A FEW OF OUR FAVORITE PLACES; AN ENVIRONMENTAL AND GEOLOGICAL EXCURSION IN CHAUTAUQUA COUNTY

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INTRODUCTION

This trip will focus on a variety of geological features and processes of particular interest to students, rather than on results of current research on a single topic. General topics include environmentally important sites, geomorphology and glacial geology, and bedrock geology including unusual structural features. The setting for this trip is the a portion of the eastern shore of the Lake Erie Basin in southwestern Chautauqua County. Upper Devonian bedrock units (mostly shale and siltstone) are overlain by Wisconsin-age glacial drift, mostly morainal material on the "escarpment" (edge of the Allegheny Plateau), with post-glacial, pre-Lake Erie lake clay dominating in the glacially-scoured lake plain below. Post-glacial erosion has produced deeply incised fluvial valleys, some with rather spectacular gorges. Human economic activities center on agrarian enterprises, with the famous Lake Erie Grape Belt dominating production in the lake valley.

This field trip will take us to (in order of stops) [1] a "pop-up" structure in Canadaway Creek near the SUNY, Fredonia campus, [2] an active and [3] inactive fly ash waste disposal site, [4] Lake Erie State Park (lake erosion, bedrock features, glacial till), [5] a glacial lake Whittlesey beach deposit quarry, [6] a scenic overview from the "escarpment" of the Lake Erie basin (lunch), and [7] a scenic-educational hike into the Chautauqua Gorge to see bedrock and glacial features, including a pre-glacial buried valley. We strongly advise that all participants bring waterproof boots, or for the more adventurous, sneakers. This apparel will be essential particularly on STOP [7] which requires considerable stream wading. Fig. 1 is a map showing locations of all stops.

DESCRIPTION AND COMMENTARY ON INDIVIDUAL STOPS

STOP 1. POP-UP STRUCTURES

Pop-up anticlines were recorded as early as 1886 by G.K. Gilbert in otherwise flat lying Devonian strata of New York and Pennsylvania (Gilbert, 1886, 1888). He attributed these structures to "thermal expansion of surficial rocks following glacial unloading" (Sbar and Sykes, 1973). Since that time others have reported similar structures (Cushing et.al., 1910, Williams, H. R. et al.,1985, and Adams, J., 1982) in which the axis of the pop-up generally strike N-S or NW-SE. Sbar and Sykes (1973) reviewed the evidence favoring a contemporary ENE to

E-W maximum compressive stress for much of the Great Lakes region of North America (Fig. 2), and suggested that "the release of a vertical load in the presence of a large horizontal compressive stress of non-glacial origin, however, may be responsible for the formation of the pop-up...".

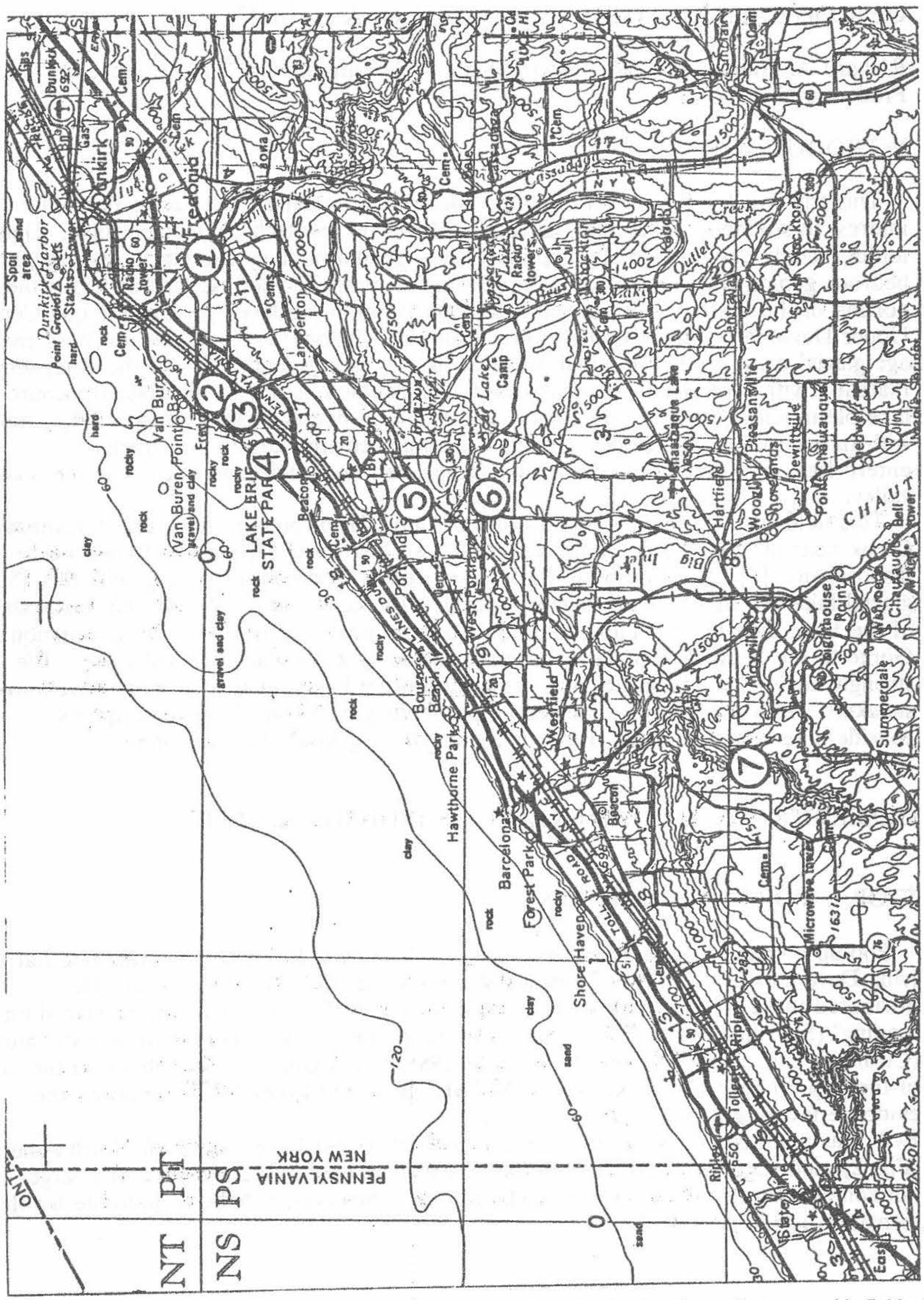


Figure 1. Map of a portion of southwestern New York State showing locations of stops on this field trip.

Pop-up anticlines in northern Chautauqua County generally have a NW-SE to N-S strike (STOP 7) but some have been found that strike E-W (STOP 1).

At this exposure notice that the shaley beds and even some siltstone beds are bent at the fold. Does this imply a certain degree of ductile deformation, and if so what was the mechanism of deformation and when did it occur? If the northwest trending structures are the result of the ENE regional compressive stress, how are the E-W trending pop-ups explained? Coates (1964) describes a 7 foot high, NW striking pop-up that developed overnight in a quarry floor in Ontario. Note that the STOP 1 fold is directly overlain by unconsolidated floodplain deposits and the constituent shale bedrock was, no doubt, subjected to fluvial erosion until "recently" (?). Because this fold represents a positive topographic feature it should be highly susceptible to erosion; note that where the fold crosses the present stream bed it has been planed off completely. Thus, if the Canadaway Creek valley is a post-glacial feature, the STOP 1 fold is probably a fairly recent feature (post-glacial), as an older fold (say, Paleozoic age) should have been eroded down to the current erosion level of the bedrock. We will compare the structural properties of this fold to folds of probable glacial origin at STOP 4 (Lake Erie State Park).

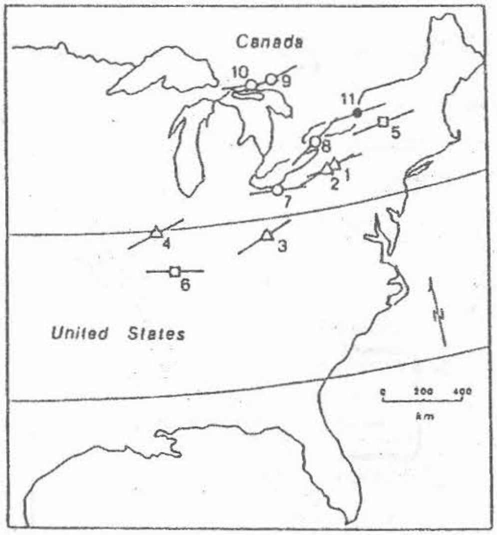


Figure 2. The status of information on intraplate stress in the eastern United States as of April 1972 based on Sbar and Sykes (1973) compilation. The strike of the horizontal component of the maximum compressive stress (S_H) is shown for hydraulic fracture tests (open triangles), fault-plane solutions (open squares), overcoring stress measurements (open circles), and post-glacial pop-ups (solid circle). From Gross, 1989.

STOP 2. NIAGARA MOHAWK FLY ASH & BOTTOM ASH DISPOSAL SITE
STOP 3. FRAME TRUCKING CO. RECLAIMED DISPOSAL SITE

Environmentally compatible disposal of toxic waste products is a major problem facing federal, state, and local governments. Western New York has gained national attention as a major dumpsite of hazardous materials, particularly in the Buffalo and Niagara Falls area (witness "Love Canal"). Chautauqua County is not immune to these problems. The county government is currently at odds with the state DEC over expansion of capacity at the Town of Ellery Landfill operation, a site in which the active dumpsite is near capacity levels. Closer to home, the Dunkirk-Fredonia area hosts a coal ash disposal site run by the Niagara Mohawk Power Corporation. We will visit the currently operational site and a nearby "reclaimed" site owned and formerly operated by the Don Frame Trucking Company (Fig. 3). This disposal cell was active from 1971 to 1985.

The Niagara Mohawk site occupies land that formerly included the Fredonia Airport on Van Buren Road (Fig 3). It primarily receives ash waste from the Dunkirk Steam Generation Plant located near Point Gratiot, Lake Erie, within the city limits of Dunkirk. This plant began electrical generation in 1949 using Pennsylvania bituminous coal as fuel. It generates 600 megawatts of power fired by about 5,000 tons of coal per

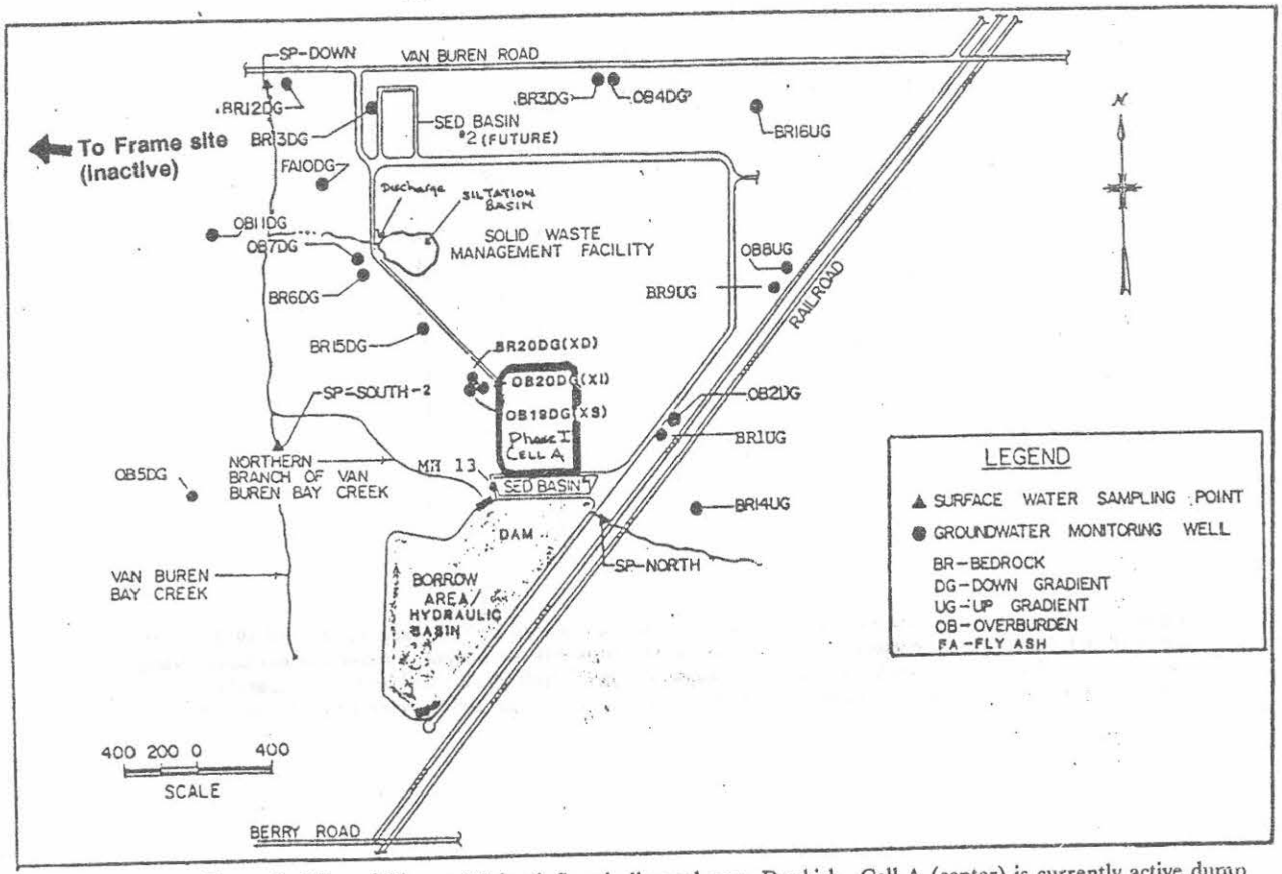


Figure 3. Map of Niagara Mohawk fly ash disposal area, Dunkirk. Cell A (center) is currently active dump site. The reclaimed "Frame site" (STOP 3) is located approximately in upper left of the map.

day. Originally the ash produced at the plant was mostly "bottom ash", the same "clinkers" or coal cinders produced by home, coal-fired furnaces. However, in 1973 new and more efficient electrostatic precipitators ("scrubbers") were constructed in the exhaust chimneys resulting in cleaner air, but creating addition solid wastes in the form of "fly ash". It is this fine grained fly ash that accounts for the majority of wastes currently dumped at the Dunkirk disposal site. An average of about 450 tons of fly ash deposited at the site every working day (Sunday excluded). Some bottom ash is also dumped at the site (avg. 1/90-2/90 was 130 tons), although much of this is bought by the Town of Pomfret for use as road aggregate. The disposal site also receives some wastes from an oil-fired plant in Oswego.

Of obvious environmental concern is the efficiency of safeguards designed to prevent aqueous leachates at the disposal site to contaminate local surface and groundwater supplies. This is controlled for the most part by clay and plastic bottom liners. Leachates are directed toward an artificial pond ("Sed Basin" in Fig. 3) that is frequently monitored for contaminants (see Table 1). Water from this pond is allowed to flow into a nearby creek after testing shows it to be free of significant contamination. Groundwater is also monitored by a series of test wells (Fig. 3) located around the perimeter of the site. Dust abatement is performed by watering trucks that obtain water from a larger artificial pond adjacent to the settling basin (Fig. 3).

TABLE 1. Example of groundwater analysis, Dunkirk Solid Waste Management Facility. Environmental Testing Facilities report 2/15/1990 for test well OB2UG.

METALS mg/L		ORGANICS ppb	
Al	2.58	Bromodichloromethane	<1.00
Sb	<1.00	Bromomethane	<1.00
As	<0.005	Vinyl Chloride	<1.00
Ba	<0.2	2-Chloroethylvinyl Ether	<1.00
Be	<0.005	Chloromethane	<1.00
B	0.64	Trichloroflouromethane	<1.00
Cd	<0.005	1,1,2-Trichloroethane	<1.00
Ca	61.0	1,1-Dichloroethane	<1.00
Cr	0.003	1,1-Dichloropropane	<1.00
Cu	<0.02	trans-1,3-Dichloropropane	<1.00
Fe	3.86	1,2,2,2-Tetrachloroethane	<1.00
Pb	<0.005	1,1,1-Trichloroethane	<1.00
Mn	0.037	Benzene	<1.00
Hg	<0.0002	Ethylbenzene	<1.00
Mo	<0.5	1,4-Dichlorobenzene	<1.00
Ni	<0.04	1,2-Dichlorobenzene	<1.00
Se	<0.002	o-Xylene	<1.00
Ag	<0.01	Bromoform	<1.00
Na	15.2	Carbon Tetrachloride	<1.00
Tl	<1.00	Chloroethane	<1.00
Zn	0.02	Chloroform	<1.00
Cr+6	<0.01	Trichloroethane	<1.00
		(...etc. All other organics = ≤1.00 ppb)	

NOTE: "<" *denotes less than minimum detection limits.*
Analyses by Environmental Testing Facilities, Inc.
Dunkirk, NY.

Metzger (1974) noted that groundwater samples taken near the active fly ash disposal cell at that time (Frame site; STOP 3) showed that efforts to contain groundwater contamination were successful. However, he also showed that water samples collected near an older dump site (near the entrance on Van Buren Road) were contaminated with high concentrations of iron and manganese. It is safe to conclude that these metals were derived by leaching of the old fly ash materials by groundwater, and that other heavy metals (not analyzed) may also have shown higher-than-background abundances. Table 1 shows that containment techniques at the current cell are successful in keeping contamination restricted to the disposal site. All metal values are quite low and abundances for organics are all below detection limits. Hopefully, this situation will be maintained in subsequent years, but this remains to be seen.

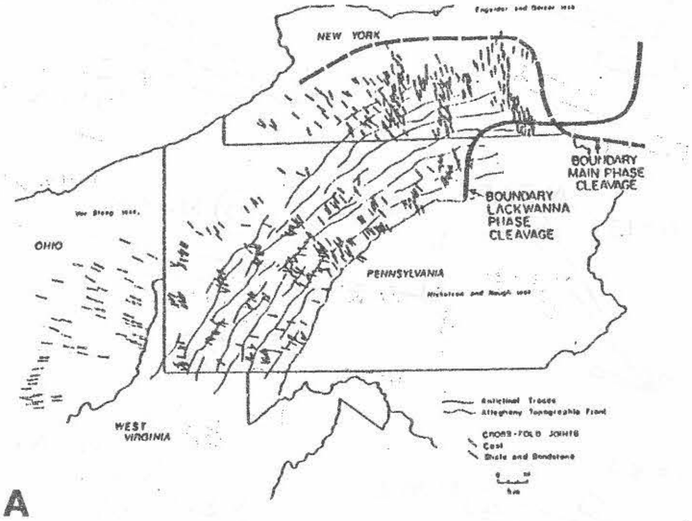
STOP 4. LAKE ERIE STATE PARK

The lake shore here offers us the opportunity to study several features of interest: (1) jointing developed in the South Wales member of the Canadaway Formation....we will also discuss additional studies on jointing in this area and across the Allegheny Plateau, (2) shoreline erosion...recent problems of severe erosion rates associated with high lake levels and how the U.S. Corps of Engineers resolved the problem at the bath-house, (3) a beautiful exposure of glacial till overlying shale bedrock along with lacustrine deposits overlying the till, and (4) septarian concretions.

JOINTS: In recent years joint patterns across the Allegheny Plateau have received considerable attention (Engelder, 1982, 1985; Engelder and Geiser, 1980; Gross, 1989). Fig. 4 shows results of these studies. Of particular interest is the noticeable change in dominant joint orientation from northwest to northeast that takes place in southern New York and northern Pennsylvania (Fig. 4C. There is also a clear need for additional data from western New York. This will in part be addressed by our discussions here at STOP 4. The strong ENE set of extensional joints (Fig. 4B) is interpreted as having formed in a neotectonic stress field with an ENE direction of maximum compressive stress (Engelder, 1982). As summarized by Gross (1989), "These features are thought to form near the earth's surface as the result of uplift and erosion and are controlled by the orientation of the contemporary tectonic stress field."

At Lake Erie State Park the South Wales member of the Canadaway Formation is well exposed at water level. It displays an abundance of joints oriented approximately N 50 W and N 30 E. Fig. 5C is a rose diagram of 134 joints measured at this location.

In preparation for this field trip RAG undertook a reconnaissance study of joint patterns in each member of the Canadaway Formation in northern Chautauqua County. Results are shown rose diagrams in Fig. 5. These diagrams show that in all cases there cases there is at least 1 strong NE joint set (N 25-35 E and/or N 65-70 E). In addition a N 30-40 W set and/or a N 50-60 W set is present in some units. However they are not consistently present in all exposures of these members. For example, the Northeast shale in Canadaway Creek has abundant NW joints, but very few are seen in Chautauqua Gorge (Fig. 5I & 5J).

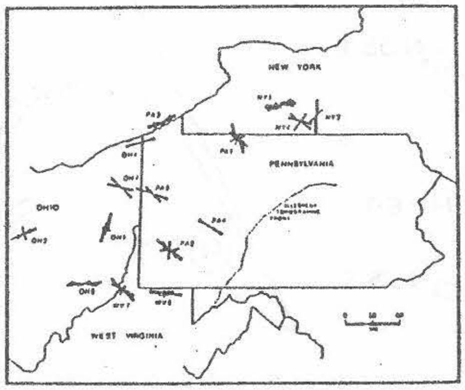


A

The distribution of cross-fold joints and cleavage within the Central Appalachians (after Engelder, 1985).

B

Rose diagrams of orientations of joints in drill cores from wells in Ohio, West Virginia, Pennsylvania, and New York. (From Terry Engelder, 1987, in *Fracture Mechanics of Rock*, B. Atkinson, ed., Academic Press.)



C

The regional ENE joint set in the northeastern United States classified as neotectonic, after Engelder (1982). The orientation of the joints are shown as solid black lines.

Figure 4. Maps of joint orientations in northeastern U.S.

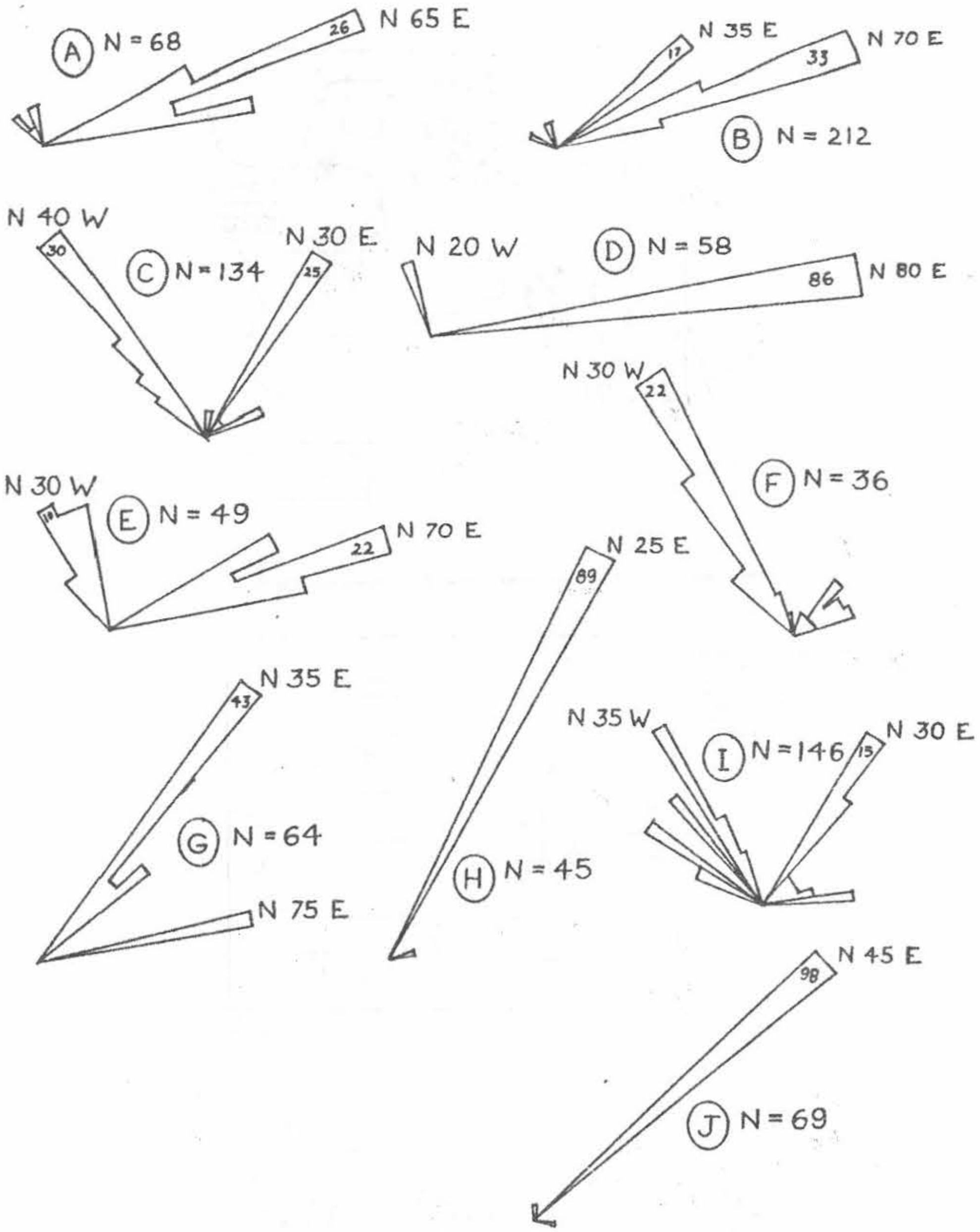


Figure 5. Rose diagrams of joints in members of the Canadaway Formation showing strong NE, and to a lesser extent, NW trends: [A] Dunkirk Shale at Point Gratiot, Dunkirk; [B] South Wales shale from Little Canadaway Creek, Portland; [C] South Wales shale from Lake erie State Park; [D] Gowanda shale from Canadaway Creek, Fredonia; [E] Gowanda shale Chautauqua Creek, Barcelona; [F] Laona siltstone from Chautauqua Creek, Barcelona; [G] Westfield shale from Walnut Creek, Forestville; [H] Shumla siltstone from Canadaway Creek, Shumla; [I] Northeast shale from Canadaway Creek, Arkwright; [J] Northeast shale from Chautauqua Gorge. N is the number of field measurements. Not all diagrams are to the same scale. Number inside the "rose petal" is the percentage of N.

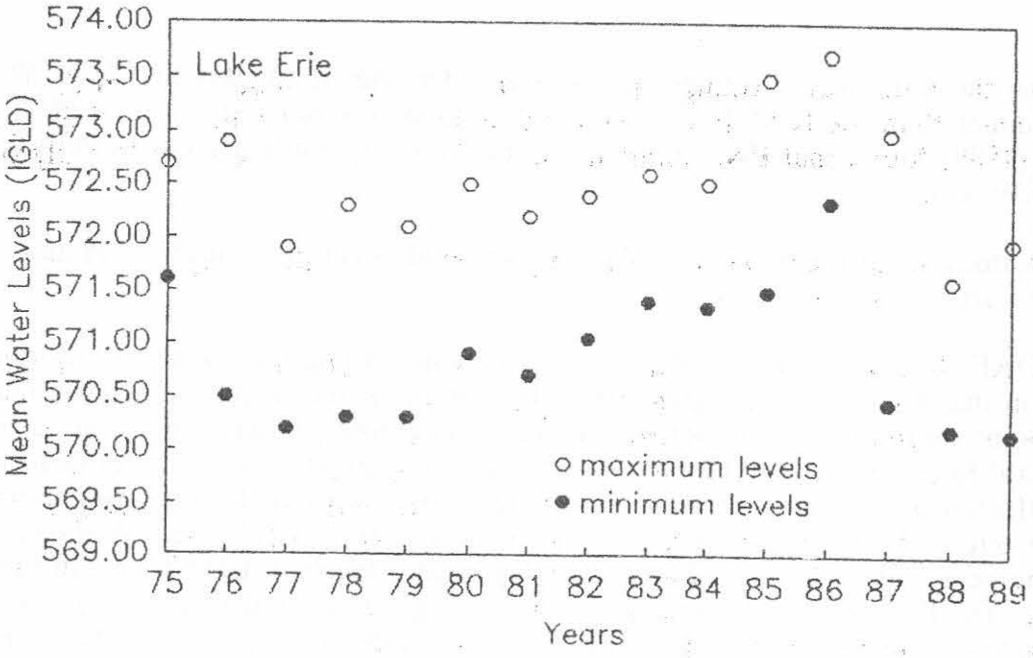
Using the criteria that younger joints abut older ones it appears that N 35 W joints are younger than the N 65 E set, and N 70 W joints are older than the N 65 E set. Gross (1989) found that ENE joints in the Lockport dolomite are consistently younger than NW sets.

How does all of these relate to earlier joint studies on the Allegheny Plateau?... that will be part of our discussion.

SHORELINE EROSION: Wave-induced erosion along the Lake Erie shoreline is a problem that has attracted a great deal of attention in recent years. From a human standpoint shoreline erosion destroys valuable lakeshore property and jeopardizes the structural integrity of buildings and other near-shore constructions. Sand beaches are also affected by increased erosion during high-water times, with sand being carried farther out in the basin during times of increased wave activity. Fig. 6A shows that the year 1986 experienced especially high water levels in Lake Erie. In fact that year set an all time record, exceeding previous highs measured in 1973 (573.51 feet). The highest level recorded in 1986 was 573.70 recorded during the summer. Levels have generally decreased since that time and were especially low during the drought of 1988 (Fig. 6A). In fact, the most recent Army Corp of Engineers lake level report suggests that lake levels will remain well below average during the summer of 1990. During times of high lake levels erosion rates increase because waves are more likely to impinge upon easily erodible glacial sediments that overlie bedrock. During low water periods waves contact bedrock which erodes less efficiently than glacial till. In addition, during low water periods wave energy is likely to be dissipated over a broad area of lake bottom, thus lessening the energy waves can expend on erosion (Metzger, 1974).

Fig. 6B shows the typical lake level pattern over any given year which is to rise during the spring and summer months and decrease during winter and fall. This is, perhaps, fortunate because winter storms can be particularly energetic. Storms at any time of the year cause strong prevailing winds to develop on the lake basin. This results in "setups", a process where water literally piles up on one side of the lake, usually the eastern or southern side. Storm setups combined with unusually high water levels can cause considerable erosion along the lake shore, and may destroy beaches. Sand carried out to deeper levels usually returns, however, as lake levels return to more normal values (Metzger, 1974). Fig. 7 shows that the Lake Erie shoreline in western New York is generally subject to light to moderate erosion.

A dramatic example of severe shoreline erosion directly affecting human activities can be observed at Lake Erie State Park. Erosion of virtually unconsolidated glacial till under lying the bathhouse was threatening to undercut this building's foundation. In 1986 the U.S. Army Corp of Engineers proposed an erosion abatement plan to save the building from probable structural damage resulting from this erosional undercutting. The bathhouse, situated on a 25 foot high bluff, was valued at about $300,000 by the state in 1986, so cost considerations dictated that constructing a new facility would be more expensive than saving the old building. The Corp of Engineers, therefore, devised a plan to construct a "rubblemound" revetment that would extend 250 feet along the toe of the bluff, and extend up the bluff to the bathhouse. The revetment project was subsequently approved for construction. It consists of a gravel fill layer overlain by large limestone boulders. A plastic filter fabric was laid down under this material to keep



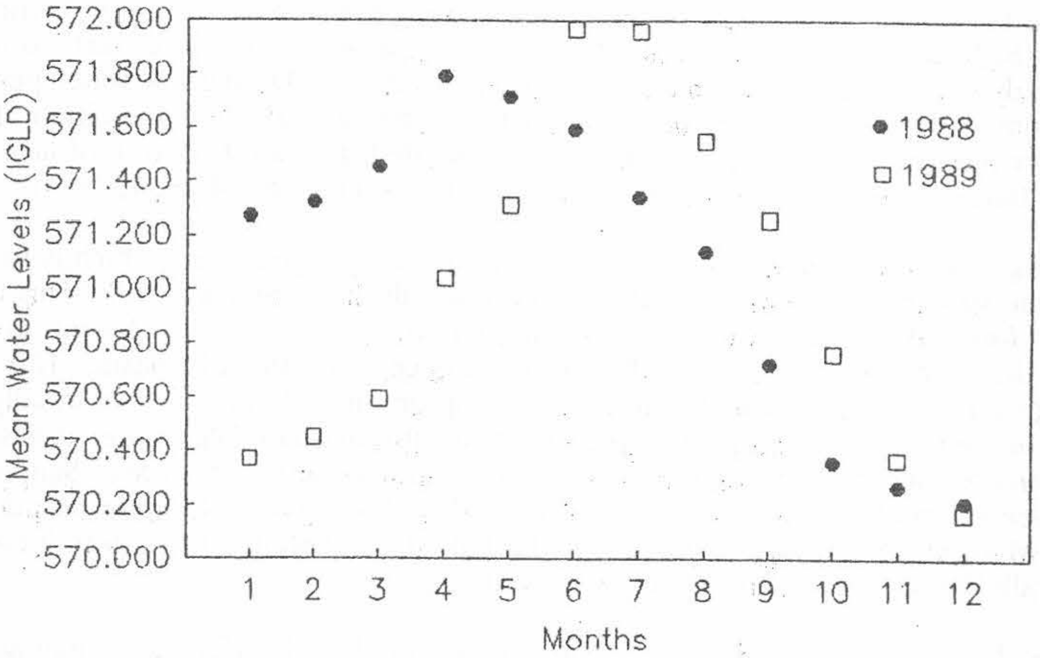


Figure 6. [A] Mean water levels in Lake Erie for the years 1975 to 1989. IGLD refers to "International Great Lakes Datum", water level at Father Point, Quebec measured in 1955. Note the record high levels in 1986; and present day low levels. [B] Monthly mean lake levels for Lake Erie in the years 1988 and 1989. Note the general tendency of lake levels to rise in spring and summer.

bluff materials from infiltrating the revetment, and a series of buried plastic pipes aids drainage. The estimated cost of the project prior to construction was $200,000. Fig. 8 shows a map view of the construction plan that was eventually completed in 1988.

GLACIAL DEPOSITS: Bedrock along the beach area is overlain by unconsolidated surficial deposits of glacial origin, deposited during the Wisconsin glacial advance. This material is well-exposed on the cliff face along the beach and consists of buff-colored, unstratified, badly sorted till, overlain in some areas by finely laminated, gray lake clay. The till consists of some recognizable local bedrock material especially in the lower horizons, but also includes pebbles through boulder-size rocks mostly of metamorphic or igneous origin. Some large blocks of relatively coherent bedrock were incorporated into the lower till layers in some areas. These blocks display local folding that may have been induced by glacial movement. We will visit one particularly well-exposed site and compare this folding to that observed in the pop-up structures observed at STOP 1.

Lake clay is exposed in some areas above the till, but has been removed by erosion elsewhere. It is thinly laminated, nearly pure gray clay in many areas but locally is mixed with sand, gravel or pebbles. The layering may represent a response to seasonal depositional conditions (varves), although this is subject to debate. Most varved clays show distinct color differences, apparently absent here. This clay was deposited by one of the precursor lakes to the present Lake Erie, Whittlesey or Warren. Judging from the low stratigraphic position of this clay relative to the till layer, the lake clay was probably deposited be the earlier lake, i.e., Whittlesey.

SEPTARIAN CONCRETIONS: A few hundred feet west of the till exposure, numerous 3 to 5 feet diameter septarian concretions are exposed at water level. According to Pettijohn (1975) the formation of septarian nodules appears to involve development of a nodular body, case hardening of the exterior with dehydration of the interior and generation of the shrinkage-crack pattern, and partial or complete filling of the cracks with precipitated mineral material, thereby producing the vein network of the nodule. Shrinkage and production of cracks imply a gel-like character of the original body.

Ultimately, development of concretions may be related to bacterial fermentation or organic matter during shallow burial. Such reactions apparently generate water, carbon dioxide and biogenic methane. This leads to an increase in the pH of the pore fluids allowing for carbonate precipitation. The carbonate cements which may include calcite and siderite, commonly develope as concretions that may be found intermittently along beds. Some of the nodules, the septarian concretions, have undergone dehydration with accompanying development of shrinkage cracks (Selley, 1988). These cracks are later filled in by precipitation of carbonate minerals (calcite and siderite) from infiltrating hydrous solutions. In addition, the relatively uncommon mineral, barite ($BaSo_4$), is a common accessory mineral in many septarian concretions.

STOP 5. GRAVEL PIT IN LAKE WHITTLESEY BEACH DEPOSITS

As the Wisconsin ice front retreated north of the high ground of the Portage Escarpment, meltwater that had previously drained southward was now trapped between

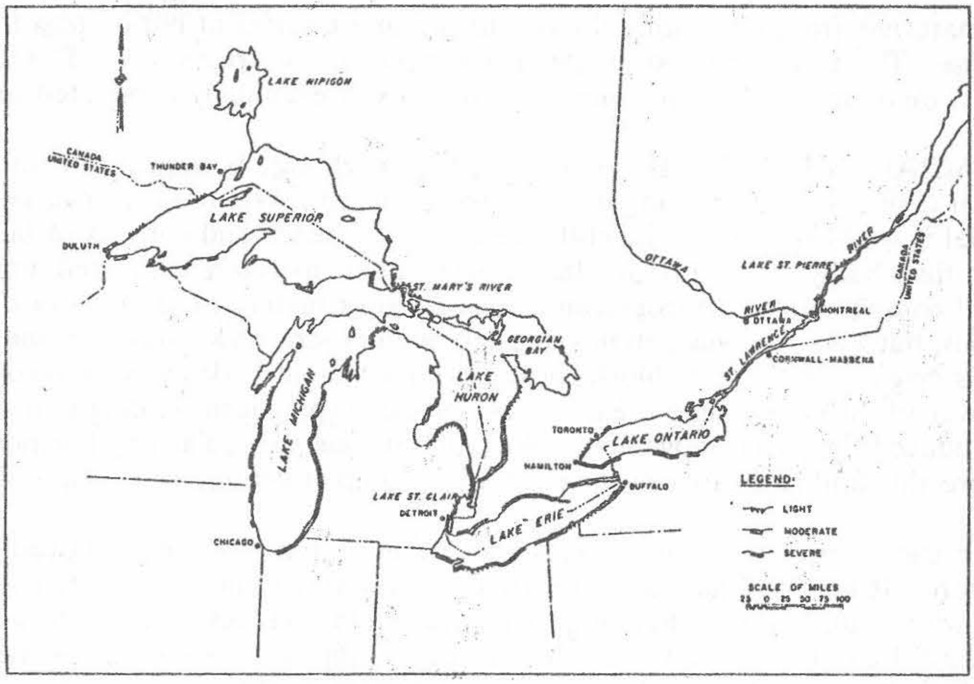


Figure 7. Map showing Great lakes and St. Lawrence River areas subjected to shoreline erosion.

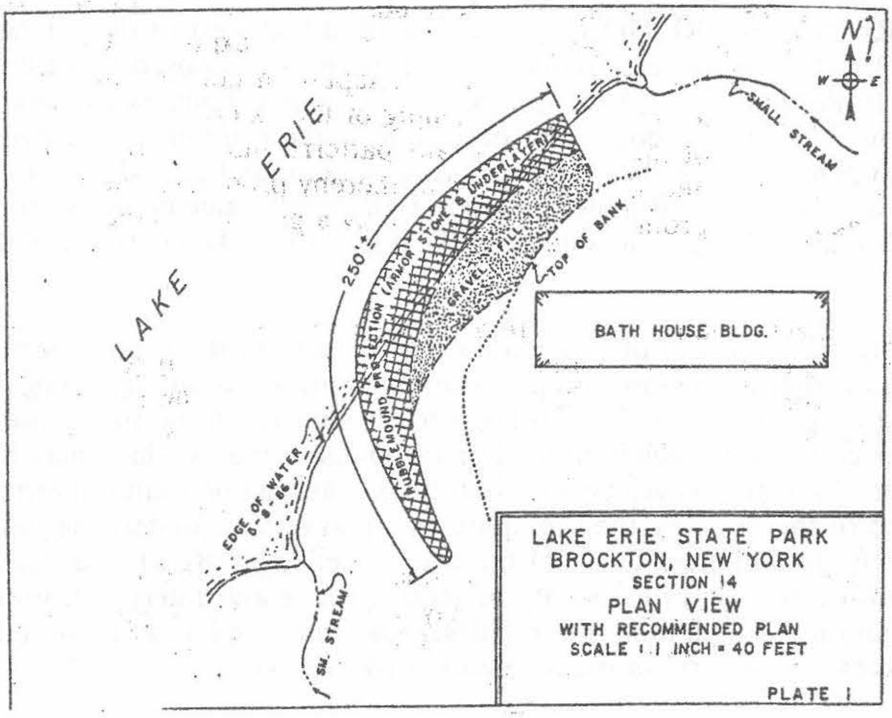


Figure 8. Map of the Lake Erie State Park revetment system.

the ice margin and the escarpment. This led to numerous small lakes and eventually to the development of three large lakes (the ancestral Great Lakes), Lakes Maumee, Whittlesey, and Warren. Two of these, Whittlesey and Warren, Formed beach terraces that are well preserved in Chautauqua County (Fig. 9). Prior to the deglaciation of the Mohawk and St. Lawrence river systems the drainage of both lakes Whittlesey and Warren was westerly. As the northeast outlet channels became ice free Lake Erie was established at it's present level. The sequence of deglaciation events for Chautauqua County is shown in Fig. 10.

In the Westfield-Fredonia area, Route 20 lies along the Lake Warren beach and Webster Road along the Lake Whittlesey beach.

STOP 5 is in a Lake Whittlesey beach deposit where the following features should be noted; the style and dip of bedding, composition of the pebbles in the gravels, and the structures and textures within the beds.

Due to post glacial isostatic rebound the elevations of these beach terraces rise fifty feet toward the east between the villages of Ripley and Silver Creek, a distance of about 40 miles.

STOP 6. THAYER ROAD OVERLOOK

The Lake Erie Basin was likely a low area rimmed on the south by a cuestaform ridge in pre-glacial times (Dreimanis, 1969;Gravenor, 1975). The sharp rise in topography in front of this overlook is called the Portage Escarpment that although modified by glacial activity is believed to have formed by subaerial erosion prior to Pleistocene glaciation. Bedrock of the escarpment consists of the Canadaway Formation (Fig. 11). Unlike the Niagara Escarpment to the east, the Portage Escarpment is not capped by the resistant strata but is dominated by shales with interbedded thin siltstones. Muller and Fahnestock (1974) asked, "If the topography be truly cuestaform, where are the resistant capping strata responsible for the scarp which is 700 to 1100 feet high in eastern Chautauqua County?"

The overlook is situated on top of the Lake Escarpment Moraine, a moraine complex that Muller (1963) correlates with the Valley Heads Moraine in the Finger Lakes region. This is the result of a stationary ice front at about 14,000 B.P. The moraine is a prominent feature from Northeast, PA to east of Gowanda, NY.

STOP 7. CHAUTAUQUA GORGE HIKE

Note: The hike will take about 3 hours and much of the time we will be walking in the stream. Consequently you should have footwear that you don't mind getting wet and that has good traction. These rocks are extremely slippery when wet...USE CAUTION.

As the ice margin retreated northward from the Portage Escarpment, north draining streams such as Chautauqua Creek were established. Some of these streams carved deep gorges across the escarpment, in most cases carving their channels into the

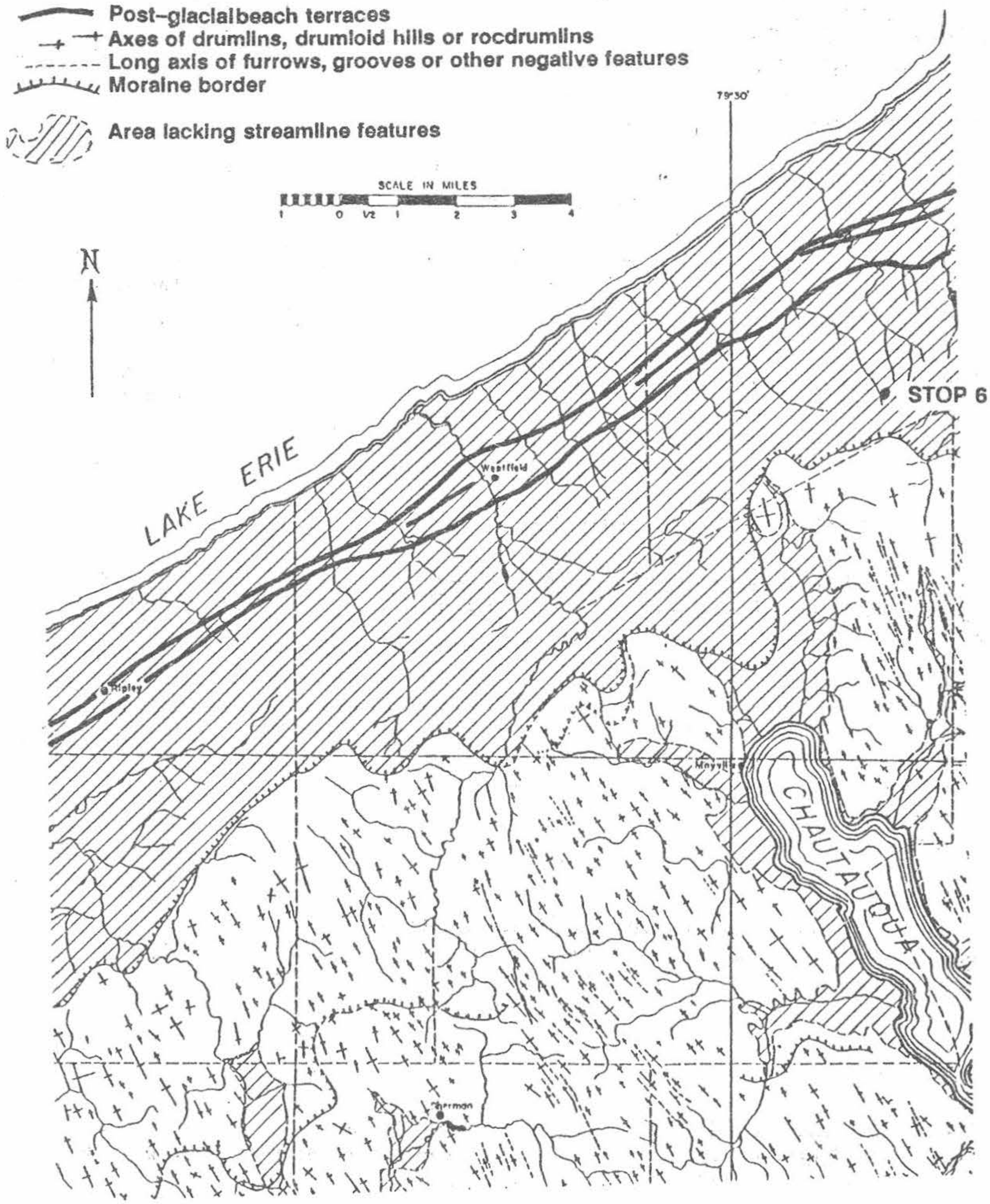
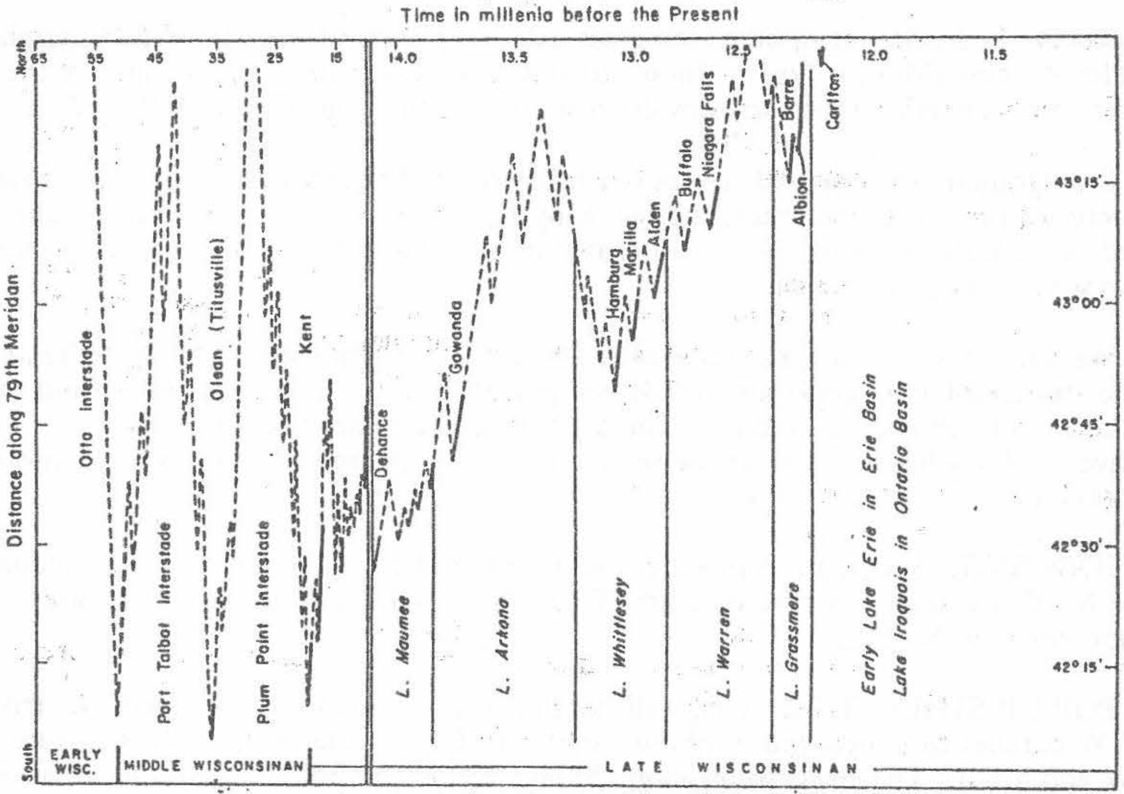
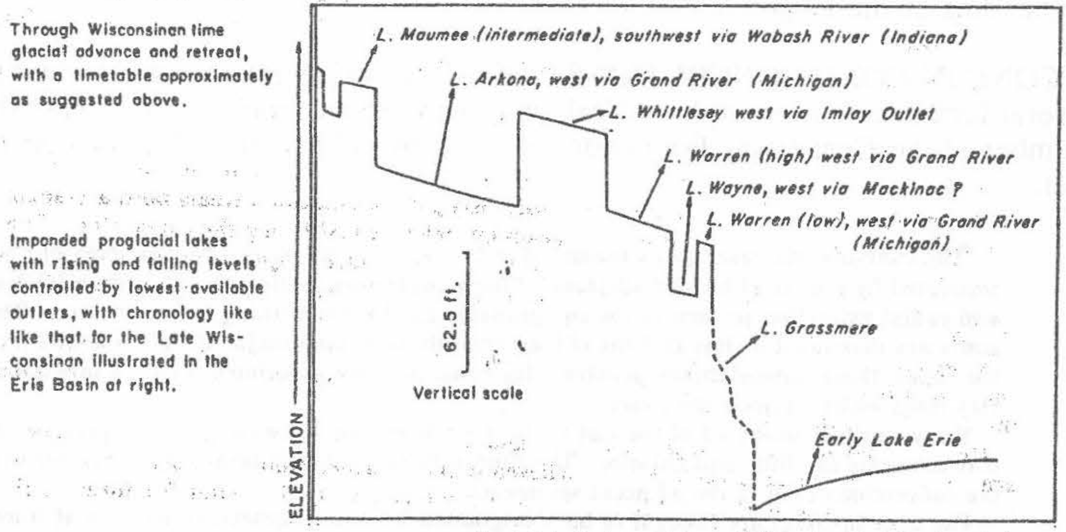


Figure 9. Map of beach terraces and other glacial features.



Postulated chronology of Wisconsinan glacial oscillations



Postulated chronology of proglacial lake levels in Erie Basin during Late Wisconsinan deglaciation

Figure 10. Postulated chronology of late Wisconsin deglaciation. From Muller, 1975.

Devonian bedrock, but in other instances exhuming parts of pre-glacial (or interglacial) valley systems (Muller, 1963). These streams head less than 10 miles south of the Lake Erie shore. Farther south streams drain southward into the Allegheny River.

Stratigraphic units we will see on our hike are the Dexterville (siltstone), exposed where we first enter the creek; the overlying Ellicott, seen high on the steep valley walls; and as we walk downstream we will cross into the Northeast (shale)that lies beneath the Dexterville (Figs. 11 & 12).

We will walk approximately one mile downstream examining the following features: The stratigraphic influence on joint development, pop-up structures, fossils from the Ellicott, cone-in-cone concretions, and a pre-glacial channel filled with kame gravels. We will also consider the sedimentology of this interval of the Canadaway Formation.

JOINTING: Systematic joints are absent in the Dexterville member but abundant in the Northeast shale. A rose diagram of 70 joints is shown in Fig. 5J. Most are approximately N 45 E.

POP-UP STRUCTURE: One well developed pop-up will be examined. It strikes N 27 W parallel to a localized northwest joint set. Dips at the crest of the structure are 15 SW and 6 NE. The structure is about 20 feet across and has an amplitude of about 2 feet. This example is quite different from the anticline seen at stop 1 in that there is no bending at the hinge.

CONE-IN CONE CONCRETIONS: Cone-in Cone concretions are known from several locations in western New York and Pennsylvania from the Northeast shale member of the Canadaway Formation. A study by Gilman and Metzger (1967) found that:

> **"The cone-in-cone concretions examined in this study occur as two hemispheres of cones separated by a layer of bedded siltstone. Microscopic examination reveals both a bladed and radial extinction pattern in the equigranular calcite constituting the concretion. The cones are disrupted by two systems of fractures: those termed major form the boundary of the cones, those termed minor penetrate the cones and are associated with the formation of clay rings which encircle the cones.**
>
> **X-ray analysis shows all of the $CaCO_3$ in the concretions to be calcite. The predominate clay minerals are illite and chlorite. The concentration of mixed layer clay is greater within the concretions than in the adjacent sediments.**
>
> **The cone-in-cones are thought to have originated from a syngenetic concretion of fibrous aragonite. The conical structures are believed to have formed while the surrounding clay materials were still plastic, and that clay was introduced along the major fractures as the cone-in-cone structure developed."**

A cross section of a typical concretion is shown in Fig. 13.

PALEONTOLOGY AND SEDIMENTOLOGY: Faunal communities of the Dexterville and Ellicott members were studied by Burrier (1977). His table of fauna from various lithologies within the Chadakoin Formation is shown in Table 2. He concluded that these strata represent regressive and transgressive facies of delta front and prodelta environments. Miller and Lash (1984) consider the Northeast shale to be

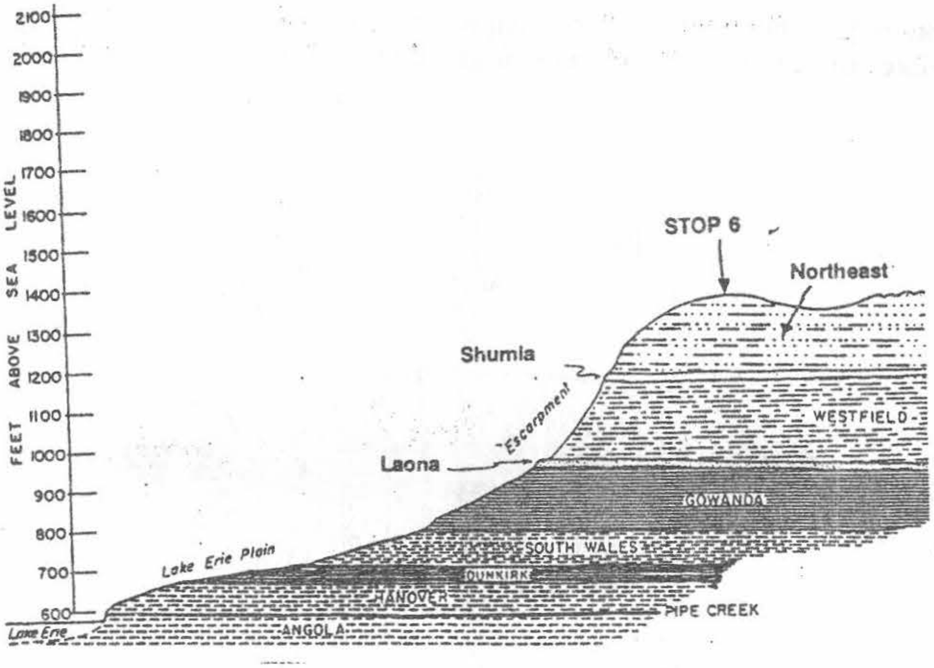


Figure 11. Cross section of the Portage Escarpment, southwestern New York State. From Tesmer, 1963.

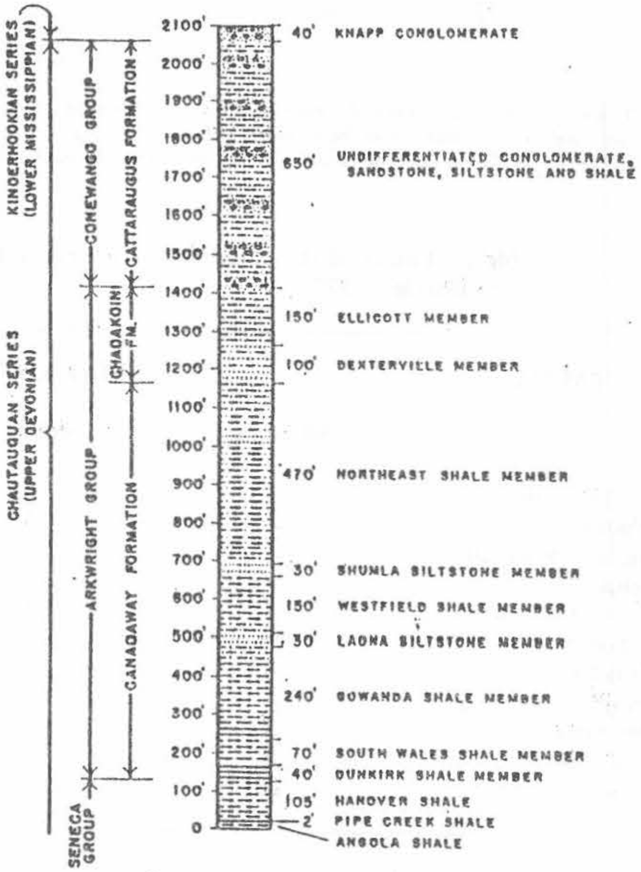


Figure 12. Generalized geologic column of Chauatauqua County. From Tesmer, 1963.

a thickening -, thinning - upwards sequence of turbidites deposited from unconfined sheet-like turbulent flows, perhaps originating from storm activity on the shelf to the east.

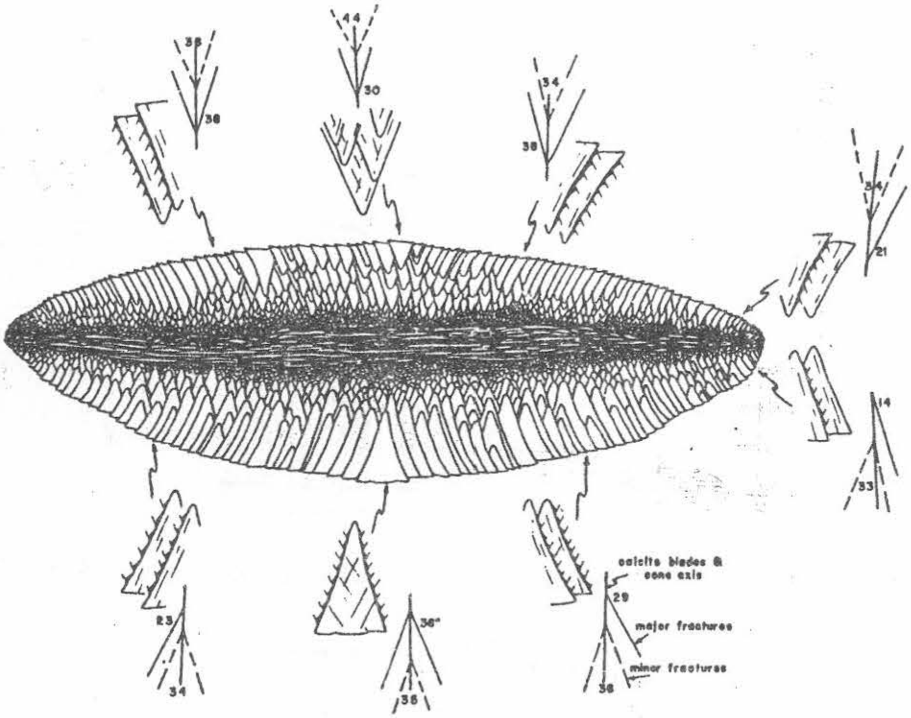


Figure 13. Drawing of a cross section of a cone-in-cone concretion. Also diagramed are the cone axes (coincident with the calcite blades) and the fracture systems as measured in several places in the concretion. Cone axes are perpindicular to bedding in surrounding shale and the medial silt. From Gilman and Metzger, 1967.

Table 2. Fauna of the Chadakoin formation, Chautauqua Gorge. From Burrier, 1977.

FAUNA	SEDIMENT TYPE		
	Siltstone	**Shale**	**Coquina**
Camarotoechia	X	X	X
Productella	X	X	X
Pugnoides duplicatus	X		X
Cyrtospirifer	X	X	X
Leptodesma	X	X	
Bryozoans	X		X
Nucloidea	X		
Goniophora	X		
Grammysia	X		
Ambocoelia	X		X
Mytilarca	X	X	X

PRE-GLACIAL VALLEY: The topographic map (Fig. 14) of the part of Chautauqua Creek known as *THE GULF* shows a pronounced change in valley shape; a narrow steep walled bedrock gorge in the region where we will start our hike, to a wide flat floored valley about a mile downstream. The north end of this wide valley segment is again constrained between narrow bedrock walls. Post-glacial erosion by Chautauqua Creek has carved a channel that in part cuts across a pre-glacial valley that was subsequently filled with glacial deposits. Muller (1963) interprets these as kame deposits. The extent and orientation of the older channel is not certain.

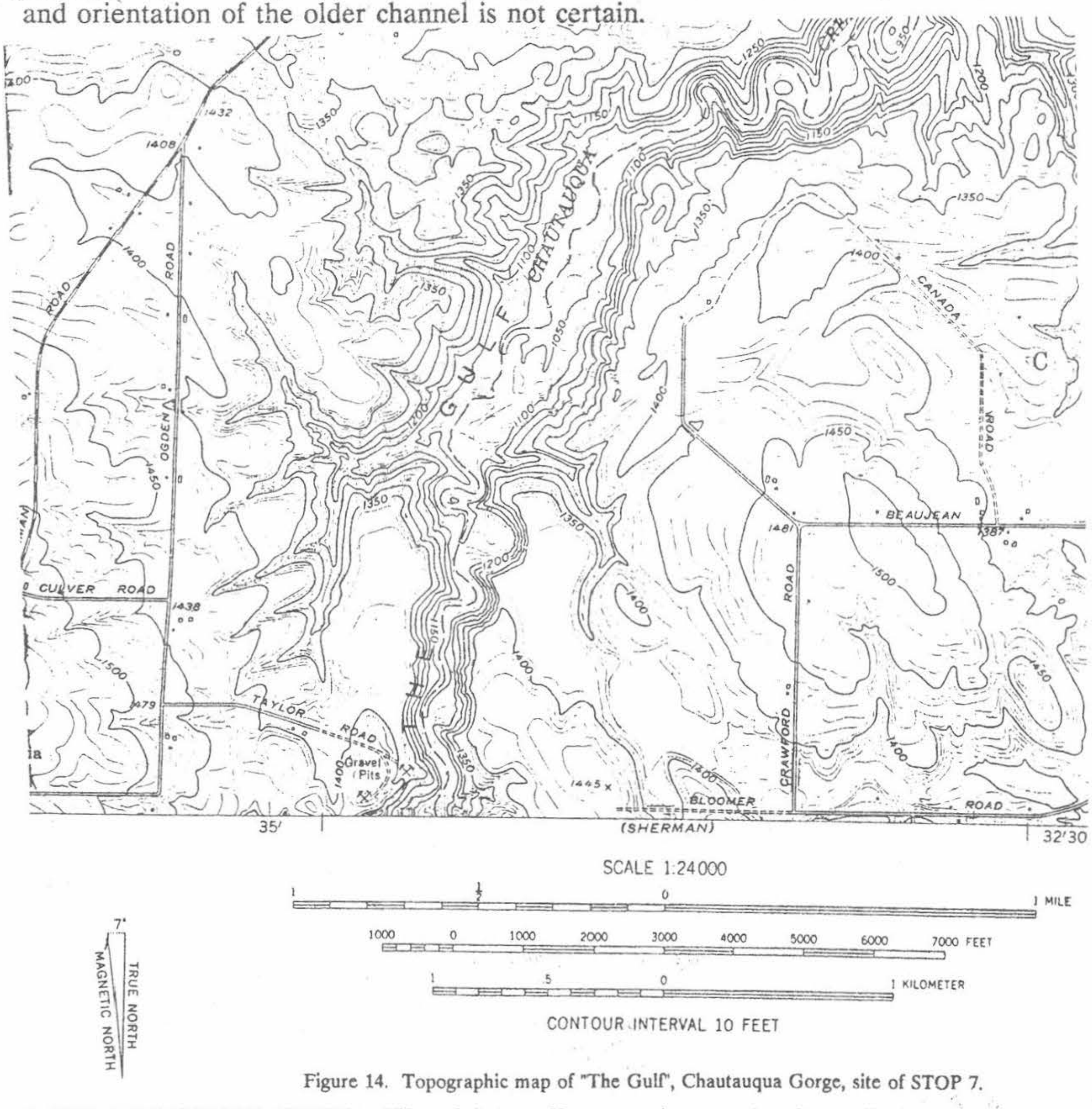


Figure 14. Topographic map of "The Gulf", Chautauqua Gorge, site of STOP 7.

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ROAD LOG

TOTAL MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0		Proceed to Temple Street entrance to the college; turn right (north).
0.2	0.2	Turn left into the parking lot of St. Paul's Church.
		STOP 1. Follow the path to Canadaway Creek to look at pop-up anticline in the Gowanda shale.
		Return to cars and turn left (north) on Temple Street.
0.4	0.1	Intersection: Proceed ahead on Temple Street.
1.0	0.6	Thruway overpass
1.4	0.6	Turn left on Willow Road.
1.9	0.5	Turn left on Route 5.
4.3	2.4	Turn left on VanBuren Road (Fireside Restaurant on corner)
4.8	0.5	Turn right into Niagara Mohawk fly ash disposal site.
		STOP 2. (permission to visit this facility may be obtained from Mr. Jacob (Dave) Guziac, NiMo, 106 Point Dr. North, Dunkirk, NY 14048 716-366-2885).
		Follow gravel road to DON FRAME disposal site.
		STOP 3. Reclaimed fly ash disposal site.
		Follow gravel road to Route 5 (reset odometer)
0.0	0.0	Turn left (west) on Route 5.
1.7	1.7	Turn right into Lake Erie State Park; keep right to beach area parking lot.
2.2	0.5	**STOP 4.** Lake Erie shoreline; environmental and geological features
		Return to Route 5.
2.7	0.5	Turn right (west) on Route 5.
3.3	0.6	Turn left (south).
3.9	0.3	Thruway overpass
4.2	0.3	Railroad underpass, DANGER: WATCH FOR STOP LIGHTS!

5.2	1.0	Intersection with Route 20 at Brocton: Continue straight ahead. Rought 20 lies along the top of the Lake Warren beach ridge; this will be discussed at the next stop.
5.9	0.7	View of Lake Whittlesey beach terrace at 10 o'clock
6.1	0.2	Turn right (west) on Webster Road.
6.7	0.6	Turn right into gravel pit
		STOP 5. Lake Whittlesey beach deposit.
6.9	0.2	Turn right (west) on Webster Road.
7.7	0.8	Turn left (south) on Fay Road.
8.2	0.5	Turn left (east) on Elliocott Road.
8.5	0.3	Turn right (south) on Thayer Road.
9.4	0.9	At about this point we leave the lake plain and proceed up the escarpment.
9.9	0.5	Turn left into Thayer Road Overview.
		STOP 6. LUNCH.
10.2	0.3	Turn right (north) on Thayer Road.
11.7	1.5	Turn left (west) on Ellicott Road.
12.6	0.9	Turn north on Cemetary Road.
12.8	0.2	Intersection (stop). Proceed straight ahead.
13.3	0.5	Turn left (west) on Route 20: Village of Portland. Route 20 follows along the lake Warren beach as we proceed toward Westfield.
17.9	4.6	Entering Westfield.
18.9	1.0	Stop light: continue ahead.
19.2	0.3	Stop light: continue ahead crossing bridge over Chautauqua Creek.
19.5	0.3	Turn left (south) on Chestnut Street.
22.8	3.3	Bear left at Ogden Road
24.2	1.4	Turn left on Taylor Road (white house on the corner).
24.8	0.6	Park at the end of the road, across from gas well.
		STOP 7. Hike into Chautauqua Gorge. Requires wading in water.
		Return to Westfield, then to Fredonia via Route 20.

TOTAL ROUND TRIP APPROXIMATELY 53 MILES.