SEISMIC RISK ASSESSMENT OF COLUMBIA COUNTY, NEW YORK

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INTRODUCTION

In 1994 the New York State Geological Survey began a pilot study to assess earthquake hazards in New York State, on a county by county basis. This effort was modeled after studies done in Portland, Oregon, and Los Angeles, California. The goals of this work were to produce:

- an earthquake ground-motion response map,
- an earthquake-induced landslide-potential map,
- an earthquake-induced liquefaction map, and
- a combined earthquake hazards map.

Our analyses were done as a function of glacial landforms. The maps produced are a result of computer-based analyses of earthquake strong ground-motions, soil depth profiles, soil engineering properties, and topographic slopes. These maps are intended to aid civil engineers, building designers, and emergency managers on the subjects of earthquake preparedness and hazard mitigation.

Columbia County was chosen for the initial study because of its proximity to the Capitol District, and also because of the quantity and quality of geologic data already available. This pilot study was a learning experience. We are still in the process of analyzing the collected data, and the preliminary results are encouraging. During this field trip we will show why such studies are needed, how these studies should be conducted, common problems, and how the results of these studies can be applied.

THE EARTHQUAKE THREAT

New York State has experienced 13 or 14 damaging earthquakes since 1737. The estimated or known magnitudes of those events range from 4.5(m_b) to 6.0(m_b)[1]. The last damaging earthquake in New York took place at 6:18 a.m. EDT, on October 7, 1983, near Newcomb, New York. That magnitude 5.1(m_b) earthquake caused damage within 6 kilometers of the epicenter, including cracked masonry walls and damaged chimneys at Adirondack camps, rotated tombstones, and small landslides. Aftershocks were recorded for several months. It is believed that this earthquake triggered a small landslide in Columbia County, over 180 kilometers away, that resulted in damage to the foundation and walls of one home.

New York's largest earthquake occurred at 12:38 a.m. EWT (equivalent to EDT), on September 5, 1944, near Massena Center, New York. This magnitude 6.0(m_b) event caused considerable non-structural damage to unreinforced masonry buildings, including schools and governmental buildings, in Massena, New York and Cornwall, Ontario. Over 5,100 (90%) of the chimneys in these communities were damaged or destroyed. Liquefaction, lateral-spread landslides, and small slumps were observed in the Massena area. Power was out in Massena for up to 2 hours after the earthquake, pipes of the community water supply were broken, and street pavement buckled. At least $17 million of damages resulted. Two people received serious injuries and many others suffered minor injuries. A damaging aftershock occurred 4 days later and additional felt aftershocks continued for 4 months. Seismograph stations in the region recorded aftershocks for up to 4 years following the main event.

Figure 1 shows the distribution of recent (October, 1975-March, 1989) earthquake activity in the New York region. These patterns and clusters of activity have stayed more-or-less stable for over 400 years. However, there is no assurance that areas currently experiencing little or no activity will stay that way. Conversely, areas with seismic

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[1] (m_b) is magnitude based on the first three cycles of the P wave, with a period of approximately one second. We do not use the Richter Scale because it is only used in California.

In Garver, J.I., and Smith, J.A. (editors), Field Trips for the 67th annual meeting of the New York State Geological Association, Union College, Schenectady NY, 1995, p. 11-23.

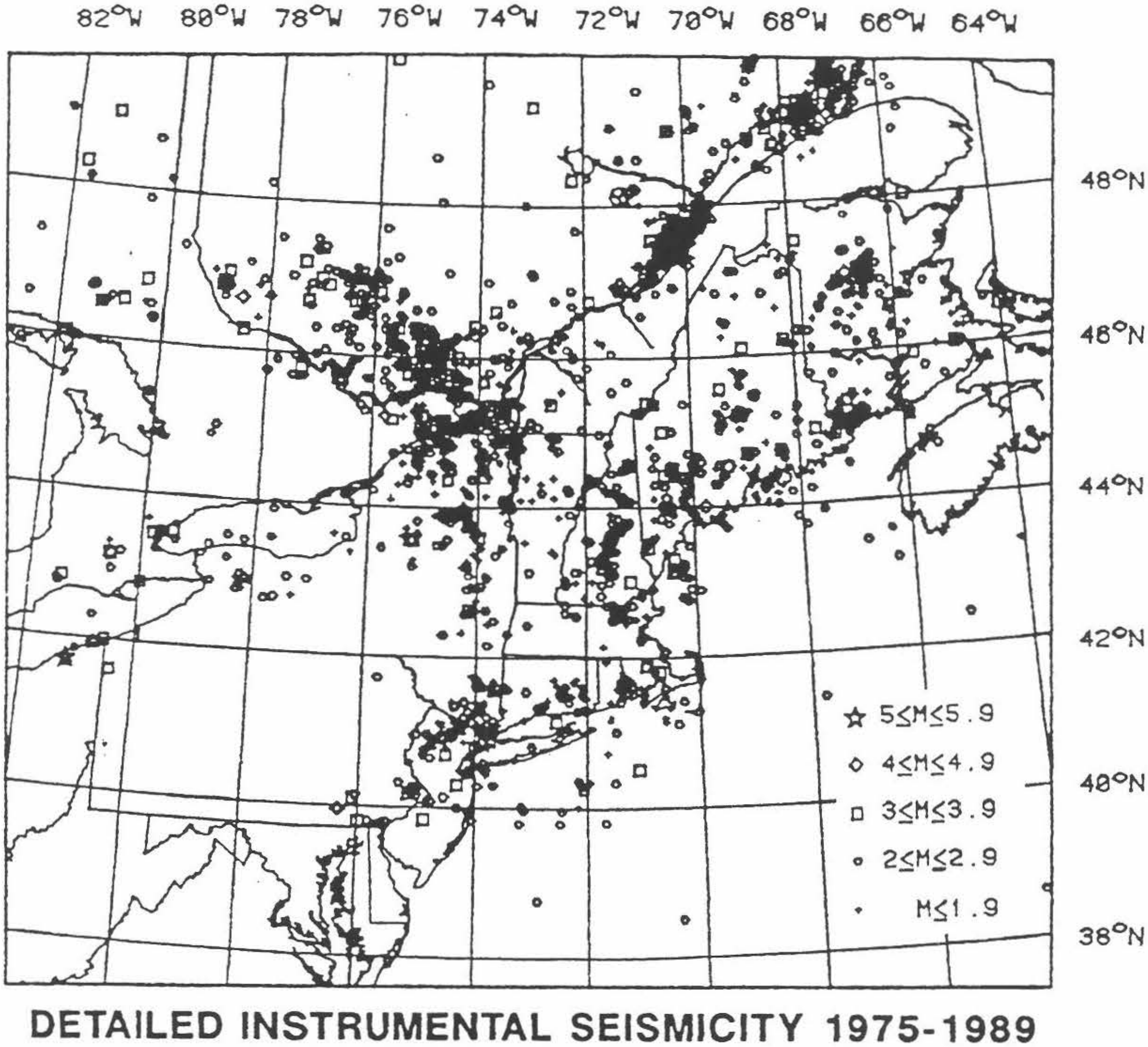

Figure 1. Earthquakes of the northeastern United States and southeastern Canada during the period of October 1975 to March 1989. Symbols show the epicenter and magnitude of each event. Figure courtesy of the Weston Observatory, Boston College.

activity may not stay active. The rates of activity in different areas of the northeastern United States and southeastern Canada vary in the historical past. Figure 2 shows that over 70 damaging earthquakes, rated intensity VI-X on the Modified Mercalli scale of 1931[2] (Wood and Neumann, 1931), have occurred in the northeastern United States and southeastern Canada since that mid-1500's. The 1983 Newcomb and 1944 Massena earthquakes rated intensities VII(MM) and VIII(MM), respectively. The magnitudes of damaging earthquakes in the northeast range from 4.5(m_b) to 7.0(m_b).

Earthquakes that produce slight damage (intensity VI [MM], magnitude 4.5 [m_b] -5.0 [m_b]) occur in the Northeast about once every 6 years. Earthquakes that produce moderate damage (intensity VII [MM], magnitude 5.0 [m_b]-5.5 [m_b]) occur about once every 30 years. Those that produce considerable damage(intensity VIII [MM],

[2] Modified Mercalli Intensity is a measure of shaking severity based on earthquake effects on people, structures and the natural environment.

magnitude 5.5 [m_b]-6.0 [m_b]) take place about once every 130 years in the Northeast. There is general agreement that earthquakes of magnitude 6.0(m_b) to 6.5(m_b) are possible anywhere and at any time in the region, including New York State. Even larger events are possible in the St. Lawrence River Valley and along the eastern seaboard. Large earthquakes occur frequently enough in our region to be of significant hazard to the concentrated populations, and aging infrastructure and industrial facilities.

EARTHQUAKE HAZARDS

The larger earthquakes of New York State have demonstrated the hazards of strong motion amplification, landslides, and liquefaction. The magnitude 4.5 (m_b) Warrensburg, New York earthquake of April 20, 1931 was a case were a relatively minor earthquake caused moderate (intensity VII [MM]) damage. Warrensburg is situated within the river valley, on lake sands and alluvium directly above bedrock. Amplification of the shaking of the site probably occurred as shear-waves were attenuated, and increased in amplitude, as they passed from bedrock into the unconsolidated materials. The 1931 Warrensburg, 1983 Newcomb, and August 12, 1929, Attica (m_b = 5.2) earthquakes all started landslides. The 1944 Massena earthquake is the only New York State earthquake where liquefaction has been documented. Landslides are generally triggered by earthquakes of at least magnitude 4.0(m_b).

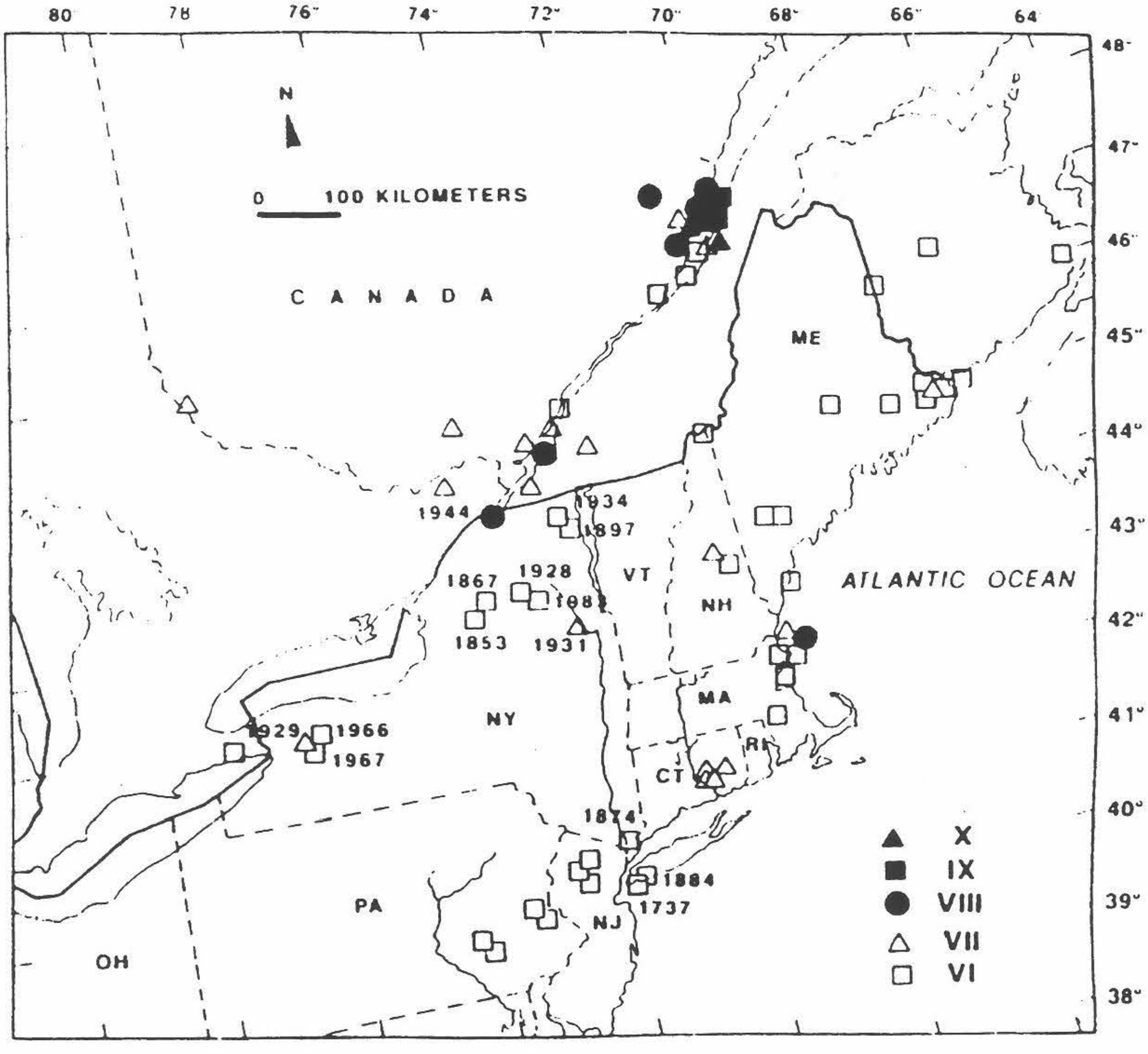

Figure 2. Damaging earthquakes of the northeastern United States and southeastern Canada during the period of 1534 to 1988. Symbols show the epicenter and epicentral intensity of each event. Epicentral intensities are given in terms of the Modified Mercalli Scale of 1931. The year of occurrence appears next to New York State events.

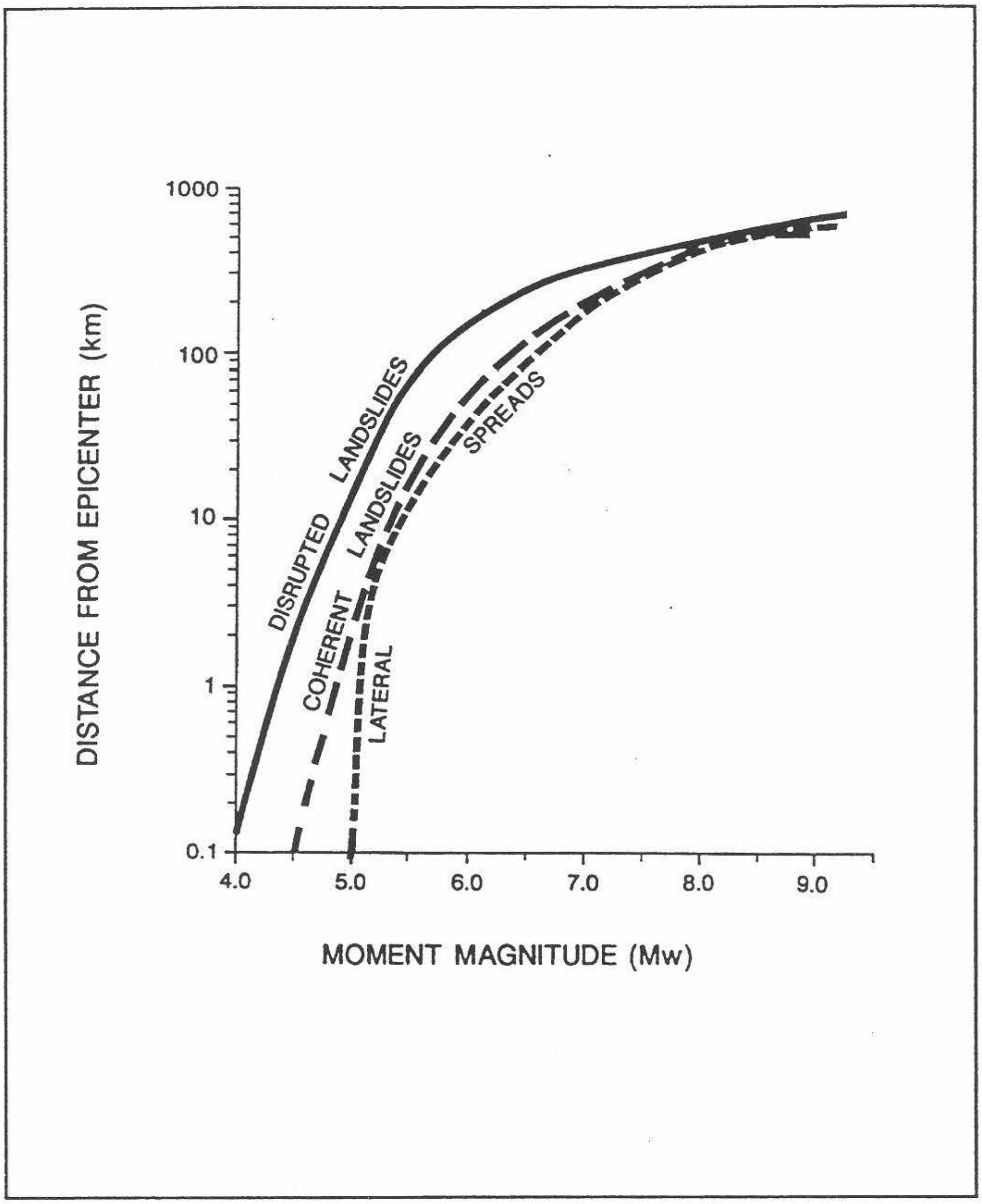

Figure 3. Relationship between earthquake magnitude and the maximun distance that three general types of landslides can occur. Earthquakes in the northeastern United States have and will trigger landslides.

Lateral-spread landslides and liquefaction are usually triggered by earthquakes of at least magnitude 5.0(m_b). The distance away from the epicenter of an earthquake where landslides occur, increases with the magnitude of the earthquake. Figure 3 summarizes data from Figure 1 in Keefer (1984). All of these hazards can result in increased building damage, damage to the infrastructure, and possibly, toxic material spills and fires.

EVALUATION PROCESS

Our first attempt to map ground motion response as a function of glacial landforms used expected values from an average, largest event that can be projected for New York State. That event would be a repeat of the magnitude 6.0(m_b) Massena Center, New York, earthquake of September 5, 1944. We assumed an epicentral distance of 10 kilometers from a Community. That earthquake at a distance of 10 kilometers, should produce a maximum horizonal acceleration of 0.35g (g = acceleration of gravity at the Earth's surface = 981 cm/sec^2) on bedrock. Acceleration values at the surface of the glacial materials were estimated using the program SHAKE91.

SHAKE91 assumes that a soil column can be represented as stacked elastic layers that are connected by springs. Each soil layer is defined by a thickness, shear modulus (obtained from soil tests or shear-waves), damping factor, and bulk density. A soil column is "shaken" using recorded or synthetic acceleration values for earthquakes, and with the assumption that the shaking is only coming from vertical propagation shear- waves. These are simplistic assumptions, but the results of this analysis have been substantiated in actual earthquakes.

The actual recordings of accelerations used in our analyses are from a magnitude 4.0 New Brunswick, Canada, earthquake of March 31, 1982, and from the November 25, 1988, magnitude 5.9, Saguenay, Quebec, earthquake. Eleven acceleration recordings were used, and they were scaled to match our magnitude 6.0(m_b) design event, at a distance of 10 kilometers. When using acceleration recordings, it is important to chose recordings of events that closely match the size, distance, and geological environment of the design earthquake. Earthquake accelerations measured on bedrock, are not frequently recorded in the northeastern United States and southeastern Canada.

To define the glacial landforms, their materials, and their engineering properties, we created or compiled the following databases:

1. 17 digitized surficial geologic 7.5 minute quadrangle maps; 1:24,000 scale;
2. digitized bedrock geologic map from 1970 NYSGS , Hudson-Mohawk Sheet, 1:250,000 scale;
3. water well inventory from 11,000 county property owners;
4. seismic refraction surveys at 50 sites, specifically including individual types of bedrock and surficial materials;
5 soil test data.

Representative soil columns were defined for each glacial unit. The soil column used to characterize glacial landforms is a one layer model over a bedrock half-space.

HIGHER RISK AREAS MAP

The final objective, to produce a map of the county illustrating the regions with a higher risk of damage from ground motion, landslides and liquefaction, is presented in Figure 4.

REFERENCES

Atkinson, G.M. and D.M. Boore, 1990, Recent trends in ground motion and spectral response relations for North America; Earthquake Spectra, v. 6, p. 15-35.

Idress, I. M., and J. L. Sun, 1992, Shake91, A computer program for conducting equivalent linear seismic response Analyses of horizontally layered soil deposits; Center for Geotech. Modeling, Univ. of CA, Davis CA.

Keefer, D.K., 1984, Landslides caused by earthquakes; Geological Society of America Bulletin, v. 95, p. 406-421.

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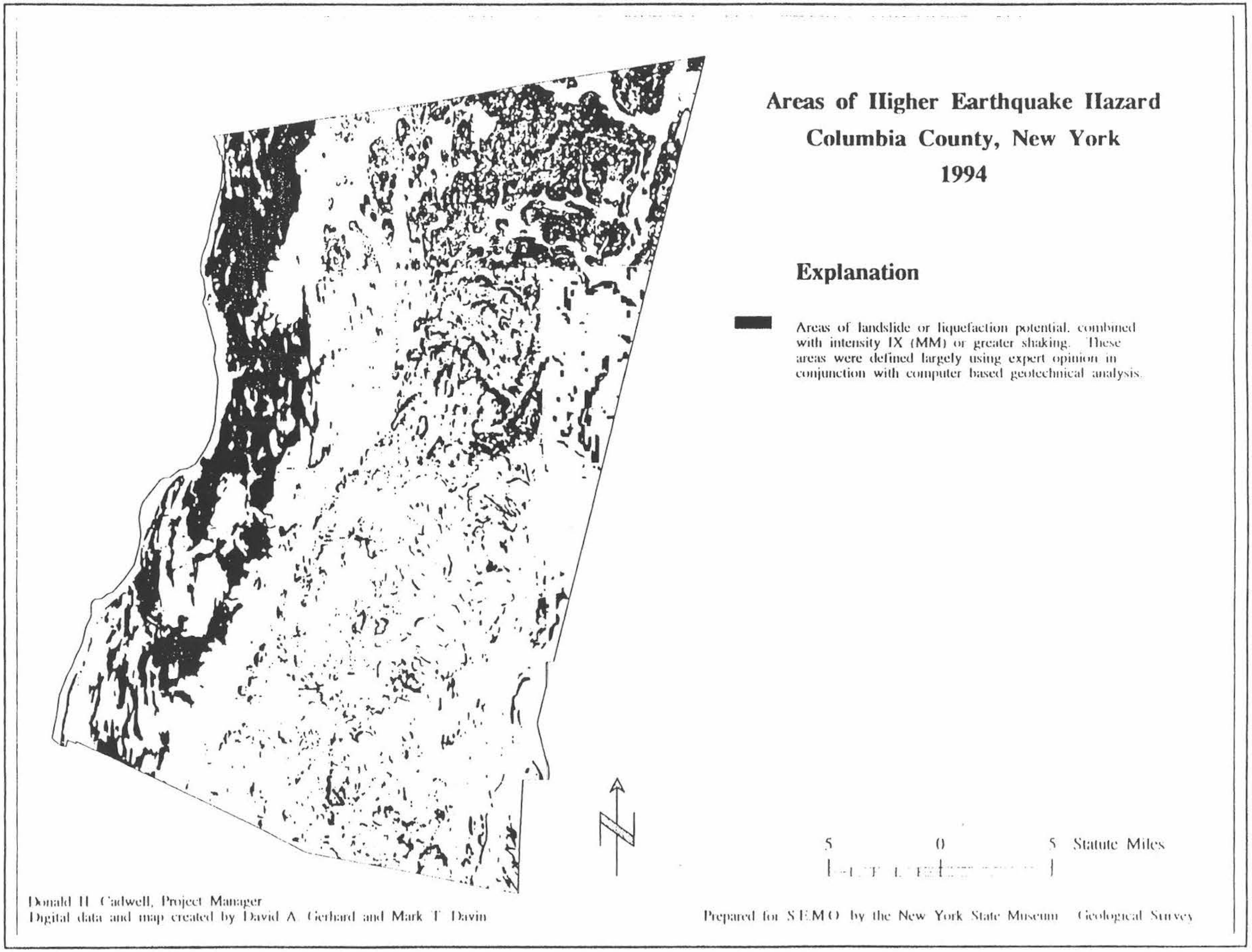


Figure 4. Areas of higher earthquake risk in Columbia County, NY.

SEISMIC HAZARD ASSESSMENT OF COLUMBIA COUNTY
FIELD TRIP ROAD LOG

For the field trip, we will demonstrate a seismic line, using both horizontal and vertical geophones, for P- (primary) and S- (shear) waves in surficial materials. Discussion will be directed toward potential landslides and liquifaction in conjunction with varying watertable conditions. Secondly, we will visit the city of Hudson and discuss the application of seismic hazard data with county & municipal planners, and emergency personnelto potential problems in downtown Hudson:, unreinforced structures, old wooden buildings, old stone buildings, and the impact of abundant water on lacustrine clays. Finally, we will demonstrate the use of this seismic-hazard data to county residents, and visit a house damaged as a result of land failure in 1983, coinciding with the 1983 Blue Mountain Lake, magnitude 5.1, earthquake, with the epicenter 180 kilometers away.

The Road Log for this trip starts on Route 9, at the Rensselaer County-Columbia County border. See Figure 5.

ROUTE DESCRIPTION	MILES FROM LAST POINT	CUMULATIVE MILEAGE
Rensselaer-Columbia County border. Proceed south on Route 9.	0.0	0.0
Railroad underpass.	0.2	0.2
Knickerbocker Lake, over hill to left. Kames, kettles and kettle lake.	0.65	0.85
Intersection with blinker light, continue south on Rt. 9.	0.25	1.1
Maple Lane Outwash sands and gravels, prograding southward to delta at Kinderhook, deposited in Glacial Lake Albany.	0.7	1.8
Intersection and light at Rts. 9 & 9H. Bear right onto Rt. 9H.	1.4	3.2
Intersection, light, Keegan Road. Continue south on 9H.	0.3	3.5
Bear right at exit for Kinderhook, Rt 9 South.	1.0	4.5
Bear right onto Rt. 9 south.	0.2	4.7
Turn right into Brosens Garden Market. Pull over to the right of the buildings, out of the way.	0.2	4.9

STOP 1 Demonstration of Seismic line

The Pleistocene equivalent to the Kinderhook Creek deposited the large delta complex into Glacial Lake Albany 18,000 to 15,000 years ago. Abundant meltwater was transported from both the retreating Wisconsinan glacier terminus and the bedrock uplands toward the delta. The present channel of the Kinderhook Creek is incised 17-20 m (50-60 ft) into the delta (Figure 6) and the location of this seismic line is on the floodplain. Water well information suggests bedrock is 12-24 m (35-55 ft) beneath the floodplain.

ROUTE DESCRIPTION	MILES FROM LAST POINT	CUMULATIVE MILEAGE
Return to Rt. 9, turn left, north.		

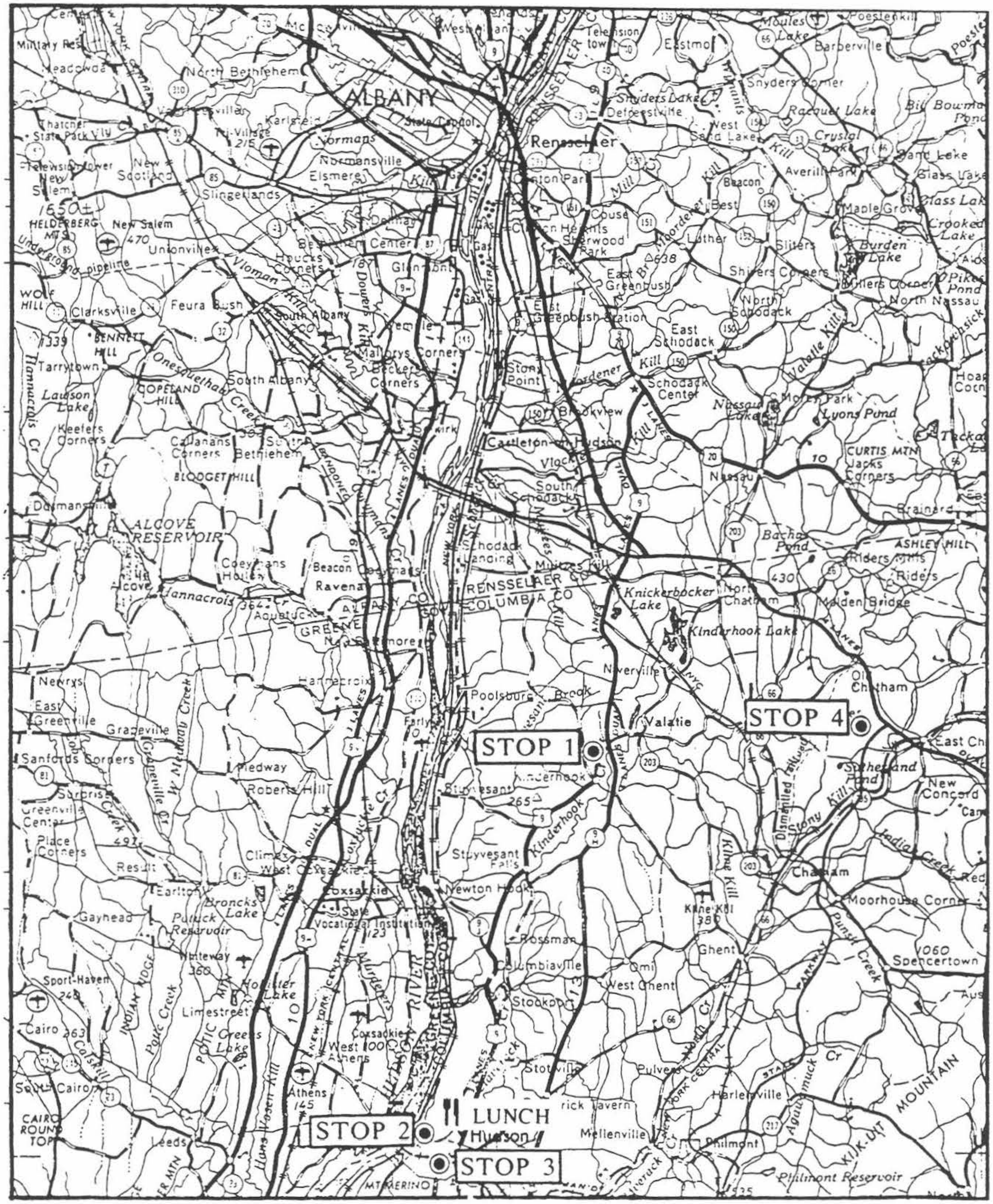


Figure 5. Schedule and location of fieldtrip stops.

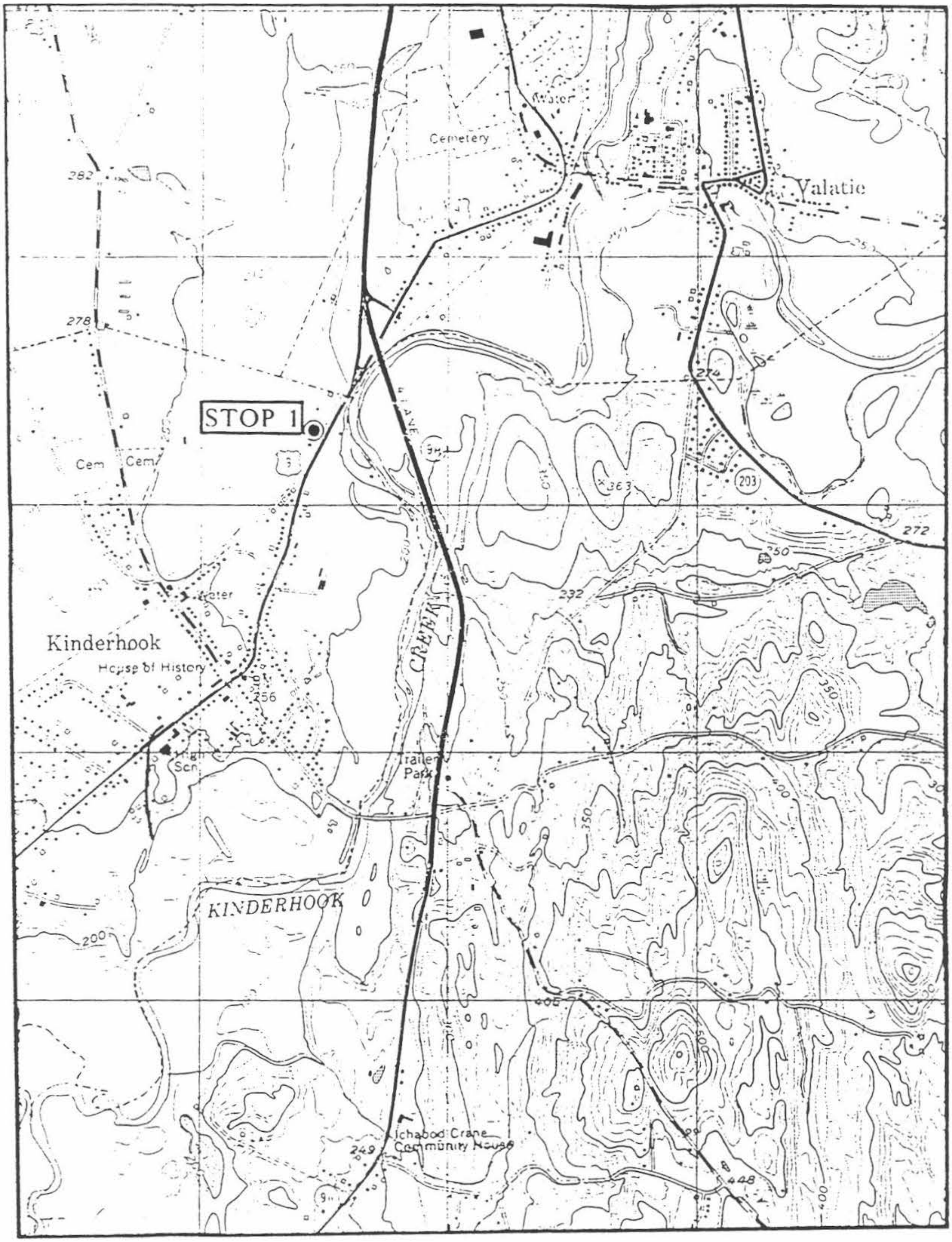
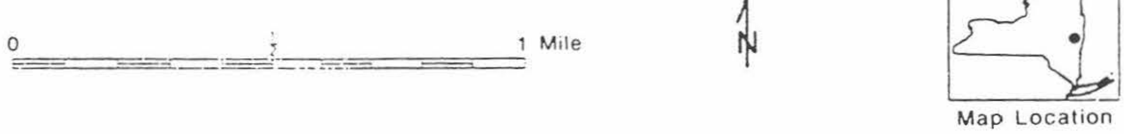


Figure 6. Portion of the Kinderhook 7.5 minute topographic quadrangle indicating location of STOP 1.



ROUTE DESCRIPTION	MILES FROM LAST POINT	CUMULATIVE MILEAGE
Intersection 9H, turn left toward 9H south.	0.1	5.0
Bear right onto 9H south (4 lane highway).	0.3	5.3
Rt. 9H reduces to 2 lane highway.	1.2	6.5
Martin Van Buren Historic Site.	1.7	8.2
Columbia County Airport.	5.0	13.2
Light at Intersection Rts. 9H and 66. Turn right onto Rt. 66, towards Hudson.	1.5	14.7
Cross Claverack Creek and enter Greenport.	1.9	16.6
Light at Healy Blvd. Continue straight on 66.	0.3	16.9
Cross railroad tracks.	0.4	17.3
Enter City of Hudson.	0.1	17.4
Light at junction with Rt. 23b. Turn right onto Rt. 23b.	0.3	17.7
Light at junction of Rts. 23b and 9. Continue straight on Rts. 9 south and 23b.	0.1	17.8
Light at intersection with State Street. Turn Right. Continue on State until 2nd Street.	0.4	18.2
Turn right onto 2nd Street. As we descend the hill, note the old marsh ahead of us.	0.8	9.0
At STOP sign, turn right onto Mill Street.	0.2	19.2
Continue to end of road.	0.1	19.3

STOP 2: Clay Pit

This clay pit, shown in Figure 7, is owned by the City of Hudson, and permission should be obtained prior to visiting the site. Today we will be able to see a small remnant of the original working area. These alternating bands of dark clay and lighter colored silt-clay are rhythmites, rhythmically deposited fine-grained lacustrine sediment. If the dark and light couplet represent an annual winter and summer accumulation, then they are varves. This 10m exposure has couplets 2-5cm thick and could represent 200-300 years of sediment accumulation into Lake Albany. When wet, these clays are very plastic.

1. What do you suppose would happen during an earthquake to the dams of Underhill and Oakdale ponds?

2. What would be the fate of these clay banks?

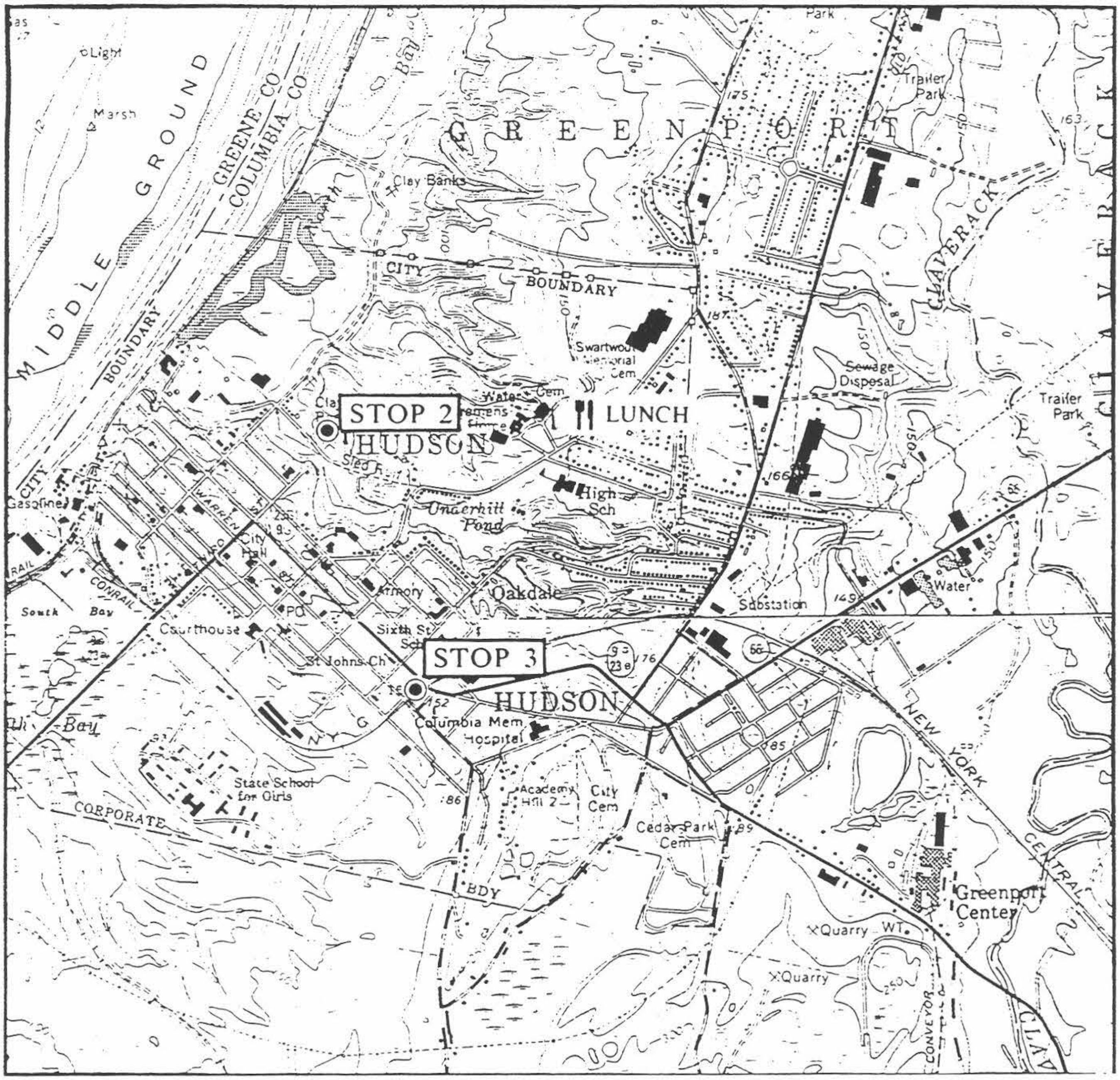
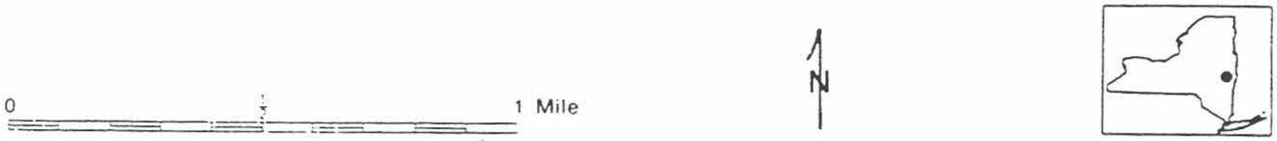


Figure 7. Portion of Hudson North and Hudson South 7.5 minute topographic quadrangles indicating location of STOP 2, STOP 3, and LUNCH.



Map Location

ROUTE DESCRIPTION	MILES FROM LAST POINT	CUMULATIVE MILEAGE
Turn around and proceed back to 2nd Street. Note the landfill to the right. Turn left onto 2nd Street.	0.1	19.4
Turn left onto State Street.	0.2	19.6
Turn left onto Carroll Street.	0.4	20.0
Turn left onto Short Street. This road becomes Harry Howard Avenue.	0.1	20.1
Note Underhill Pond to right. This is a man-made pond within the gully.	0.1	20.2
Turn left into entrance for Fireman's Home.	0.3	20.5

LUNCH

Note: To eat lunch at the Pavilion it is necessary to obtain permission in advance.
If time permits, the Fireman's Museum is excellent.

ROUTE DESCRIPTION	MILES FROM LAST POINT	CUMULATIVE MILEAGE
Return to entrance of Firemen's Home. Turn right onto Harry Howard Avenue.		
Turn right onto Carroll Street.	0.5	21.0
At light, bear right on State Street.	0.1	21.1
At light, turn left onto 3rd Street.	0.2	21.3
Turn left onto Columbia Street.	0.1	21.4
Turn right on 7th Street. PARK on side of road, Center Square Park.	0.5	21.9

STOP 3: Discussion of buildings, etc., City of Hudson.

See Figure 7 for specific location. Discussion will concentrate on types of building structures, and location of emergency services.

ROUTE DESCRIPTION	MILES FROM LAST POINT	CUMULATIVE MILEAGE
Leave Center Square Park, turn left on Warren Street.		
At blinker and stop sign, turn left on Prospect Street. Pass Columbia Memorial Hospital	0.2	22.1
At blinker and stop sign, continue straight.	0.2	22.3

ROUTE DESCRIPTION	MILES FROM LAST POINT	CUMULATIVE MILEAGE
At yield sign, bear right on Columbia Street.	0.05	22.35
At light at Green Street. Continue straight on Rt. 66	0.15	22.5
Enter Town of Claverack.	1.0	23.5
Light and intersection Rts. 66 and 9H. Continue on Rt. 66 toward Chatham.	1.9	25.4
Enter Hamlet of Ghent. Continue on Rt. 66.	5.8	31.2
Enter Village of Chatham.	5.8	37.0
Light and intersection Rts. 66 and 203.	0.6	37.6
Intersection Rts. 66 and 295. Bear right onto Rt. 295. Do not cross railroad tracks.	0.4	38.0
Underpass for Taconic State Parkway.	2.5	40.5

NOTE: This road log has stopped several miles from the property owner of STOP 4 because this is a private residence and the NYSGA trip has been given special permission to visit. The owners prefer not to be disturbed by an onslaught of people in the future.

STOP 4: Home damaged by land slump.

The damage resulted from land failure on October 7, 1983, coinciding with the 1983 Blue Mountain Lake, magnitude 5.1, earthquake, with the epicenter 180 kilometers away.

ROUTE DESCRIPTION	MILES FROM LAST POINT	CUMULATIVE MILEAGE
At the end of the stop turn around and return to the Taconic Parkway and I-90 access road.		
Intersection with I 90 access road. Turn onto access road for I 90.	0.0	0.0
Stop, get ticket for I 90. Keep LEFT onto I 90 Westbound.	0.7	0.7
Exit at Exit B1, for Albany, Hudson, Rt. 9 and I 90. 8.0 8.7		
Pay toll (cars $ 0.30 in 1995).	0.5	9.2

Keep right if you want to exit onto Rt. 9. Then turn left on 9 to return to Columbia- Rensselaer County border and start of road log.

Keep left for I 90 to Albany, Schenectady and to return to Union College.

End of Fieldtrip.