LAND INSTABILITY IN THE GENESEE RIVER VALLEY - LIVINGSTON COUNTY

Types of instability

Land instability in the Genesee River Valley in Livingston County takes three forms: River-bank failure during meander migration, landsliding, and subsidence over abandoned salt mine workings. River-bank failure is a completely natural process possibly influenced by controlled discharge from the U.S. Army Corps of Engineers Mount Morris Dam in Letchworth State Park. Landsliding is a natural process along the Genesee River. Subsidence over abandoned salt-mine workings is a process induced by mine collapse. Only the subsidence stop (1) and the meander migration stop (2) will actually be visited on this trip.

Subsidence and other events in the Boyd-Parker area[2]

At 05:43 EST on 12 March 1994, an energy release equivalent to that from a magnitude 3.6 earthquake took place from a source beneath the flat valley floor of the Genesee River under Boyd-Parker State Park near Cuylerville in the SW Geneseo 7½' quadrangle (Figure 6).[3] This energy release was recorded on seismographs managed by Lamont-Doherty Observatory in Palisades, New York and by other seismographs in the U.S. and Canada. This energy-release event was first reported as an earthquake, but subsequent analysis seems to indicate that the energy release was simultaneous with the fall of roof rock in the Akzo salt mine beneath the bridge on Route 20A over Little Beard's Creek.

This event at depth was accompanied by dramatic events occurring at the surface. These included sharp shaking felt by residents immediately above the failed mine workings, lateral displacement of the Route 20A bridge over Little Beard's Creek, failure of the west abutment of the bridge, ground-surface subsidence, and open fracturing of the ground surface.

It was soon learned that changes had occurred below ground. These included the collapse of pillars previously supporting the mine roof, failure of the roof, and inflow of water into the mine at an initial rate estimated at 4000 gal/min. The area in which subsidence has taken place is referred to here as the Boyd-Parker area after the park located close to the center of the area. The initial subsidence area is designated as S-1 on the map accompanying the road log (Figure 9).

Episodic as well as gradual subsidence of the ground surface and steady inflow of water into the mine continued from 12 March 1994 to early April. On 06 April 1994 at 05:00 EDT, this slow subsidence was punctuated by the sudden drop of

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[2] This summary is based largely on Lundgren (1994a and 1994b)

[3] See road log for figures cited in this section.

an approximately 4000 square foot area on the south side of Route 20A. This subsidence, estimated to be on the order of 10 ft (3 m) created a lake along this reach of Little Beard's Creek. This subsidence area is designated as S-2 on the map (Figure 9).

The gradual subsidence of area S-1 was punctuated by another event on 23 April 1994 when an open fissure having a circular plan formed around the outer edge of S-1. Then on 25 May 1994, yet another subsidence event occurred in the area designated as S-3 (Figure 9). This event was manifested by the formation of a sinkhole 600 ft in diameter and 70 ft deep in the center.

The inflow of water into the mine instantaneously created severe problems for the Akzo Salt company, problems that have been the main focus of attention on the part of Akzo and the New York State Department of Environmental Conservation. These problems have been extensively covered by the Rochester newspapers and have received daily mention on TV and radio. Closing of the mine and the continued occurrence of events have already had substantial economic and other impacts on the community.

Relationship between subsidence and mine workings

The map accompanying the road log (Figure 9) illustrates that subsidence area S-1 lies directly above a rectangular section of the salt mine set off from the main mine area at its southern end. In this section, the salt pillars left to support the roof were approximately 20 ft on a side. This is in contrast to the extensive mined area immediately to the north where the salt pillars were approximately 80 ft on a side. Subsidence area S-3 also lies above a rectangular section of the mine in which the pillars were 20 ft on a side. The 2 mine sections in which pillars 20 ft x 20 ft were left are bordered on the west and south by unmined salt or by a continuous "wall" of salt. The map (figure 9) shows the dimensions of the partial walls of salt on the eastern side of these two areas. Since the seismic event recorded on 12 March 1994 has been attributed to the fall of a volume of roof rock approximately 12 ft x 600 ft x 600 ft, then the implication is that a number of 20 ft x 20 ft columns failed almost simultaneously in order to make the fall of such a large block of roof rock possible. Subsidence at the surface (S-1) was simultaneous with the seismic event, indicating the rapid propagation of fractures (faults) upwards from the mine 1000 ft below.

Although extensive drilling has been carried out and surface surveys have been made, none of the findings are available from either Akzo Nobel or from the New York State DEC at this time (June 1994). Therefore the actual displacement of rock layers and surficial materials is not known. The subsidence event in area S-3 also is apparently located directly above a second area of the mine in which the 20 ft x 20 ft mining method was used. This subsidence event differed from that at S-1 in a significant respect. Whereas subsidence at S-1 has been relatively gradual, except for the occurrence of event S-2 within the S-1 area, subsidence at S-3 was instantaneous creating a "sinkhole" reported to be 70 ft deep in the center. This geometry has suggested to observers who do not have access to the site that unconsolidated materials may have been transported downwards in the phenomenon known as "piping."

Implications

The subsidence events to date have occurred above a stratigraphic section that consists of approximately 400 ft of unconsolidated valley fill deposits that lie on eroded Onondaga limestone. Therefore failure above the mine involves failure in a 450 ft sedimentary rock section and the overlying unconsolidated materials. Since the Onondaga is in direct contact with the valley fill, there has been much debate about the "source" of the water flowing into the mine. Akzo Nobel representatives have generally maintained that this source is the Onondaga, which is a confined aquifer west of the valley. Many other geologists who have examined the situation have argued, however, that the source more likely is a combination of the Onondaga and the valley fill above. The importance of this is that to the extent that the valley fill serves as "source" inflow of water into the mine can affect hydrologic relationships over a much larger area than if the source is a confined aquifer (Onondaga).

MEANDER MIGRATION - GENESEE RIVER

Meanders

Even cursory examination of the Geneseo 7.5' quadrangle or of aerial photographs reveals that the Genesee River meanders freely across the valley floor in the Geneseo quadrangle. The most recent oxbow lake to have formed is readily evident in the SW ninth of the Geneseo quadrangle. There, the photorevised 1978 edition shows the 1950 course of the Genesee as relatively straight. The 1978 photorevision shows an oxbow lake, documenting that a major meander was formed and cut off within little more than 20 years.

Meander activity at two locations south of Route 20A has been of substantial concern. Meander migration immediately south of Route 20A (see figure 6 and 8 with road log) threatened the bridge over the highway and the highway itself. Therefore the U.S. Army Corps of Engineers controlled this migration by placing rip-rap on the concave bank of this meander. As is evident from the map, this meander is also very close to cutoff .

A prominent set of meanders at the southern edge of the Geneseo quadrangle has been migrating rapidly since 1938, cutting into an unpaved road sometime in the 1950s and progressivley removing farmland from cultivation. The main meander here, informally designated as the Christiano meander (see figure 7 with road log), illustrates the meander migration process very well. The actual physical process very much resembles the failure process seen at Stop 2 at Irondequoit Bay in the Monroe County segment of this trip. This process and the results are described in the road log below.

Implications

Since complete meander loops can form in the valley on a time scale of 2 to 3 decades, migration and cutoff are factors in land-use decisions in the valley. The most visible evidence of this is the engineered approach to meander control at the Route 20A meander. In addition, land owners engaged in agriculture have apparently attempted to create artificial (premature) cutoffs to control meander migration. Cutoff of the Christiano meander will eventually stop its further progression but with unkown implications downstream. Meander migration that impinges on the walls of the valley also has the potential to trigger landslide activity. This may have been the case at the site of the Oxbow Lane landslide (see figure 6 with road log). No structures existed on that landslide at the time of failure, but the event illustrated the potential for damage should structures be placed in similar settings in the future.

REFERENCES CITED

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Schuster, R. L., and Krizek, R.J., eds., 1978, Landslides - Analysis and Control. Transportation Research Board, National Research Council, Special Report 176. National Academy Press, Washington, D.C., 234 p.

Wang, W. J., 1990, The Distribution and Development of Landslides at Irondequoit Bay, Monroe County, New York: Master's Thesis in the Department of Geological Sciences, University of Rochester, Rochester, New York.

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ROAD LOG (MONROE COUNTY SEGMENT)

This road log begins at the red light at the intersection of Empire Boulevard and the exit ramp from Exit 8 of Route 590N (See figure 1). To reach this point from the University of Rochester, we will follow I-390S to 590N and follow the white 590N signs to Exit 8 (Empire Boulevard, Route 404, Webster)

Note: This road log is designed explicitly for free-lance use. The copies of parts of the Rochester East 7.5' quadrangle reproduced below show stop locations and provide coordinates using the 10,000 foot New York Coordinate system grid shown on all USGS topographic maps of New York State.

Mileage

Total	Incremental	
00.0	00.0	Empire Boulevard (Route 404) at Exit 8 of Route 590N. Turn right (east) onto Empire Boulevard. Once you cross Irondequoit Creek, be prepared to make a left turn with caution.
01.1	01.1	Left into parking area at New York State Historic Marker (Irondequoit Bay). Walk through the parking lot of the Bounty Harbor Restaurant (assuming permission) and along the shore to the site shown in figure 1.)

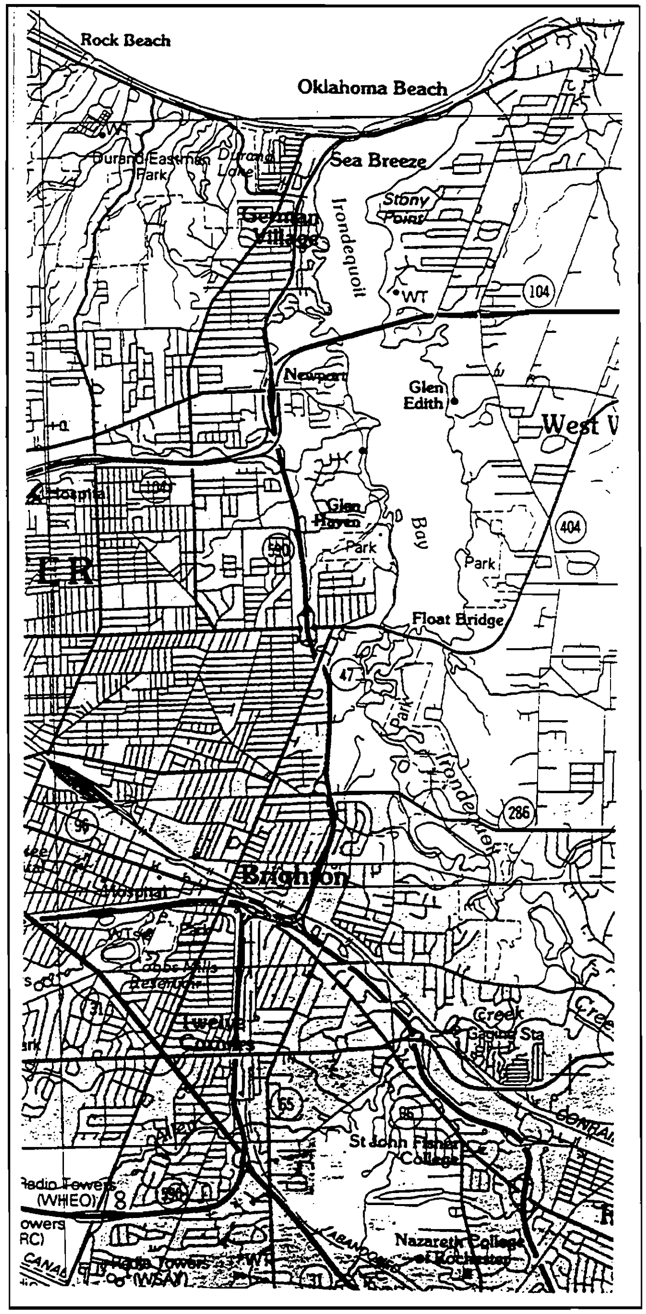


Figure 1 Map of Irondequoit Bay showing approaches on 590N and Route 404. From USGS 1/100 000 Rochester quadrangle.

STOP 1 (Wang sites SE-01-88 and SE-02-88: Note that these sites are only accessible with permission of the land owner. They may or may not be accessible at the time of the NYSGA field trip. If they are not, then they will be viewed from the parking area at the New York State Historic marker site.

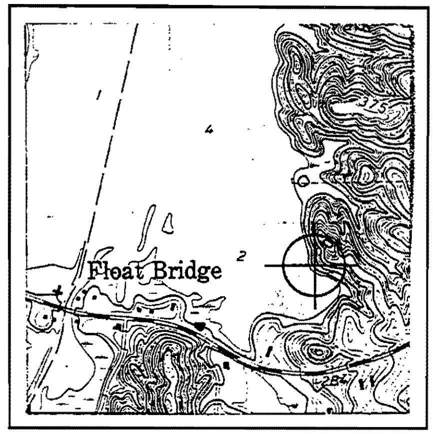


Figure 2 Stop 1 (Wang site SE-01-88 and SE-02-88. NYS 10 000 ft grid coordinates (784100E/159500N)

Discussion topics: (1) The inception of slope instability on previously stable forested slopes. (2) The initial removal of the soil-zone slab. (3) Interaction among different types of slope failure.

These sites are the key to our interpretation of slope instability and evolution. Landslides have been evolving dramatically in the 6 years since observations were begun by Wang.

The pre-landslide character of the slopes at this site is evident from the still vegetated slopes around and above the active landslides on the east side of the bay. Oak, maple, poplar, and other large trees are rooted in the meter-thick soil blanket developed on slopes as steep as 40°. Up to 1951, the entire slope at this site was stable and completely covered by bushes and trees, many of them 50 years old or older. The slope first became unstable sometime between 1953 and 1960.

In 1988, when Wang made his first observations, multiple landslides were already evident (Figure 3). Figure 3 illustrates what we infer to be the initial stages in the destabilization processes affecting Irondequoit Bay slopes. The meter-high scarp surrounding the landslide complex reveals a meter-thick soil zone. Initial slope failure entailed the downslope movement of slabs the base of which is approximately the base of the soil zone. This slab carried with it all of the trees rooted in the soil zone. Even large oak trees have been transported down slope while initially remaining in upright position. Slab A began to move down slope in April 1990 to the position shown in April 1993.

This initial movement of the soil-zone slab effectively removes the protective cover from the slope, but it does not change the value of the slope angle. This process of block sliding takes place on differing scales as may be seen from the way in which the main scarp of this initial and largest landslides is itself cut by the scarps of several smaller landslides. Some of these smaller landslides are similar

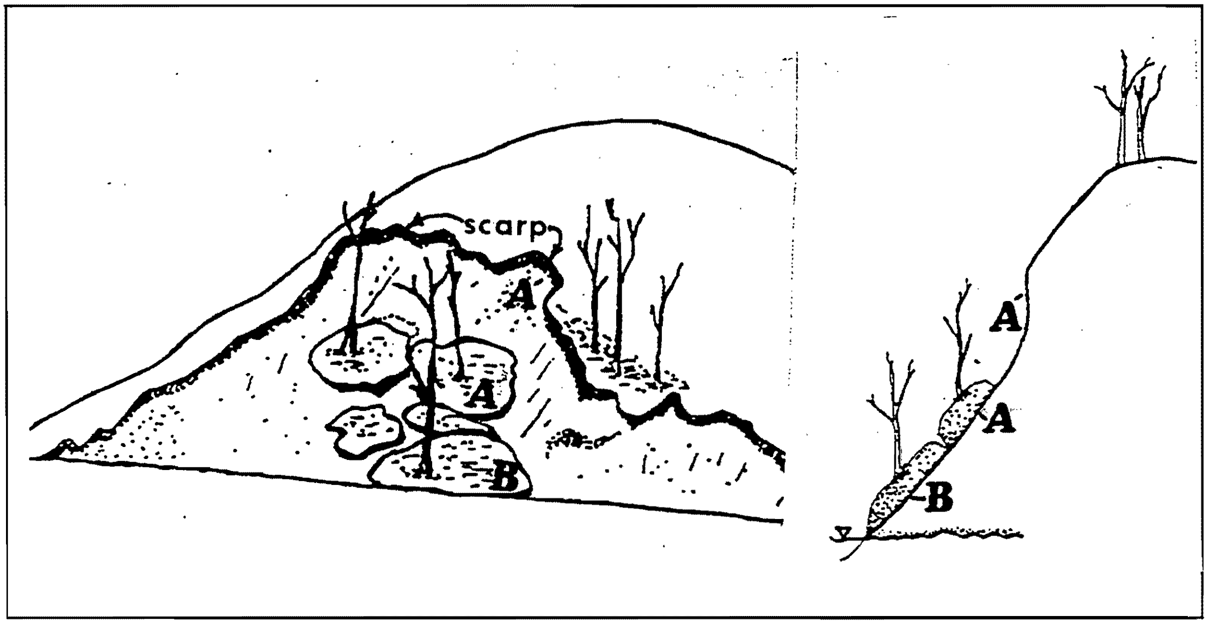


Figure 3 Views of landslides at Stop 1 (Wang site SE-01-88). Based on photograph taken April 1993. Highest point on scarp is 17 m (56 ft) above water level. Slab A was in place at A′ until April 1990. Since then it has been moving slowly downslope. Slab B has reached water level and is being undercut.

in character to, but younger than the largest scarp. In other words, some of these smaller landslides have the same character as the largest slide

In addition to these slab-like landslides, the lower part of the slope displays slumps,landslides created by failure along a spoon-shaped slip surface. These slumps typically form in material from which all vegetative cover has been removed. The most recent of these have all formed in the summer and fall of 1993. These slumps apparently are triggered by undercutting at the shoreline, especially if the slope above has been denuded of vegetation. The formation of these slumps creates regions where the slope is very steep, commonly vertical. These vertical faces are inherently unstable, and failure occurs here through topple and fall as illustrated at stop 2. It appears that once this stage has been set in motion, a threshold has been crossed so that slope steepening becomes the rule.

01.1 01.1 Exit left from parking area using extreme caution. Proceed uphill on Empire boulevard. We will wait on the shoulder until everyone has safely exited.

02.8 01.7 Left onto Bay Road (Seaway Trail Sign)

03.1 00.3 Bayview Family YMCA.
Park in lot.

STOP 2 (Wang site SE-09-88)
Access from Bayview YMCA Parking lot. From Bayview YMCA walk down road to burned-out building and through it to the ORV trail marked by orange paint blazes. Continue to Stop 2 at the shoreline. (Alternative access from Smith Road at Empire Boulevard. Smith Road terminates at the east shore of Irondequoit Bay adjacent to a quonset hut owned by the Rochester Canoe Club.)

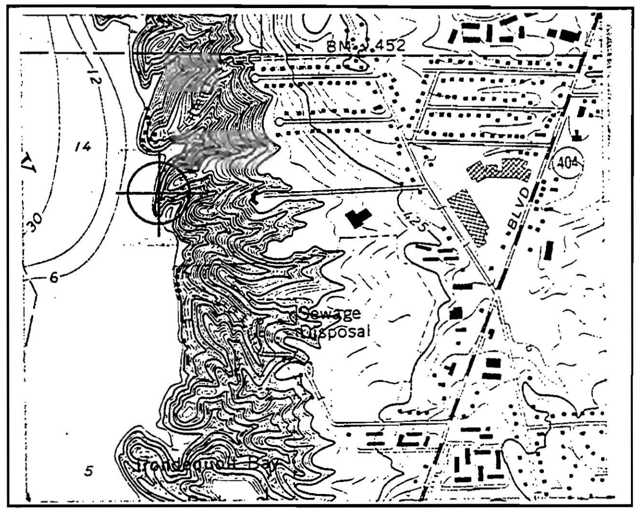


Figure 4 Stop 2 (Wang site SE-09-88) NYS 10 000 ft grid coordinates: 783500E/1165200N

Discussion topics: (1) Lake Iroquois sediments. (2) Present-day processes, especially topple and slump observable in real time. (3) Inception of bluff development in the 1960s.

This site displays 3 bluffs (very steep unvegetated slopes), each of which is vertical in its upper part. The highest bluff rises 26 m (85 ft) above water level. The vertical upper face of these bluffs is created in a cohesive clay unit. Earth slump and earth flow of the non-cohesive materials that underlie this clay unit set the stage for the opening of vertical joints in the clay unit. Blocks of the clay unit as large as 2 m on a side then fall from this free face, sometimes remaining intact and sometimes breaking into numerous small blocks.

Below the vertical face are fans of material that has fallen from above and then accumulated at the base. Some vegetation has taken root in this material. During the summer and fall of 1993 and the late spring of 1994, these aprons were being eroded by wave action, and this erosion and undercutting of the base was triggering earth slumps 2.5 to 3.6 m (8 to 12 ft) high at the base of the bluffs. Earth flow is also common in the fans. Most of the steps in the process can be observed in real time whenever waves and boat wakes break along the base of this bluff.

These 3 bluffs first appear in the 1961 aerial photographs; they cannot be recognized in older photographs. They are interpreted as the end product of landslide processes that first operated on steep but vegetated slopes. Remnants of these slopes are still present. Complete removal of the original soil blanket and the vegetation rooted in that blanket set the stage for the operation of slump processes. Undercutting by wave action during periods of high lake level (as in 1973 and 1993) removed the protective aprons, cut a shelf under the vertical bluff, and set the stage for earth topple noted above.

03.4 0.2 Return to Bay Road. Left (north) on Bay Road.

05.0 1.6 Over bridge above Route 104 and left onto the entrance ramp to 104 west. Keep right.

05.4 0.4 Right into parking area overlooking the Bay Bridge.

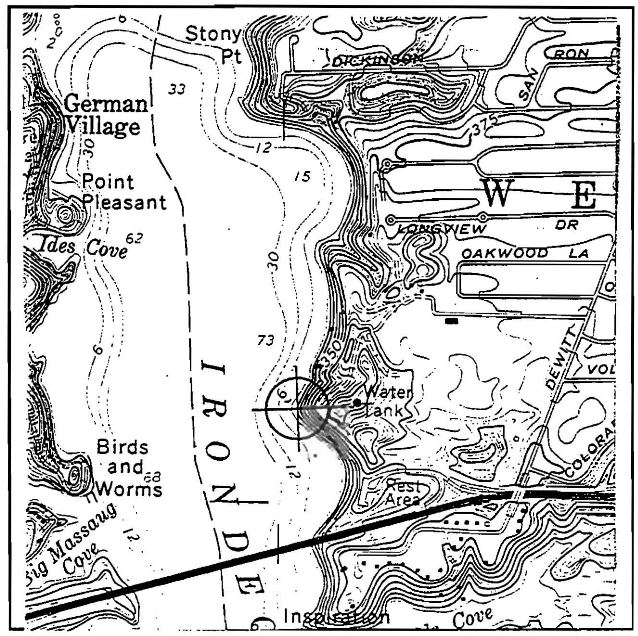


Figure 5 Stop 3 (Wang's site NE-05-88). NYS 10 000 ft grid coordinates: 780200E/1173700N

STOP 3 (Wang site NE-05-88) - Walk north along trail to water tower and then down the west-facing slope west of the water tank at the Webster Water pumping facility.

Discussion topics: (1) Use of multiple scarps in establishing landslide history (oldest and highest scarp dates from 1930 or earlier). (2) Role of high water level and wave activity in setting the stage for slump activity. (3) Probability of future landslide activity. (4) Nature of Lake Iroquois sediments.

This slope displays at least 6 different landslide scarps ranging in age from 1930 (or older) to 1994. The oldest scarp (top at 33 m - 110 ft) above water level outlines a landslide area (probable earth block slide) visible on the 1930 aerial photograph. The entire slope within this oldest scarp displays none of the large trees that are uniformly present in the area outside of the scarp line. There were few large trees on this slope even in 1930. The upper part of this oldest landslide is covered by grass, bushes, and by a few trees less than 15 cm (6 in) in diameter.

All of the other scarps lying within the slope area bounded by the oldest scarp are displayed at lower elevations ranging from 8 m to 33 m (27 ft to 108 ft) above water level. Each scarp bounds a separate landslide, some of which are earth slumps. The youngest of these landslides, re-activated in 1993 when lake level was at a 20-year high, illustrates the conversion of a steeply sloping landslide site to an earth slump and vertical bluff.

The earth slump displayed in the lowermost 15 m (50 ft) of this slope began to form prior to 1978. It exposes an excellent sample of the type of section generally seen north of the Route 104 bridge. A clay layer at the base of the slope is overlain by at least 6 m (20 ft) of sand and silt displaying the climbing ripples characteristic of all northern sections. The upper edge of the scarp of this slump was at 15 m (50 ft) above lake level in May 1994. The upper 2 m of section display clay and silt layers with prominent pillow structures.

The inferred history of this site is as follows: (1-pre 1930) Undercutting at the base; large-scale earth-block sliding of blocks made up of the soil horizons. There were few trees left on this slope after this event. (2) Removal of tree cover, followed by episodes of high lake level led to the inception of the processes active in 1993-1994. (3) Undercutting of the base of the slope by wave action during periods of high water level. Major periods of high water level occurred in 1952, 1973, and 1993. (4) Failure by earth slumping, flow, and topple. These three types of landslide activity occur in conjunction with one another as illustrated by relationships expected to be visible in October 1994.

END OF MONROE COUNTY SEGMENT OF TRIP

ROAD LOG (LIVINGSTON COUNTY SEGMENT)

If continuing to Livingston County segment of trip, cross the Irondequoit Bay Bridge and follow 590S to the I-390S ramp marked for Corning. The road log starts at the entry to this ramp. The potential stops are shown on the map of the SW ninth of the Geneseo 7.5' quadrangle (Figure 6). The road names used here are those used on this map and are spelled as on the map. As of June 1994, access to this area is controlled by security guards, and it is not known what the situation will be on 09 October 1994.

Cumulative	Incremental	
00.0	0.0	I-390S ramp from 590. (Monroe County)
22.6	22.6	Exit 8 (Geneseo exit) onto Route 39/20A . Follow Route 39/20A signs west.
27.8	5.2	Main Street - Geneseo. Continue to follow 39/20A
28.9	1.1	Follow 39/20A signs and descend into the Genesee River Valley.
30.1	1.2	Bridge over Genesee River. Meander on east side of bridge protected by riprap.

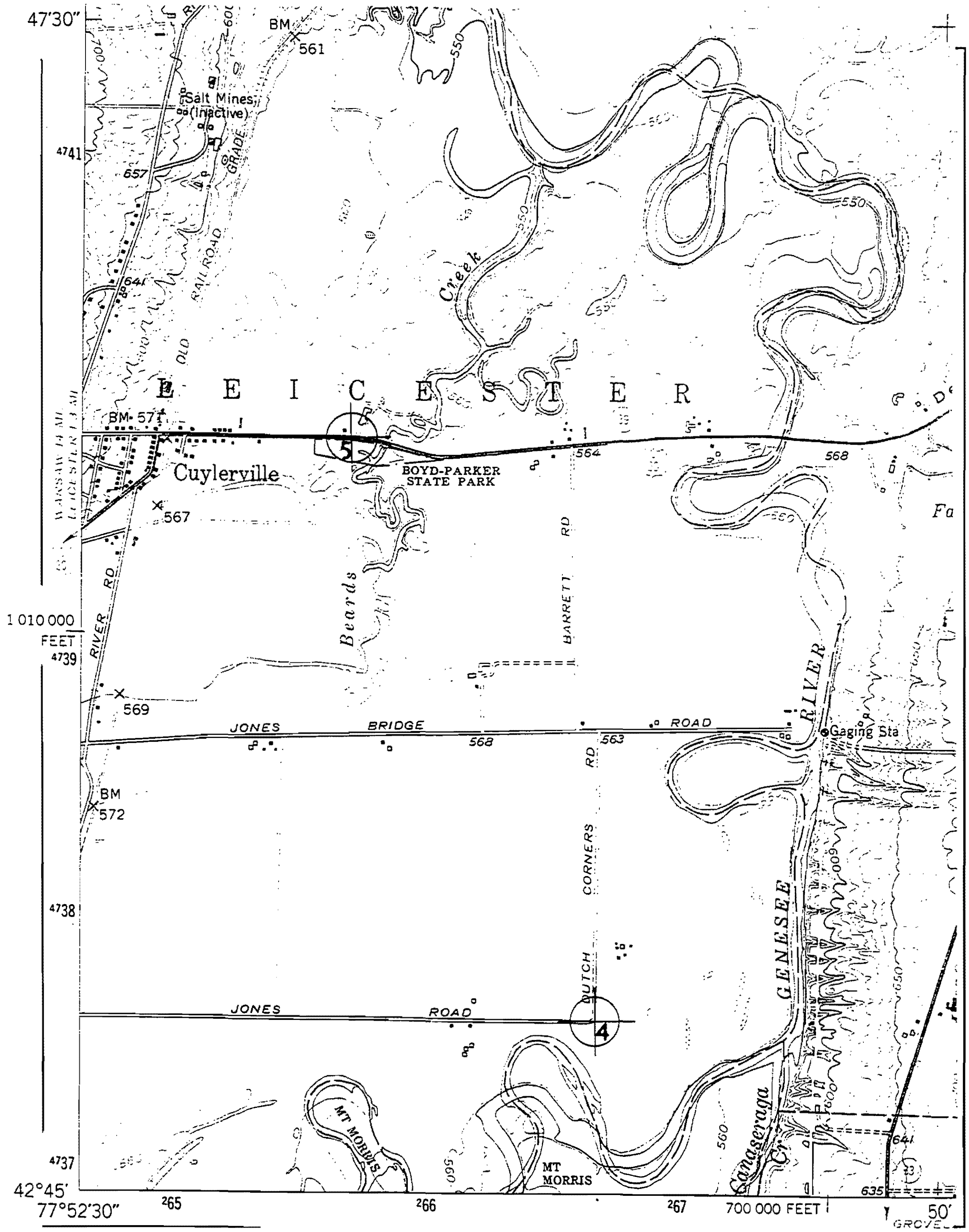


Figure 6 SW ninth of Geneseo 7.5' quadrangle (1/24000). Photorevised 1978. Meanders are numbered for reference to figures 7 and 8 and text. Possible locations for discussion of subsidence in the Boyd Parker area are the west edge of Boyd Parker Park or a site to be chosen on the trip.

Discussion topics: (1) Rates of migration of Christiano meander (this stop) and Route 20A meander (compare figures 7 and 8), (2) Meander migration process at times of high discharge, (3) Possible role of controlled discharge controlled by the Mount Morris dam.

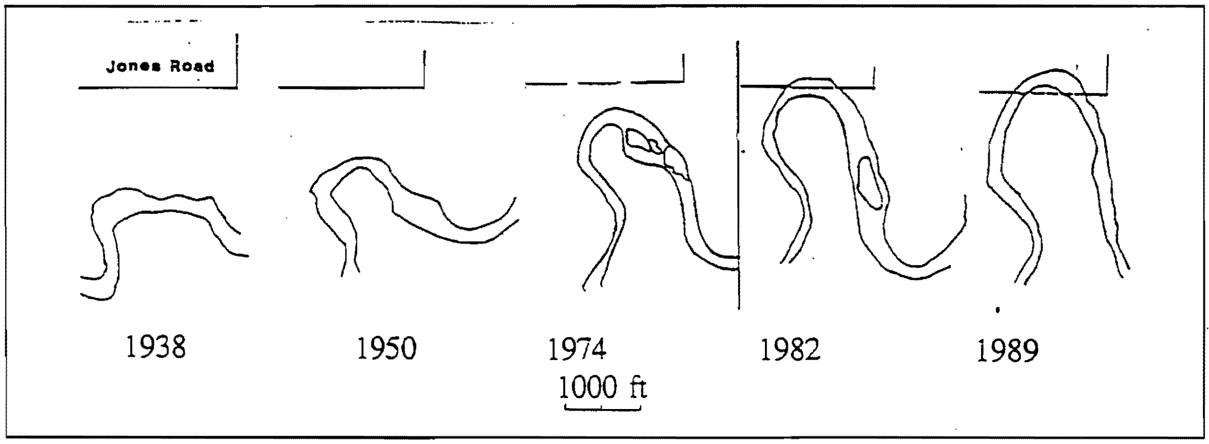


Figure 7 Map of Christiano meander(MS-3) position 1938 - 1989. Plotted from aerial photographs by BOCES summer students 1989.

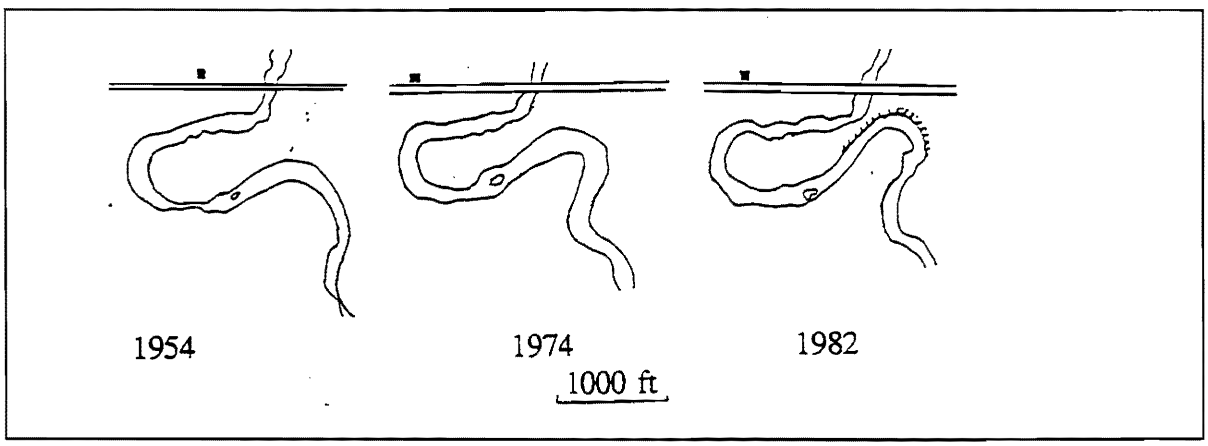


Figure 8 Map of Route 20A (MS-1) meander 1954-1982. Compiled from aerial photographs by BOCES summer students 1989.

Stop 5 Route 20A east or west of the site of the bridge over Little Beards Creek at Boyd Parker Park. This bridge was destroyed by subsidence 12 March 1994. It is not known at this time (June 1994) if this site will be accessible. See figure 9.

30.6 0.5 Intersection of Barrett Road (as spelled on USGS map) and Route 39/20A. South on Barrett Road.

31.3 0.7 Intersection of Jones Bridge Road and Dutch Corners Road. South on Dutch Corners Road to barrier.

31.9 0.6 Barrier.

Stop 4 See figure 6. Genesee River at intersection of Jones Road and Dutch Corners Road (NYS 10 000 ft grid coordinates: 703100W/1002800N).

Discussion topics: (1) The sequence of subsidence events (see figure 8), (2) The relation between subsidence and the mine workings, (3) Hydrologic questions, (4) Future prospects for subsidence and hydrologic impacts.

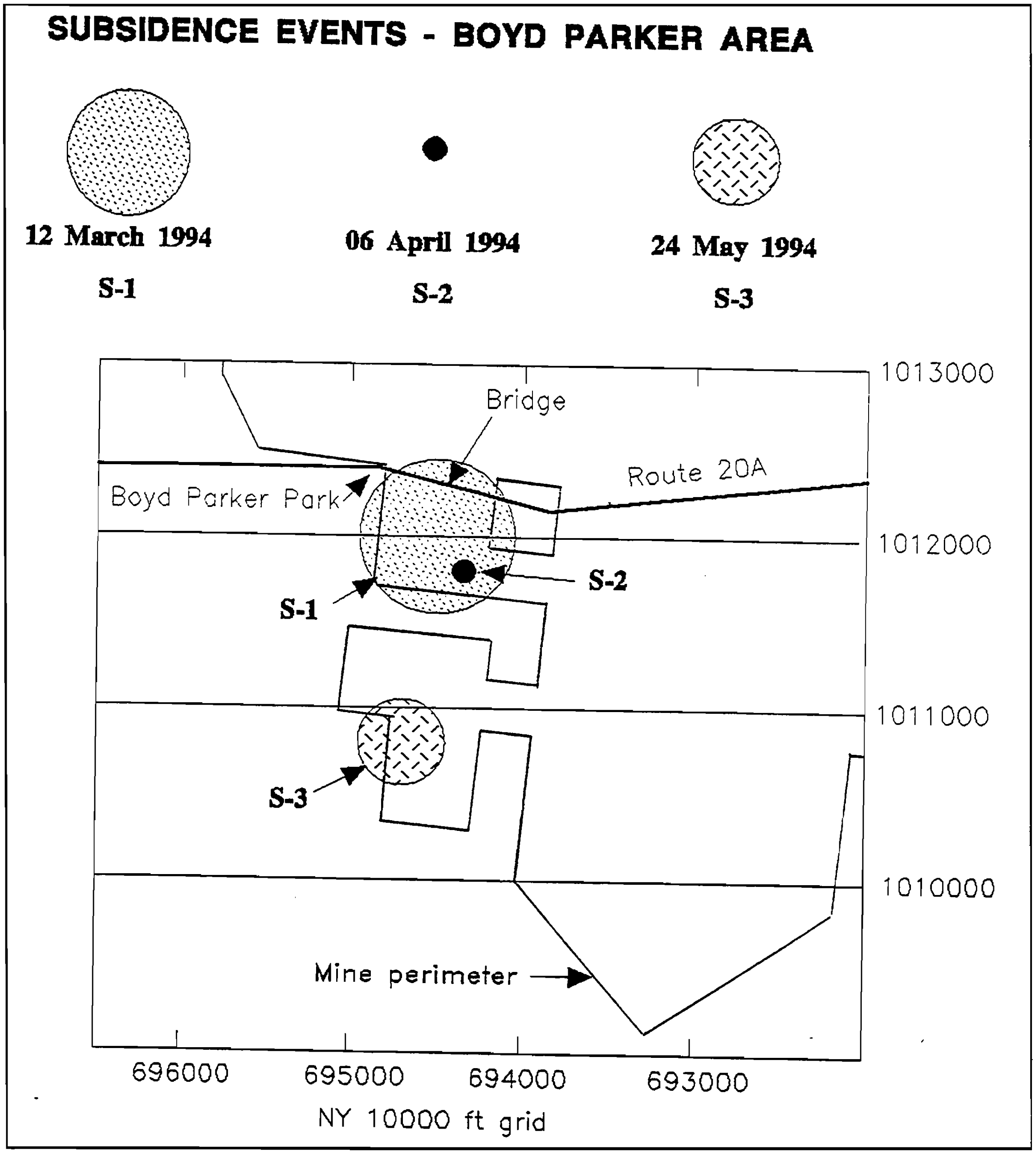
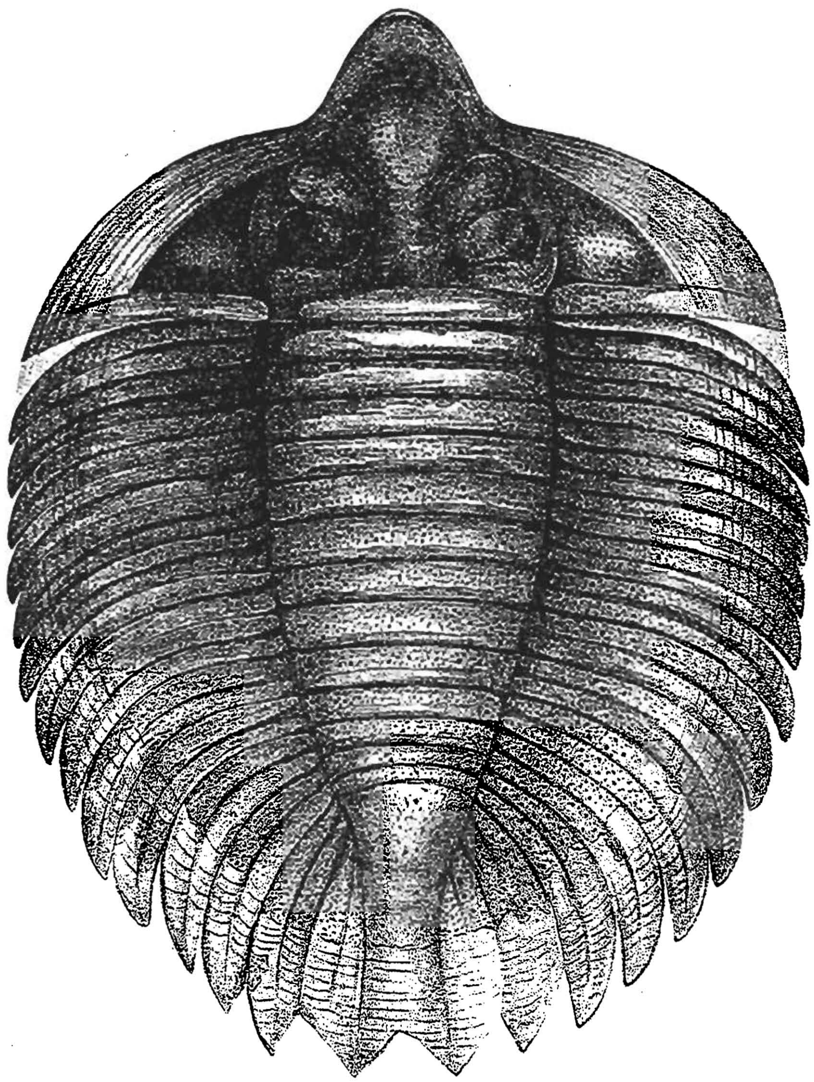


Figure 9 Approximate locations of subsidence features and mine perimeter. Subsidence features based on field mapping. Mine perimeter from map provided by Akzo Salt, Inc. All boundaries schematic.



Actinurus boltoni

[From Hall, 1843, Geology of the Fourth District, Plate 19, Figure 1]