Trip B-1

SUBSIDENCE AND LANDSLIDES IN TULLY VALLEY, CENTRAL NEW YORK

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INTRODUCTION

On this field trip we will examine two aspects of recent geologic activity in the Tully Valley: Fractures apparently opening in response to subsidence and slow-moving earth slides located on tributaries to the Tully Valley. The following guide is divided into two sections that reflect these two different features of the Tully Valley region. Please note that these stops are on private property and PERMISSION MUST BE OBTAINED PRIOR TO ACCESSING THE PROPERTY.

OPEN FRACTURES IN THE TULLY VALLEY

[This section prepared by G. Gleason and W. Hackett]

The purpose of this portion of the field trip is to examine the spatial relation between sets of open fractures and local subsidence in the Tully Valley, Onondaga County, NY. The study areas are located on the east and west slopes of the Tully Valley in Onondaga County (Figure 1). On the Otisco Valley USGS 7.5 minute topographic quadrangle, this location is at the north end of what were two brine fields. On this field trip we will visit the study area on the east side of Tully Valley (STOP 1 of Figure 1).

Local Geology of the Fractures

Exposed bedrock in the study area is Middle Devonian Hamilton Group shale. The strata are horizontal to sub-horizontal. Older strata at depth include layered rock salt deposits of the Upper Silurian Salina Group (~1,200 to 1,400 ft below grade) that have been mined by solution methods in the last 150 years. The valley was carved out by glaciers during the last ice age (10,000 to 20,000 years ago), and as a result has the typical

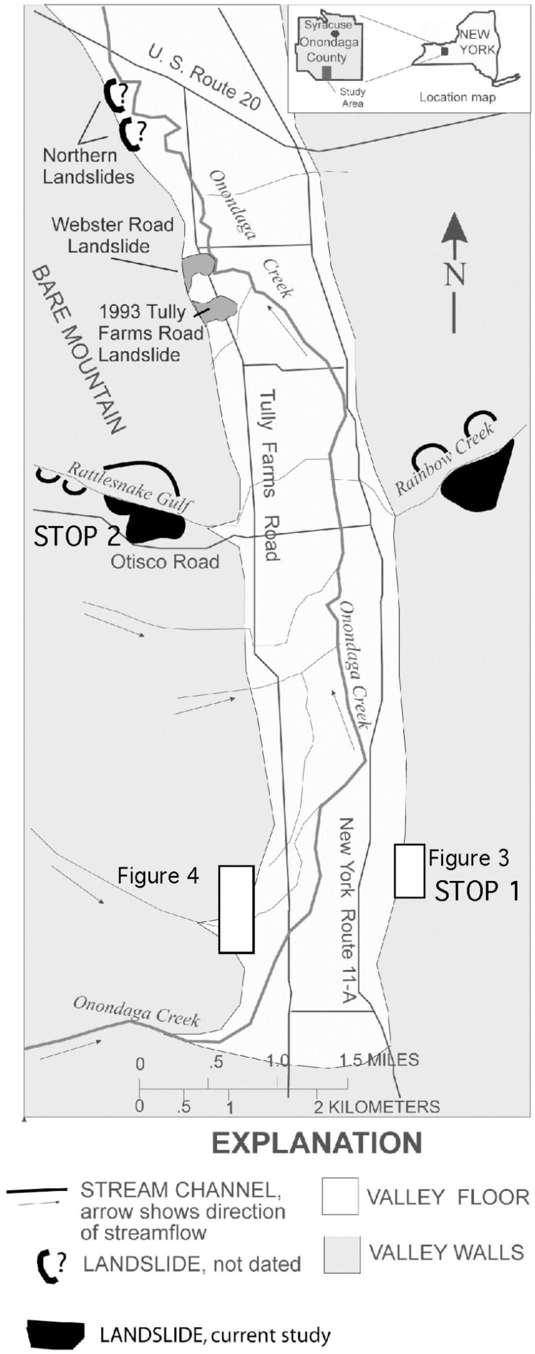


FIGURE 1—Locations of field trip stops. Mapped fractures are in boxes labeled Figure 3 & 4. Location of Rattlesnake Gulf and Rainbow Creek landslide areas in relation to the southern end of the Onondaga Creek Valley (Tully Valley), in central New York.

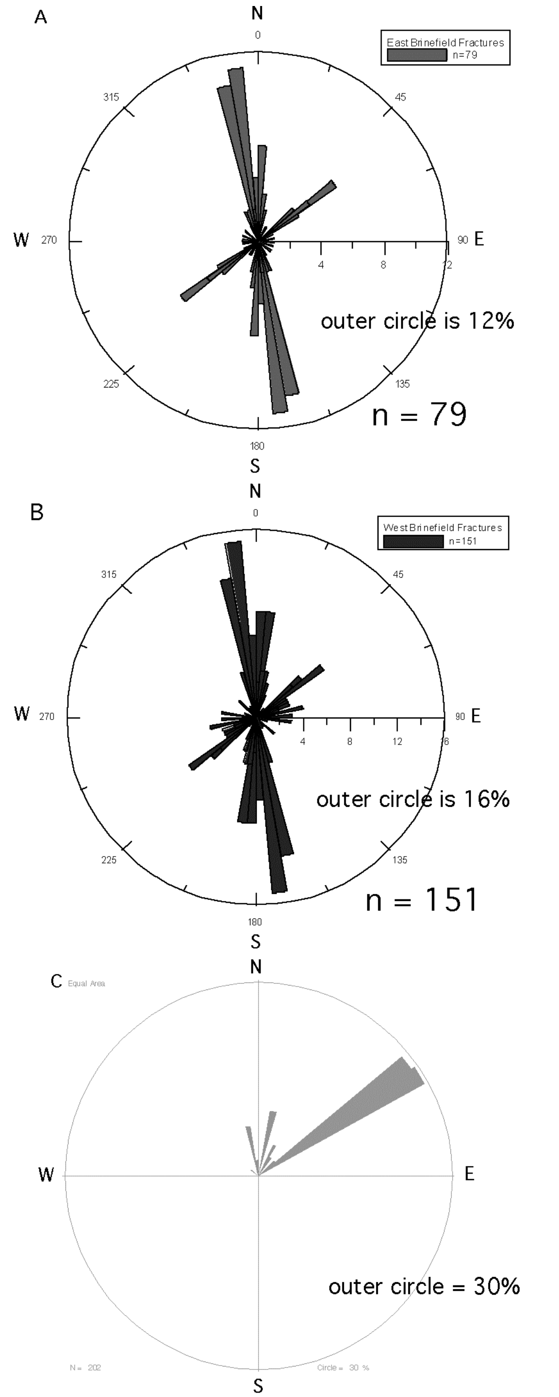


FIGURE 2—Rose diagrams of trends of fractures in Tully Valley. A) Number of fractures on East side. B) Number of fractures on West side. C) Length of fractures on East side. In all plots, data are in bins of 5 degree increments.

U-shape created by valley glaciers. Subsequently, the valley was partially filled with glaciolacustrine and fluvial deposits related to the glacial meltwater (Kappel & Miller 2003).

In Central New York, three joint sets have been identified and studied (e.g., Parker 1942; Engelder 1982; Engelder et al. 2001). Following Parker (1942) we will refer to these as set I striking roughly N10W; set II striking E-W, and set III striking roughly N65E. Sets I and II have been interpreted as cross-fold and strike joints developed during the Alleghanian orogeny as they have a geometric relation to other structures of that time (Parker 1942; Engelder and Geiser 1980). The origin of set III is more enigmatic. Crosscutting relations between the joint sets have not been well exposed. A correlation between the orientation of set III and the horizontal shortening direction of the current stress field lead Engelder (1982) to propose that the set was neotectonic. However, further work by Gross and Engelder (1991) on neotectonic joints in other localities demonstrated that the set III joints could not be young. More detailed work on the set III joints in the Finger Lakes region of NewYork revealed that these joints are offset by sets I and II, thus pre-dating the Alleghanian orogeny (Engelder et al. 2001).

Brine Mining History

Solution brine mining began in the Tully Valley in the late 1800's. Solution brine wells remove material by pumping water into the desired halite bed, allowing it to dissolve the halite, and then pumping brine back out through a different chamber in the well. The material was removed from halite beds in the Syracuse Shale, which are found at approximately 1,200 to 1,400 feet of depth. This method was further expanded through the technique of drilling wells in linear patterns allowing the dissolution cavities to connect (Yanosky and Kappel 1998). "Wild Brining", the practice of allowing unknown amounts of groundwater to infiltrate a well and dissolve halite as well as allowing brine to leave the well, was also practiced in the Tully Valley (Briggs and Sanford 2000). This technique did not allow for an understanding of cavity geometry or size and therefore potentially increased the possibility of collapse.

The brine wells were drilled on both sides of the valley floor at the south end of the valley. The fields were appropriately named the east and west brinefield. Mining began first in the east field around 1888. Production in both fields peaked around 1950-1960 before the east field was closed in 1960. The west field continued production until 1988 when the last wells were shut down. Ultimately, the brining period resulted in the removal of approximately 31,000 acre-feet of halite. With the removal of this quantity of material, widespread land surface subsidence occurred. Some areas on the valley floor were shown through repeated surveying to have subsided up to 40-50 feet over several decades. Subsidence observed on the valley floor was widespread, and open bedrock fractures appeared upslope on the valley walls of both the east and west fields.

Description of the Fractures

The fractures are either in exposed bedrock or observed as linear depressions ("coffin holes") in the covering soil. Fractures in the bedrock are typically open, and have gaps from 10 to 60 cm wide. Depths of these openings vary from 0.5 to 15 m. Many times the linear depressions are along a line with level "bridges" or covered segments between them. The width of these "coffin holes" probably reflects collapse of the soil into the bedrock fracture below. The linear depressions are typically 1 to 3 m wide, although their lengths vary considerably (2 to 10 m).

The trends of the on-line linear depressions were measured, and dip was assumed to be vertical. When the fractures in the bedrock were exposed, both trend and dip were measured on the fracture surface. On both sides of the valley, the dominant set of fractures trends just west of north-south (NNW; Figures 2a & b) corresponding to set I of Parker (1942). A second set trends 060˚, corresponding to set III of Parker (1942). A few E-W trending fractures were also recorded (set II of Parker, 1942). However at least on the east side, the 060˚ direction clearly dominates with 60% of the **total length** (+/- 5˚), and each other direction accounts for less that 10% of the total (Figure 2c).

In the east brine field, the open fractures are grouped up-slope (to the east) from three sinkholes, two of which are easily seen on the map (Figure 3). This spatial relationship to sinkholes is also observed in the west field, where fractures are more numerous above the three sinkholes in that field (Figure 4).

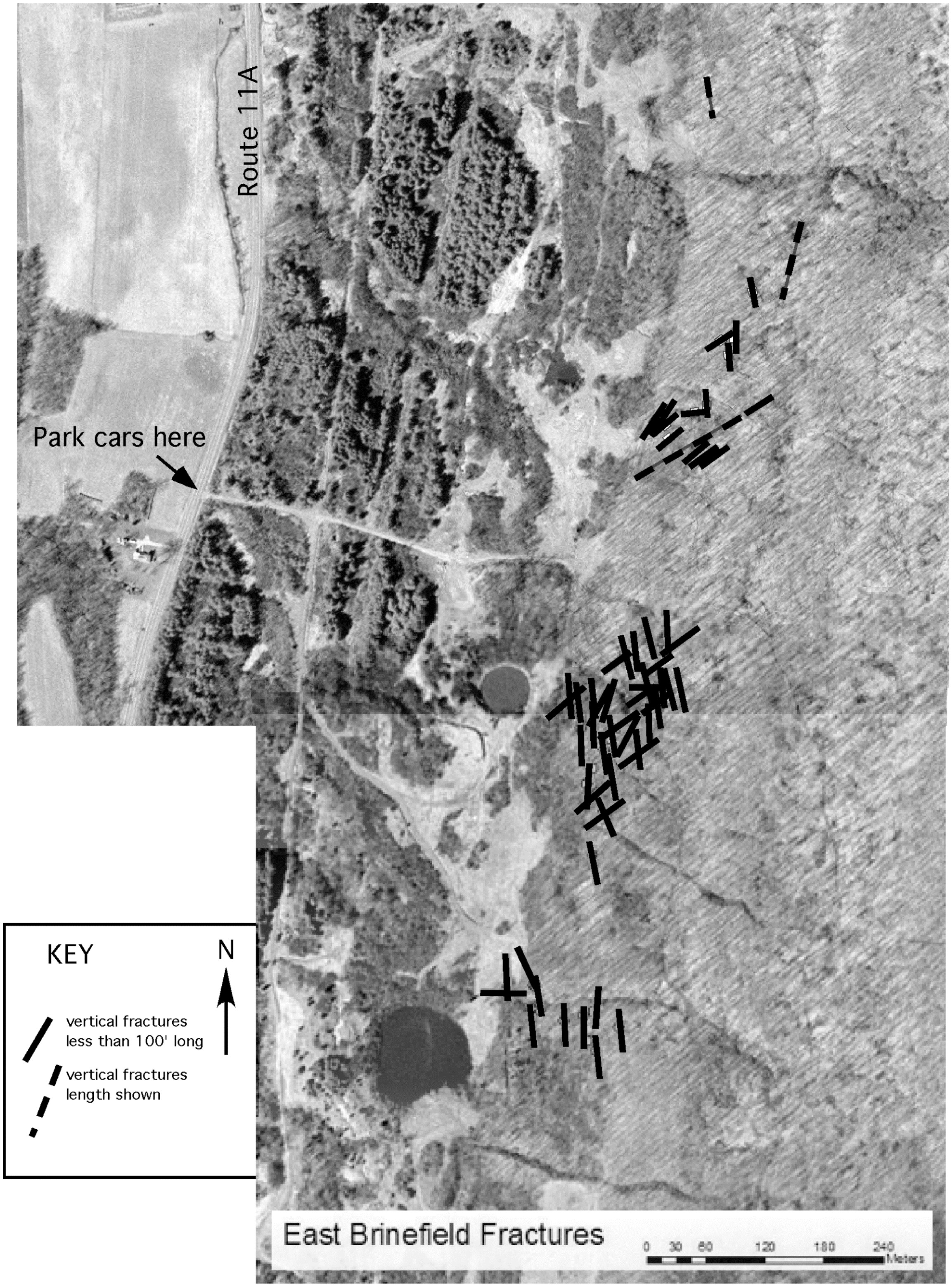


FIGURE 3—Aerial photo of STOP 1 on the East wall of Tully Valley. Open fractures cluster upslope from sink holes

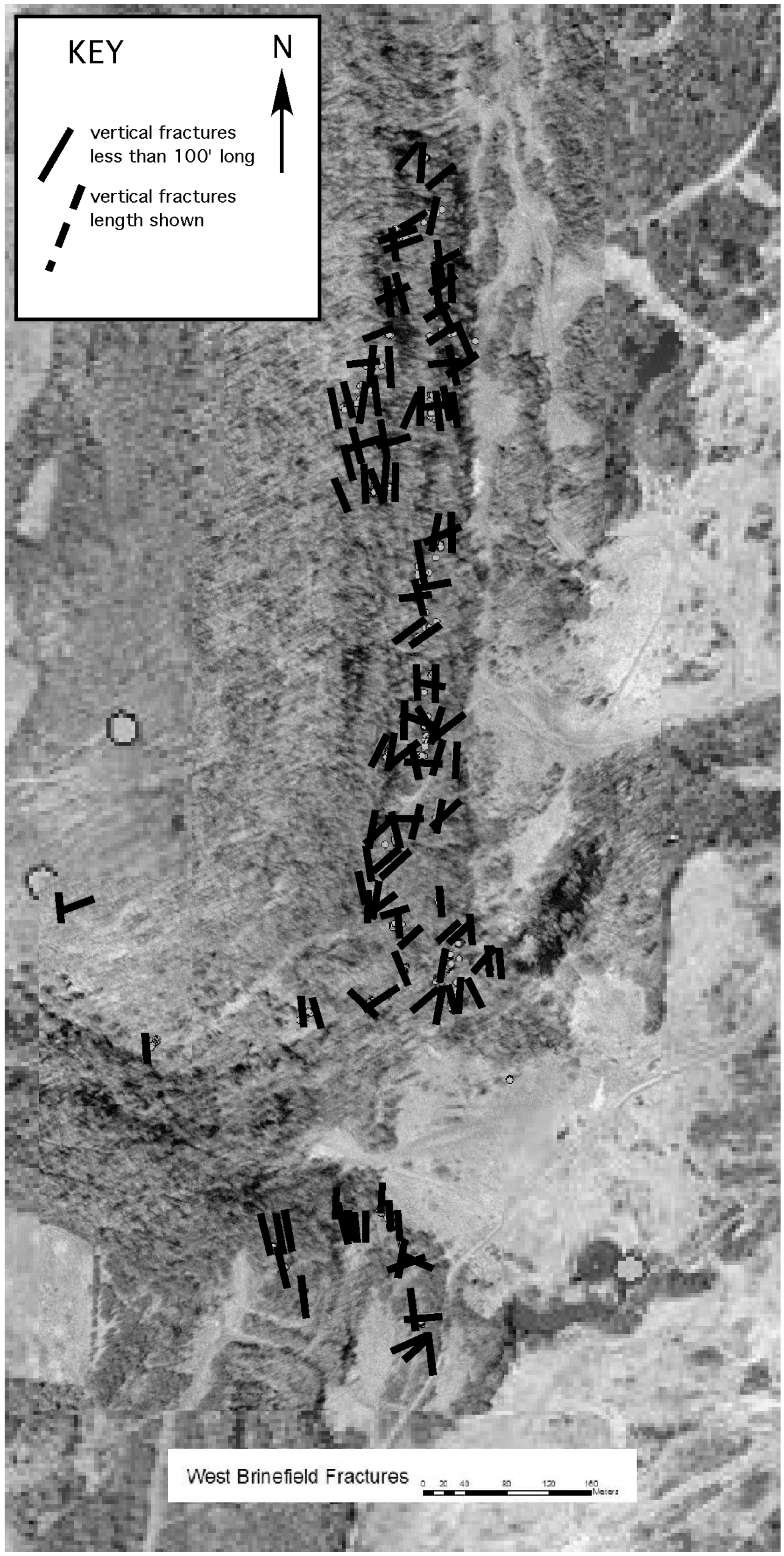


FIGURE 4—Aerial photo of the West wall of Tully Valley showing distribution of fractures.

PRESENT CONDITIONS AND HISTORIC DENDROGEOMORPHOLOGICAL ASSESSMENTS OF THE RAINBOW CREEK AND RATTLESNAKE GULF LANDSLIDES

[This section prepared by K. Tamulonis]

Introduction to the Landslides

The Tully Valley, New York is a 6-mile-long glacial trough located in the eastern Finger Lakes region of the Allegheny Plateau and has a landslide history dating back to 9,870 ^{14}C yr B.P. In 1993, the largest landslide in the state since the early 1900's occurred on the west wall of the valley. Presently, two slow-moving earth slides, Rainbow Creek and Rattlesnake Gulf, are located in tributary valleys to the Tully Valley (Figure 1). Precipitation, ground-water level, and land-surface movement measurements and dendrogeomorphology indicate that movement on the Rainbow Creek and Rattlesnake Gulf landslides occurs on two scales: shallow displacement following precipitation events, and deep-seated, rotational movement, which was determined through analysis of tree ring data, a five-year moving precipitation average, and time at the Rattlesnake Gulf landslide.

Rainbow Creek Landslide

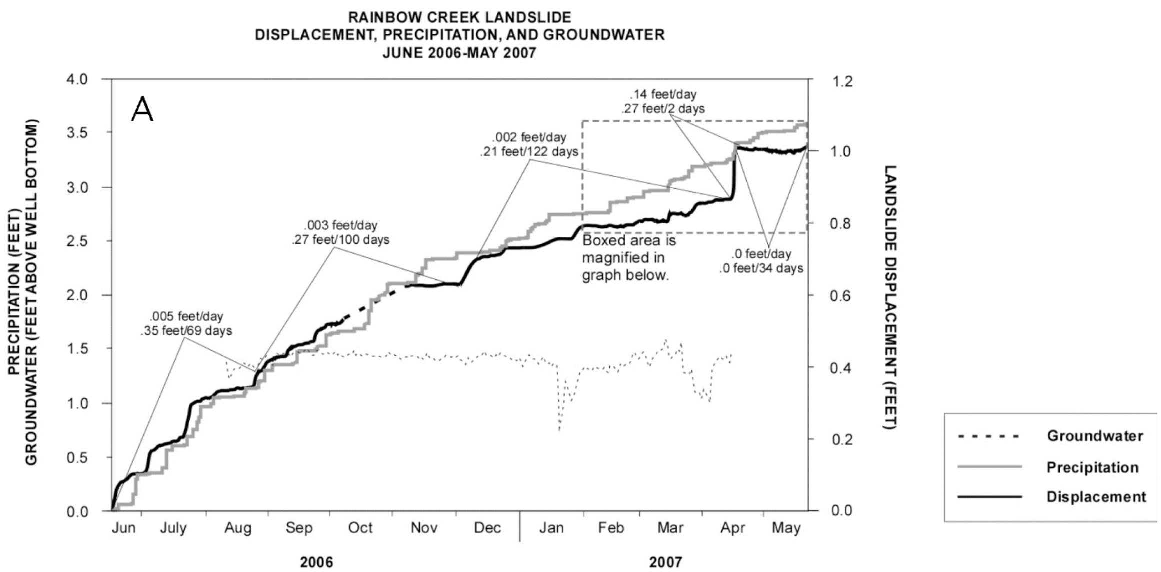
The main body of the Rainbow Creek landslide is located on the south side of Rainbow Creek, covers approximately 34 acres, and is at an elevation of 820 feet to 1180 feet above sea level. Rainbow Creek is the only major tributary to the Onondaga Creek on the eastern Tully Valley wall. The landslide surface slopes between 20°NW to 45°NW, and the landslide material is primarily laminated clay and silt and well-sorted fluvial sand and gravel. The unconsolidated sediment is underlain by stable Middle Devonian shale and siltstone of the Delphi Station and Lower Pompey members of the Skaneateles Formation of the Hamilton Group (personal communication, Gordon Baird, June, 2007). Throughout the summer and fall of 2006, landslide material along the northernmost scarp was composed of more than ten feet of laminated clay and silt overlain by a 40-foot-thick layer of interbedded, well-sorted silt, sand, and gravel, which coarsened upward. This material was rotated and oriented at N9°-75°E, 12°-34°SE. Following the 2006-2007 winter, portions of the fluvial silt, sand, and gravel package along the northern scarp were eroded, exposing approximately 25 feet of rotated, laminated silt and clay, underlain by eight feet of poorly sorted glacial till. This silt and clay is oriented at N59°-61°E, 9°-20°SE. Smaller slumps are located on both the north and south sides of this tributary stream valley for a distance of at least 0.5 miles east of the main landslide body, and several landslide 'scars' (where bedrock is exposed within the sediment covered stream banks) also surround the landslide.

Rattlesnake Gulf Landslide

The Rattlesnake Gulf landslide covers approximately 23 acres, and the landslide surface slopes 15° to 45° northwest at an elevation of 1140-1260 feet above sea level. Unlike the Rainbow Creek landslide, the Rattlesnake Gulf landslide does not have smaller active landslides upstream of the main body, though several scars are located upstream and on the north side of the stream valley several bedrock landslide scars are seen directly across from the active landslide. Landslide material is primarily composed of laminated silt and clay, although well-sorted fluvial sand is exposed at several locations within the landslide. The rotated silt and clay is oriented at N46°-88°W, 14°-55°SW, and the middle Devonian Delphi Station, Pompey, and Butternut members of the Skaneateles Formation underlie the unconsolidated, sliding material (personal communication, Gordon Baird, June, 2007).

Landslide Data Collection

Beginning in Summer 2006, displacement and ground-water level measurements have been recorded at the two landslides, and precipitation data recorded from the Tully Valley floor (Table 1). Data records from both landslides show that shallow displacement corresponds to precipitation events and heightened ground-water levels, and increased ground-water levels in the shallow, unconsolidated sediments lag precipitation events by up to two days. The Rainbow Creek landslide and the northwest portion of the Rattlesnake Gulf landslide experienced the most activity in July 2006, which was the wettest month for the 11-month data collection period (Figures 5 and 6). The center of the Rattlesnake Gulf landslide was most active in March 2007 (Figure 7). Displacement magnitude is greatest in the northwest portion of the Rattlesnake Gulf landslide due to proximity to the over-steepened scarp and the unstable toe, and there is an eight-month lag time for shallow stress release to translate up slope from the northern scarp to the center of the landslide. The activity pattern at the Rainbow Creek landslide is similar to that of the northwest portion of the Rattlesnake Gulf landslide.



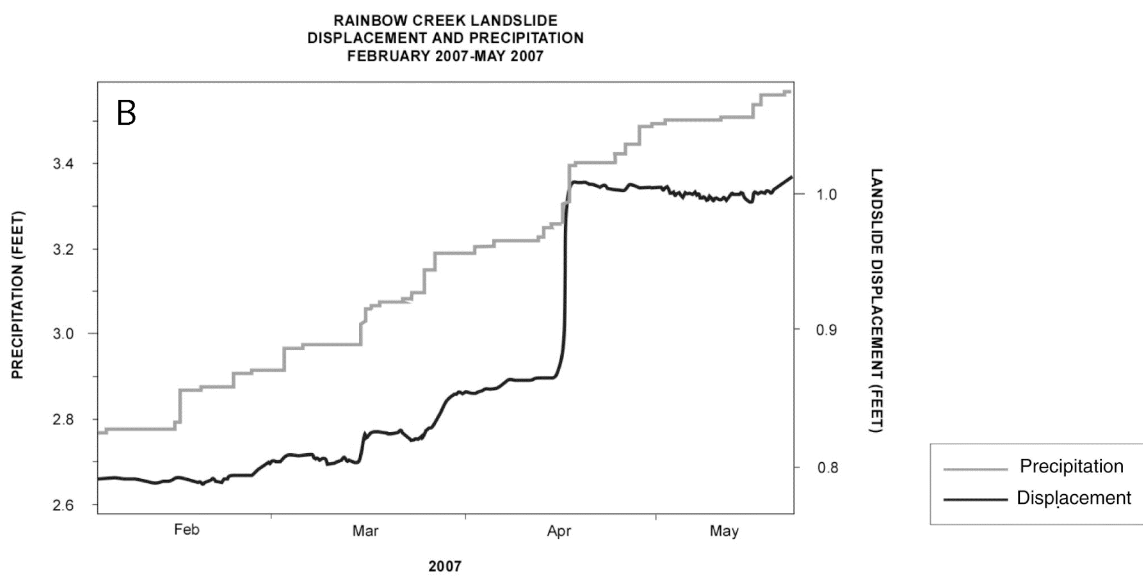
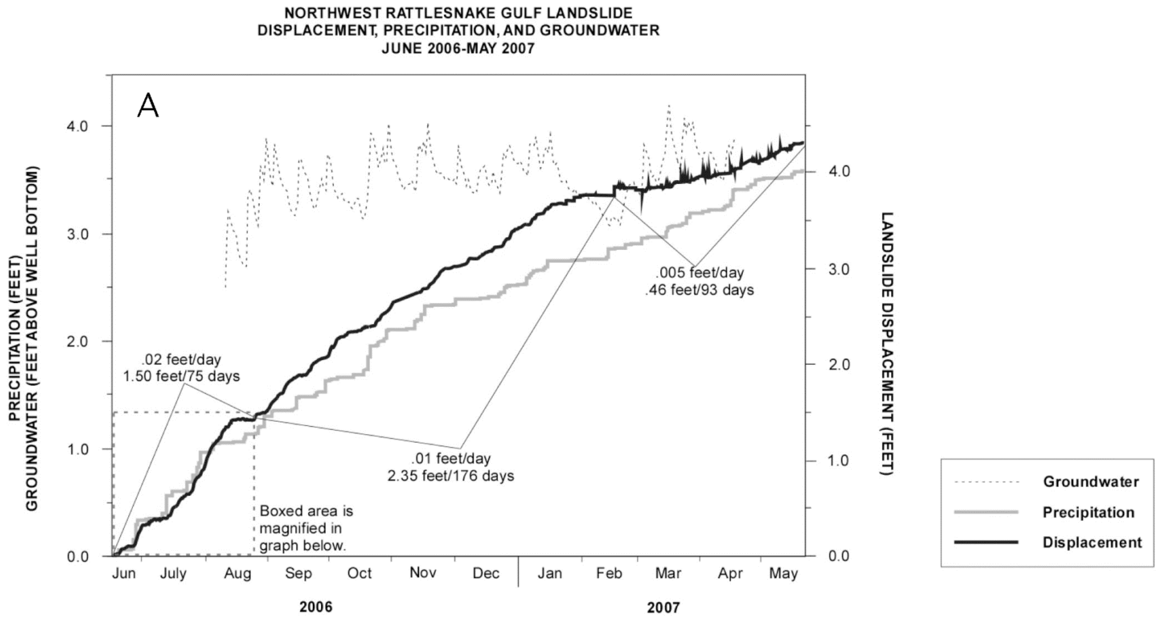


FIGURE 5—A) Graph of precipitation, ground-water level, and land-surface displacement in the Rainbow Creek Landslide area – June, 2006, through May, 2007. B) Detail of precipitation and land surface displacement from February, 2007 through May, 2007.



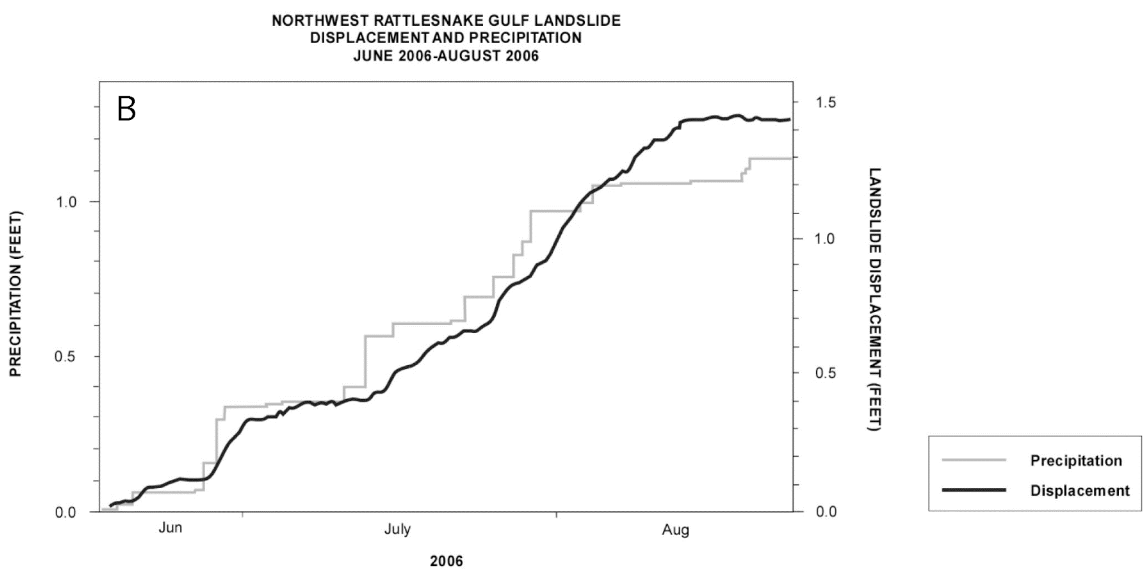


FIGURE 6—A) Graph of precipitation, ground-water level, and land-surface displacement in the northwest part of the Rattlesnake Gulf landslide, -- June, 2006 through May, 2007. B) Detail of precipitation and land surface displacement from June, 2006 through August, 2006.

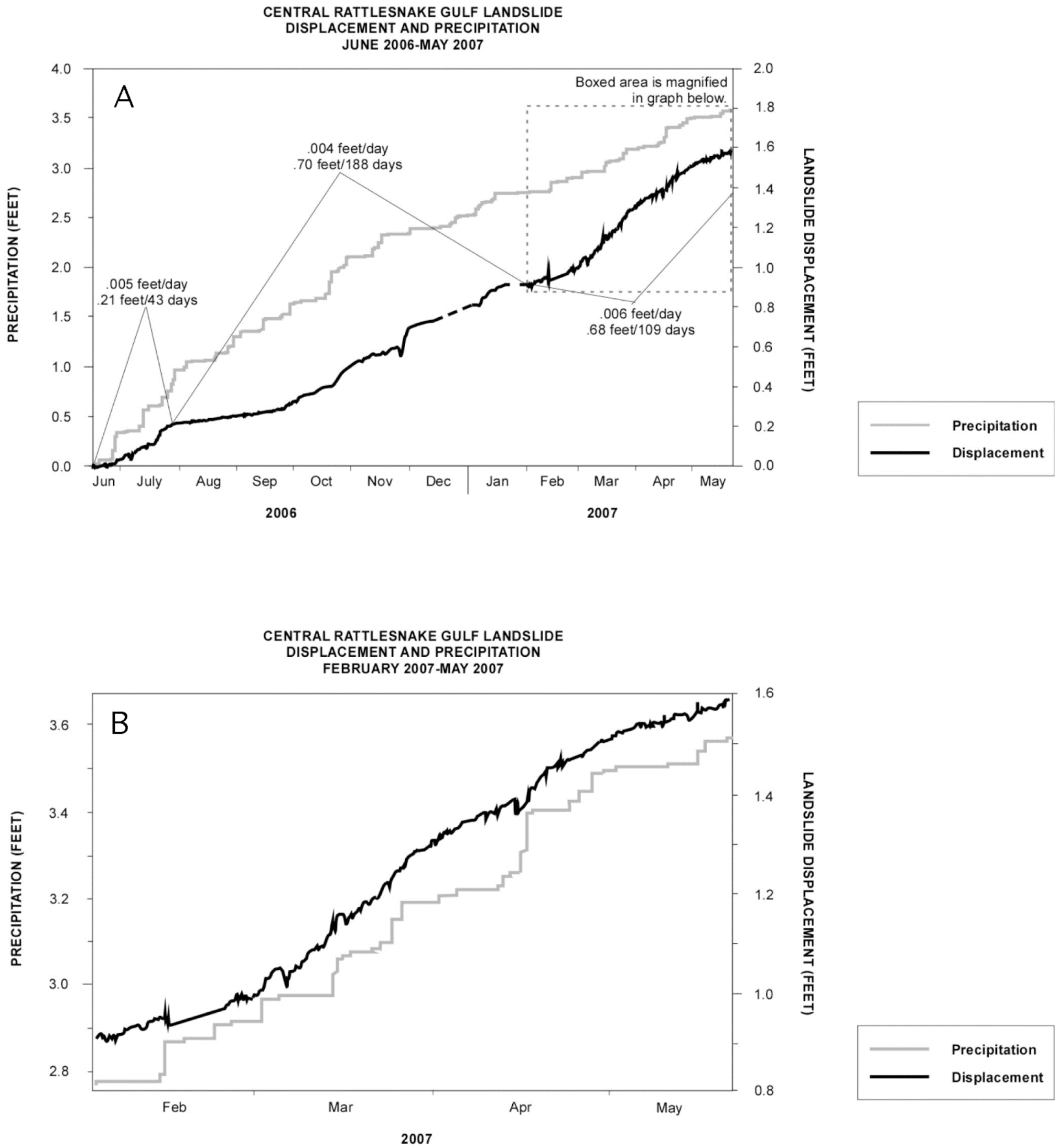


FIGURE 7—A) Graphs of precipitation, ground-water level, and land-surface displacement in the central part of the Rattlesnake Gulf landslide—June, 2006 through May, 2007. B) Detail of precipitation and land surface displacement from February, 2007 through May, 2007.

TABLE 1—Monthly precipitation and displacement for the Rainbow Creek and Rattlesnake Gulf Landslides Tully Valley, New York.

	Precipitation (inches)	Rainbow Displacement (inches)	Northwest Rattlesnake Displacement (inches)	Central Rattlesnake Displacement (inches)
2006				
June*	3.95	1.20	3.6	0.48
July	7.61	2.52	8.4	2.04
August	4.01	1.32	6.0	0.36
September	4.03	1.20	7.2	0.96
October	5.68	1.08	6.0	2.16
November	2.81	0.24	4.8	2.28
December	2.12	1.20	4.8	1.32
2007				
January	2.83	0.72	3.6	1.32
February	1.77	0.12	1.2	1.08
March	3.42	0.72	1.2	3.60
April	3.73	1.68	2.4	2.40
May**	0.93	0.12	2.4	1.08
Total	42.89	12.12	51.6	10.08

* Precipitation and displacement record-June 19-30, 2006

** Precipitation and displacement record-May 1-21, 2007

Dendrogeomorphology

Dendrogeomorphology uses dendrochronology (tree ring study) to determine landform evolution because tree rings provide dates for significant historic geomorphic events. A total of 97 tree cores and cross sections were collected from and surrounding the two active landslides. Tree rings were measured and reaction wood was identified in order to determine years when tree ring growth changed from concentric to eccentric (Figure 8), and it was assumed this change in growth pattern occurred due to landslide movement. With this data, event indexes were generated to temporally analyze landslide activity. At the Rattlesnake Gulf landslide, a multiple Fourier function regression model correlates the event index, five-year moving-precipitation average, and time, implying there is a multi-year lag between precipitation and deep ground-water discharge into the landslide, which causes more deeply-seated movement. Model cyclicity also suggests that Rattlesnake Gulf landslide activity has an approximate 70-year cycle, with destabilizing years noted in 1927 and 2000. Drought periods followed by persistent (3 month or greater) above-average monthly precipitation, corresponding high stream discharge eroding the landslide toe, and harvesting of mature trees above and within this landslide may also be displacement triggers. At the Rainbow Creek landslide, there is no clear correlation between annual precipitation, three or five-year moving precipitation averages, time, annual average temperature, and the event index.

ACKNOWLEDGEMENTS

The authors would like to thank Bill Kappel for introducing each of us to the study areas, and for facilitating access to the private property. We also thank B. McAninch and B. Kappel for reviewing the manuscript and for their helpful comments.

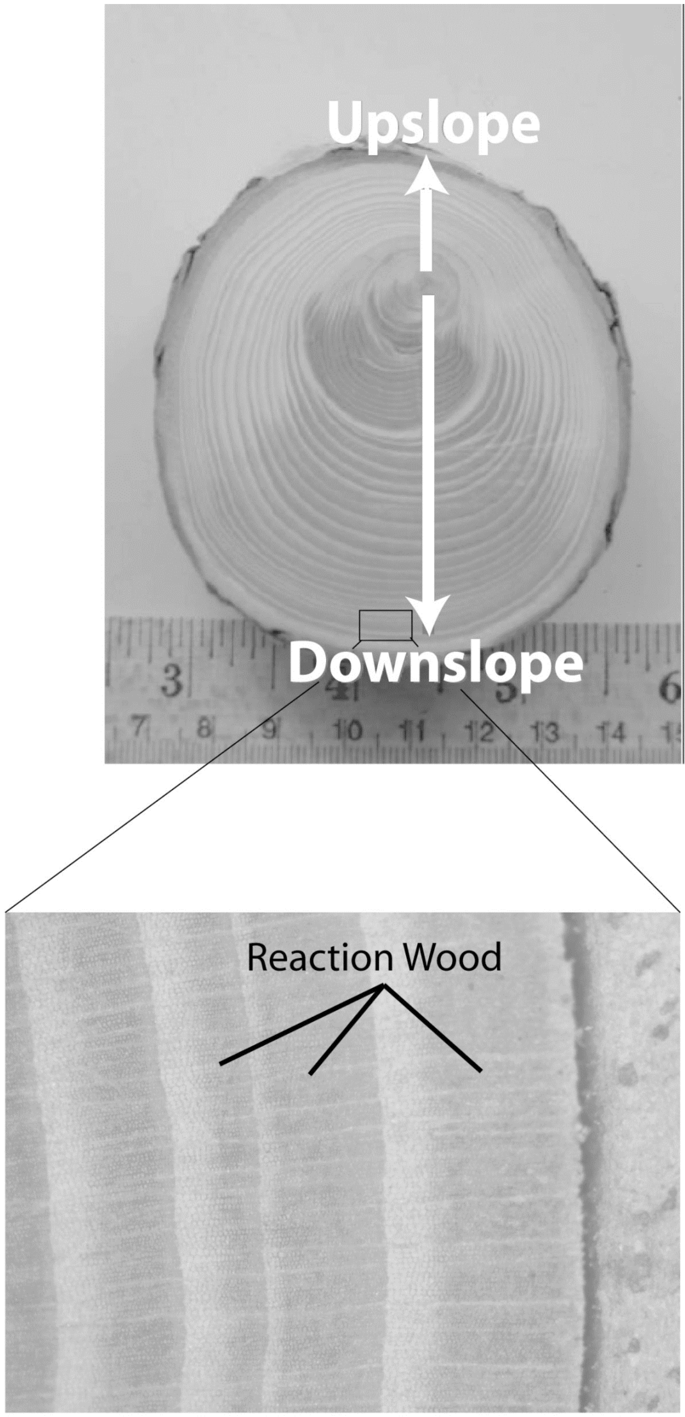


FIGURE 8—Example of a small trees cross-section showing the change from concentric tree-ring growth to eccentric tree-ring growth due to the tree becoming tipped over in a landslide and correcting its orientation back to a near-vertical position via reaction wood growth.

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ROAD LOG FOR TRIP B-1

SUBSIDENCE AND LANDSLIDES IN TULLY VALLEY, CENTRAL NEW YORK

The two field sites described in the road log are on private property. As such, it is imperative that we respect the rights and wishes of these land owners. Please do not visit these sites on your own, as it may jeopardize future field-trip opportunities. Over the past 15 years it has become increasingly difficult to maintain our access agreements to these sites as individuals and even groups of people have entered these properties without obtaining land-owner permission. We strive to maintain good relations with the land owners and do not want the inappropriate actions of a few to ruin the educational opportunities for many others who wish to enter these areas. The USGS can, and does act as the 'point of contact' for the property owners and we would be happy to facilitate your future access to these sites. Please contact Bill Kappel (USGS, Ithaca, NY) for any questions as to access for you and your classes.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Start at parking lot north of Old Main building on SUNY Cortland campus. From parking lot turn left (E) on Gerhart Dr., at the yield sign turn left (N) onto Graham Ave.
		At bottom of hill (traffic light) turn right (E) on to Groton Ave, (also Rt. 222).
		At Main St. (traffic light) go straight through intersection, road becomes Clinton Ave. Stay on Clinton Ave. Bear left (N) at the Mobil gas station (traffic light), road is still named Clinton Ave. and go under I-81 overpass.

0.0	1.6	CORTLAND CAMPUS TO I-81N
15.9	14.3	Turn left (W) onto I-81 North entrance. Exit at Tully exit (exit 14). At stop sign at end of ramp, turn left (N) on to Rte 281 N.
		I-81N TO TULLY INTERCHANGE
		At traffic light turn left (W) on to Rt. 80 and go through the I-81 overpass and take an immediate right (N) on to Route 11A. Go down the back side of the Tully (Valley Heads) Moraine and continue north until you see a red house on your left. Just ahead on your right you will see a red pipe gate, pull over and park to the side of the locked gate. You need prior permission to enter this property.
18.4	2.5	NYS-RTE 80/RTE 11A TO STOP #1 - BRINEFIELD FRACTURES
		Walk east on the dirt road to base of slope (~1200 ft), proceed north (left) on dirt road approximately 300 ft. Stop where fracture from northeast intersects road.

STOP 1A. LONG, NORTHEAST TRENDING FRACTURE NEAR EAST BRINEFIELD

This is one of the largest fractures in this area, both in exposed length and depth. This vertical fracture trends 060˚and is exposed for 540 feet along strike. The width of the fissure opening is about 0.3 m (1 ft) and the measured depth is 11.5 m (38 feet). The orientation of this fracture correlates to set III of Parker (1942). Possible fringe cracks intersect the southeast wall of the fissure, trend 075˚, and are vertical.

Walk in the 060˚ direction along strike to place where tree roots jut over the fissure, but the tree is no longer there.

A tree trunk was removed from this spot last spring for tree ring analysis. The time of root exposure, and thus the time of fracture opening, may be determined by recognition of a change in the characteristics of the tree rings of the roots. Analysis is still in progress as of this writing. The hypothesis is that the fracture opened in response to collapse at depth after the final surge in salt removal by solution mining about 1950-1960.

Walk down slope to road, continue North to small east-west trending gully.

STOP 1B. CROSS-CUTTING RELATIONS BETWEEN FRACTURE SETS

On the South side of gully the two sets of open fractures intersect. The longer vertical fracture trends 055˚, is open about 0.3 m (1 ft), and is straddled by a tree—not unlike what the tree at the previous stop looked like before removal for tree ring analysis. Again, oriented as set III of Parker (1942). Possible fringe cracks intersect the southeast wall of the fissure, trend 083˚, and are vertical. A small fracture oriented 352˚/86˚E (corresponding to set I of Parker, 1942) appears to offset the 055˚ fracture. If this is correct then the timing relationship is consistent with Engelder et al., (2001); that is, set III is older than set I and II hypothesized to be related to the Alleghanian orogeny.

Walk west to return to dirt road. Walk south 275 m (~900 ft) past intersection with dirt road to next group of open fractures.

STOP 1C. CLUSTER OF FRACTURES UPSLOPE FROM SINK HOLE

Note that no fractures occur along this road between the long fracture of STOP 1A, and this cluster. This cluster of open fractures appears to be spatially related to the sinkhole just to the west on the valley floor. Walking uphill along an east trending dirt road, one can see several fractures of the three orientations on both sides of road.

Return to dirt road by walking west, downhill. Walk north 75 m (250 ft) to intersection with dirt road we came in on. Turn west, walk back to US11A and cars.

23.9	5.5	BRINFIELD FRACTURES TO STOP #2 – RATTLESNAKE GULF LANDSLIDE

Turn around on Route 11A back (S) to Solvay Road (~1 mile) and take a right. Travel to the end of Solvay Rd and take a right on Tully Farms Road (N). Travel about 3 miles until the intersection of Otisco Road. At Otisco Rd, turn left (W) and travel uphill ~1 mile to a small red house on the right. You will need prior permission to enter this property as the driveway is small, and the home owner does not want surprise 'guests'!

At the west side of the house follow the road down the hill along the tree line to the NW. At the stream channel, turn uphill SW and cross the channel at grade. Follow the logging road and take the second spur to the right (N then NW). Follow that road until you see a wooden recorder box on your right (about 10 feet lower than the road). The slide is further to the north, downslope – again it is quite dangerous to walk around the area as many fractures are hidden in the understory and the slope is quite unstable and slippery, when wet.

STOP 2. RATTLESNAKE GULF LANDSLIDE

At this site we will observe the ongoing land-surface movement of the Rattlesnake Gulf Landslide area. Review of New York State aerial imagery (circa 1937 to present) indicates that this slide area has slowly coalesced into the large slide we will see today. Also, the use of dendrochronology to determine previous landslide movement allows the casual observation of 'J-ayed' trees to be refined to specific years of movement. The genesis of the slide continues today at two different scales – shallow displacement related to rainfall infiltration into the shallow weathered fine-grained soils, and more deeply seated ground-water induced movement. Also the effects of toe-cutting of the slope can be observed along Rattlesnake Gulf Creek which influences the movement of slide material as it makes its way from the upper scarp to, and into the creek, to be carried down to the floor of the Tully Valley and Onondaga Creek.

To return to SUNY Cortland campus, take Otisco Road downhill to T
Farms Road, turn right (S) and take Tully Farms Road to Solvay Roac
left (E) and at the intersection with NYS-Route 11A, turn right (S) an
uphill to the Burger King and NYS-Route 80. Cross Route 80 and tak
entrance ramp on to I-81 South – left hand entrance. Travel south on I
back to the Homer exit. Exit at Homer, and at the 'T' (NYS-Route 28
intersection, turn left on to Route 281 (S). Follow 281 until it intersec
Route 222 (Groton Road at 3rd traffic light) – get in left hand turning l
the light. Turn left on to 222 (Groton Road) and go to Graham Road, t
the hill to the SUNY Cortland campus.

45.1	21.2	LANDSLIDE TO SUNY CORTLAND campus

END OF FIELD TRIP