Lake Ontario Coastal Geology and Land Management: Processes, Products and Policy

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This field trip carries us to some of the most dramatic freshwater scenery to be found in New York State. From the broad sand beaches of the eastern shore to the bedrock shelves, gravel beaches and till bluffs of the southeastern shore, geomorphology, sedimentary processes and human activity are manifest. Balancing the needs of citizens with those of the natural world so that the region can be both enjoyed and nurtured is an ongoing issue. We will look at examples of various shoreline geomorphologies, explain as best we can the processes shaping them and consider some of the policy questions involved.

Along the eastern shore of Lake Ontario, sand is arrayed offshore and on broad beaches backed by dunes. The extensive beaches are separated by a few, low till bluffs. Beach/dune barriers protect extensive wetlands and bays. Obvious human impacts are limited to only a few areas of the shore. Determined efforts by governmental agencies, citizen groups, and individuals have had a marked positive effect on preservation, conservation, and low-impact recreational utilization.

The southeastern shore is marked by bedrock shelves, gravel beaches and high till bluffs. Wetlands and bays are less extensive than in the east. Evidence of human activities is ubiquitous: industrial sites, harbors, houses, farms and orchards, state and local parks. Efforts at conservation by government and various citizen groups are less in evidence along the southeastern shore which is not surprising given its greater extent and history of exploitation. Southeastern shore residents most often express concern about lake level and its effects on property, shore-related activities, and boating activities.

Glacial and post-glacial sediment in this region rest on Ordovician strata which is locally exposed along the shore.

Stop #1. Chaumont Barrens (We will not visit this locality but it will be discussed at the Friday evening briefing.)

Chaumont Barrens Preserve is a global ecological rarity: 1630 windswept acres of an intact alvar landscape. "Alvar" comes from the term coined by Swedish geologists to describe expanses of level, exposed limestone bedrock found on islands off the southeastern coast of Sweden. Northwestern Jefferson County features a chain of similar outcrops of level, exposed limestone, which supports a characteristic mosaic of rare ecological communities. Jefferson County is the southeastern limit of the alvar mosaic, which occurs in fewer than 100 scattered locations in New York, northern Michigan, Ontario and along an escarpment of Cambro-Ordovician limestone and dolomite at the edge of the Canadian Shield. Chaumont Barrens is the best preserved occurrence in New York.

The Chaumont Limestone and other units of the Ordovician Black River Group are the rocks on which the Chaumont Alvar is based (Isachsen and Fisher, 1970). They are light gray, fine-grained and rich in cephalopods, corals, stromatoporoids, gastropods, brachiopods, trilobites and burrows. Cephalopods, in particular, are commonly seen in outcrops on the preserve. Rectilinear joints, some of which are enlarged by solution, break the rock surfaces. Strata dip to the southwest at less than one degree.

There is some controversy about the origin and fate of the very thin, discontinuous soil cover. During glacial retreat, some 10,000 years ago, pro-glacial Lake Iroquois covered the area of the present-day barrens to depths of at least tens of feet. Wave-driven currents probably winnowed away sediments overlying the bedrock. This alone may be enough to account for the thin, discontinuous soils. Another idea holds that, during glacial retreat, ice dams formed to the northeast of this area. With further melting, the ice dams burst, loosing enormous volumes of water which exploded across the bedrock clearing any sediments which may have been deposited there whether on the surface or in solution-widened joints. Finally, some of the soil materials may have been washed into joints over time as they were widened by solution.

Whatever the cause, soils throughout northern Jefferson County are thin and alkaline. At Chaumont Barrens and other alvar sites, soils are often just a few inches thick. The areas with thinnest soils and few fissures flood deeply during heavy rains and spring runoff, then bake dry throughout the summer and early fall. Water movement is thought to be predominantly sheet flow across the landscape, mostly NE to SW, across a very subtle 1% slope. Artesian features are known in the area, however, so upwelling may be a partial source of flood waters. The hydrology of this region is not well understood but it is clear that the annual cycle of flooding and drought greatly limit the variety of life that can survive here.

The alvar mosaic at Chaumont includes three rare natural communities: limestone woodland, calcareous pavement barrens, and the rarest of all, alvar grassland. Limestone woodlands occur on shallow soils over limestone. The canopy may be entirely deciduous, entirely coniferous, or a mixture of the two. Ground cover can include a delightful array of wildflowers under deciduous stands, which tend to have a rather open canopy. The conifer stands are dense and dark, with only scattered spongy moss colonies beneath.

At Chaumont the calcareous pavement barrens community is made up of variable-sized patches of barren rock; platy gravel colonized by mosses, lichens, and a few small wildflowers; deep fissures sculpted into the joints, and patches of shallow soil inhabited by shrubs, a few trees, and open grassy areas. The arrangement of patches feels very random on the ground, but an aerial view reveals a striking NE/SW arrangement of alternating woody and open areas parallel with the regional joints. The pattern occurs because shrubs and trees frequently sink roots into the fissures where moisture and protection allow them to survive.

Alvar grasslands are the rarest part of the community mosaic, both in number and size of occurrences. In the U.S., there are only a handful of occurrences and those are found in northwestern Jefferson County, and northern Michigan. Extremes of flooding and drought alternate in the alvar grasslands every year. The resulting vegetation looks like a prairie, and contains prairie species rarely found in the northeastern United States. Prairie plants may have migrated here during a mid- to late-Holocene warmer/drier interval some 5000 years ago. Then, as the climate became more moist, prairie plants were replaced almost completely throughout the Northeast by plants attuned to more moist conditions.

Stop #2. Black Pond – El Dorado Beach

A newly built road, parking area, and boardwalk allow easy access to a set of contrasting ecosystems that have been subjected to minimal human impact over the last century or two. The outlet from Black Pond to Lake Ontario is a geomorphic boundary for Lake Ontario coastal classification. Sandy beaches extend to the south and bedrock coast to the north. Black Pond with surrounding sedge, scrub and forested wetlands is protected from wave attack by the dune-capped barrier beach and offshore shoals. The size and age of the trees on the dune tops and eastern faces demonstrate the stability and relict nature of the highest dune crests. Along the lake or western dune faces, grasses and scrub (sand cherry) growth prevail. Recent snow fence installation, dune-grass planting and walking path demarcation including a walkover to the beach face and conservation signage have encouraged a recovery of local vegetation and dune sand accumulation.

Beach sand at this locality contains rock fragments, quartz, magnetite and garnet (among other grains) and masses of shells and shell debris of Zebra- and Quagga-mussels. Beach berms, runnels and other ephemeral features of sandy shores are seen here as a result of changing lake level and storm waves. Reworking of previously accumulated sediment prevails since there is no source of sand other than limited long-shore drift, minor erosion of till and exchanges with the subdued nearshore sandbars.

Offshore, to the south of this location, side-scan sonar records and sub-bottom profiles collected in conjunction with surface sediment samples and vibracoring reveal a one to several meter thick sheet of very well sorted sand. On it are scattered meter-scale, circular and elongated patches of what appear to be mussel colonies (Figure 1). Side scan sonar records disclose exposed bedrock just offshore from this locality (Figure 2). The bedrock looks to be festooned with mussels and is marked by fracture patterns like those seen on land in Henderson and adjacent townships to the north and east and at the Chaumont Barrens. The boundary seen on shore between the unconsolidated sediment surface cover to the south and exposed bedrock to the north continues offshore to depths of roughly 30 m (100 feet).

Captions for Figure 1 and 2.

Figure 1. Bottom features thought to be patches of zebra mussels on very fine sand. North is to the left. Half, side-scan tracks are illustrated. Orientation of elongation is roughly east/west perpendicular to the shoreline. Location is approximately 3 km south of Stop #2 at a depth of approximately 15 m. These features have not been sampled but their very low relief, numbers, location on a relatively stable sediment surface opposite beaches with large amounts of mussel shells makes it likely that they are clumps of zebra/quagga mussels.

Figure 2. Bedrock. North is to the left. Water depth approximately 10 m. Located approximately 1 km southwest of stop #2. Rock surface has on it boulders. Rock mass is fractured and pitted. Fractures and pits look to be populated by large numbers of mussels. Orientation of fractures approximates that seen in bedrock on shore to the north

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Stop #3. Southwick Beach State Park.

The sweeping extent of this low relief beach offers one of the best known vistas in eastern Lake Ontario. Sands on the beach, in the dunes and on the gently sloping foreshore are fine- to very fine grained. A history of intensive recreational use, sand mining and exploitation by private groups and government management agencies has significantly modified this section of formerly dune-capped barrier beach.

The adjacent marsh was once a fen. Evidence for the prior existence of a fen comes in two forms. First, this is the type locality for a very rare moth, Hemileuca sp. (bog buckmoth), known from only 10 localities, world-wide and all of them fens. Hemileuca has not been seen in this wetland since the 1960's. Second, the site is now marsh but it has a "false bottom" – underlain as it is by a deeper peat mat. It is reasonable to assume that the fen was flooded and that the present marsh developed over it. The marsh is now valued as habitat for a variety of uncommon breeding waterbirds and migrating waterfowl.

Waves during the summer months are either southerly or face-on to the beach while in winter, they are more northerly. Sand-bars formed under each of those regimes serve as sand reservoirs with some transport onshore and off with little net movement. Sand is extracted from the system as dunes accrete and migrate and as barrier bars are breached and new inlets form with their bay-mouth bars. Dune accretion is likely greatest during times of low lake level and least when it is high.

Cooperative restoration efforts by The Nature Conservancy and New York State over the last three years have seen the installation of two dune walkovers and snow fencing to protect the transplanted and very rare Ammophila champlainensis (Champlain beachgrass). This grass is found only here, a few sandy beaches on Lake Champlain and at a few sites along the St. Lawrence River in Quebec.

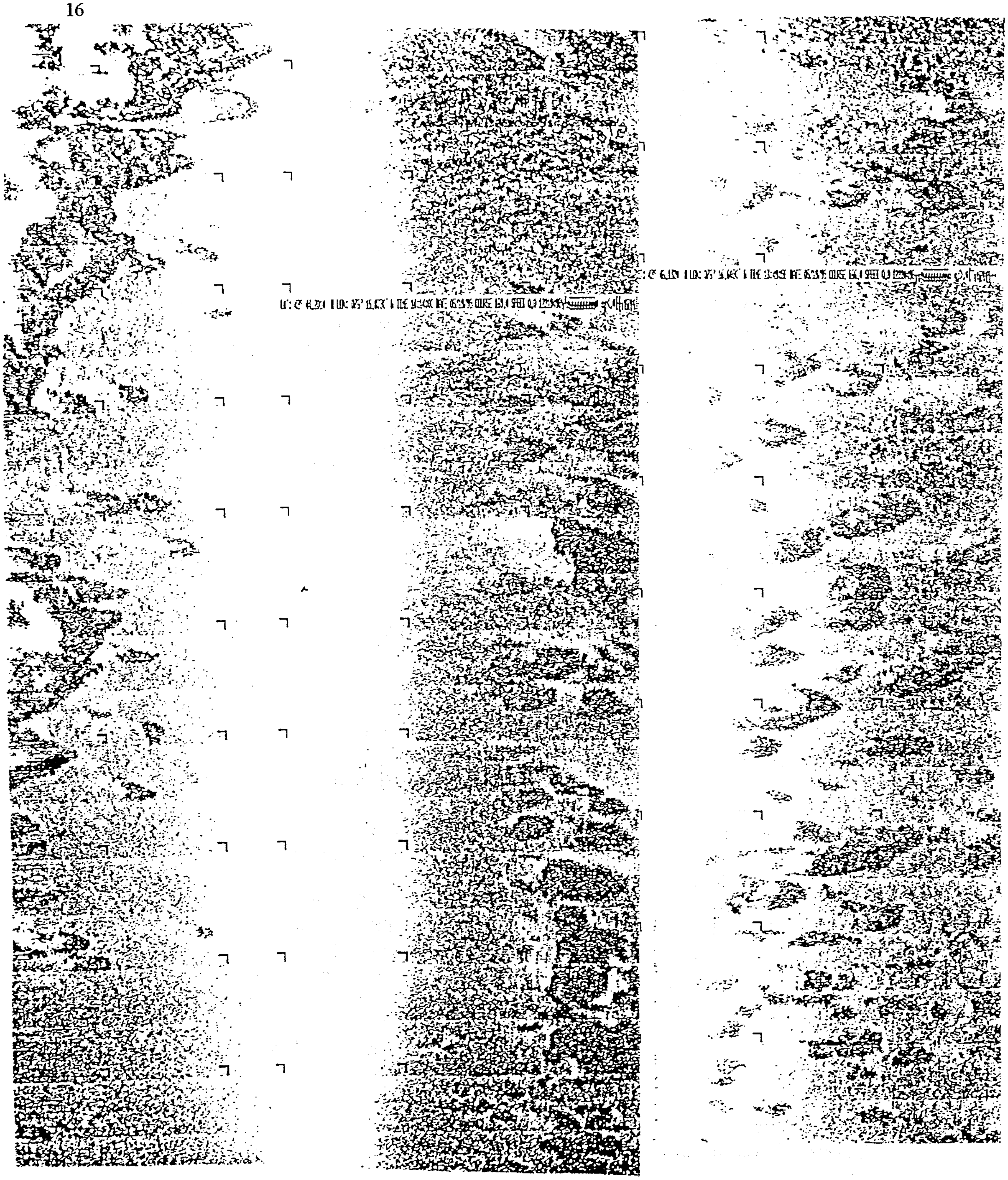

FIGURE 1.

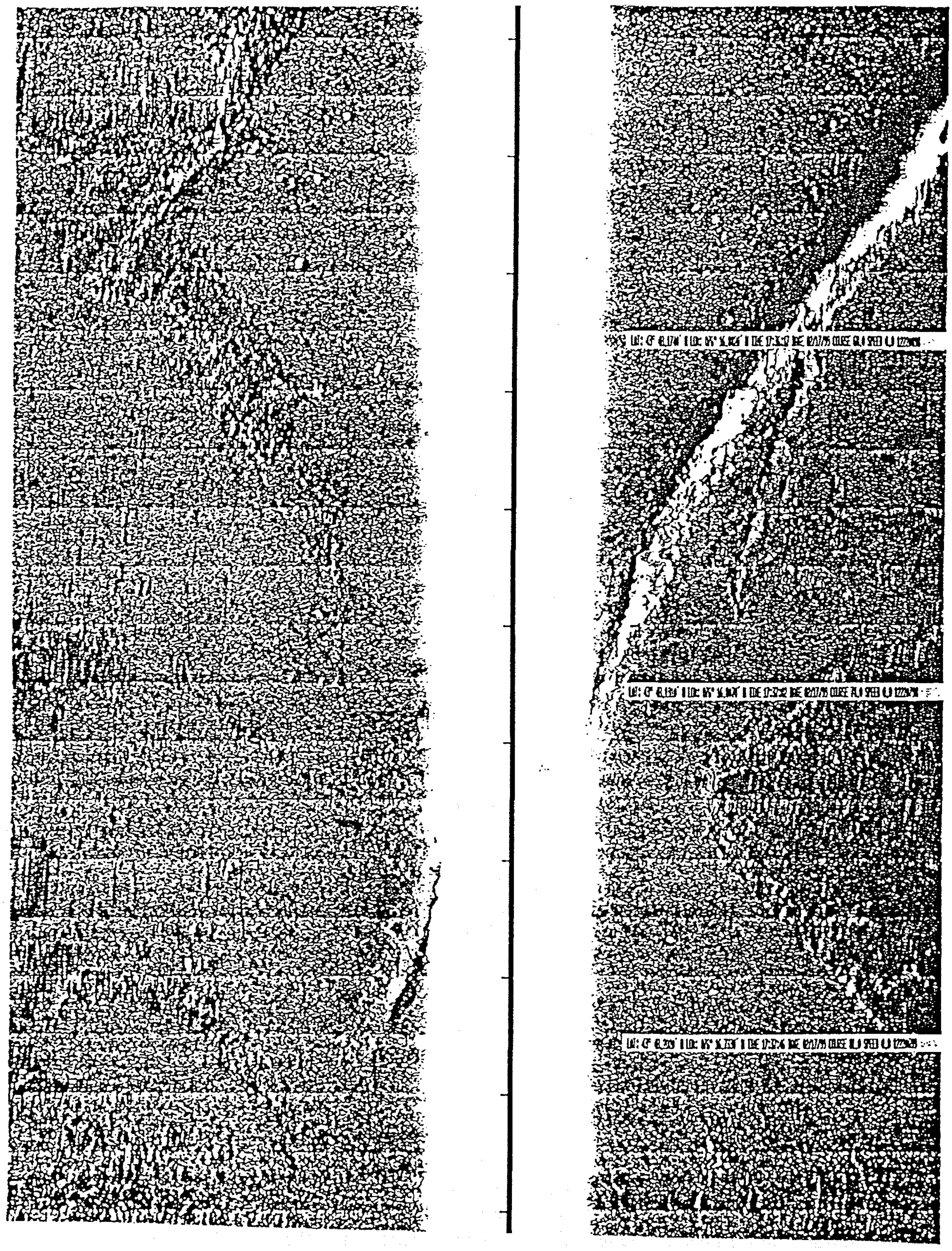

FIGURE 2.

Sand dune accumulation has already begun along with natural propagation of the dune grass and self-sown wormwood. Proposals for restriction or exclusion of camping from the lakeshore along a former dune line met with intensive public resistance. Campers clearly enjoy parking their vehicles between the access road and beach where there used to be a well developed natural dune ridge. The prevailing westerly winds of summer as well as the sight and sound of breaking waves make this section of the park very attractive.

Stop #4. Sandy Island Beach: Dune Reconstruction and Planned Development.

At this location, an early 20th century inlet through the barrier into Sandy (North) Pond was abandoned and became the locus of a dune. In more recent decades, a blowout formed at the dune site carrying sand from the beach into Sandy Pond and thereby almost duplicating the earlier inlet. The barrier and its dunes extend about two miles to the north where another a modern-day inlet opens into Sandy Pond. Other inlets that have opened and closed along the barrier in this century are recorded in aerial photography starting with a series in 1938 and continuing through 1988.

Until this year, crumbling and abandoned facilities, debris of all kinds and a cobble beach made this a much-degraded site. We will view new developments on the lakefront where Oswego County has constructed day-use park facilities. Beginning with land acquisition, The Nature Conservancy has supported both this development and that of NYSDEC as it "restored"the dune flanking the park to the north. To restore the dune meant that first, 44,000 ft3 of sand were moved from landward edge of the advancing blowout back to the beach/dune line. Plantings on the restored surface are now well established and are protected by fencing. Another significant volume of sand was moved to the beach face from the rear of what is now the parking lot to cover what had become the cobble surface of the beach. Finally, a gated, fenced, and cobbled access roadway has been established from the new parking lot north along the dune/beach line to ensure vehicular access for those home owners north of the site along the barrier. The addition of upland sand to this beach provides the opportunity for an experiment in sand movement along this section of shore.

Offshore just south of this location, seismic and side-scan records indicate that the sand sheet is patchy on an eroded till and/or bedrock surface (Figure 3). Vibracores taken in the sand sheet nearby disclose a layer of 2-10 cm diameter gravel resting either on well-sorted sands very much like those presently found on the beaches or on organic-rich peaty clays and silts. This gravelly surface is apparent in the seismic records where it marks the top of seismic Unit #2 (Figure 4). We take this gravelly sand to be a beach deposit which indicates that post-glacial Lake Ontario water levels were as much as 25 meters (80 feet) below present. This lower stage may be the "Dune Stage" of Sutton, Lewis and Woodrow (1970), a lower lake level whose existence was postulated on a much more limited data set. Carbon 14 AMS dating analysis results for the peaty deposits below the gravel may be ready by the time of the NYSGA 2000 field trip and should help to date the lower lake stage.

Captions for Figures 3. and 4.

Figure 3. Side-scan sonar record of patches of sand on till on hard substrate. North is the left. Location is 4-5 km southwest of stop #4 in water depth of approximately 15 m. Sand patches fill low areas on the substrate surface. Edges of patches often are "finger" on to the substrate in irregular patterns. Seismic records show the patches to be less than 1 m thick.

Figure 4. Seismic record of strata at and below the lake bottom. East is to the left. Individual seismic units are noted. Depth markers on the record approximate unit thicknesses. Unit 1 appears to merge with Unit 2 toward the east end of the record and with Unit 3 toward the west end of the record. This suggests that part of the modern sand sheet is derived from a sand mass emplaced earlier at this location and Unit 2 is likely to be discontinuous over this region.

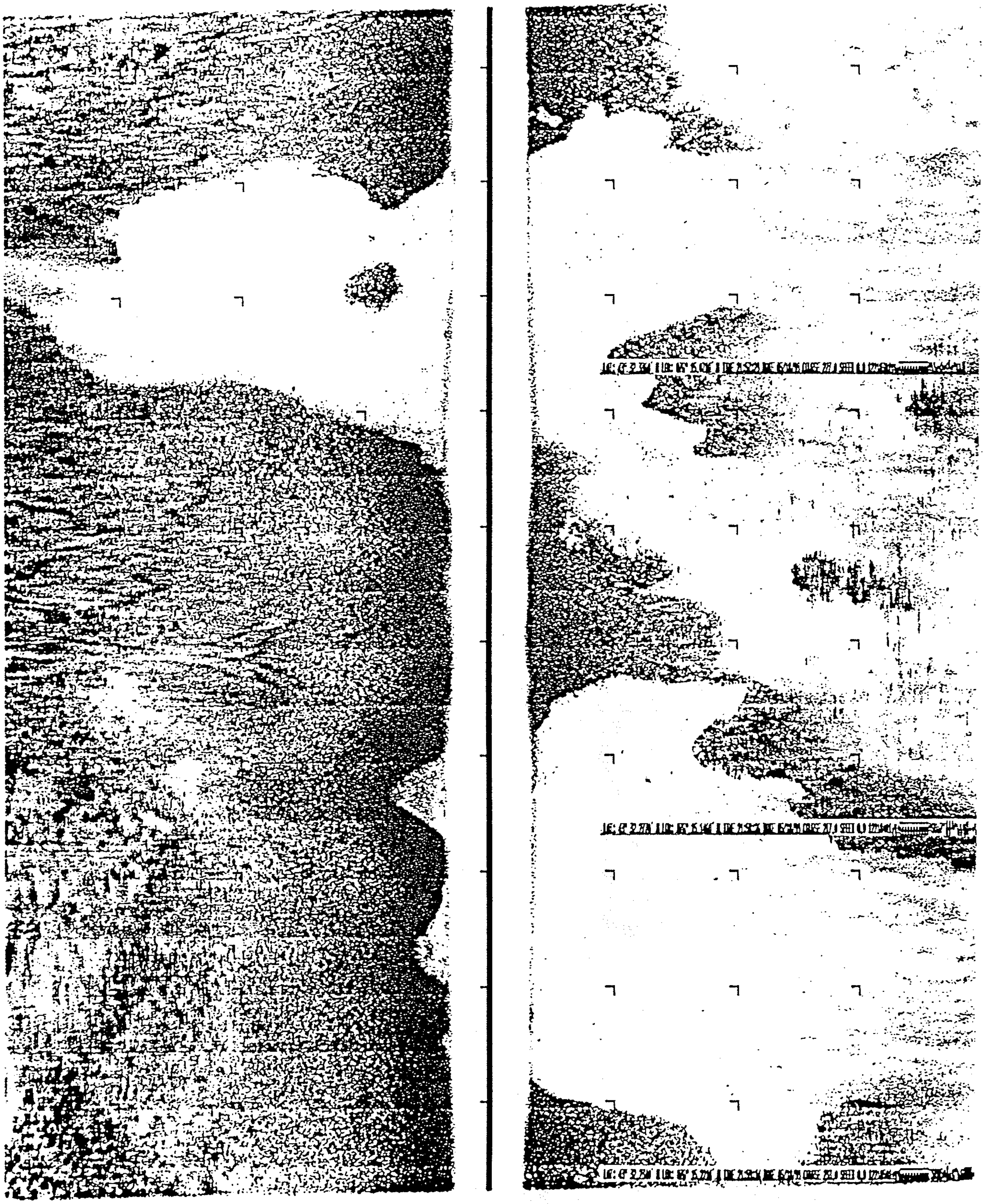

FIGURE 3.

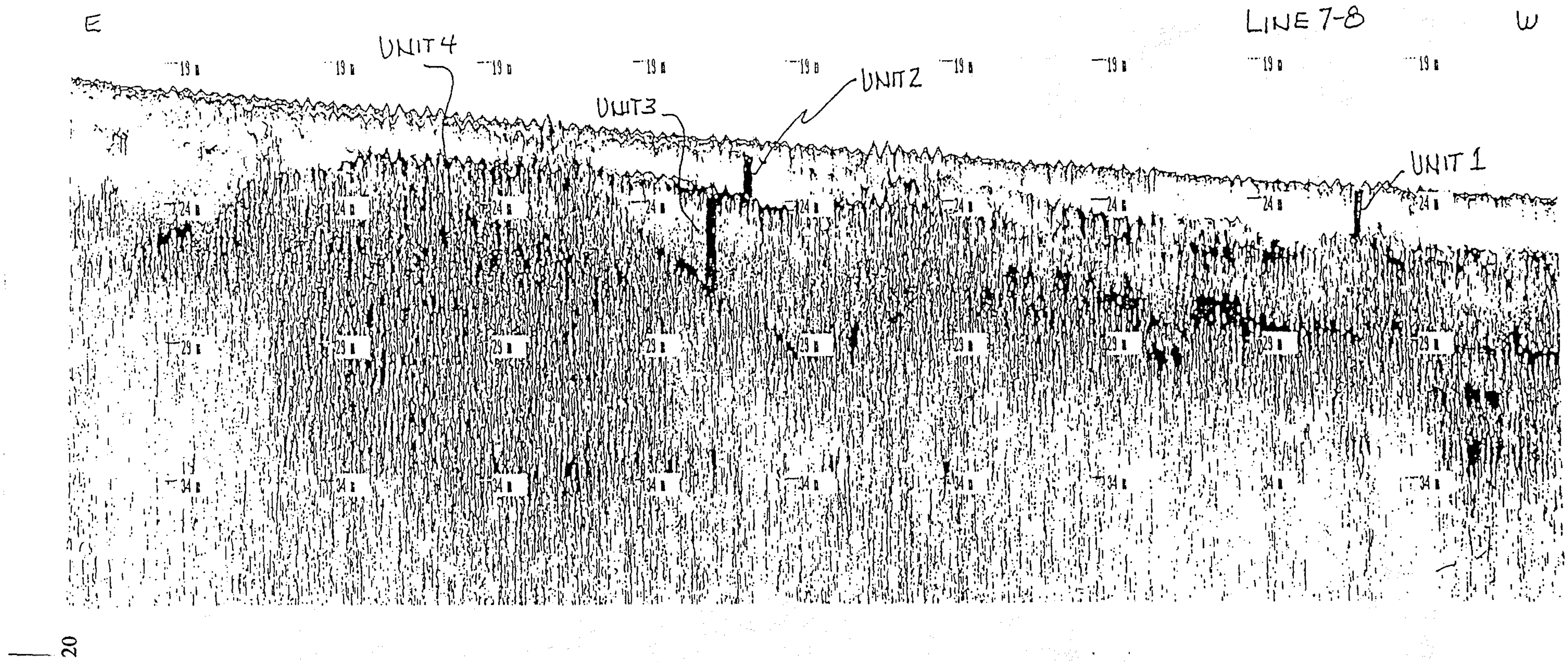

FIGURE 4.

Stop #5. Shoreline at the Energy Center, Nine Mile Point.

Driving around to the southeastern shore of Lake Ontario, instead of dune-capped, sandy, barrier-beaches and adjacent wetlands and bays we see bluff exposures of till over bedrock. This location provides an example. The "beach" here is made up of minimally rounded boulders and slabs. The beach is developed on bedrock. The overlying till is exposed where continued erosion prevents establishment of vegetation. The steep bluff face and lack of trees on it suggest that erosion events recur on a decadal frequency, a frequency less than that seen further to the west. The presence of glacial-scour marks on the exposed bedrock indicates resistance to erosion and suggests an explanation for lesser erosion rates of the till at this locality.

The bedrock seen here is the Late Ordovician Oswego Sandstone (Isachsen and Fisher, 1970). Bedding planes exhibit light greenish-gray, fine-grained sandstones marked by low-angle, trough cross-strata and parting lineations. Rip-up clasts are found at the base of sandstone beds and some units display sole marks. Fossils are not seen at this locality. At other locations nearby, the Oswego is arrayed in fine-upward sequences typical of fluvial and/or tidal channels. The Oswego is part of a thick Late Ordovician basin-fill sequence the base of which is the Black River Group carbonates of Stop #1. Between that location and this more than 500 m of clastics from black shale to this sandstone are covered by the glacial and younger sediments. Next above the Oswego and not exposed on the south shore of Lake Ontario until the Genesee River Gorge in Rochester, is the red and green Queenston Shale which marks the top of the basin-fill.

Just east of this location are three nuclear power plants, a concentration of such plants greater than that found at any other location in the country. Siting the plants on stable bedrock near an abundant supply of cooling water and distant from large population centers made the location environmentally and politically attractive. In a linked location-decision, an aluminum-can production plant, located just to the west of here, also uses Lake Ontario waters for cooling and draws on the power grid for electricity. Cooling ponds at the plant required modification of many acres of wooded coastal wetlands. The ponds provide an expanded habitat, yielding some impressively large carp and other species.

For several miles east of the power plants, the coast consists of bedrock cliffs with a shallow bedrock platform just offshore. The cliffs, although accessible by road, are dangerous to scale because of groundwater seepage, clay-rich soils and slimy overgrowths. Cliff-edge trees at these locations often have roots exposed and locked into cracks suggesting a very slow rate of erosional retreat.

Stop #6. McIntyres Bluff: Drumlins and adjacent barrier-beach fronted wetlands.

West of the city of Oswego in the township of Sterling, the bedrock is no longer exposed along the lakeshore. Here are a series of north-south trending drumlins and connecting barrier beaches in front of ponds and wetlands, a geomorphic pattern which persists for about 30 km to the west. The drumlins have been truncated by storm-wave undercutting, particularly during periods of high lake level, and further eroded by a combination of mass wasting, streamlet runoff and wind erosion. The nature of the spring thaw, snow cover and rain-event sequencing generates a lot of inter-annual variability in the amount and style of slumping and sliding as well as gully washout and alluvial fan development. Long-shore wave-driven transport, which moves predominantly toward the east, redistributes the eroded till of the drumlins and deposits a progressively more rounded sand and gravel barrier. The fines are redeposited in the deeper waters of the lake or in the lows of inter-drumlin ponds and wetlands. The bluffs of drumlins show a variety of heights and morphologies, which are measured to be more and less steep, with and without gully development, and multiple kinds of alluvial fans and scarps at the toe of the bluffs along the beach.

The model (Pinet et al, 1998; Pinet and McClennen, 1997) that goes a long way to explain many of the observed patterns (Pinet et al, 1992), has a focus on the causal changes in bluff morphology as the erosion processes cut through the drumlin hills. Groundwater-flow and run off keep the bluff faces wetter in the initial stages of bluff retreat. After the crest portion of the drumlin has been removed the bluff faces are generally drier due to the landward direction of runoff and water table gradients, and exposure to wind. The local bluff height and retreat rates control to some extent the volume of drumlin till deposited on the beach. In combination these factors seem to explain the early, youthful, mature and old age stages of bluff retreat morphologies. They are modulated by inter annual weather and lake level variations. The last stop of the field trip at Chimney Bluffs State Park will show a more fully developed example of the coastal retreat patterns and interpretations introduced at McIntyres Bluff.

Stop #7. Chimney Bluffs State Park (under development).

At this location, we see an unusual landscape cut into a flat-topped drumlin. The landscape, like that at McIntryre's Bluff, is made up of spires, pinnacles and razor-edge ridges, some ending at lake-edge in sheer cliffs and all separated by steep-sided valleys. The drumlin is flat-topped (as are all of the other drumlins near the lake shore in this region) as the result of beveling by wave erosion in proglacial Lake Iroquois. Its crest stands about 50 m above the lake.

This landscape is the product of groundwater seepage (sapping), erosion by flowing water and wind, and solifluction. The solifluction effects are dramatic. In the spring, frozen cliff surfaces thaw over large areas in a matter of hours. Masses of till are loosed into the valleys as dense mudflows. The flows easily raft along boulder-sized clasts delivering them as part of a muddy slurry to the beach where the flows dewater and deposit their sediment load in fans. Valley surfaces are denuded as much as several cm in a day with the southwest, more fully exposed, faces experiencing the highest rates of loss. Once on the beach, waves erode the fans in several weeks or months. The biggest boulders are left at the fan head and form boulder-trains on the floor of the lake as the cliffs retreat. Cobbles and coarse sand are moved along the beach to the east and finer sediments are carried into the open lake. Ridge-ends are undercut by waves during lake high-stands and cliff-collapse is common at that time, adding to the rate of retreat. At the west end of Chimney Bluffs, faulting in the till has led to differentially rapid erosion along fault surfaces and the development of ephemeral caverns and clefts.

The west end of the Chimney Bluff drumlin is especially instructive. There, varved clays, apparently derived from the top of the drumlin as it was eroded by Lake Iroquois waves, are exposed in a 3-6 m cliff. The varves lap on to the till of the drumlin, thin up-section, are coarser toward the drumlin and show soft-sediment deformation caused by masses of gravelly sediment sliding down side of the drumlin.

New York State is slowly developing the park and, unlike developments at most lakeshore locations, is working to make a virtue of rapid erosion. However, the issue is joined because the edge of the low bluff just north of the lot in which we parked has retreated approximately 10 m in 35 years. Permanent structures at this location will have a finite lifetime independent of the life of the materials used to build them.

Observations on management policy for the lake shore

The effects of wave erosion and changing lake levels when combined with the desire to protect and preserve various shoreline habitats and at the same time utilize the lake shore for recreation and year-round living leads inevitably to conflicting views of management. We offer these observations on the situation.

*<u>Patterns of erosion and coastal retreat over the 20th Century have motivated numerous lakefront property owners to build defensive structures, a losing proposition</u>. The obvious lack of substantial sediment input from land and coastal erosion at some locations leading to gravel- rather than sandy shores has decreased the attractiveness of the beaches. Property owners and land managers must deal with this pattern of coastal evolution often at considerable private or public expense. The desire for shoreline stability around private lands is in unavoidable conflict with the patterns of change so prevalent on unconsolidated sediment coasts of large water bodies. Even without tides, the storm waves, winds and flood level patterns of Lake Ontario cause rapid and substantial changes in coastal configurations. It is clear that preparing fixed shore defenses

against the unending and highly variable wave regime of Lake Ontario is not likely to succeed. Even massive stone emplacement structures show signs of undermining and collapse in the course of only decades, as seen along the protected but beachless section of shore in Fair Haven Beach State Park or just east of the jetties at Sodus Bay.

*Rates of erosion are highly variable from place to place along the shore and with time. Rates of a few feet per year are generated during intense weather events experienced every decade or so, making prediction and management decisions very challenging. Public understanding of the erosion processes and patterns appears to be quite limited based on some of the engineering attempts made in the name of saving coastal property. At McIntrye's Bluff and Chimney Bluff, for example, reducing groundwater flow and runoff to the top of the bluff face appears to be much more effective and economical strategy for erosion control. In other areas, local governmental bodies may decide that zoning of shorelines will be necessary to reduce the cost of inevitable property loss.

*Lake levels have a critical impact on the extent of erosion and changes in habitats experienced in an individual storm or season and deserve particular attention in any management analysis and planning. High lake levels greatly increase the rate of drumlin erosion by waves, for example. Lower lake levels broaden beaches but make inlet and river channel shallow reducing access to the open lake. Habitat extent and character vary with lake level with often profound effects. The Prairie Plover nested on the eastern shore sandy beaches until 1984 but since then has not been seen. Has the regulation of lake levels narrowed the eroded dune zone at the back of the beach sufficiently to exclude these former residents?0

*Our experience of wave effects and lake levels over the last century may not provide a solid basis for management if climate were to change. However, over the long term all should accept the predominant and persistent patterns of erosion and coastal retreat along most of the unconsolidated sediment sections of eastern and southeastern Lake Ontario. The fluctuations and occasional depositional building of the shore while natural will eventually be counteracted by a return of erosional patterns.

*To conserve a natural setting may require that it be permitted to change naturally. This simple concept has important implications for all of those who would take advantage of Lake Ontario's resources. Letting nature have its way may be a goal but it is likely to be a difficult concept to include in a management plan.

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Woodrow, D.L., McKinney, D.B., Cortes, A., and Williams, J.J., 1990, Chimney Bluffs, NY: An Eroded Drumlin, Badland Topography, Glaciolacustrine Clays and Longshore Transport of Sediments (abs): Annual Meeting, Northeast Section, Geological Society of America.

Road log in miles. Distances are approximate.

0.0 Exit 45 I81. Proceed north on I81 to Exit 47.
2.3 Exit 47 I81. Proceed to NY 12 north.
13.9 Turn left (south) to DePauville Road.
15.5 Turn right (north) to Van Alstyne Road.
16.5 Chaumont Barrens on the right.

STOP #1 Chaumont Barrens. (not visited on this trip)
Return to I81 and proceed south to Exit 41.
31.7/0.0 Junction I81/NY 178. Proceed west on 178.
8.8 Village of Henderson, continue on 178.
9.6 Junction of NY 178 and NY 3. Turn left (south) on NY 3
12.4 Turn right (west) on Bolton Road to entrance of NYSDEC Black Pond Wildlife Management Area.(BPWMA)
13.8 Entrance to BPWMA with parking. Follow boardwalk through wetland, across the leeward side of the dunes and then through the dunes to the beach.

STOP #2. ElDorado/Black Pond Natural Area.
Most northerly part of the Eastern Shores expanse of open beach, shore backed by 15-20 m dunes, mussel shells as clasts, bedrock visible to the north.
Retrace route to NY 3 and proceed to the right (south.)
18.1 Entrance road to Southwick Beach State Park.

STOP #3. Southwick Beach State Park.
Proceed to southernmost part of beach front camping area. Expanse of open beach backed by low dunes.
Retrace route to NY3 and turn south. NY 3 passes War of 1812 Sandy Creek battlefield and swings east around Sandy Pond, the largest of the bays along the eastern shore.
30.5 Turn right on Oswego County 15 at Lindsey Restaurant and proceed to the end of the road.
32.8 Sandy Island Beach parking lot. Walk to beach along resident's access road.

STOP #4. Sandy Island Beach.
Southern end of expanse of sandy beach. Restoration of dune blowout and beach. Gravel berm with sand offshore and dunes behind. Armored section of beach visible to south.
Retrace route to NY3. Turn to right (south).
44.1 Turn right (west) on 104B, toward Oswego.
47.1 Bear right (west) on Oswego County 1.
51.8 Turn right (north) on Nine Mile Point Road.
53.5 Turn left (west) on Lake Road .
55.4 Turn right (north) on access road to Nuclear Learning Center parking lot. Walk past front of Nuclear Learning Center and down the lawn to the beach.

Stop #5. Beach west of nuclear power stations.
Ordovician Oswego Sandstone overlain by till. Glacial grooving of bedrock. Till exposed in bluff.
Retrace route to Lake Road (Oswego County 1A). Turn right on 1A
56.4 Turn right (west) on Oswego County 1. Proceed on 1 into City of Oswego.
62.6 Turn left (south) on Fourth Street.
62.8 Turn right (west) on Bridge Street (NY 104). Cross over the Oswego River and NYS canal.
64.8 On the right, note the entrance to SUNY College at Oswego main campus.
68.2 Bear right on NY 104A.
71.7 Junction with Old State Road at a 5-points. Bear half-right (west) to McFarland Road which is unnamed at this junction.
73.2 Bear left on Farden Road.
74.1 Turn right on Center Road.
74.2 Turn right on McIntyre Road and proceed to parking area on side of road just before steep incline. Note: the road to the lake shore is often washed out and may be impassible to all but fourwheel drive, high-clearance vehicles.

Stop #6. McIntyre's Bluff.

Till exposure with erosional topography. Gravel beach and barrier across wetland to east, alluvial fans, wave erosion.

Return to 104A by turning right on Center Road at beginning of McIntyre and then right to NY 104A at thefirst stop sign.

84.9 Straight ahead to NY38 (104A curves off to right (west)).
89.3 Turn right (west) on NY 104.
103.6 Turn right (north) on Lake Bluff Road. Proceed north on Lake Bluff Road
106.6 Continue north on Garner Road.
109.6 Turn very sharp left on East Bay Road.
110.6 Parking lot at Chimney Bluffs State Park.

Stop #7. Chimney Bluffs State Park (under development).

Extreme examples of erosional (badlands) topography. Wave-bevelled drumlin capped by lag gravel; faulting in till, varved clays, boulder trains in lake.

Return to NY 104 by following East Bay Road south

113.4 Lummisville Road. Turn right (west) and proceed to junction with Lake Bluff Road.
114.4 Turn left (south) on Lake Bluff Road.
119.5 Turn right (west) on NY 104
137.0 Lyons, NY. Junction with NY 31. Continue south on NY
144.6 New York State Thruway, Exit 42.
151.3 Hobart and William Smith Colleges, Scandling Center.