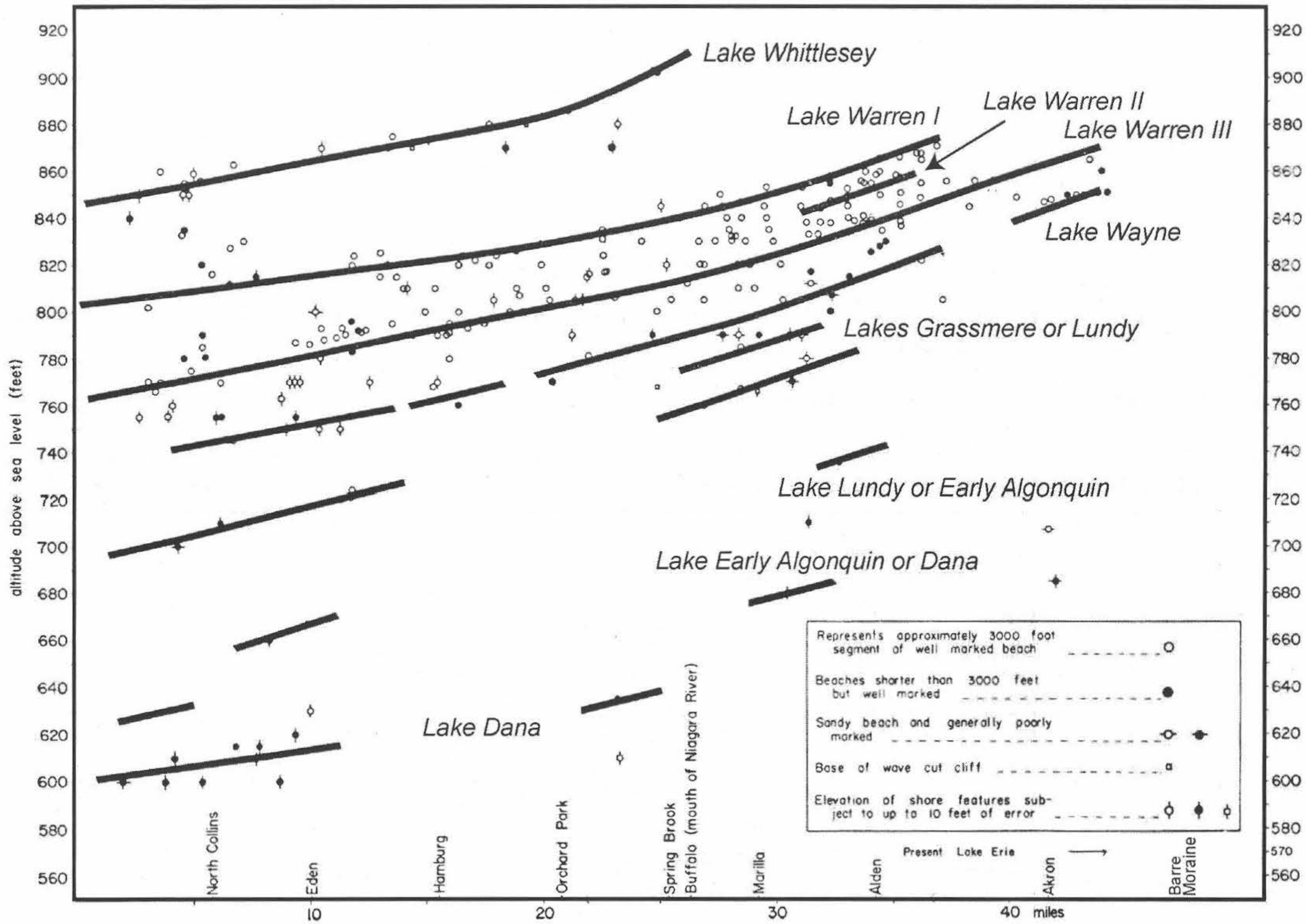
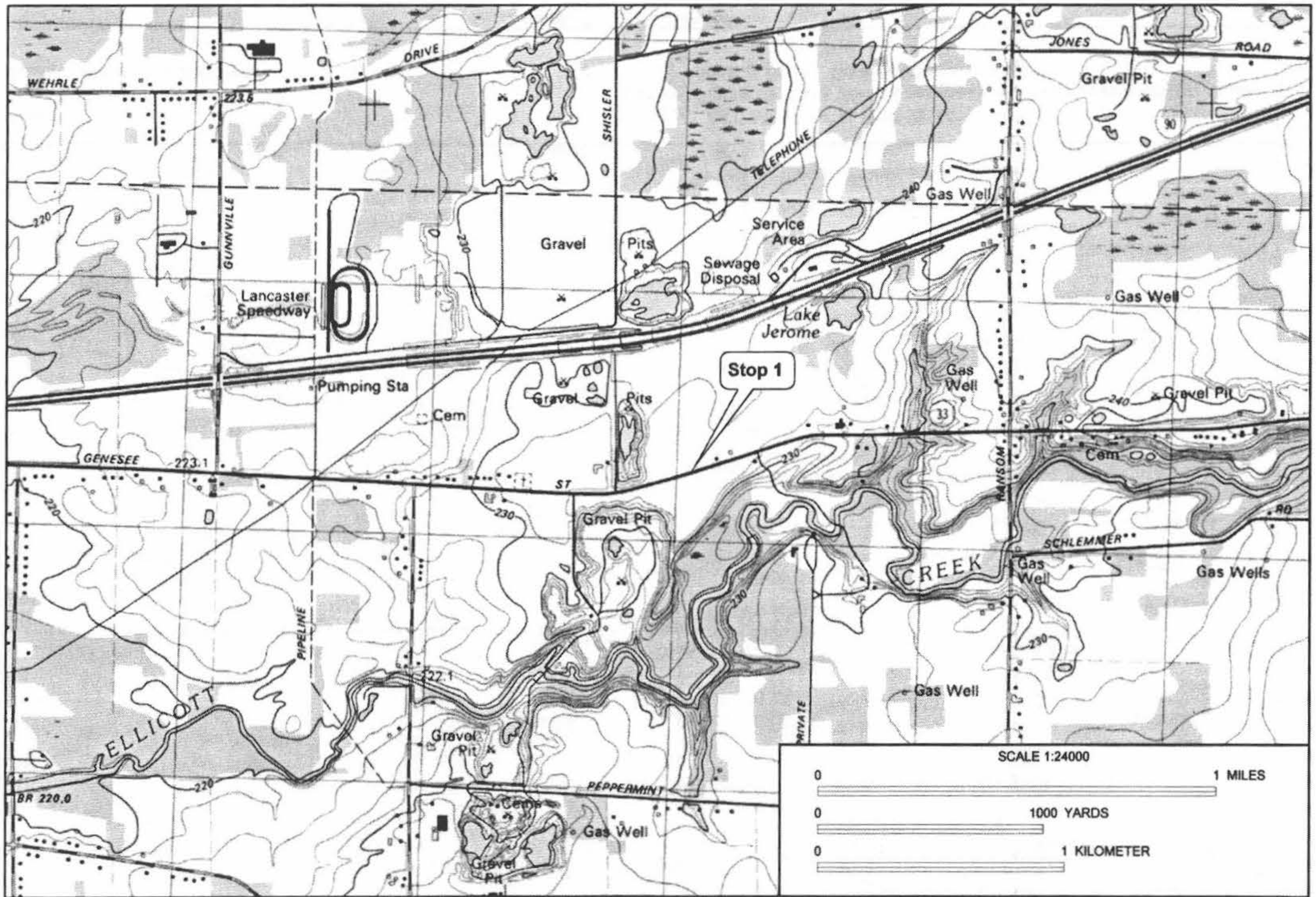
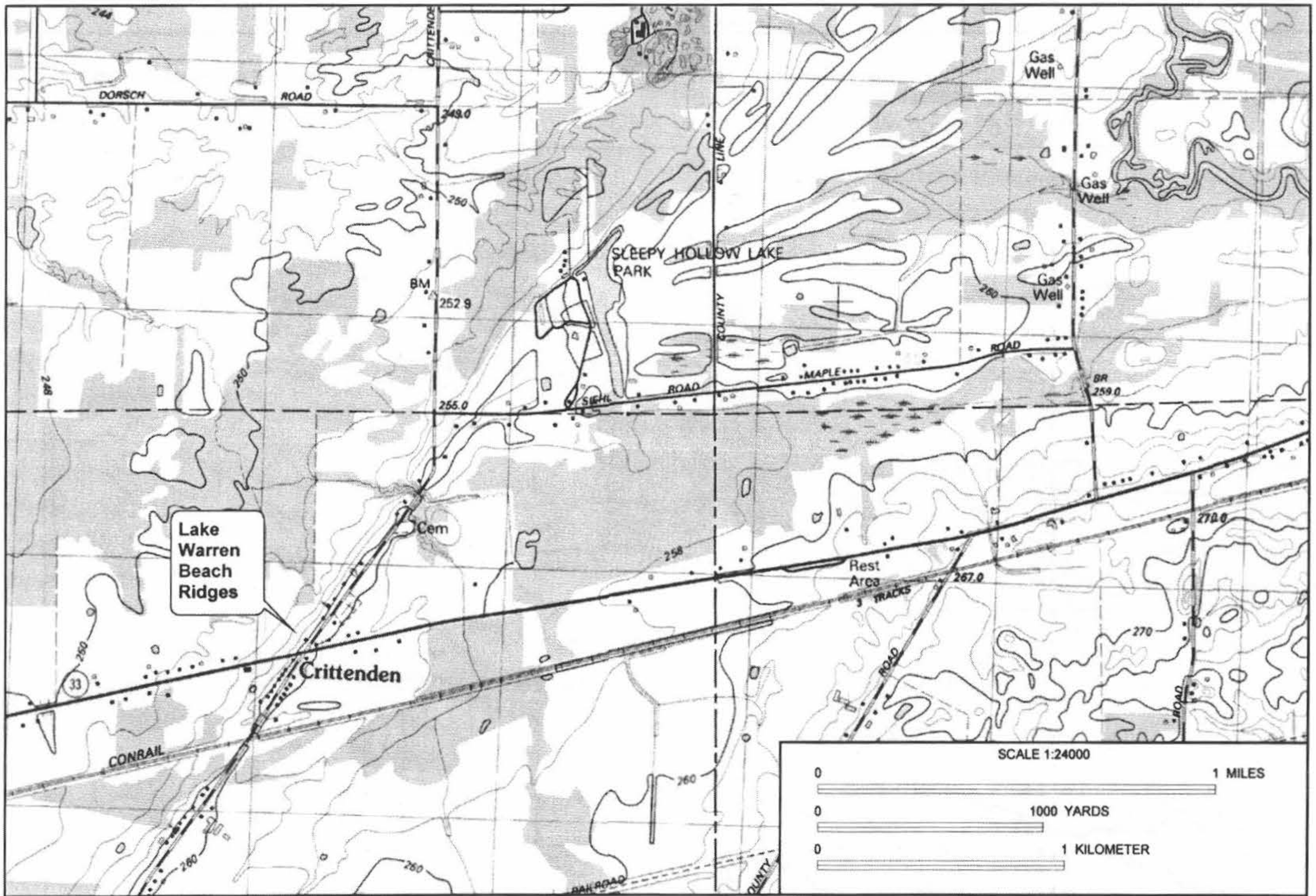


Figure 8. Glacial Lake shorelines in the Lake Erie Basin (modified from Calkin, 1970). The increasing elevation of the shorelines from southwest to northeast is a result of isostatic rebound from a greater ice load in the north.



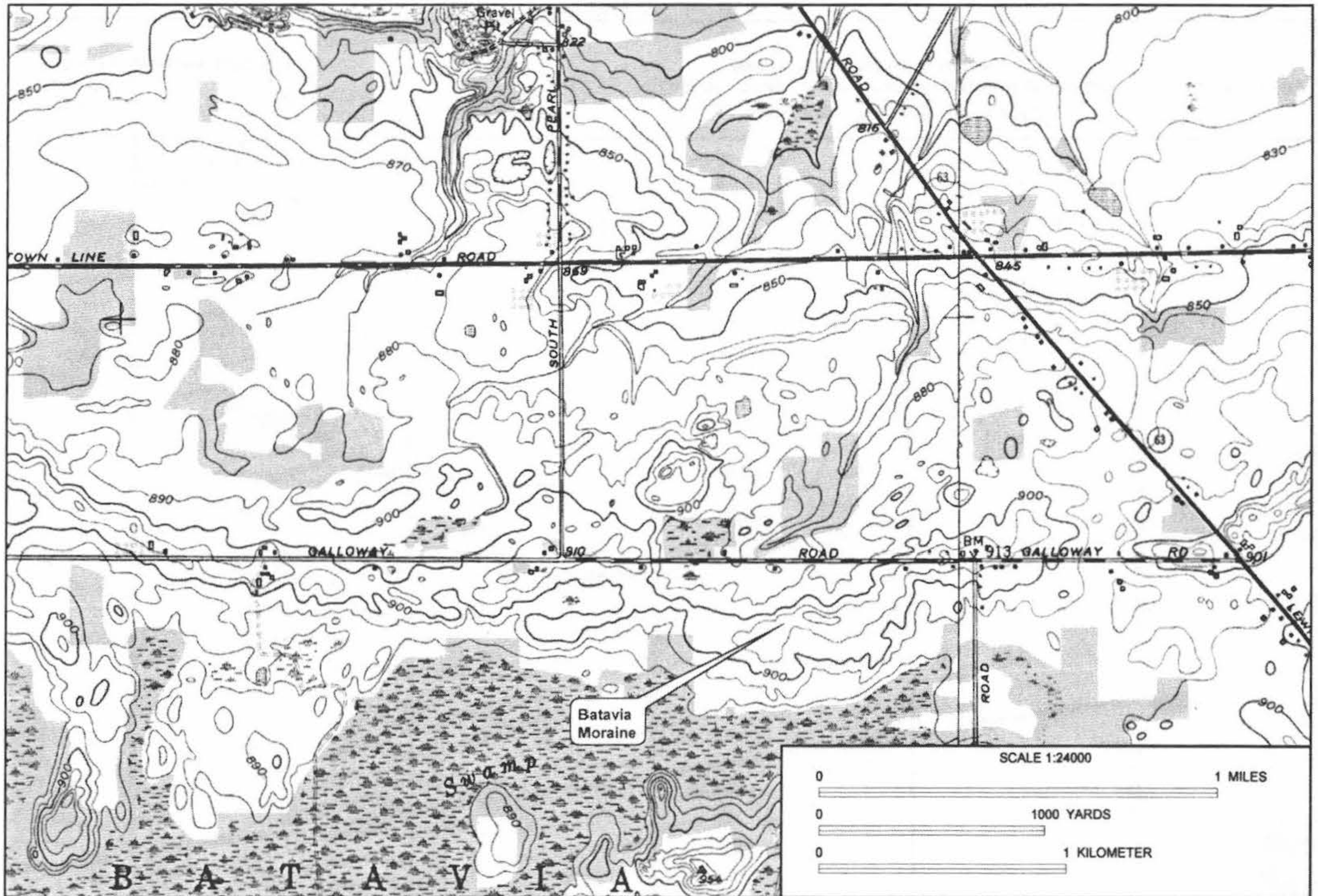
Name: LANCASTER
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 042° 56' 45.00" N 078° 36' 39.09" W
Caption: Figure 9. Buffalo-Niagara Falls moraine complex. Contour interval 2 meters.



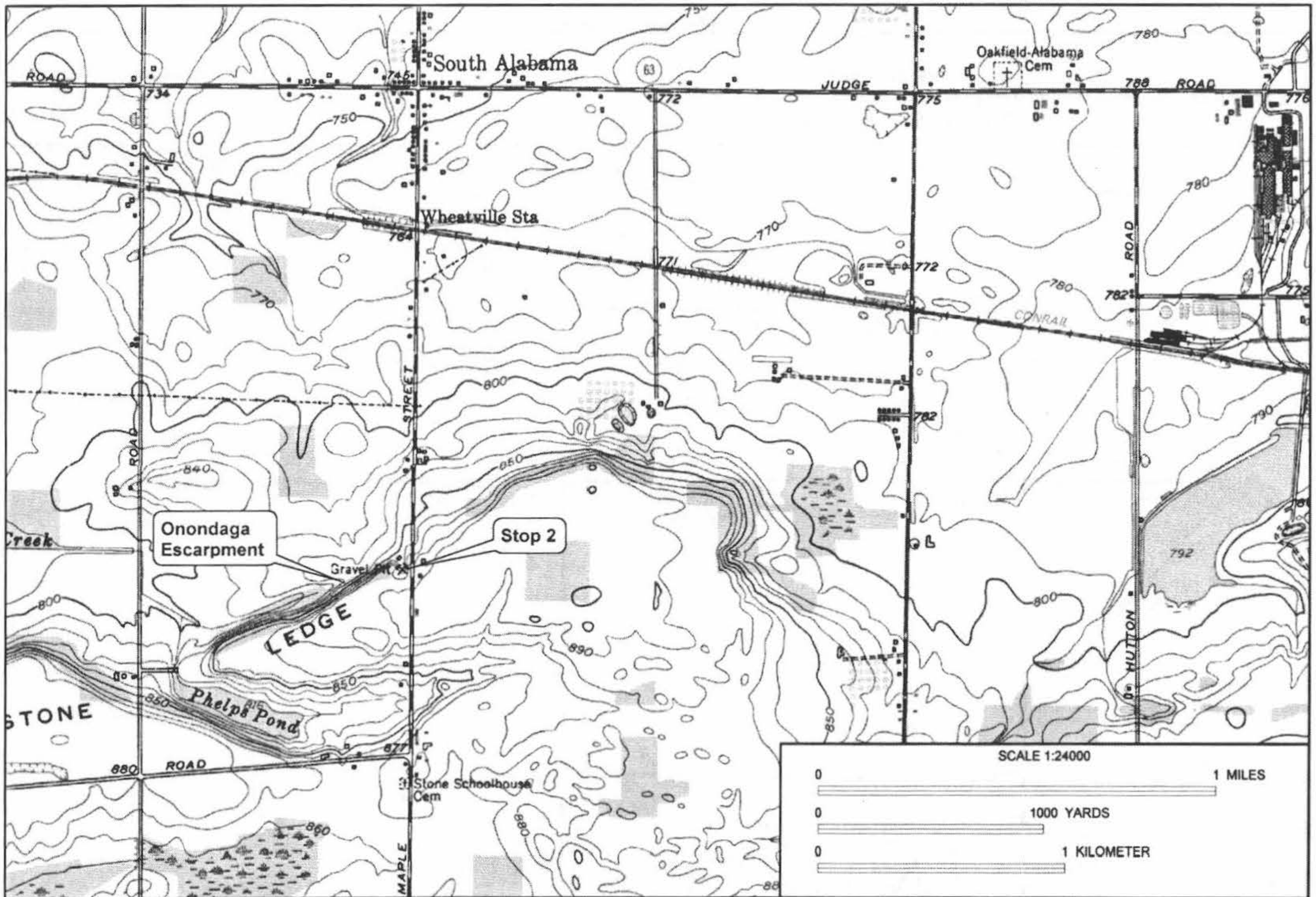
Name: CORFU
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 042° 57' 10.64" N 078° 28' 02.11" W
Caption: Figure 10. Lake Warren beaches fan out into several distinct ridges north of Rt 33. Contour interval is 2 meters.



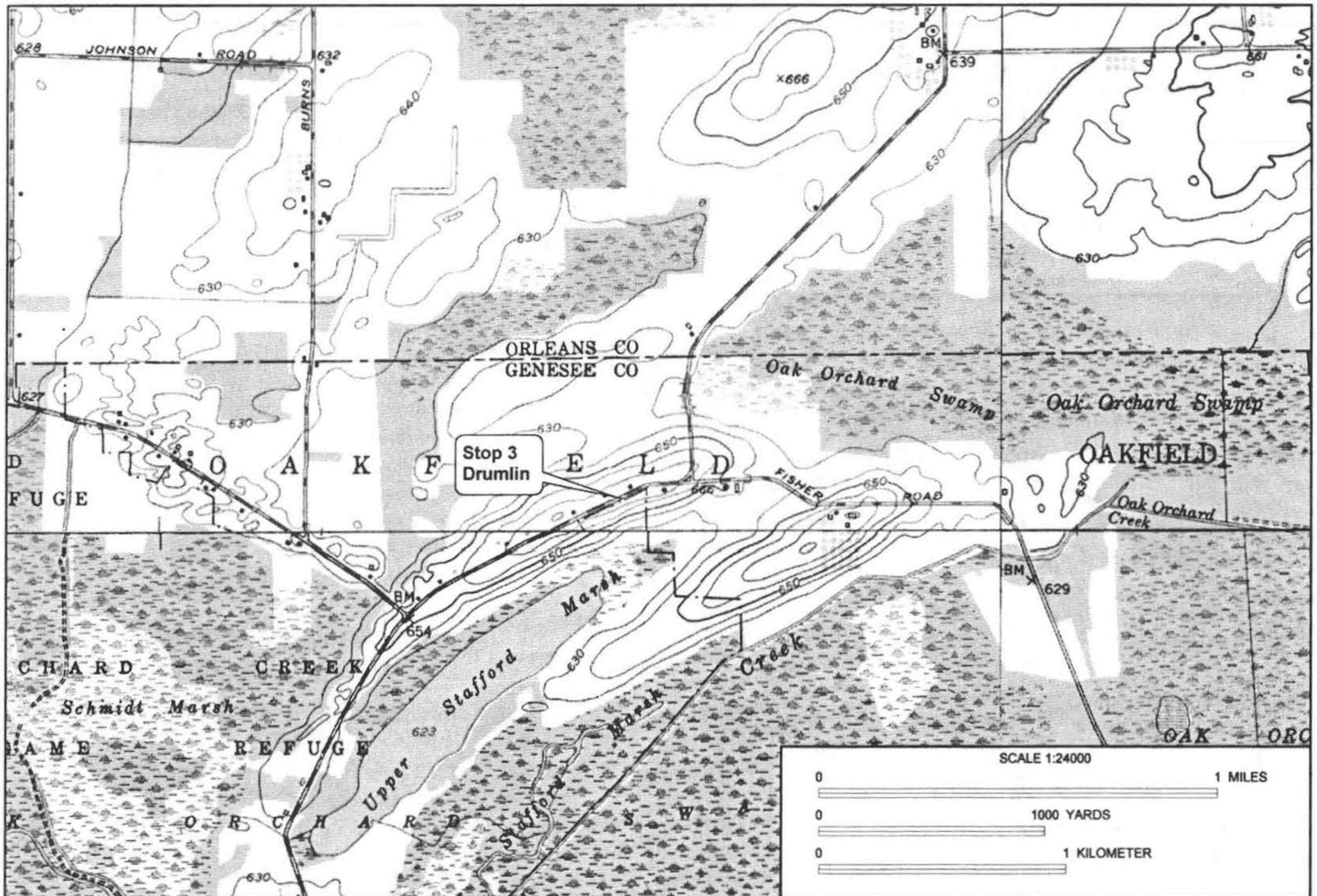
Name: OAKFIELD
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 043° 02' 12.32" N 078° 15' 53.46" W
Caption: Figure 11. Batavia moraine along Galloway Road; mile 42.6 to 44.3. Contour interval is 10 feet.



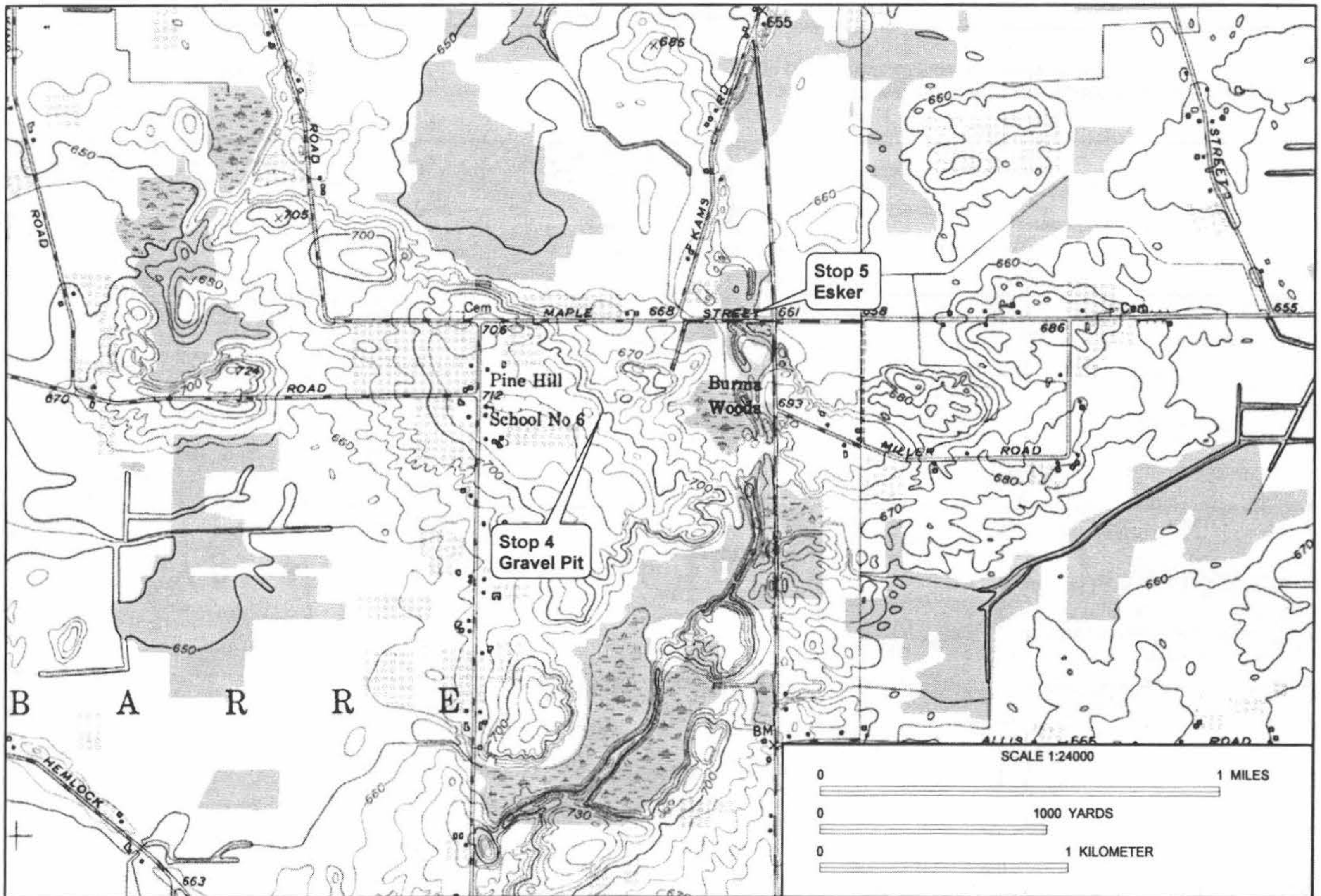
Name: OAKFIELD
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 043° 03' 38.07" N 078° 19' 25.50" W
Caption: Figure 12. Onondaga Escarpment at elevation of approximately 880 feet. Contour interval is 10 feet.



Name: OAKFIELD
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 043° 07' 39.96" N 078° 16' 01.17" W
Caption: Figure 13. Scattered drumlins idicate NE-SW flow of ice during late stage of glaciation. Contour interval is 10 feet.



Name: KNOWLESVILLE
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 043° 10' 49.68" N 078° 15' 35.82" W
Caption: Figure 14. Gravel pit near esker preserves soft-sediment deformation structures (Fig. 15). Contour interval is 10 feet.

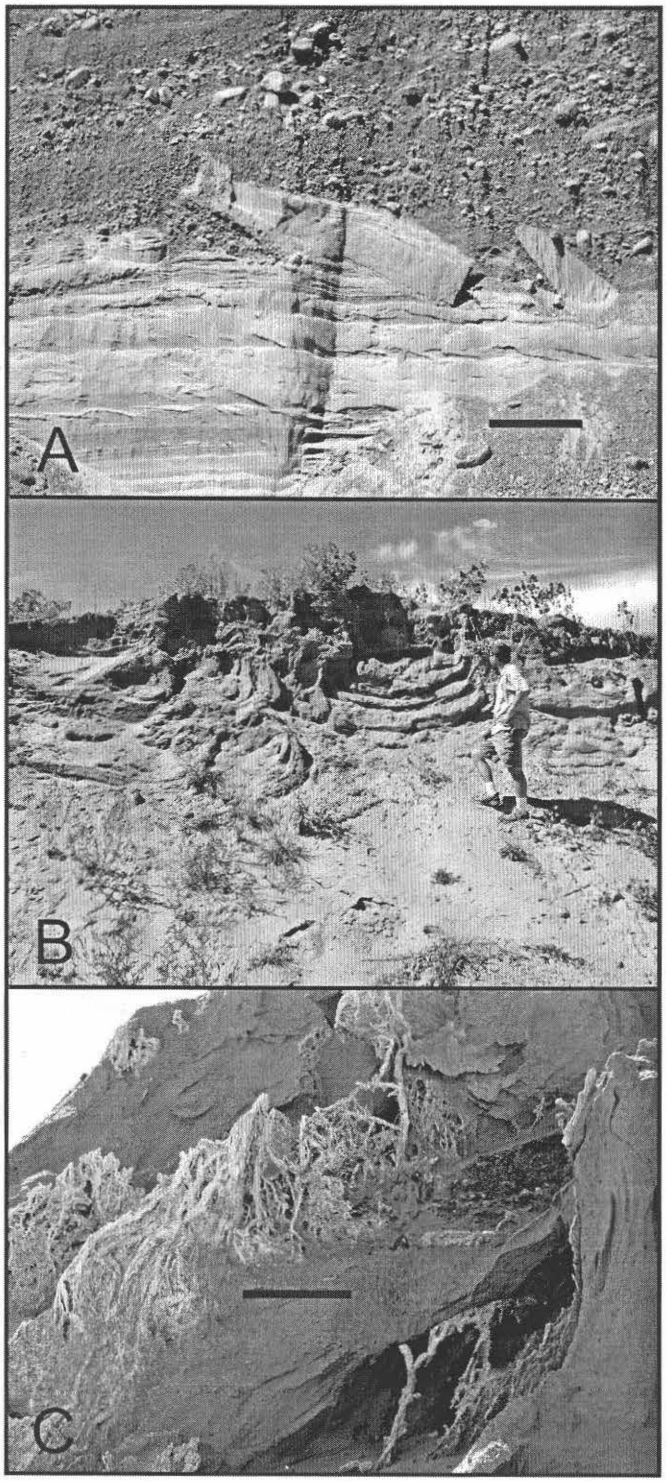
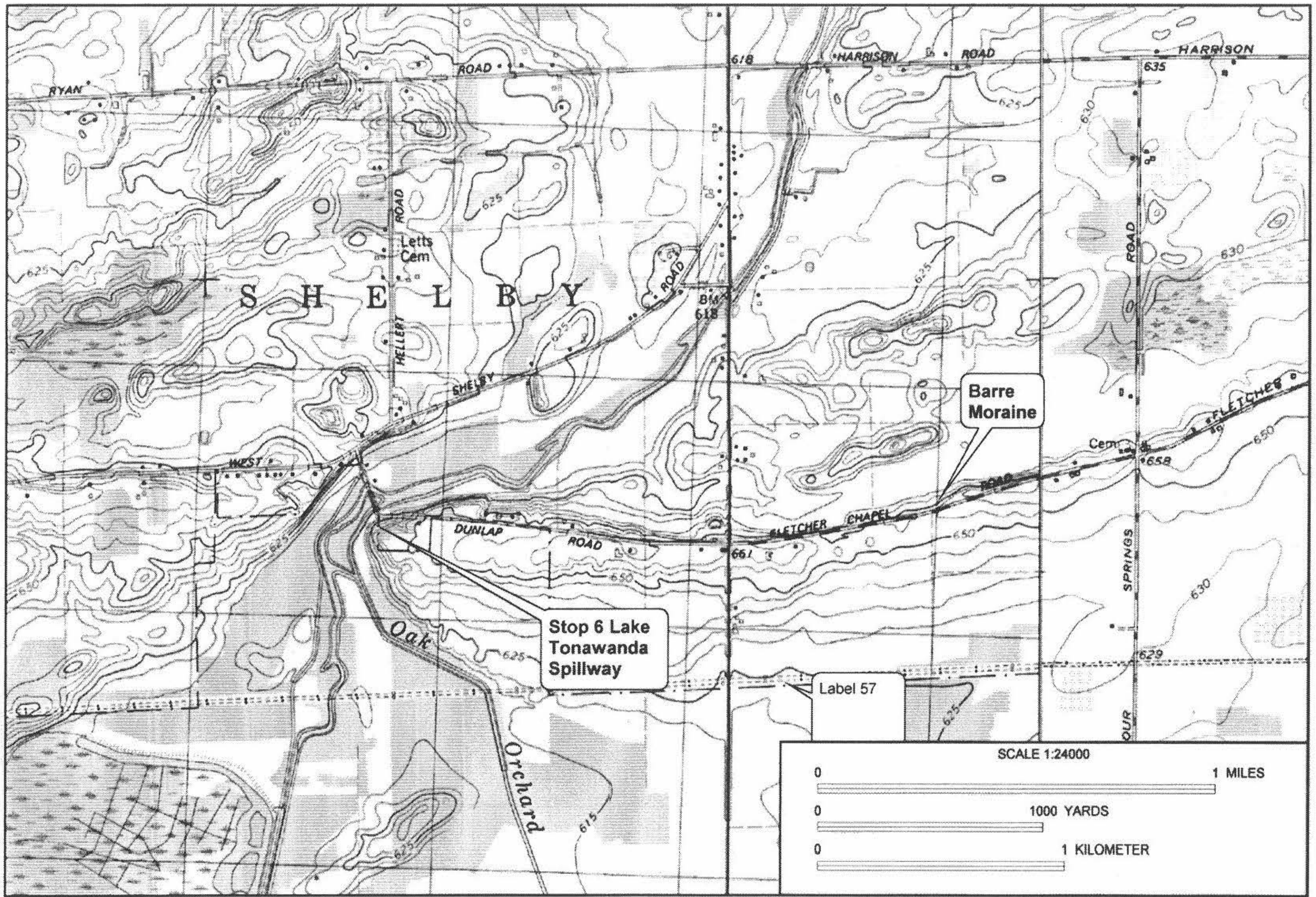
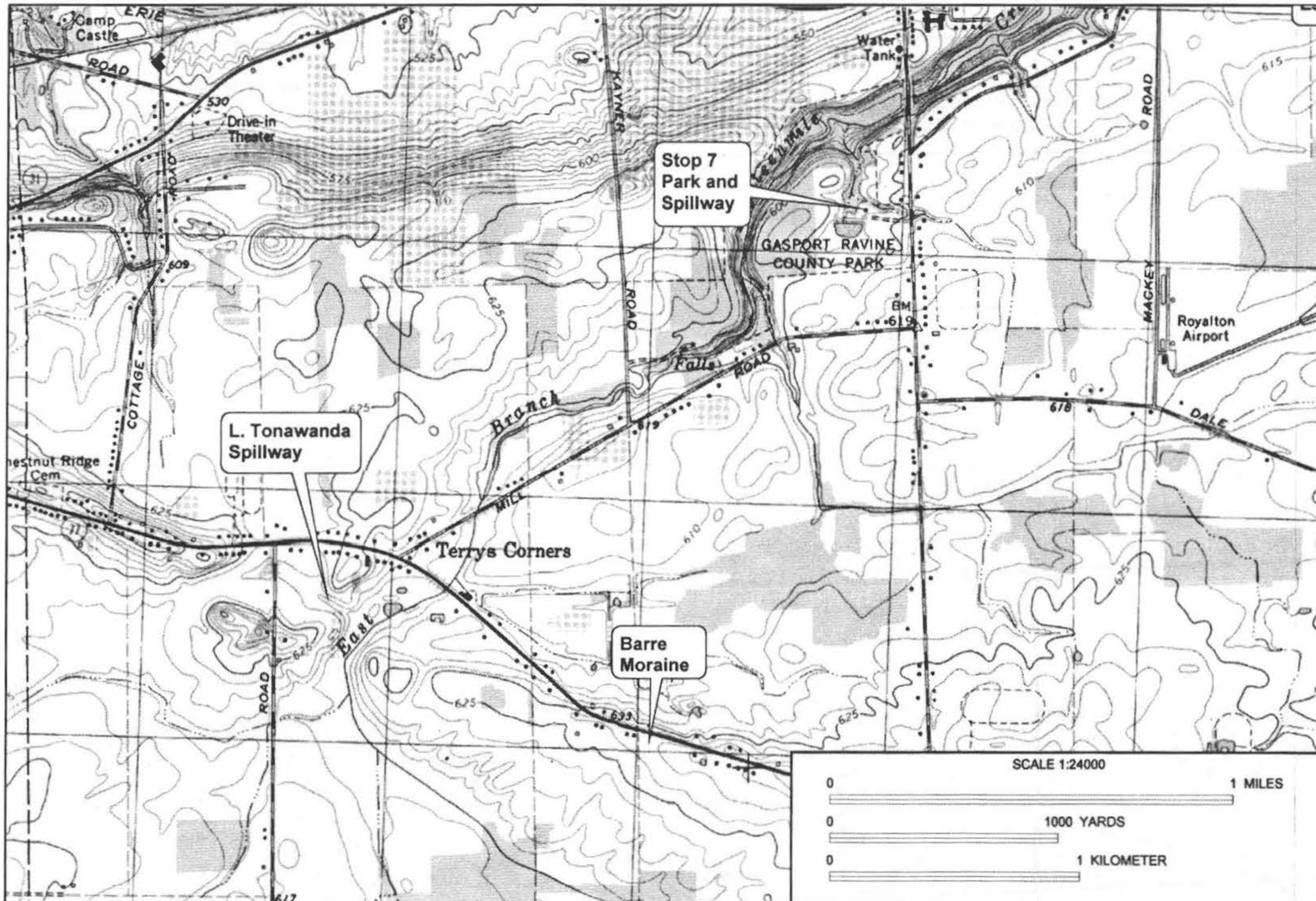


Figure 15. Gravel pit at Stop 4 preserves interesting sedimentary structures indicative of apparent brittle-style deformation (A) as well as soft-sediment deformation, possibly slumping and/or groundwater discharge (B). Root masses replaced by calcium carbonate are aligned along fracture traces(C). Scale: Bars in A and C are 1 foot.



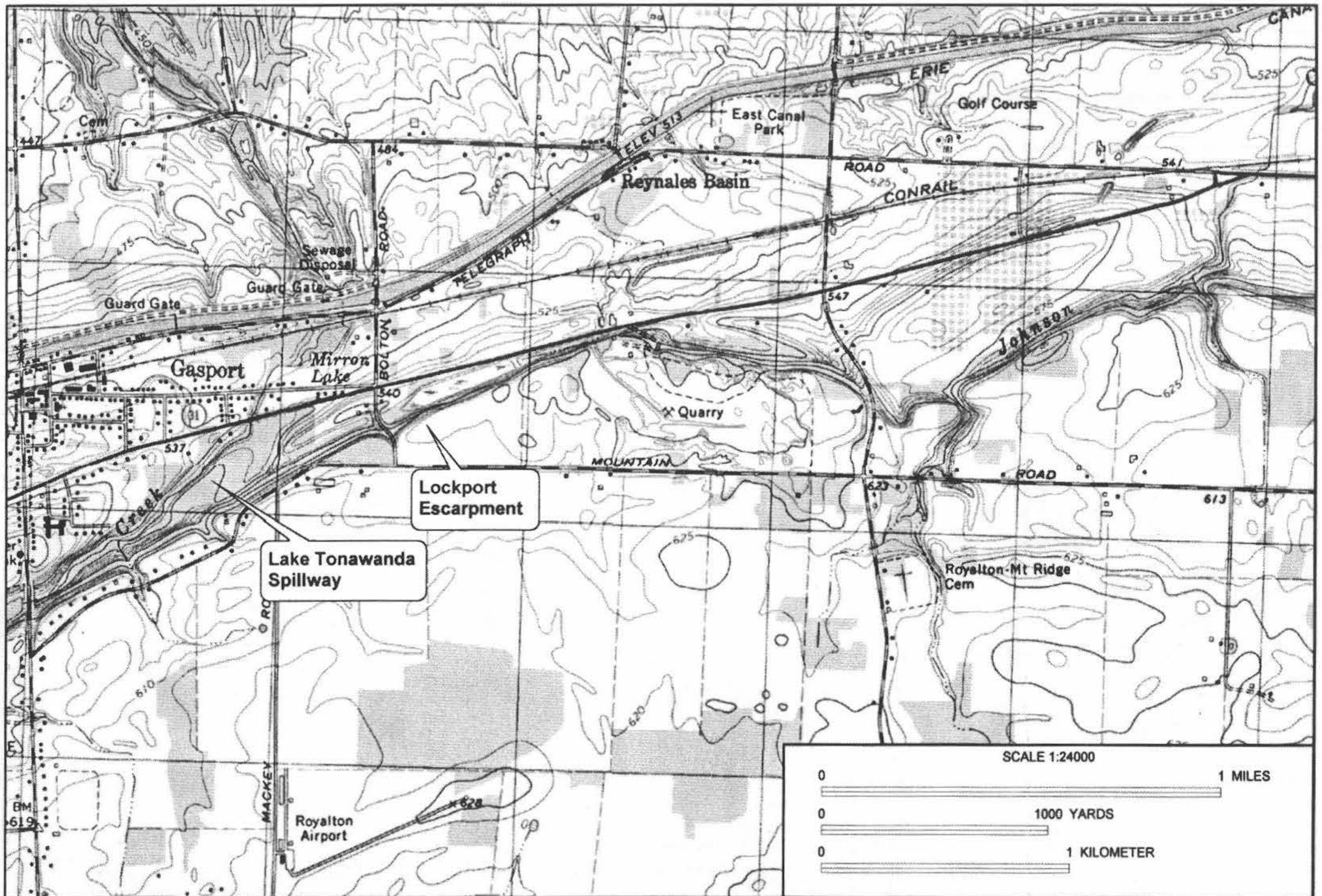
Name: MEDINA
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 043° 09' 37.48" N 078° 23' 38.89" W
Caption: Figure 16. Lake Tonawanda spillway is occupied by Oak Orchard Ck. south of Medina. Contour interval is 10 feet.



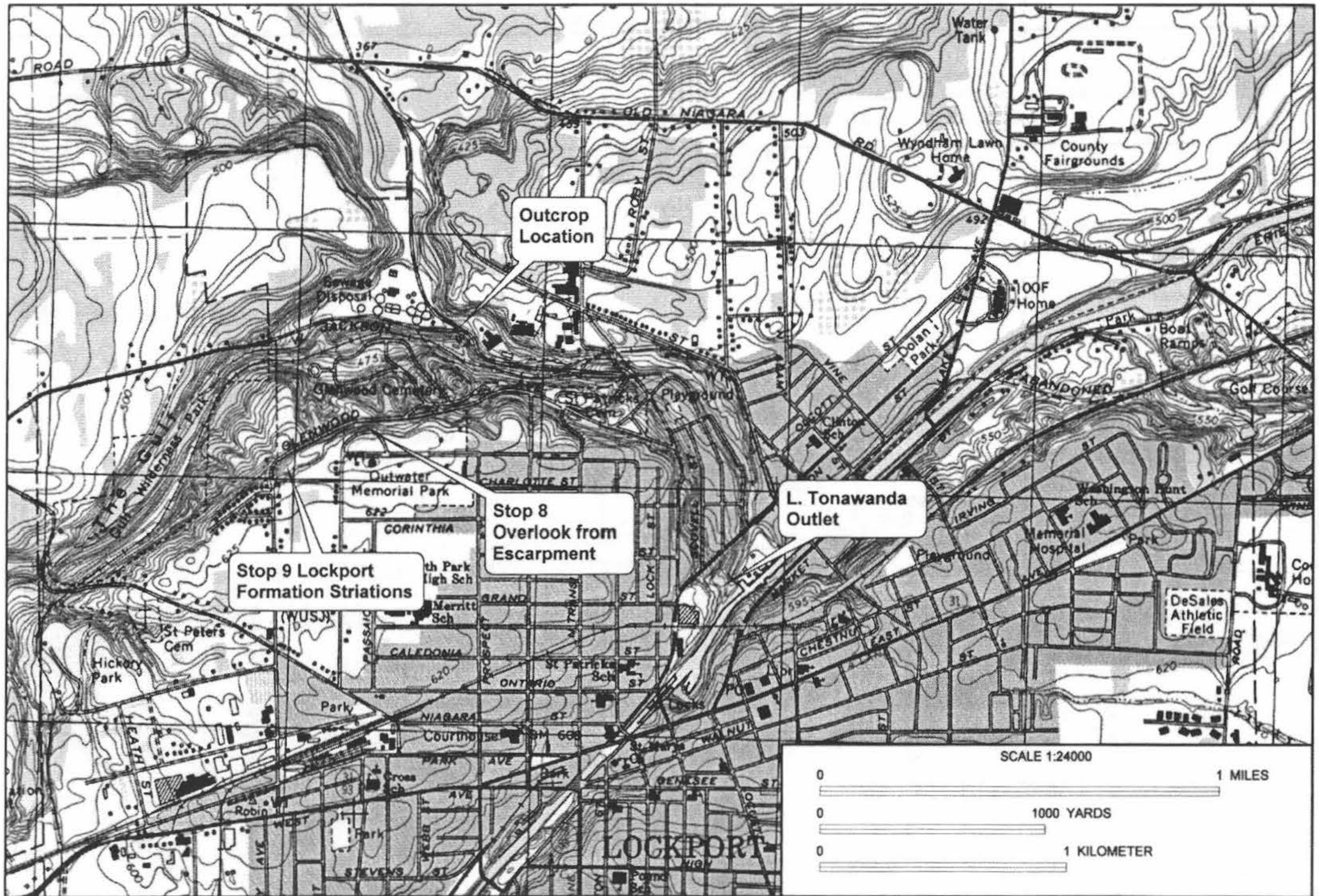
Name: GASPORT
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 043° 10' 39.91" N 078° 35' 14.75" W
Caption: Figure 17. Lake Tonawanda spillway south of Gasport. Contour interval is 10 feet.



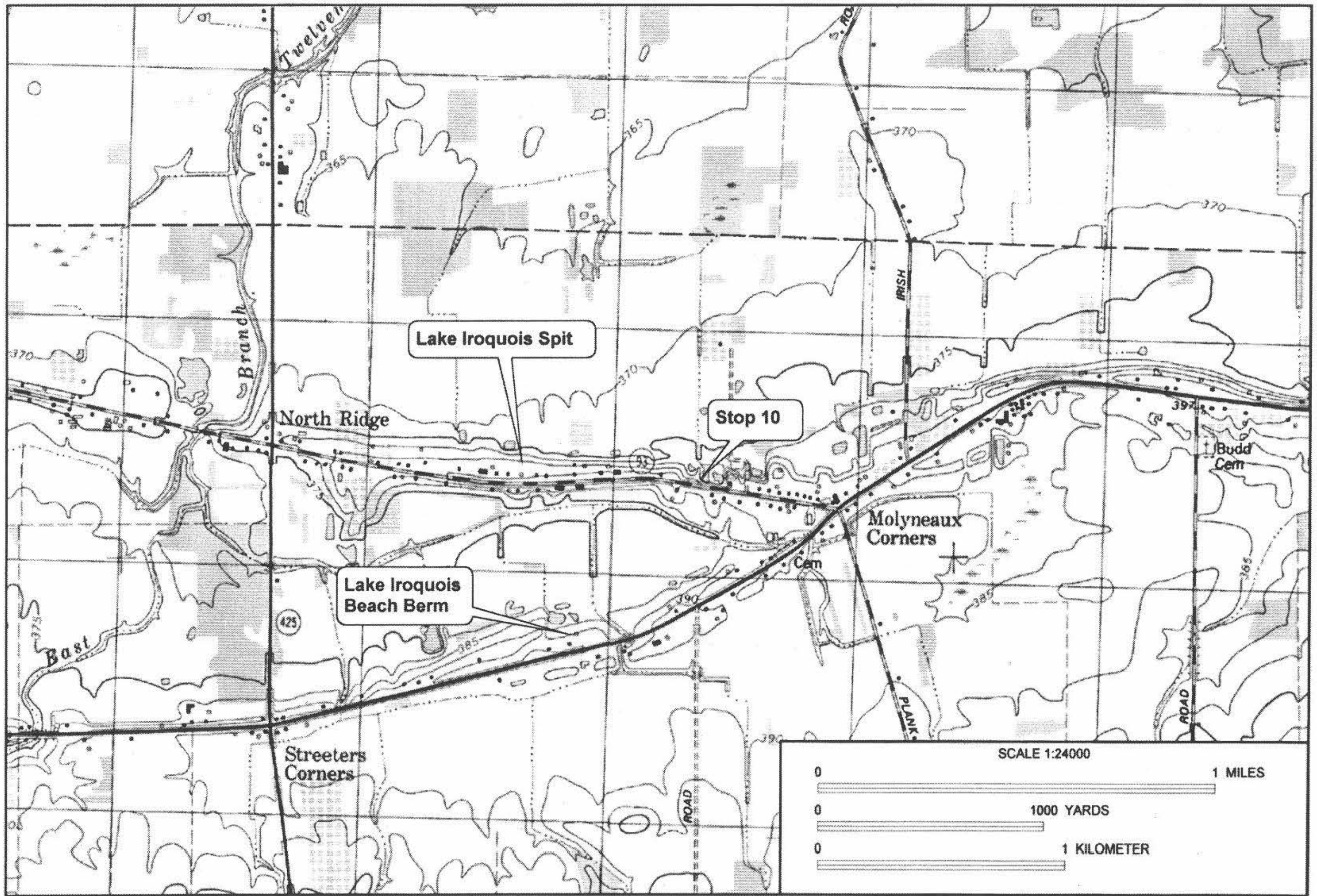
Name: GASPORT
Date: 9/6/2006
Scale: 1 inch equals 2000 feet

Location: 043° 11' 45.55" N 078° 32' 39.07" W
Caption: Figure 18. Lockport Escarpment near Gasport. Contour interval is 5 feet.



Name: LOCKPORT
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 043° 10' 46.97" N 078° 41' 35.35" W
Caption: Figure 19. Escarpment and Lake Tonawanda spillway at Lockport. Contour interval is 10 feet.



Name: CAMBRIA
Date: 9/4/2006
Scale: 1 inch equals 2000 feet

Location: 043° 12' 43.98" N 078° 48' 23.59" W
Caption: Figure 20. Lake Iroquois shoreline features northwest of Lockport. Contour interval is 5 feet.