# SOME GENERALIZATIONS AS TO STRATIGRAPHY IN THROUGH VALLEYS AT THE VALLEY HEADS MORAINE IN CENTRAL NEW YORK

by Allan Randall

In the 1980's, the U.S. Geological Survey evaluated the aquifer potential of 18 through-valley reaches around the northern perimeter of the Susquehanna River basin. These valley reaches are distributed from Schenevus Creek (east) to Burns and Wayland (west), and are unique in that large volumes of ground water could be withdrawn seasonally from stratified-drift aquifers without significantly depleting streamflow at points downvalley. The resulting report (Randall and others, 1988) describes the geology of each valley fill by means of text, map, sections, and tabulated well records. The large through valley from Tully south to Preble, which constitutes the southern end of this year's Friends excursion, was not evaluated in detail because it had been described in two earlier geohydrologic reports, but was considered as part of a geologic overview.

Part of that overview (Randall and others, 1988, p. 45-47) is reprinted below, with minor updating, in order to insert in the geologic literature some generalizations that may be of interest to members of the glacial-geology fraternity. The reprinted text follows a description of the mapped units, which included ice-contact deposits, outwash, fine-grained lacustrine deposits, till, morainal till, and several categories of postglacial alluvium.

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## *Distribution of Lacustrine Deposits and Till*

The reconnaissance study of through valleys revealed two consistent and complementary geologic patterns. The first has to do with the distribution of lacustrine deposits, the second with the distribution of till. Extensive lacustrine deposits are found in the eastern and westernmost through valleys, where large lakes apparently formed after an initial period in which ice-contact deposits formed amid abundant stagnant ice. Clay, silt, and very fine sand settled on the lake bottoms; coarse sand and gravel was trapped in ponds to the north for a time but eventually prograded southward across the lake-bottom sediment as deltaic or fluvial outwash. The central valleys, but contrast, show little evidence of an extensive lake south of the present divide. Although lenses of lake deposits occur here and there, the supply of coarse sediment generally kept pace with melting of the ice. The distribution of lacustrine deposits among the valleys is as follows:

Valleys containing extensive lacustrine deposits beneath surficial outwash:

East: Bridgewater Flats, Madison-Bouckville, Pinewoods, Fabius, Sheds (lacustrine but no outwash), Tully, Schenevus Creek (lacustrine south of shallow headwater reach)

West: Bath, North Cohocton (?), Wayland, Burns.

Valleys not containing extensive lacustrine deposits: Preble Dry Valley, Harford,

Caroline, Willseyville Creek, Pony Hollow, Beaver Dams.

Valleys in which information is insufficient for classification: Labrador Pond, Alpine.

Several through valleys, mostly along the central part of the Susquehanna River basin perimeter, have a layer of till near the top of the valley fill close to the divide. At Harford, till was recognized beneath a few feet of gravel in several test holes and in streambank exposures (Randall and others, 1988, fig. 4). In Preble dry valley, soils maps suggest surficial till north of the divide. At Tully, sandy-silty till was observed overlying gravel at the corner of Gatehouse Road and Route 80, at the very head of the south-sloping outwash, and in other exposures downslope to the north (Andrews and Jordan, 1978, p. 327; D.E. Andrews, Syracuse Univ, oral commun. 1978). Muller (1966) suggested an ice readvance to perhaps 4 miles south of Tully on the basis of topographic evidence. In the east limb of the Fabius valley, in Pinewoods valley, and in North Cohocton valley, soils maps and(or) numerous exposures and auger holes suggest that a till layer several feet thick mantles the valley floor near the divide (figs. 20, 22, 32 of Randall and others, 1988). In several other valleys, the surface of the stratified drift near the divide is dotted with knobs and kettles that indicate abundant buried ice when meltwater flow ceased; the ice might have resulted from a late readvance of the glacier.

Exposures and well records suggest that a few hundred feet of drift, all or mostly stratified, underlie these till layers and hummoky areas. If so, the ice sheet must have left great thicknesses of meltwater deposits in these valleys during its initial retreat, readvanced briefly to or just beyond the divide in at least the central part of the perimeter of the Susquehanna River basin, then dissipated without leaving more than a trace of outwash.

The explanation for the apparent complementary distribution of till and lacustrine deposits in through valleys probably lies in the dynamics of ice flow during deglaciation. The central valleys lie south of the Lake Ontario basin and deep within the lowest part of the Appalachian Plateau, where obstructions to ice flow were less than to the east and west. Furthermore, most are at the south end of the Finger Lakes troughs, where ice flow was especially vigorous, as evidenced by the deep incision of these valleys (von Englen, 1961; Coates, 1966; Mullins and Hinchey, 1989). Ridge tops near the eastern and western valleys are slightly higher, and the eastern valleys lie in the lee of the Adirondack Mountains and Tug Hill. Perhaps the ice in these areas may have been more sensitive to climatic cycles and thus retreated farther north during warm years, allowing large proglacial lakes to form in and north of the through valleys.

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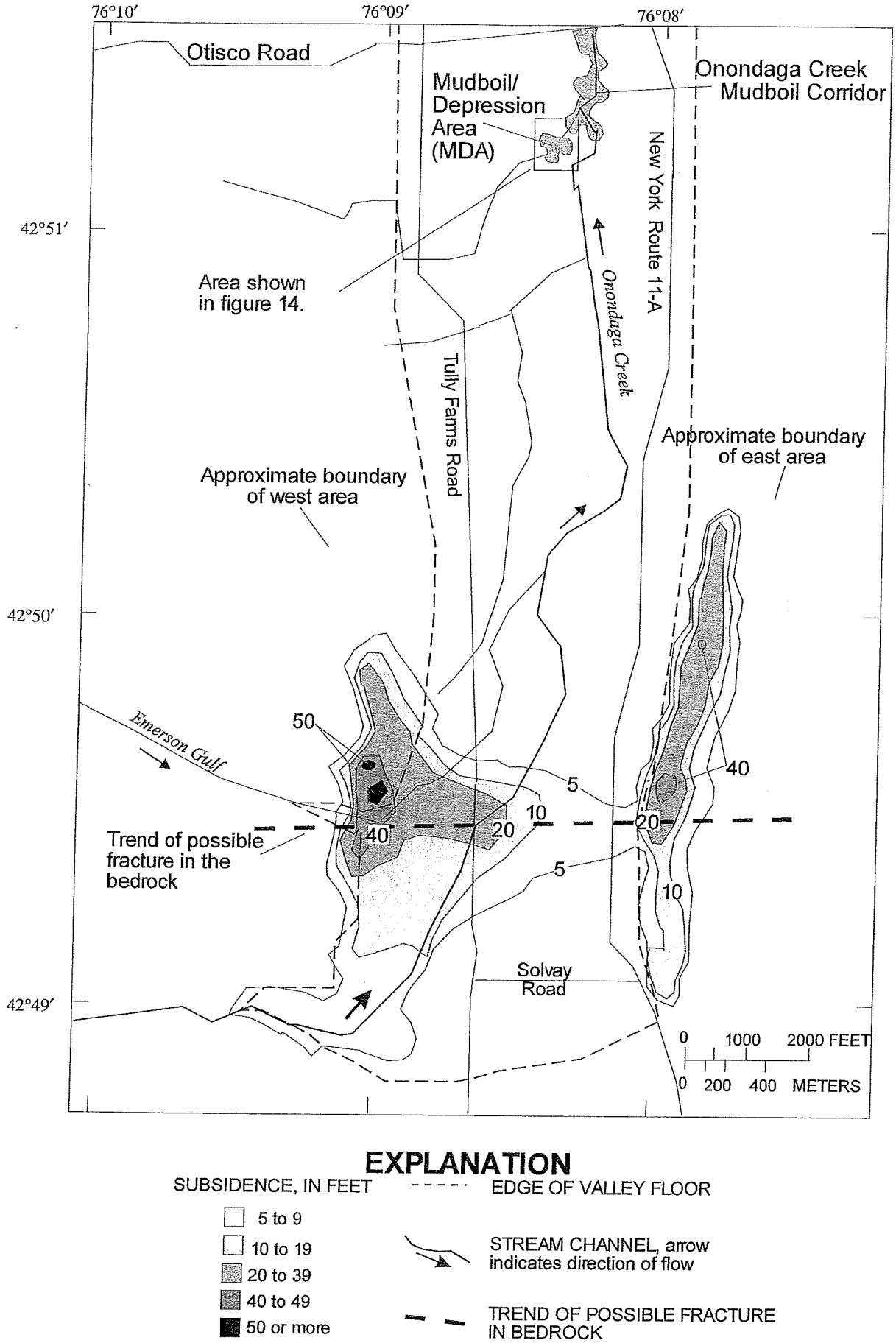



**Figure 13**. Extent and depth of brinefield subsidence (1957-93) in east and west areas and along a possible bedrock fracture in southern part of Tully Valley. (Modified from Walker and Mahoney, 1993, fig. 7. Location is shown in fig. 2.).

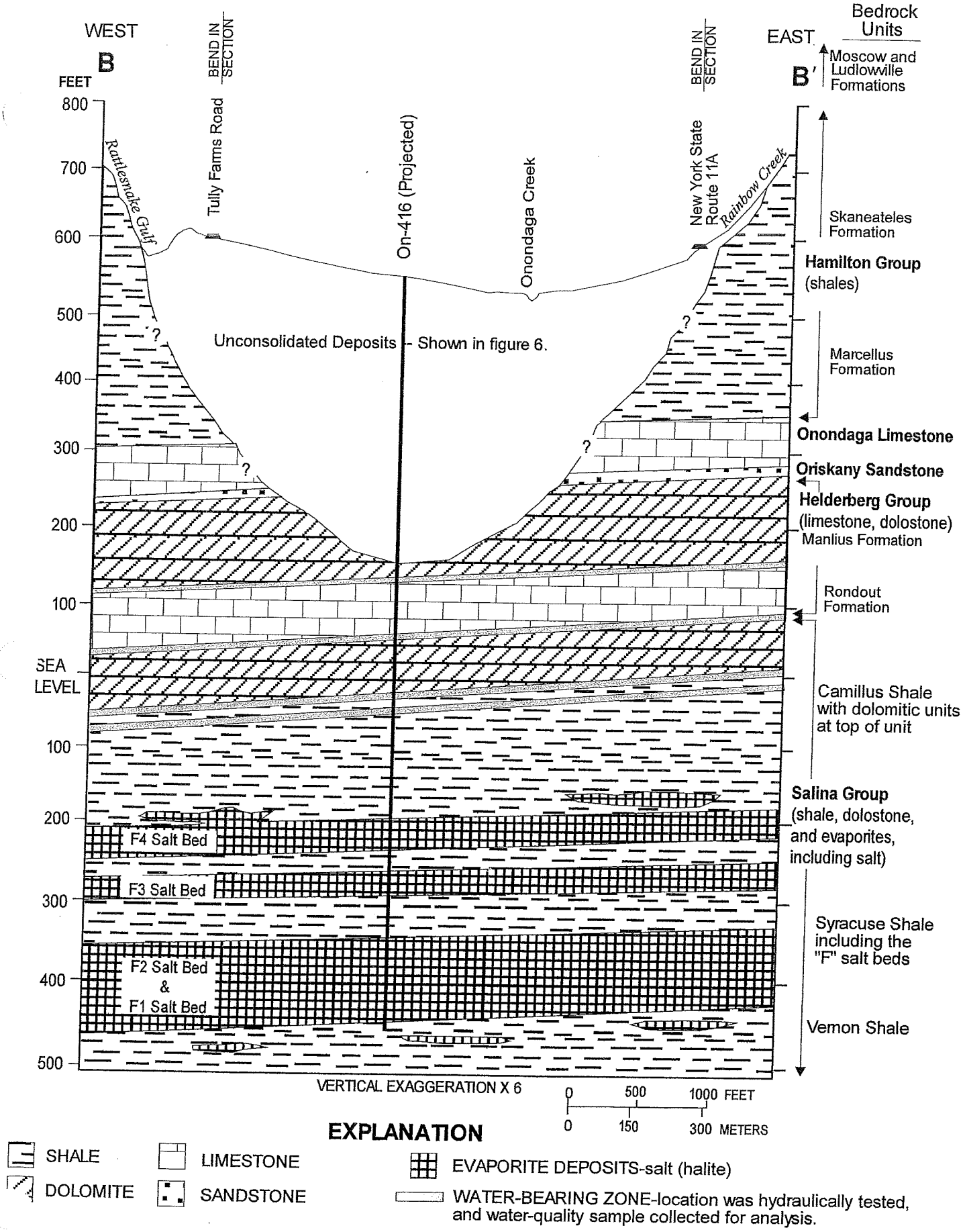
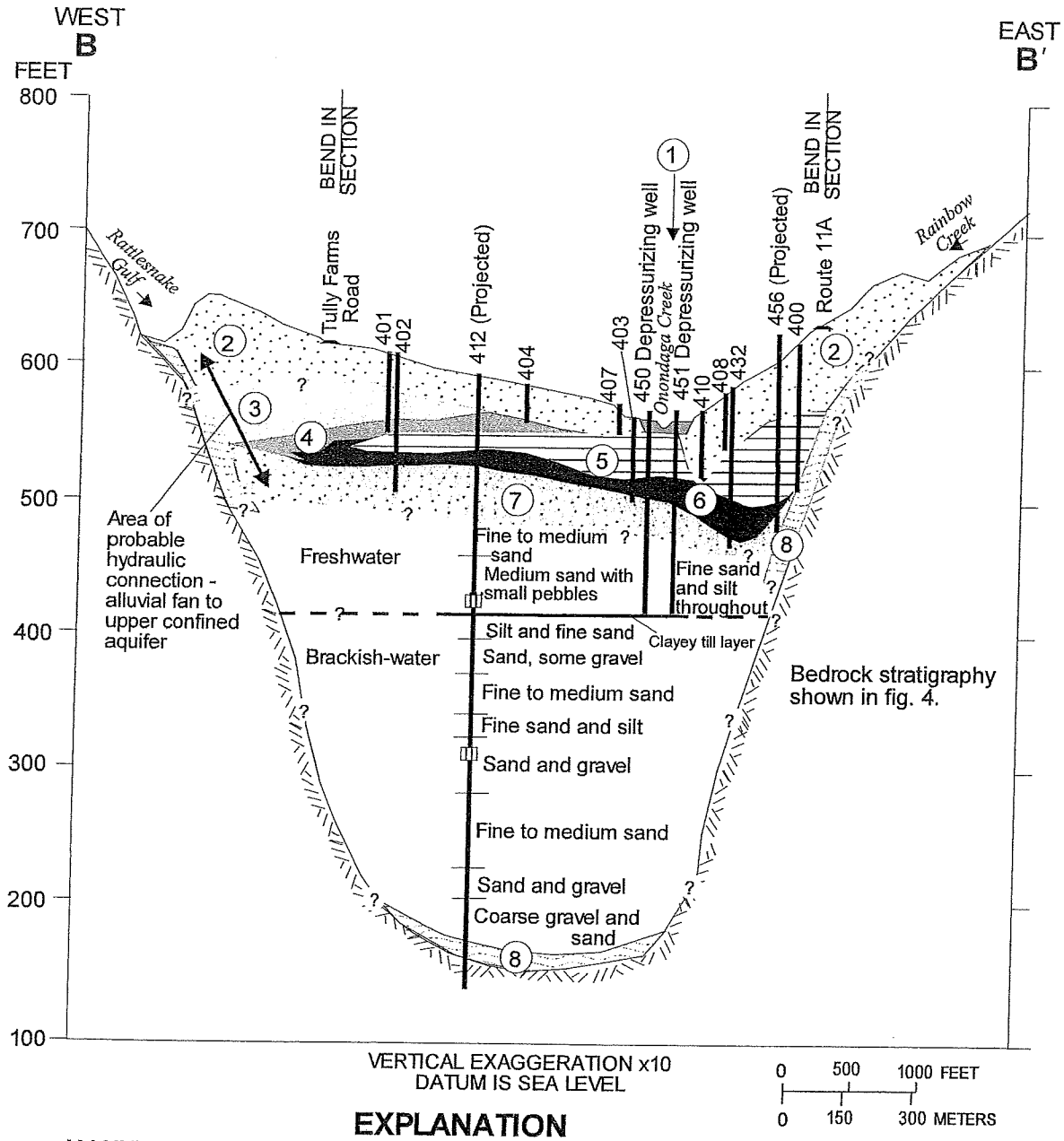



**Figure 4.** Geologic section B-B' showing major bedrock units below Rattlesnake Gulf and Rainbow Creek from lower valley walls to top of Vernon Shale. (Modified from Getchell, 1982, plate 1. Location of section is shown in fig. 2.)




## EXPLANATION

### ALLUVIAL DEPOSITS

(1) FLOODPLAIN AND MUDBOIL DEPOSITS - Silt, sand and gravel deposited by Onondaga Creek and upstream mudboils.

(2) FANS - Sand and gravel deposited by Rattlesnake Gulf and Rainbow Creek.

### LACUSTRINE DEPOSITS

(3) LAMINATED SAND AND SOME SILT/CLAY - Mostly fine to medium sand interbedded with minor amounts of silt and clay deposited by Rattlesnake Gulf as it flowed into a proglacial lake.

(4) LAMINATED SAND AND SILTY-CLAY - Approximately equal parts of very fine sand interbedded with silty-clay that settled-out further in the proglacial lake.

(5) LAMINATED SILTY-CLAY WITH SAND - Mostly silty-clay interbedded with occasional layers of medium-to-fine sand that settled out furthest in the proglacial lake. Coarser sand is found along Otisco Road; finer sand-to-silt wisps are found further north and south of Otisco Road. Firms top of confining unit over liquifiable sand and silt unit in the mudboil areas.

### LACUSTRINE DEPOSITS (cont'd)

(6) CLAY AND SILT - Massive unit that generally covers most of valley floor north and south of mudboil areas. Forms confining unit over upper aquifer and grades from clay at surface to silt at depth.

(7) SILT AND SAND - Massive, grading from silt and very fine sand at the top to medium to coarse sand and fine gravel with silt at bottom of unit. Unit is under artesian pressure and forms upper confined aquifer.

### OTHER GLACIAL DEPOSITS

(8) TILL - A dense unit of sand, gravel, and boulders embedded in a clay matrix. This unit may underlie entire glacial sequence in the valley.

BEDROCK

410 — WELL AND NUMBER, without "On" prefix

MONITORING ZONE PERFORATED IN STEEL CASING, perforated after hydraulic testing of deeper bedrock zones and grouting of the bedrock section of deep well On-416.

**Figure 6**. Geologic section B-B' showing upper unconsolidated deposits along Otisco Road and deeper unconsolidated deposits projected from well On-412, southwest of mudboil/depression area. (Location of section is shown in figs. 2 and 3.)

# Remediation of Mudboil Discharges in the Tully Valley of Central New York

## What is a Mudboil?

The Tully Valley mudboils are volcanolike cones of fine sand and silt that range from several inches to several feet high and from several inches to more than 30 feet in diameter. Active mudboils are dynamic ebb-and-flow features that can erupt and form a large cone in several days, then cease flowing, or they may discharge continuously for several years.

Mudboils have been observed in the Tully Valley in Onondaga County, in central New York State, since the late 1890's. Mudboils have continuously discharged sediment-laden (turbid) water into nearby Onondaga Creek, which flows to Onondaga Lake. The discharge of sediment causes gradual land-surface subsidence (fig. 1) that, in the past, necessitated rerouting a major petroleum pipeline and a buried telephone cable, and caused two road bridges to collapse. The water discharged from mudboils can be either fresh or brackish (salty).

Mudboil activity was first reported in the Syracuse, NY Post Standard, in a short article dated October 19, 1899:

*"Tully Valley—A Miniature Volcano*

*Few people are aware of the existence of a volcano in this town. It is a small one, to be sure, but very interesting. In the 20-rod gorge where the crossroad leads by the Tully Valley grist mill the hard highway bed has been rising foot after foot till the apex of a cone which has been booming has broken open and quicksand and water flow down the miniature mountain sides. It is an ever increasing cone obliterating wagon tracks as soon as crossed. The nearby bluff is slowly sinking. Probably the highway must sometime be changed on account of the sand and water volcano, unless it ceases its eruption."*

This newspaper article accurately describes Tully Valley mudboils and presages the collapse of the Otisco Road bridge 92 years later in 1991. The article indicates that land subsidence occurred nearby, but gives no indication that Onondaga Creek was turbid; this was either an oversight by the reporter or was not a concern.

In 1991, the Onondaga Lake Management Conference identified the Tully Valley mudboils as the major source of turbidity being discharged into Onondaga Lake. Beginning in the fall of 1991, the Conference created the Mudboil Working Group (representing local, State, and Federal agencies) to

USGS

**Figure 1.** (right) Mudboil/ Depression Area, known as the "MDA", as of November, 1994. View of land surface subsidence is toward the west from the MDA dam. (Location shown in fig. 3).

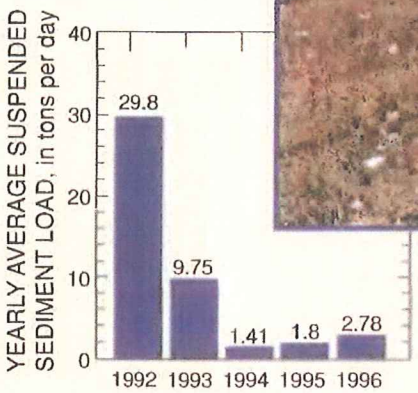



**Figure 2.** (left) Yearly average suspended-sediment load discharged to Onondaga Creek from the mudboil/depression area, water years 1992-96.

(1) develop a plan of study to identify the cause of mudboil activity, and (2) formulate ways to reduce or eliminate mudboil discharges, and thereby decrease or stop associated turbidity in Onondaga Creek, and nearby land subsidence. The U.S. Geological Survey in co-operation with researchers from the New York State Department of Environmental Conservation and Syracuse University, began the first comprehensive, long-term study of mudboil activity in the Tully Valley. The study plan was to: (1) define the mechanism and extent of mudboil development; (2) drill test wells to define the glacial stratigraphy (layering of glacial materials) and thereby delineate ground-water flowpaths within the valley, including drilling a deep test well to penetrate the salt beds below the mudboil area; (3) monitor the flow and sediment concentrations of mudboil discharges to calculate the amount of water and sediment discharged to Onondaga Creek; (4) identify remedial actions to reduce those discharges; and (5) monitor the results of those actions.

Flow from a mudboil is driven by artesian pressure that forces water and sediment upward from two sand and gravel aquifers through a 60-foot-thick layer of dense silt and clay. The artesian pressure within the aquifer can lift water 20 feet above land surface within most of the valley floor and 30 feet above land surface near Onondaga Creek. The source of the artesian pressure is surface water entering the ground-water system along the valley walls — primarily at the southern end of the valley at the Tully Moraine and from the alluvial fans at the mouth of Rattlesnake Gulf and Rainbow Creeks.

The flow of water from the mudboils changes seasonally in response to changes in artesian pressure in the two aquifers. In the spring, when ground-water recharge is greatest, the mudboils in the main mudboil/depression area (MDA) (fig. 3, inset map) can discharge 400 gallons per minute or more. As recharge to aquifers declines during the summer, artesian pressure in the aquifers also declines, and flow from mudboils typically decreases to 200 gallons per minute or less. The rate of mudboil flow does not change in response to individual rainstorms but does respond to seasonal variations in precipitation.

Suspended-sediment discharge from the MDA to Onondaga Creek was measured between October 1991, and September, 1996. The daily average suspended sediment load for water years[1] 1992-96 are shown in fig. 2. Most of the suspended sediment is very fine clay and silt with a small fraction of very fine sand.

Chemical analyses of mudboil discharge in the MDA indicate that the source of water is either the confined freshwater aquifer or an underlying brackish-water (salty) aquifer (fig. 4). Chloride concentrations in the upper,

[1]Water year - This is the 12-month period from October 1 through September 30. The water year ending on September 30, 1996 is the 1996 water year.

Purpose of the Onondaga Lake Management Conference:

*"To prepare and implement a comprehensive Management Plan to define a cleanup strategy for Onondaga Lake, rehabilitate the Lake ecosystem, and restore beneficial uses of the Lake to the citizens of Onondaga County."*

—Statement from: Citizens Advisory Committee, General Goals and Objectives, April 1991

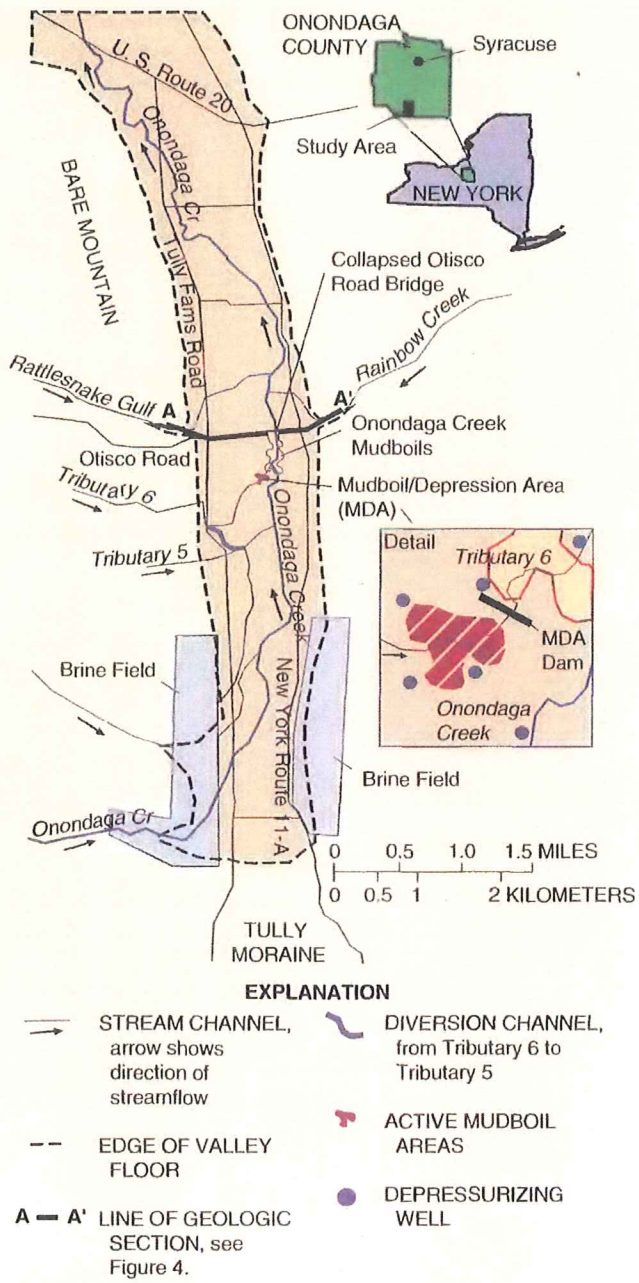



**Figure 3**. Principal geographic features of Tully Valley, N.Y., and locations of brine field, diversion channel, and mudboil areas. Inset map shows detail of MDA and locations of several depressurizing wells and outlet dam.

freshwater aquifer range from 37 to 430 milligrams per liter (mg/L) and from 2,000 to 7,100 mg/L in the lower, brackish-water aquifer. The difference in chloride concentration between these two aquifers is due partly to the greater density of the saltwater, which causes the brackish water to concentrate in the lower aquifer.

Remedial efforts near the Tully Valley mudboils include: (1) diverting flow from the tributary that feeds the MDA to an adjacent tributary; (2) installing depressurizing wells at several locations around the MDA and along Onondaga Creek to decrease the artesian pressure; and (3) constructing a dam and sediment-settling impoundment to detain mudboil sediment that would normally discharge to Onondaga Creek.

## Surface-Water Diversion

Flow from the upper 0.7 square miles of the Tributary 6 drainage was diverted south to Tributary 5 (fig. 3), in June 1992. This diversion reduced total annual surface water inflow to the MDA by about two-thirds, which, in turn, reduced sediment loading to Onondaga Creek by half — from about 30 tons per day before diversion to about 15 tons per day thereafter.

## Aquifer Depressurizing Wells

Depressurizing wells were installed near the collapsed Otisco Road bridge during the winter of 1992-93 in an effort to reduce artesian pressures in the upper aquifer and thereby slow nearby mudboil activity. The wells were drilled to the base of the freshwater aquifer, and 10-foot-long well screens were installed to allow artesian-pressured water to flow out of the well while holding the fine-grained sand and silt in place. These wells have a combined discharge of about 25 gallons per minute of sediment-free water and have modestly reduced artesian pressure in the freshwater aquifer by about 1 pound per square inch, or about 2.5 feet of hydraulic head. Nearby mudboil activity did not increase, and no new mudboils have developed since the wells were installed. Furthermore, the discharge of nearby mudboils has been sediment free, indicating possible stability in the area.

Eight additional wells were installed in the aquifers underlying the MDA and Onondaga Creek in the summer of 1996 to further reduce artesian pressure and slow mudboil activity. Total ground-water discharge from all wells averages about 350 gallons per minute. The chemical quality of water discharged from these wells varies with position around the MDA; most of the flows from depressurizing wells screened in the upper aquifer around and downgradient from the MDA are slightly brackish to salty, indicating that water from the lower aquifer is migrating upward into the base of the upper, freshwater aquifer. Water quality upgradient (south) of the MDA, is generally fresh. Discharge from individual wells range from less than 5 gallons per minute to more than 100

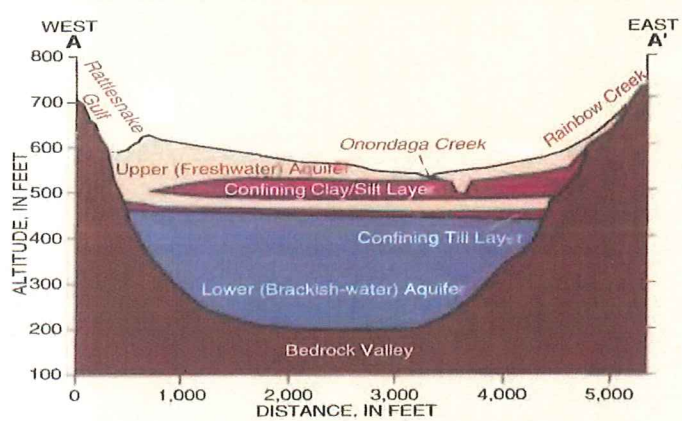



**Figure 4**. West-east geologic section between Rattlesnake Gulf and Rainbow Creek along Otisco Road, showing upper and lower glacial aquifers and confining clay layers.

gallons per minute, depending on location and the aquifer material —flow from a coarse sand is much greater than flow from a fine-grained sand.

## Impoundment Dam

A temporary dam was constructed at the outlet of the MDA (fig. 3, inset map) in July 1993 to reduce the average daily load of sediment discharging to Onondaga Creek. The impounded water covered several mudboils and allowed most of the silt and sand to settle out before flowing to Onondaga Creek. Also, the weight of water over active mudboils, and the additional weight of sediment settling on the mudboils decreased mudboil discharge. The impoundment, in conjunction with the depressurizing wells, has slowed mudboil activity in the MDA, and should slow land subsidence in this area as well.

The impoundment reduced the average daily load of sediment discharged from the MDA to Onondaga Creek, from 15 tons per day in 1992 to about 1.5 tons per day during water years 1993 and 1994, but by 1995, the entire impounded area was filled with sediment. Consequently, sediment loading to Onondaga Creek increased from 1.8 tons per day in water year 1995 to 2.8 tons per day in water year 1996 (fig. 2).

The dam was reconstructed to allow the outflow elevation to be raised in the summer of 1996. The intent is to slowly increase the height of water over the remaining mudboils in the MDA while the surrounding depressurizing wells are in operation. The increased amount of water and sediment over the active mudboils are expected to slow mudboil activity and cause the wells to discharge increased amounts of sediment-free water to the Creek.

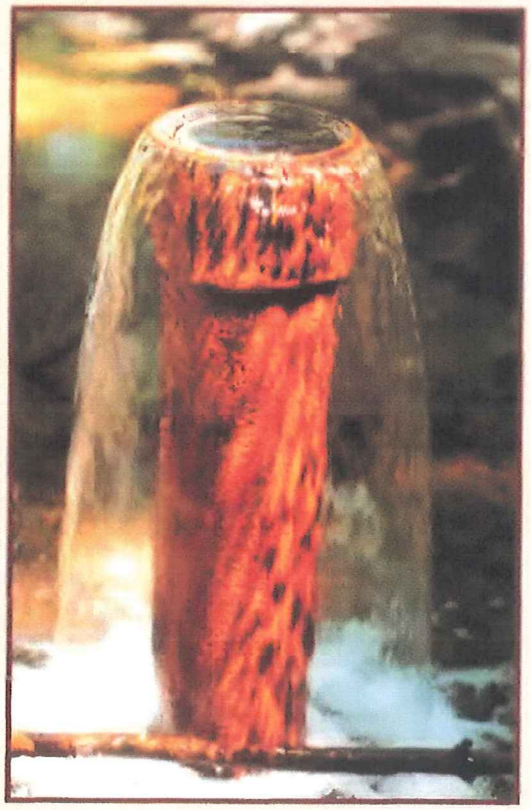


**Figure 5.** Depressurizing well flowing at a rate of more than 100 gallons per minute near the MDA.

## Conclusions

The Onondaga Lake Management Conference's primary goal is to restore the lake's ecological integrity. As one of seven major issues identified by the Conference, the Tully Valley mudboils "must be controlled to improve the water quality of the Creek and Lake, and their habitats." The Conference has funded the study of the mudboils within the mudboil/depression area and along Onondaga Creek since 1991 and has funded these remediation projects which should, in time, slow mudboil activity.

Mudboils will persist in the Tully Valley as long as the two confined aquifers have artesian pressure that will 'push' water above land surface. The remediation projects are designed to (1) reduce artesian pressure that drives mudboil activity, and (2) decrease the discharge of sediment. These projects are expected to slow, but not stop, mudboil activity. As a result, turbidity in Onondaga Creek will decline, as will the rate of land subsidence in the Tully Valley. The results of this work will assist the Onondaga Lake Management Conference in improving the water quality of Onondaga Creek and Onondaga Lake.

*—William M. Kappel and Wendy S. McPherson—*

## Sources of Technical Information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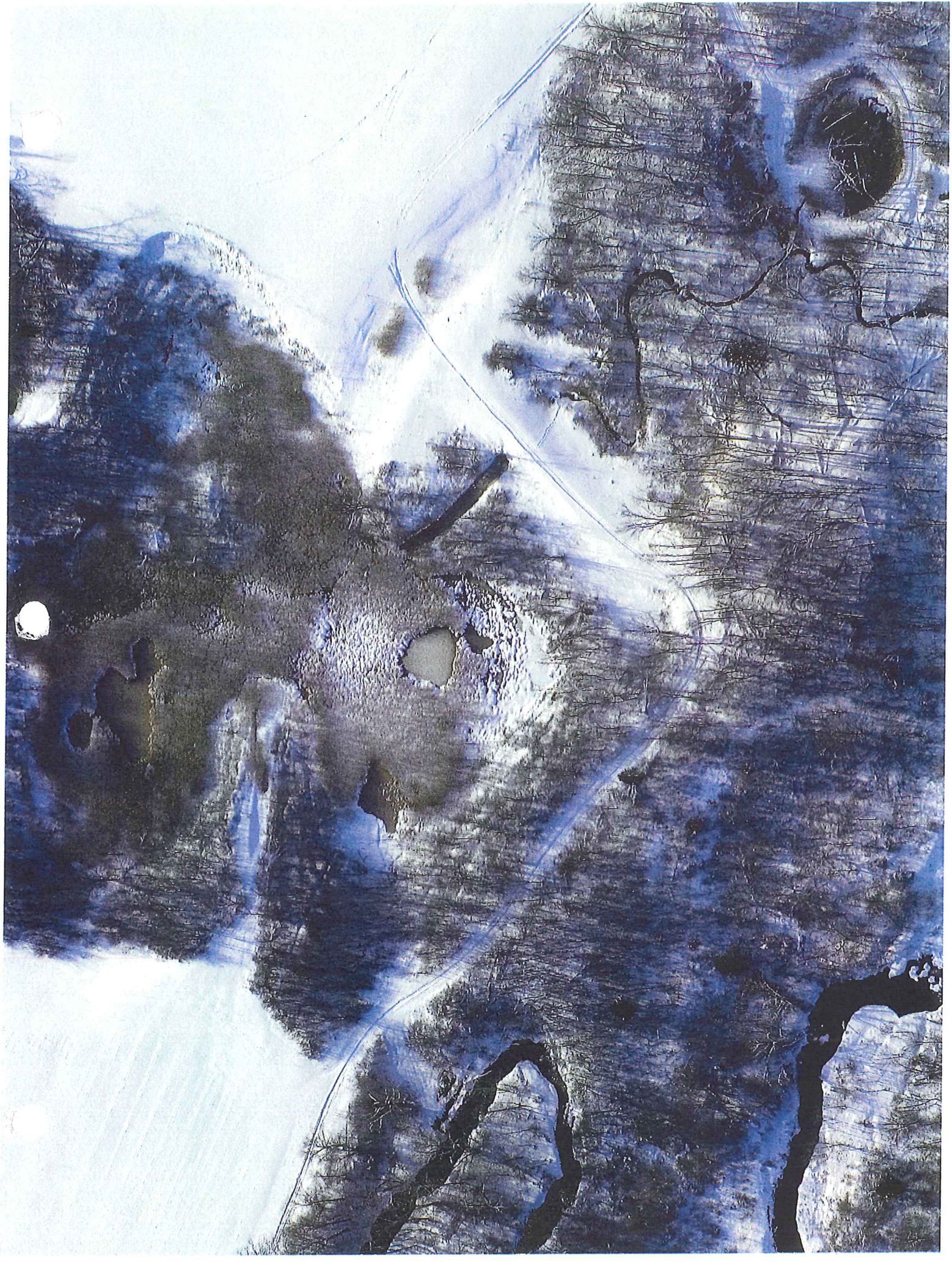
Waller, R.M., Subsidence in New York related to ground-water discharge *in* Geological Survey Research 1977, U.S. Geological Survey Professional Paper 1050, p. 258.


## For more Information:


Subdistrict Chief
U.S. Geological Survey
903 Hanshaw Rd
Ithaca, N.Y. 14850


This fact sheet and related information can be found on the World Wide Web at: ***http://ny.usgs.gov***



Saturday, May 21, 2005
PM Session

# Landslide Hazards in Glacial Lake Clays - Tully Valley, New York

## Introduction

At approximately midday on April 27, 1993, a large landslide occurred along the foot of Bare Mountain in LaFayette, Onondaga County, New York, about 12 miles south of Syracuse (figs. 1, 2). The slide moved rapidly east toward the middle of the Tully Valley and impacted approximately 50 acres of land, destroyed three homes, and resulted in the evacuation of four other homes. Debris from the slide, consisting mostly of remolded clay, covered Tully Farms Road with up to 15 feet of earth for a length of some 1,200 feet. Springs that developed near the top of the slide discharged either freshwater or brackish water, which contained concentrations of dissolved evaporites (salt and gypsum) and other minerals. The total volume of earth moved by the slide is estimated to be about 1.3 million cubic yards. According to the New York State Geological Survey, this slide is the largest to have occurred in the State in more than 75 years. Most residents were away from their homes at the time of the slide, and so there were no fatalities or serious injuries caused by the slide.

**Figure 1.** Oblique aerial view of the Tully Valley landslide taken April 30, 1993, 3 days after the slide. Debris moved toward the viewer, in the process covering Tully Farms Road (dashed line) up to 15 feet deep with reddish remolded clay. Three people were rescued by helicopter behind the white house (lower left) from the

rapidly advancing landslide. Springs located between red arrows.

## Physical Setting

Tully Valley is located in the Finger Lakes region of New York State. Like the Finger Lakes, Tully Valley is a glacially carved valley into which lake sediments were deposited. Tully Valley is approximately 6 miles long and on average about 1 mile wide along the valley floor. Onondaga Creek flows north through the valley and eventually drains to Lake Ontario. The valley walls generally consist of colluvium (weathered bedrock) and glacial till (dense soils) over bedrock. The valley floor consists of more than 400 feet of glacial lake deposits (gravel and sand grading upward to silt and clay at land surface). The valley floor terrain slopes gently (generally less than 10°) from the valley walls toward the center of the valley. Land use in Tully Valley is mostly agricultural and low-density residential. Brine mining (solution mining of salt) took place from 1889 to 1986 at the southern end of the valley.

Along the west side of the valley, several older landslide areas have been identified (fig. 2). However, none of the previous landslides were known to local residents or were reported in newspapers or historical records dating back to about 1780. Therefore, the frequency of landslide events in Tully Valley has not been established reliably. As the 1993 landslide has shown, though, the potential damage from such an event can be catastrophic.

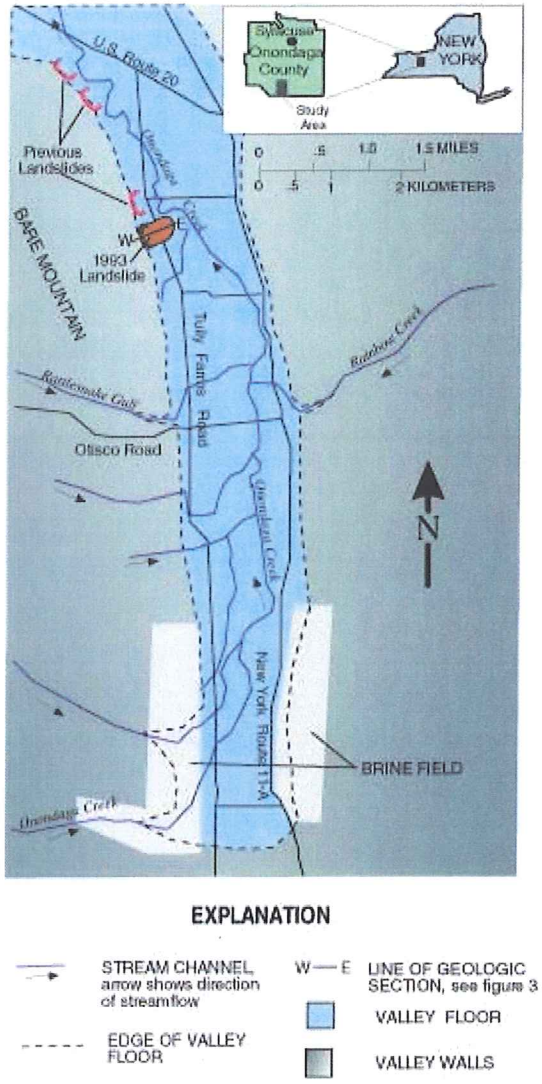



**Figure 2.** Major physical features in Tully Valley, including the 1993 landslide, previous landslides, and the brine-mining area at the southern end of the valley.

## Hydrogeology of the Tully Valley

Profiles of soil stratigraphy before and after the 1993 landslide are shown in figure 3. A massive, red, soft to firm lacustrine silty clay deposit interfingers with coarse sandy soils and a varved clay sequence (fig. 4) that lies against the steeply dipping weathered shale bedrock. The upper thin cover of stiff silty clay traps artesian-pressured ground water in the coarse sand interfingers. Below the massive red clay and the coarse interfingers, a dense till confines and separates brackish water from the overlying freshwater in the coarse interfingers. A few local wells derive domestic water supply from this lower aquifer; however, the water quality has gradually degraded to a point where some wells were abandoned in the late 1980's.

During a normal year, highest ground-water pressures develop in the coarse interfingers during spring -- following snowmelt runoff and spring rains and preceding the development of foliage on the forested hillside. Once the trees leaf out, ground-water pressures decline rapidly. Review of winter 1992-93 weather records indicates that heavy winter snowfall was followed by a large snowstorm (the blizzard of March 1993) and above-normal rainfall in April. Melting winter snow increased the saturation of near-surface soil strata. A rapid melting of the blizzard's snow and nearly constant rainfall in April contributed to greater than normal surface and subsurface flow toward the slide area from the adjacent Bare Mountain.

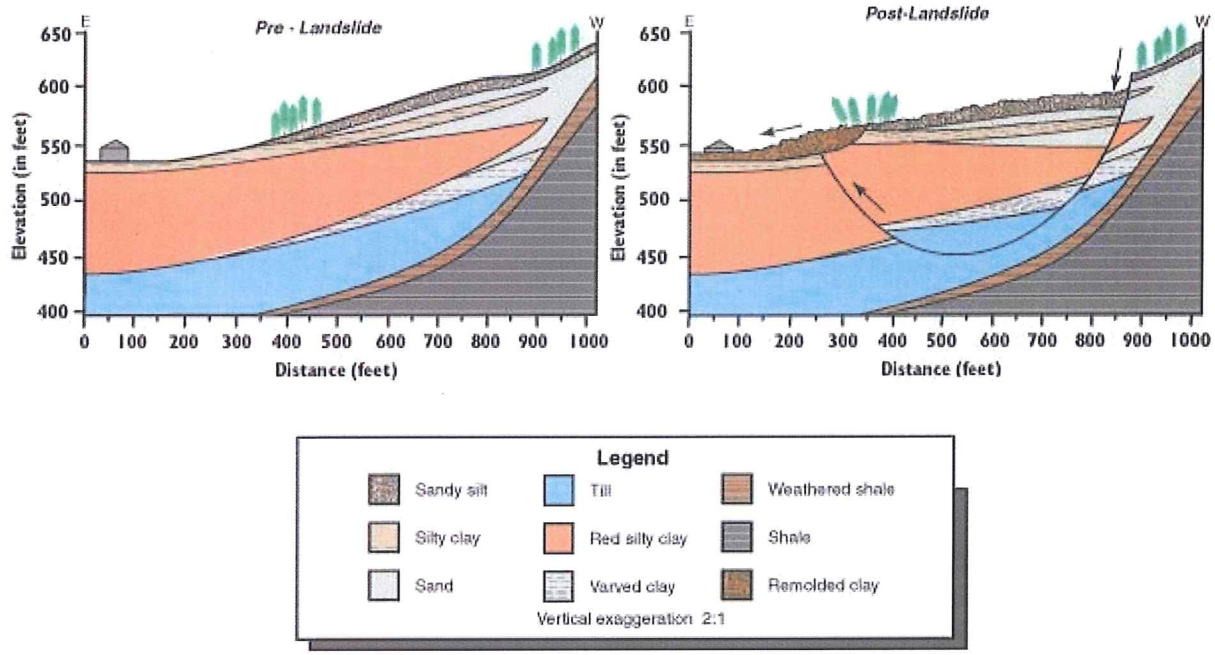



**Figure 3.** Soil stratigraphy before and after the 1993 landslide.

Review of available data from the New York State Department of Environmental Conservation (NYS-DEC) and statements by local residents indicate that there were signs of developing instability months to years prior to the 1993 landslide. As early as 1990, evidence of ground cracks, bulging, and slumping was noted by the NYS-DEC near what would be the southwest corner of the slide. The foundation of one house was slowly being pushed into the cellar space and had to be repaired in 1992, and the surface of a wetland in what would become the southern extent of the landslide area rose and fell. Even if these features had been reported to local officials, they probably would not have been sufficient for accurate prediction of the landslide location or timing.

**Figure 4.** USGS and Syracuse University scientists using a vane shear device to measure undrained shear strength of an exposed stratum of glacial lake clay at the top of the 1993 Tully Valley landslide.

## Landslide Susceptibility Mapping

Large parts of New York State are covered with glacial lake sediments (including the Finger Lakes region and the Hudson and Mohawk River Valleys) and are subject to landsliding. In the aftermath of the 1993 Tully Valley landslide, residents and public officials were concerned about the potential landslide hazards in settings similar to the Tully Valley. In response, the U.S. Geological Survey prepared a map of 160 square miles of southern Onondaga County showing the susceptibility to landsliding categorized as low, moderate, or high (Jäger and Wieczorek, 1994). The landslide susceptibility was quantitatively modeled by using statistical analyses of the relationship between an inventory of landslides and the areal distribution of lake clay deposits, limits of glacial lakes, and categories of slope steepness. The map, at a scale of 1:50,000, is being used by the towns of Tully and LaFayette, as well as agencies of Onondaga County, for land-use planning and for zoning decisions within the 160-square-mile area. Landslide susceptibility maps would be useful for other areas with glacial lake clay deposits where landsliding is possible.

### What You Can Do

**To mitigate slide hazards, vigilant observation and reaction to changing conditions are important.**

- **Become familiar with the land surface and ground-water conditions around you.**
- **Observe and record occurrences and changes in land surface features such as cracks, bulging, and slumping.**

- **Note changes in water quality (color, taste, smell), other than normal seasonal changes.**
- **Note development of new springs and changes in the clarity of spring discharge (muddiness, color change).**
- **Inform local authorities of changes and new developments that you observe.**
- **Support and collaborate with local authorities and research groups engaged in subsurface investigations and data collection.**

*Gerald F. Wieczorek*, USGS, Reston, Va.; *Dawit Negussey*, Syracuse University, Syracuse, N.Y.; and *William M. Kappel*, USGS, Ithaca, N.Y.

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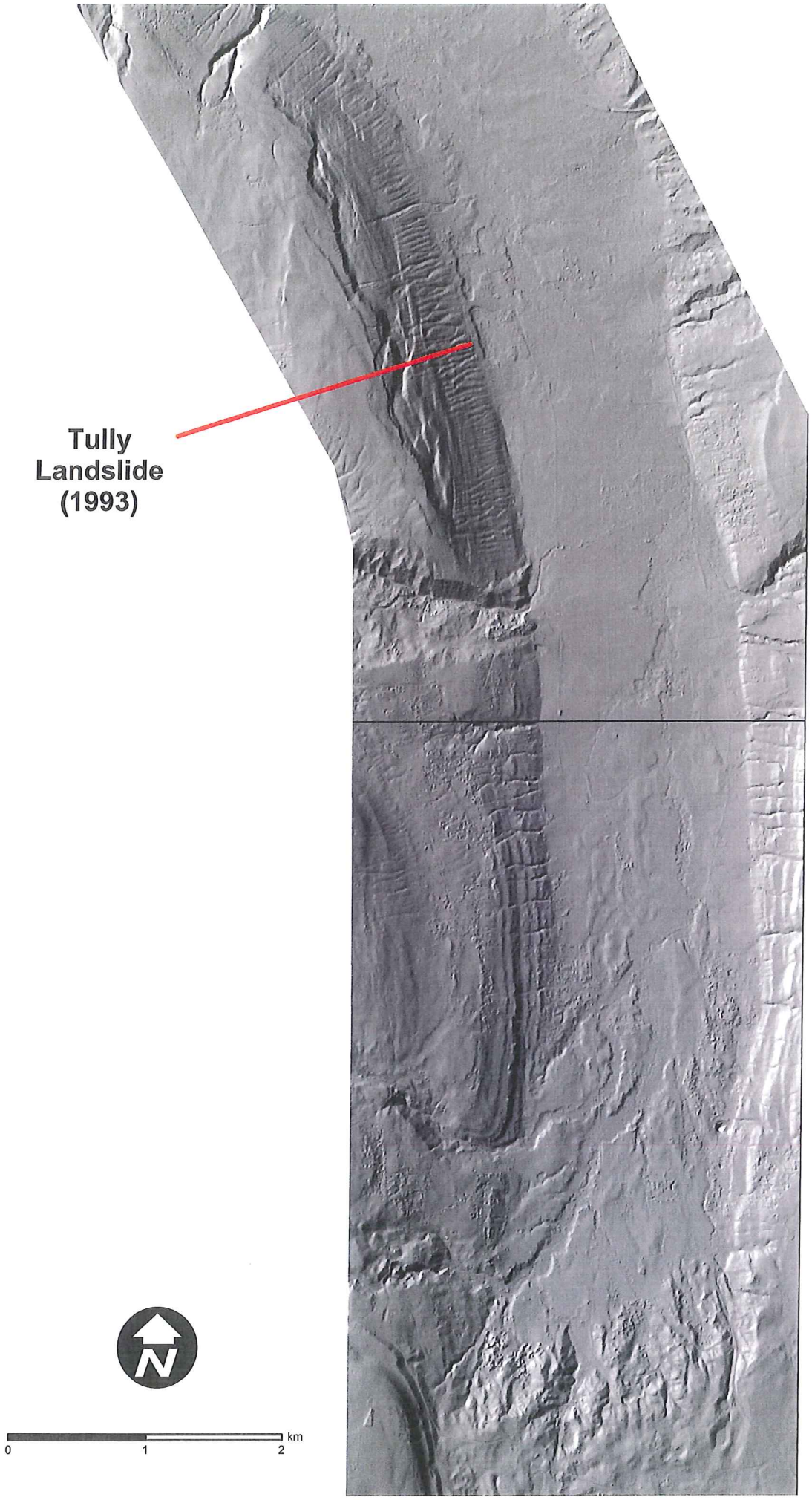
**For more information, please contact:**

*National Landslide Information Center*
*U.S. Geological Survey*
*Box 25046, Federal Center*
*Mail Stop 966*
*Denver, CO 80225*
*Telephone: 1-800-654-4966*
*E-mail: highland@gldvxa.cr.usgs.gov*

# LIDAR



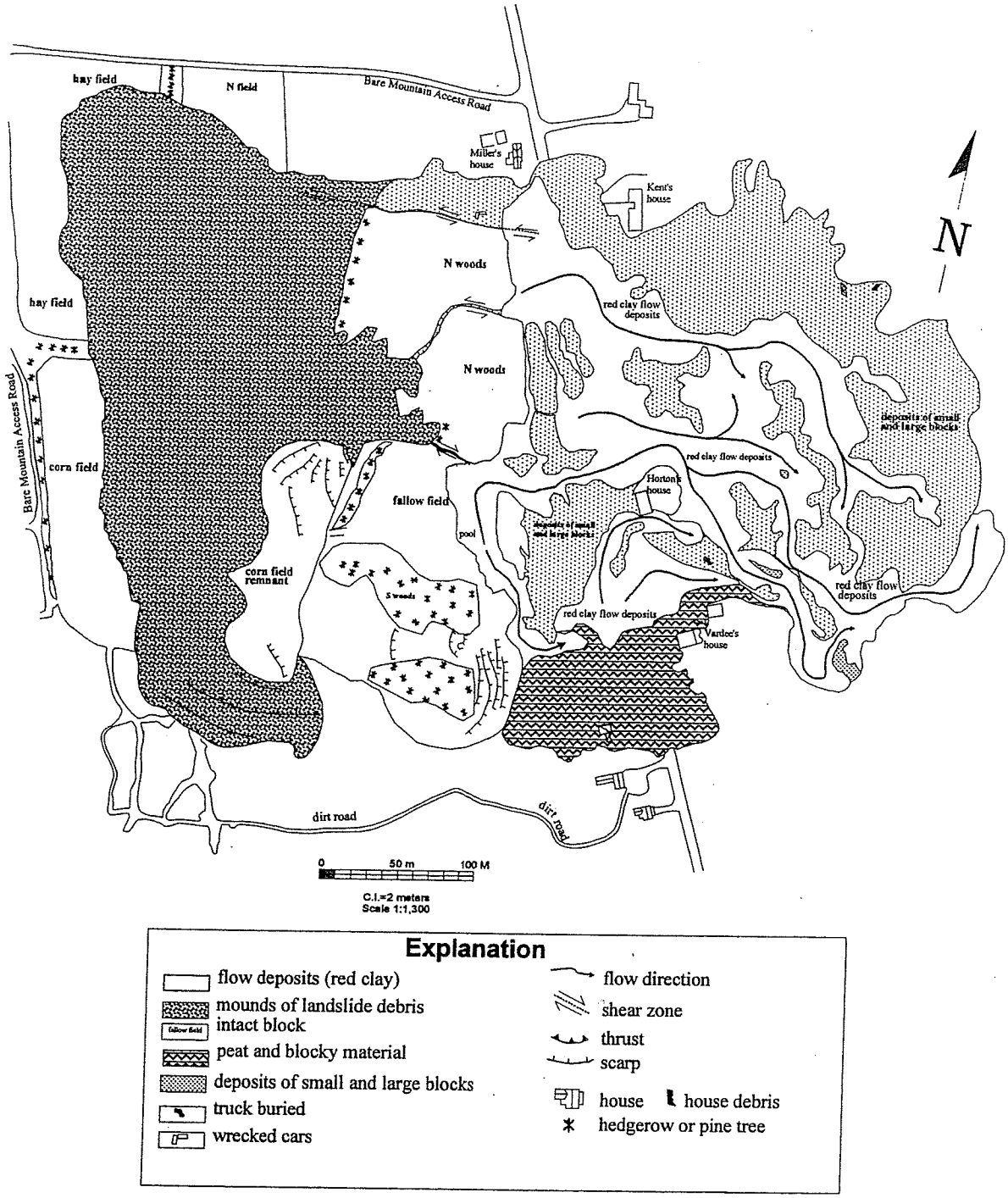



Figure 4.1 Photogeologic map of the Tully Valley flowslide, showing the direction of the flow channels through which the red mud flowed over the blocky flow unit, traced by means of a photogrammetry analysis, from source area (west of the road) up to the flow lobe (east of the road).

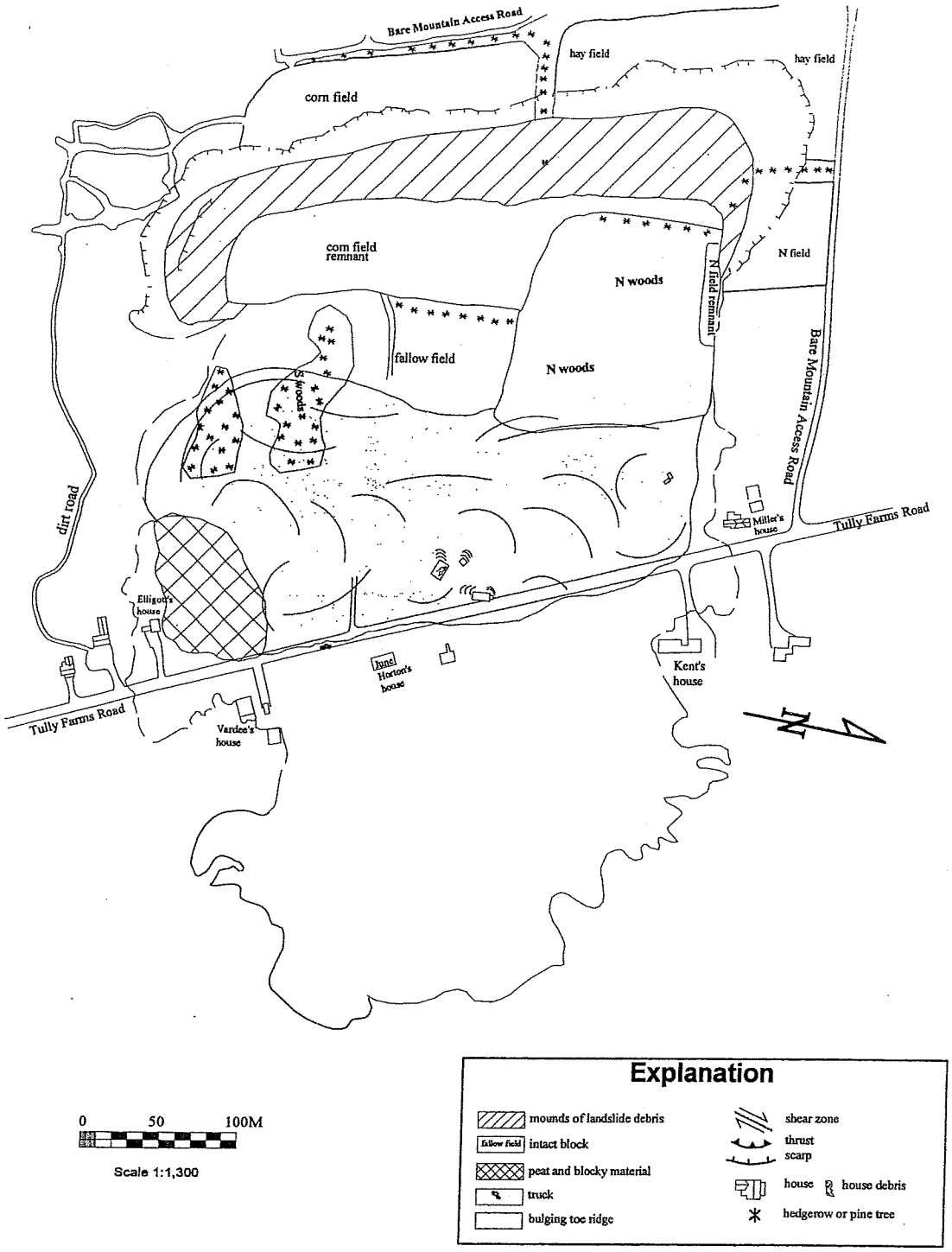



Figure 4.4 Stage I of the Tully Valley Flowslide (initial failure and bulging of toe ridge). The final boundaries of the flowslide are marked as a dashed line for both Stages I and II.

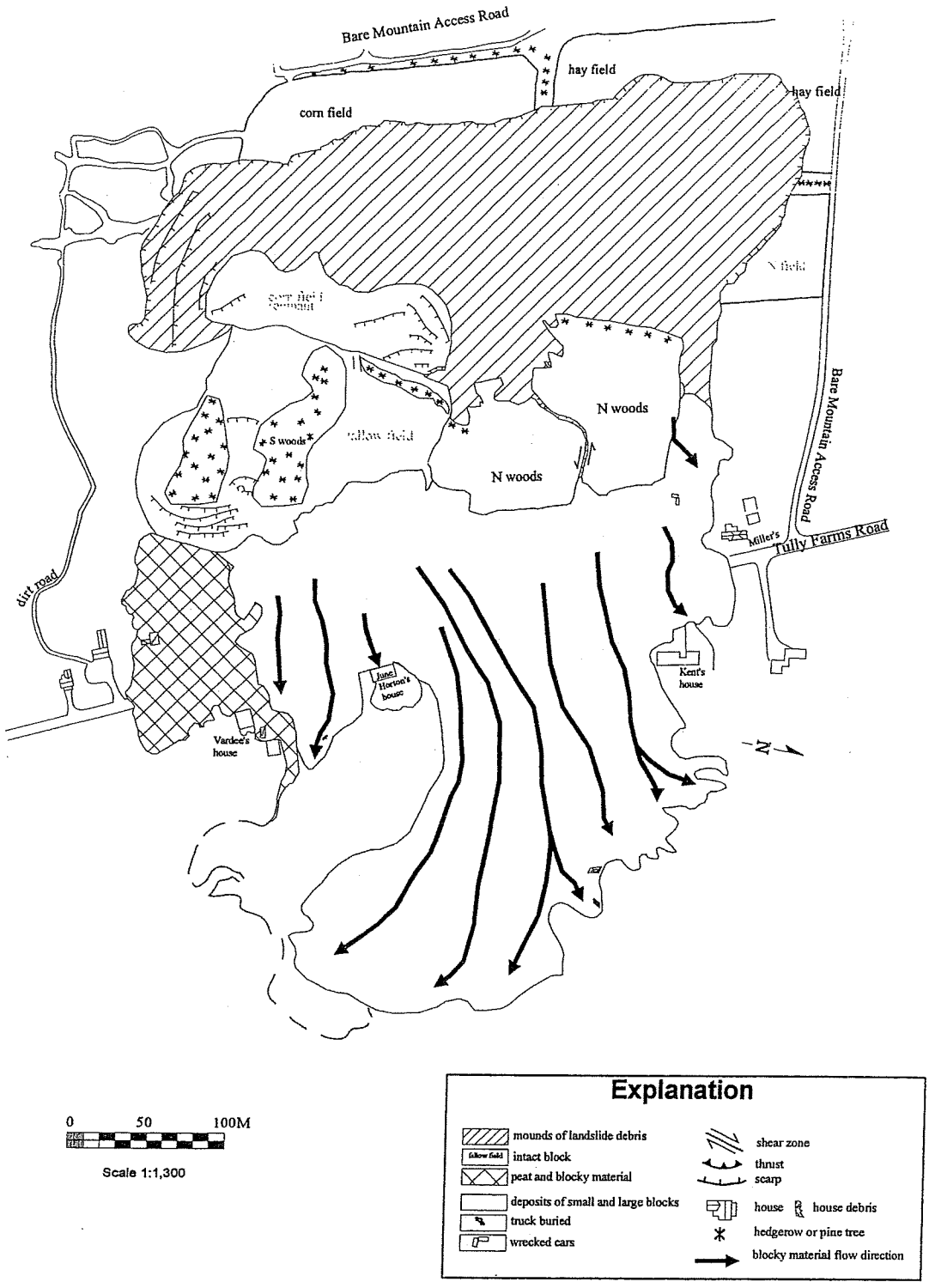



Figure 4.5 Stage II (blocky flow unit depostion) of the 1993 Tully Valley Flowslide.

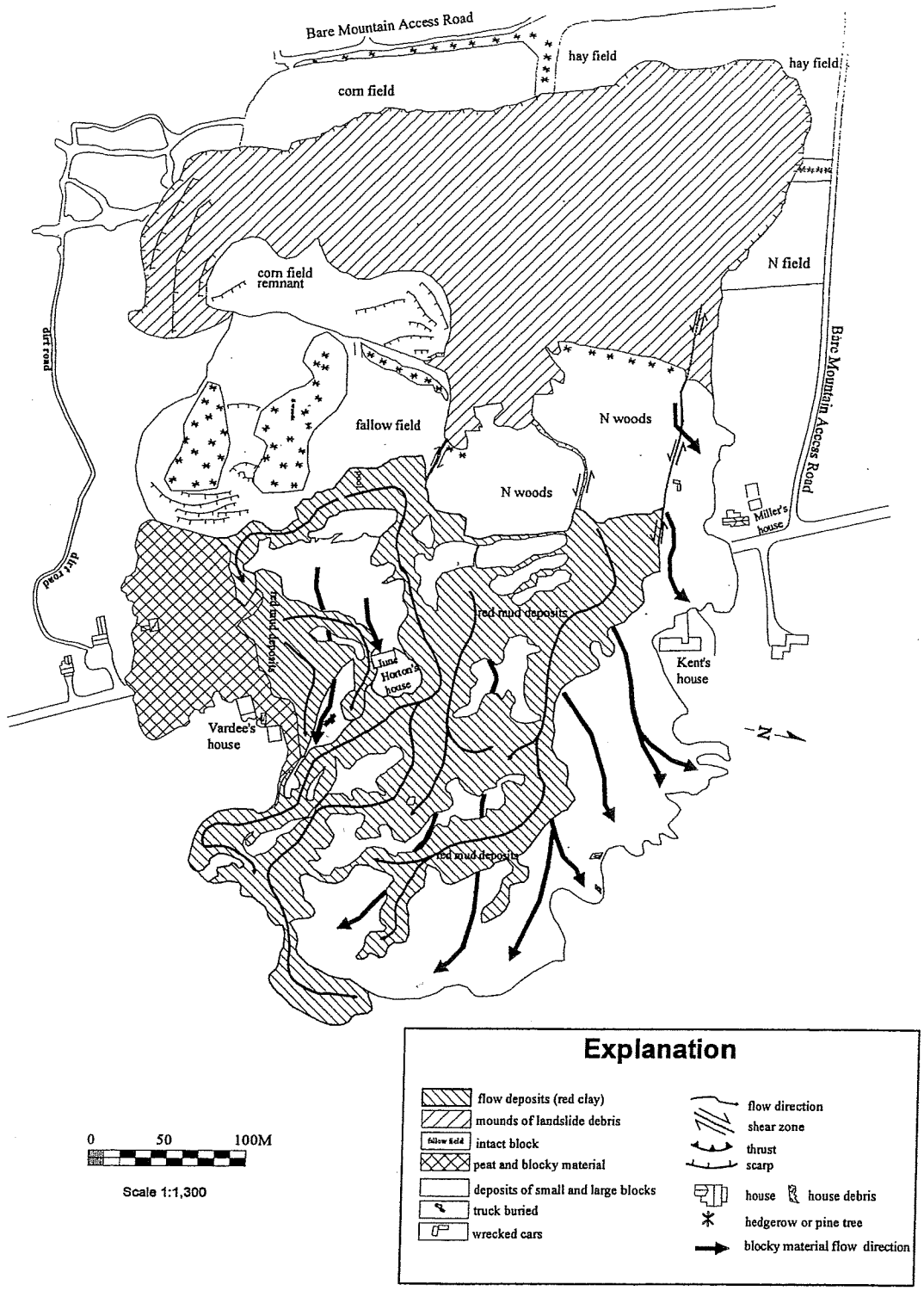



Figure 4.6 Stage III for the 1993 Tully Valley Flowslide (red mud extrusion and flow).



**Figure 4.** Test pit dug in the 2 landslide areas - (A) the Tully Farms Road pit dug just east of Tully Farms Road, just north of a destroyed home and (B) the Webster Road pit dug on the south side of Webster Road, just west of Onondaga Creek. (See fig. 1 for locations.)

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# History of Landslides at the Base of Bare Mountain, Tully Valley, Onondaga County, New York

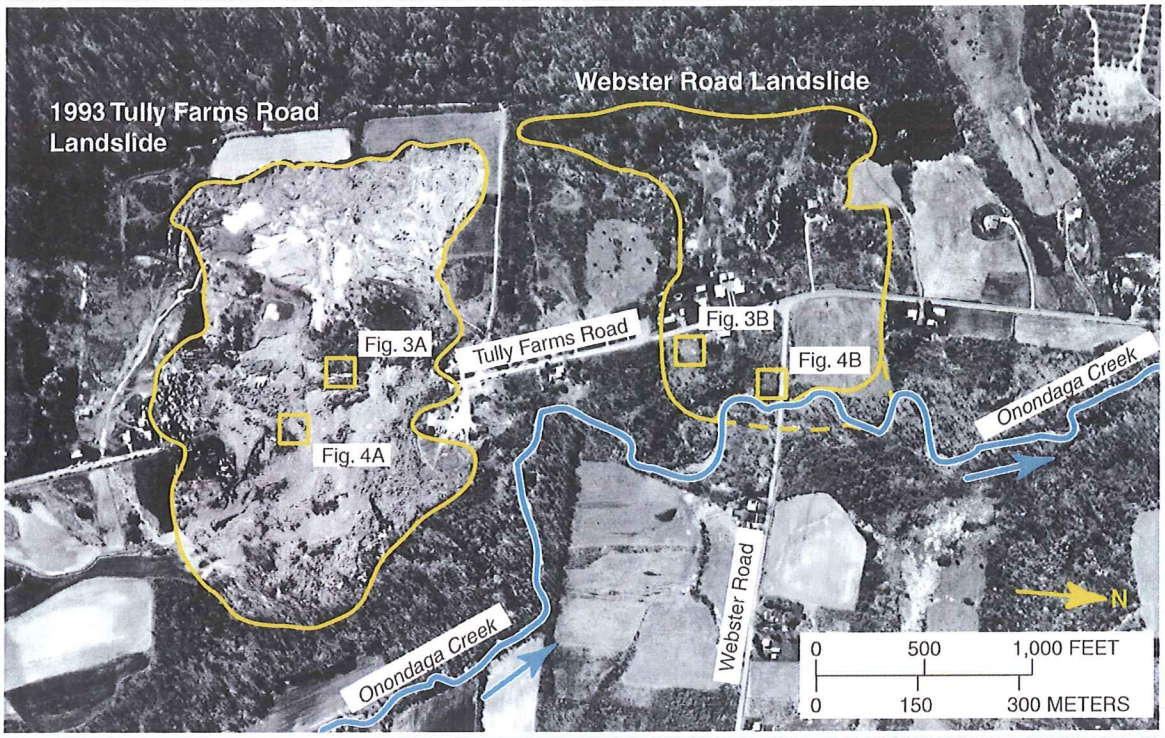


**Figure 1.** Aerial view of the Tully Farms Road landslide taken May 1, 1993, 4 days after the slide occurred and the approximate location of the Webster landslide, just to the north. Dashed line indicate probable extent of the Webster Road landslide beyond Onondaga Creek, and boxes indicate location of pictures shown in figures 3 and 4.

On April 27, 1993 a large landslide occurred along the foot of Bare Mountain in the Town of LaFayette (fig.1), about 12 miles south of Syracuse. This was the largest landslide to occur in the State since the early 1900's, according to the New York State Geological Survey. Debris from the landslide covered 1,500 feet of Tully Farms Road with more than 15 feet of mud and three homes were destroyed. Most residents were away from their homes at the time, and no fatalities or serious injuries were reported.

Federal and State environmental agencies and several universities have conducted studies in the area to identify the cause of this landslide and assess the potential for future landslides. These studies indicate that several landslides have occurred at the base of Bare Mountain but are not recorded in town records or histories, which date back to the late 1700's. Knowledge of how and when these older landslides occurred could provide an indication of the potential for future landslides along the foot of Bare Mountain.

Department of the Interior
U.S. Geological Survey

Fact Sheet 190-99
June 2000

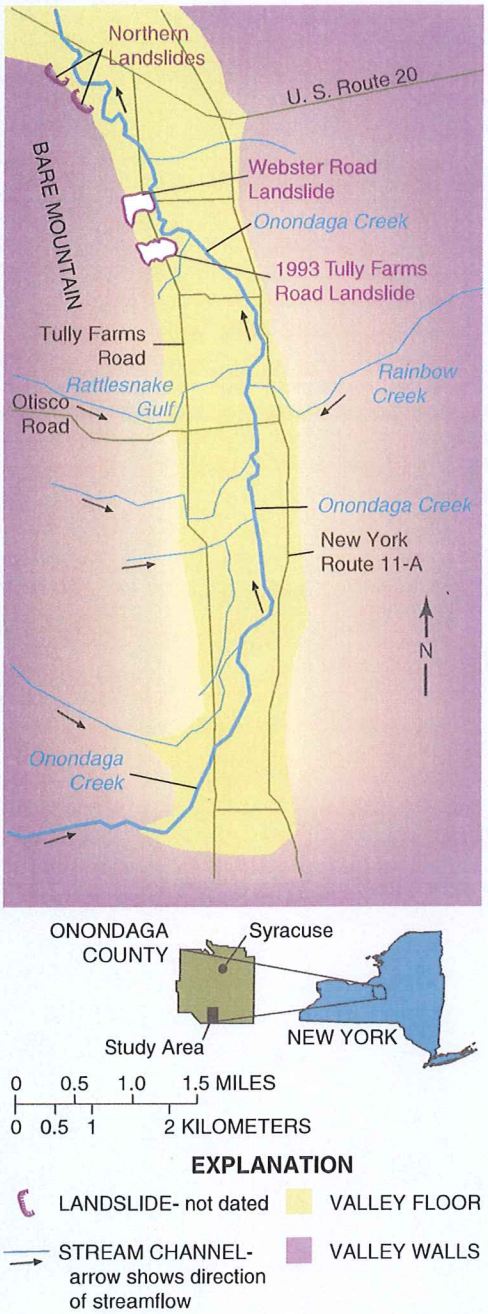


**Figure 2.** Physical features in the Tully Valley, including the 1993 Tully Farms Road and Webster Road landslides and 2 other landslide areas at the base of Bare Mountain.

## PHYSICAL SETTING

Tully Valley is a north-south-trending glacial trough along the northern limit of the Appalachian Uplands. The valley is about 6 miles long, and its floor is 1 mile wide. Onondaga Creek flows northward through the valley (fig. 2). The valley walls consist of colluvium (weathered bedrock) and till over bedrock. The valley floor is underlain by more than 400 feet of glacial-lake (lacustrine) deposits that grade upward through two sequences of gravel and sand to silt and clay. At land surface the valley floor is mantled with a 60-foot-thick silt and clay unit; some of the clays within this unit are saturated and extremely soft. These materials were deposited during and after the last period of glaciation, which ended about 14,000 years ago.

## PREVIOUS INVESTIGATIONS

Investigation of the 1993 Tully Farms Road landslide revealed an old, inactive landslide area less than 300 feet north of the 1993 site, and upon further investigation along the foot of Bare Mountain, evidence of two more landslides was found about 1.5 miles north of the 1993 site (fig. 2). Jäger and Wieczorek (1994) investigated possible landslide evidence in five valleys near or adjacent to Tully Valley and constructed a landslide-susceptibility map of a small part of southern Onondaga County. The map (scale 1:50,000) was based on results of their landslide-susceptibility model that used the distribution of glacial clays, the extent of former glacial lakes, and slope steepness as variables. The map classifies the region into areas of low, moderate, and high landslide susceptibility. That study identified the Webster Road landslide described below, as well as several other landslide and earth-flow features in the Tully Valley.

## GEOMORPHOLOGY OF TULLY FARMS ROAD AND WEBSTER ROAD LANDSLIDE AREAS

The geomorphology (geology and physical character) of the Webster Road landslide is strikingly similar to that at the 1993 Tully Farms Road landslide. The scarp of the Tully Farms Road landslide is 30 to 50 feet high and 1,400 feet long, whereas the scarp of the Webster Road landslide is 40 to 50 ft high and about 1,200 ft long. Several large blocks of transported soil, some of which retained vegetation and trees, were found at the base of

A.

B.

**Figure 3.** Hummocks found in (A) the 1993 Tully Farms Road landslide area and (B) the Webster Road landslide area (See fig. 1 for locations)

the slope at the Tully Farms Road site and within the toe of the landslide (fig. 3A). These blocks have weathered since 1993, such that the topography now resembles an area of hummocky ground at the toe of the Webster Road landslide (fig. 3B). Thus, the Tully Farms Road and the Webster Road landslide areas are about the same size, and the two landslides seem to have displaced similar volumes of material from the lower slope of Bare Mountain.

### Age of Webster Road Landslide

A 10-foot-deep test pit was dug into 1993 landslide material along Tully Farms Road (fig. 4A), and a similar pit was dug along Webster Road (fig. 4B) to compare the soil horizons in the two landslide areas. The test pit at Tully Farms Road exposed glacial-lake clay at the bottom, overlain by a postglacial alluvium (silt, sand, and gravel deposited in running water) that was in turn overlain by a well-developed soil horizon containing roots and a mat of compressed vegetation at the buried, former land surface. Overlying this buried surface was the mudflow material deposited by the 1993 landslide.

The test pit at Webster Road (fig. 4B) and a natural exposure along the west bank of Onondaga Creek (fig. 5), 150 feet south of Webster Road, are both within the toe of the Webster Road landslide, and both reveal a stratigraphy similar to that at the Tully Farms Road test pit (fig. 4A). The glacial and postglacial sediments at the Webster Road landslide and streambank sites are overlain by a soil zone with compressed organic matter (primarily grass and small pieces of wood) capped by a massive clay unit that resembles the mudflow material found in the toe of the Tully Farms Road landslide. Two samples of the peatlike organic and woody material found directly beneath the mudflow at the Onondaga Creek streambank site yielded radiocarbon dates of 6,160 ± 40 years before present (B.P.), and 6,110 ± 50 years B.P. Attempts to find similar buried organic layers at the two northernmost landslide areas (fig. 2) were unsuccessful.

Further investigation of the Onondaga Creek streambank exposed a second organic layer composed of small, ovoid-shaped logs oriented southwest-northeast. These logs were in a gravel unit overlying till several feet below the 6,100-year-old organic horizon. The radiocarbon date of 9,870 ± 40 years B.P. obtained for one log suggests that the logs were all of postglacial age. Their parallel orientation and crushed condition indicates that they probably were buried in an older landslide whose magnitude could not be estimated from the sparse exposures along the bank.

## Possible Causes of Landslides at the Base of Bare Mountain

The cause of the Webster Road landslide remains uncertain but has been attributed to a combination of geologic and hydrologic factors, four of which are:

1. Interbeds of clay within the sand and gravel deposit at the base of the hillside. The fresh scarp face of the 1993 landslide reveals interbeds of clay within the sand and gravel deposit. These clay layers could have trapped ground water in the coarse sand and gravel, and this may have led to soil movement when the artesian pressure exceeded the weight of the overlying soil. Also, below the clay and sand and gravel interbeds is a thick lacustrine unit with a stiff upper part and an extremely soft middle that possibly created a "slip surface."

2. A dense till layer below the clay, sand, and gravel. This unit confines brackish water in the bedrock aquifer and separates it from freshwater in the upper aquifer. Pressure from the confined brackish water may have increased the artesian pressure in the overlying glacial and colluvial sediments.

3. Instability of the lower hillside in the Tully Farms Road landslide area before 1993. Ground cracks, earth bulging, and slumping on the lower hillside were noted by the New York State Department of Environmental Conservation in 1990, and a basement wall of a house along Tully Farms Road was slowly failing in 1992, apparently from the increasing soil pressure on the wall facing Bare Mountain.

4. Greater-than-normal snowfall in the winter of 1992-93, followed by the blizzard of March 1993. The subsequent melting of this snow increased the water content of near-surface soils and increased the artesian pressures in the confined interbed unit. This condition, followed by heavy rainfall in April, increased the already greater-than-normal surface-water and ground-water flow throughout the Tully Valley and increased pore-water pressures within the interbed units along the base of Bare Mountain. This pressure, coupled with the unstable soil conditions along the lower slope, resulted in the April 27, 1993 landslide.

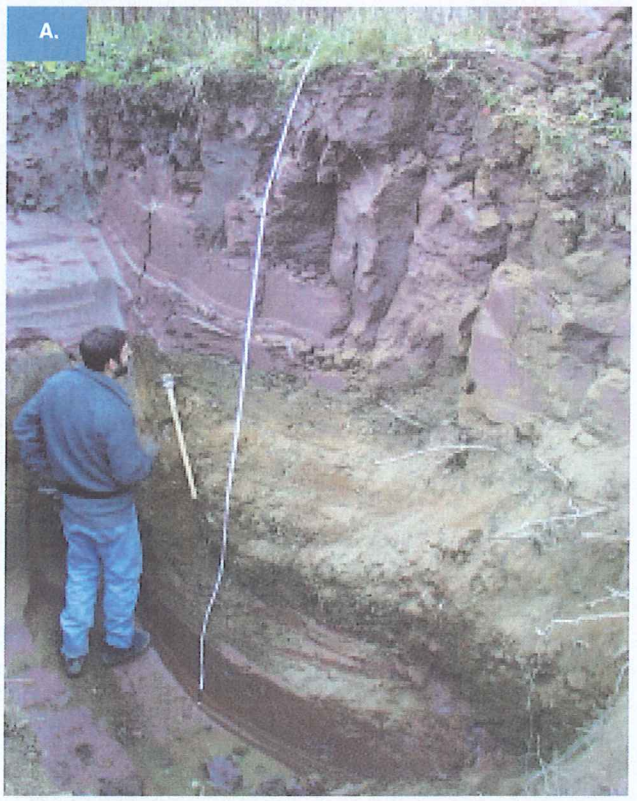



**Figure 4.** Test pit dug in the 2 landslide areas - (A) the Tully Farms Road pit dug just east of Tully Farms Road, just north of a destroyed home and (B) the Webster Road pit dug on the south side of Webster Road, just west of Onondaga Creek. (See fig. 1 for locations.)

**Figure 5.** Onondaga Creek streambank exposure south of Webster Road showing the interface between the old land surface and the overlying mudflow materials. Wood fragment (within box) at the interface was dated at 6,160 years before present.

The similarity of geologic and hydrologic conditions at the Tully Farms Road landslide to those at the Webster Road site indicates that the 6,100 year-old Webster Road landslide could have been triggered by similar precipitation patterns. This is supported by paleoclimate data obtained from sediment cores from several nearby Finger Lakes, which indicate highly changeable climatic conditions during postglacial time. The climate data spanning that period indicate an overall trend of warm, dry conditions with cool, wet intervals. Information provided by sediment cores from two nearby Finger Lakes (Mullins, 1998; Dywer and others, 1996) indicate that the Mid-Holocene Hypsithermal period (8,500-3,400 B.P.) was one of the more variable climatic periods in the Finger Lakes region. Thus, a wet episode 6,100 years ago could have triggered the Webster Road landslide.

### Conclusions

Recent investigations of the Tully Farms Road landslide have yielded several clues as to the cause of this landslide. The stratigraphy and hydrology of the Bare Mountain hillside and the greater-than-normal precipitation before the landslide were the principal contributing factors. Some form of land-surface movement also occurred near the Webster Road crossing of Onondaga Creek, as indicated by the presence of a buried soil horizon with compressed organic material truncated by mudflow material. Radiocarbon dating of organic materials indicates that the Webster Road landslide occurred about 6,100 years B.P. and that another occurred about 9,870 years B.P. Studies of sediments from nearby Finger Lakes indicate changeability in the postglacial climate. These data suggest that increased precipitation might have been a contributing factor in the Webster Road landslide, as was the case at the Tully Farms Road landslide in 1993.

The discovery of old landslides along the base of Bare Mountain underscores the need to assess the potential for future landslides in the Tully Valley.

*By Donald L. Pair[1], William M. Kappel[2], and Moira S. Walker[1]*

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[1] University of Dayton, Dayton, OH 45469-2364
[2] U.S. Geological Survey, Ithaca, NY 14850-1248

## CARBON -14 DATING - HOW DOES IT WORK?

The radioactive isotope of carbon, 14C, originates in the upper atmosphere from the collision of cosmic ray-produced neutrons with elemental nitrogen. The newly formed 14C atom quickly oxidizes to carbon dioxide (14CO2) and is readily distributed throughout the earth's atmosphere. A small percentage of this radioactive carbon ends up in the biosphere, where metabolic processes keep the 14C content of living organisms in equilibrium with the 14C content in the atmosphere. When an organism dies, its 14C content diminishes with a half-life of 5730 years. The amount of 14C remaining in the sample indicates the time of death of the organism.

For example, when a sample's 14C count is one-half that of the modern standard, the sample is one half-life old, that is, it dates from about 5700 years BP (before present). A sample count of one-quarter that of the modern standard would be two half-lives, about 11,500 years BP, and so on. The precision of a 14C date is a function of the counting statistics for the sample and standards and is conventionally reported as one standard deviation of the average counts. For a 14C age younger than 10,000 years BP, the precision is generally reported as +/- 100 years or less.

### COOPERATING AGENCIES

**Onondaga Lake Cleanup Corporation**

**University of Dayton**

**New York State Geological Survey**

**Town of Lafayette**

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### For More Information Contact:

**Subdistrict Chief**
**30 Brown Road**
**Ithaca, New York 14850-1248**

This fact sheet and related information can be found on the World Wide Web at: ***http://ny.usgs.gov***

# Tree Rings Record 100 Years of Hydrologic Change Within a Wetland

## *WHAT ARE TREE RINGS?*

*Tree trunks grow wider from the continued divisions of thin layer of living cells just inside the bark. Some cells form new bark, but most others give rise to concentric layers of wood (tree rings). In addition to strengthening the tree, rings carry water and minerals from the roots to the leaves. The age of a tree can be determined by counting the rings in the lower trunk because only one ring forms each year. Additionally, the widths of rings often indicate what environmental conditions were like during the tree's lifetime. For example, rings of trees growing on well-drained, upland soils usually are narrower during drought years and wider when rainfall is plentiful; the opposite may be true for some wetland trees exposed for long periods to saturated soil conditions. By measuring ring widths of old trees, scientists can estimate how conditions varied over hundreds or sometimes even thousands of years. Narrow rings sometimes also form when trees are damaged by floods, volcanic and glacial activity, defoliation by insects, and even earthquakes. Thus, tree-ring studies also can be used to document the occurrence of natural disasters in places where records are unavailable. A more recent application uses tree rings to study contamination of water, air, or soil by measuring the concentrations of heavy metals and other pollutants within the rings themselves.*

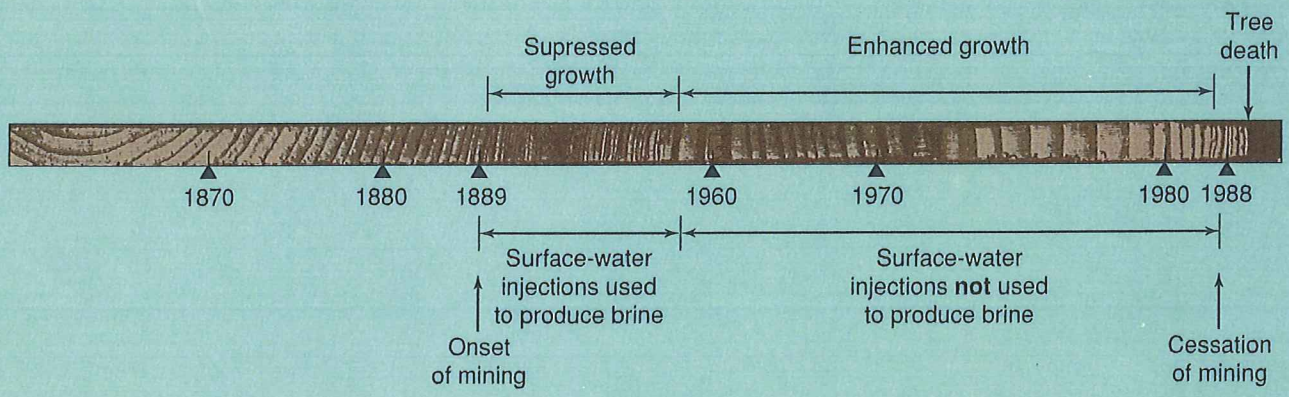


**Figure 1.** Photograph of core sample (1.5 x life size) removed from the oldest white pine that grew in the wetland. The tree died in late 1995 or early 1996. (Photograph by D. Usher, USGS)

## INTRODUCTION

One of the primary responsibilities of the Water Resources Division of the United States Geological Survey is to monitor the amount and quality of waters in our rivers, lakes, and wetlands. Hydrologists can evaluate these important resources in the present day, but how can they determine what conditions were like in past decades or even centuries? Moreover, are conditions part of a natural cycle or caused primarily by human activities? It is sometimes possible to answer these questions by examining the annual growth rings of trees (fig. 1). Each ring can be assigned an exact year of formation, and yearly differences in ring widths can be used to compare past and present conditions on a flood plain, along a river, or within a wetland. Thus, tree rings provide information that otherwise might be difficult or even impossible to obtain.

Hydrology and tree growth were investigated within a small wetland in the Tully Valley of central New York, about 20 miles south of Syracuse. In late 1994 it was noted that some wetland trees were dying, and local residents reported that flow of a small stream draining the wetland seemingly increased and became more brackish since the mid to late 1980s. The wetland is about 3 miles north of an extensive salt mining operation known to have degraded local water quality, but no effects of mining had been confirmed previously near the wetland. The oldest wetland trees started to grow before the onset of mining in 1889, and thus tree-ring studies were undertaken not only to investigate recent hydrologic change within the wetland, but also to search for evidence of any other changes during the last 100 years.

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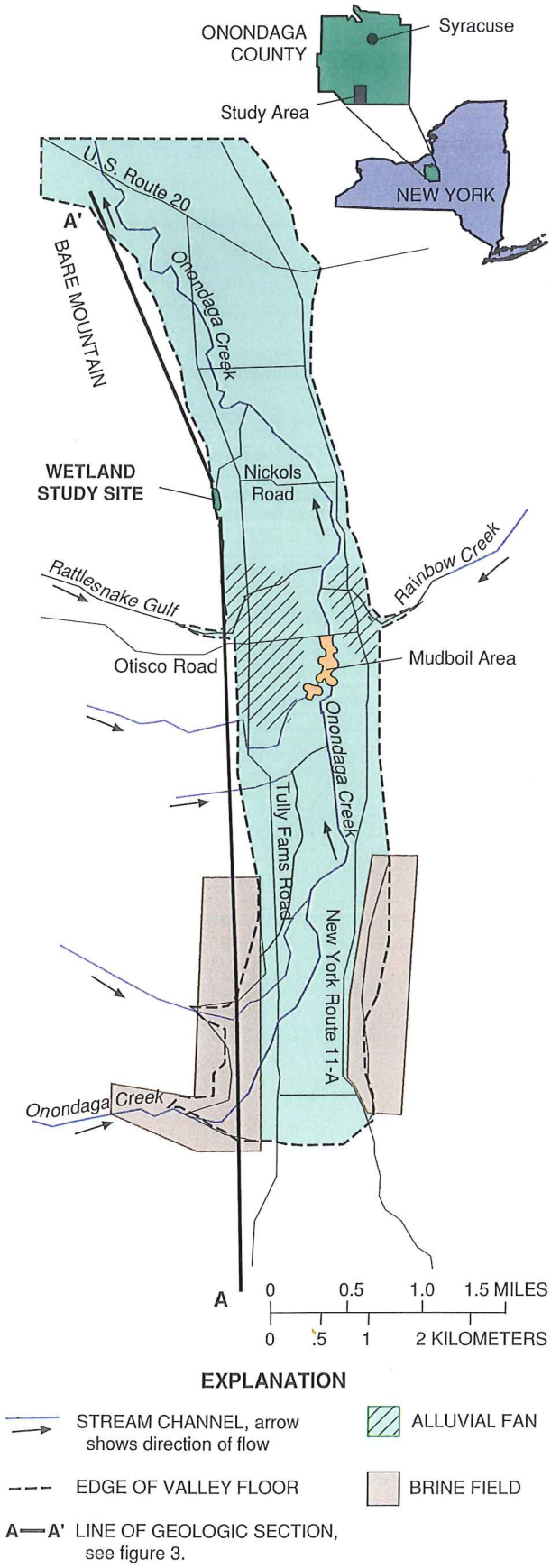


**Figure 2.** Map of the Tully Valley showing the location of solution-brine fields and study wetland.

## THE WETLAND

The Tully Valley (fig. 2) is within the Finger Lakes Region of the Allegheny Plateau. The small (2 acre) wetland is in the northwestern part of the valley at the base of Bare Mountain. Ground-water flow feeding the wetland is from a series of fresh- and brackish-water springs at the foot of the mountain. Freshwater springs are fed by precipitation infiltrating the hillside slopes, whereas brackish springs are fed from the deep shale-bedrock flow system. Concentrations of sulfate, sodium, and chloride in brackish flows are naturally high because they leach into the groundwater as it moves slowly through fractures in the mineralized bedrock. Flow from the freshwater springs typically is least during summer, increases in fall, remains fairly constant throughout winter, and increases again during the spring in response to rain and snowmelt. Brackish discharge is more uniform than freshwater discharge, although brackish flow generally also is greatest during the spring. Thus, fresh and brackish waters flow into the wetland during the spring, but brackish discharge predominates during summer. Several small drainageways in the wetland form a small stream that carries outflow to the northeast. Flow of this stream is entirely from the fresh- and brackish-water springs at the base of Bare Mountain.

## HISTORY OF SOLUTION-BRINE MINING

A considerable saltworks industry developed by the mid 1800s along the western side of Syracuse. Over-exploitation of local salt reserves spurred the discovery in the late 1880s of salt layers approximately 1000-1400 feet below land surface at the southern end of the Tully Valley. Mining operations began in 1889 and continued until the late 1980s, during which approximately 200 million tons of salt were removed. In order to mine the salt, operators injected surface water into the salt layers through a series of wells and then lifted the dissolved salt (brine) to the surface. Company records from the turn of the century estimated that 40-60% of injected waters were "lost" to the surrounding bedrock and/or glacial deposits. Injection practices were abandoned in the late 1950s because it was determined that groundwater flow into the caverns were sufficient to dissolve additional salt deposits. Up to one billion gallons of brine per year were pumped after injection practices were abandoned. Mining activities were reduced greatly in 1986 and ended in 1988.

Removal of nearly 150 feet of salt caused the land surface to collapse in parts of the brine fields as early as the 1920s. Large collapses occurred during the 1940s, and surface subsidence of 5 to over 40 feet has occurred since the 1950s. No subsidence was documented as far north as the study wetland, however.

## TREE-RING ANALYSES

White pine trees generally are clustered near the center of the wetland on moss-covered hummocks at slight elevations above the series of small drainageways. Only a few pines grow in northern and southern parts of the wetland. Pines range in age from 20 to 130 years, in diameter from 7 to 20 inches, and in height from 15 to 30 feet. Numerous trees were in poor health in late 1994, particularly within the central part of the wetland, and at least four died during the ensuing year. Two pencil-sized corings from each of 17 white pines were collected with a steel increment borer designed to extract samples of rings without harming the tree. Cores were placed to dry in paper drinking straws and subsequently sanded to make the rings easier to see. The rings of each paired cores were measured and crossdated with each other (the process whereby each ring is assigned an exact year of formation) and averaged together to form one composite ring-width series for each tree.

## TREE GROWTH

### A. During the Period of Injection-Mining

Ring growth of white pines at poorly drained sites, such as the study wetland, would be expected to be less than that of upland-grown trees. However, study trees formed much narrower rings than expected, but only after the early 1890s (fig. 1). Moreover, these unusually narrow rings continued to be formed until about 1960. In other words, the long series of very narrow rings coincides with the precise interval that surface-water injections were used to dissolve the salt and lift it to the surface. During this period much of the injected water "lost" to the bedrock flowed along northerly-rising fractures and discharged at the land surface, as the brackish springs at the study wetland (fig. 3). Saturated soil conditions reduced the amount of oxygen available to pine roots, thus stunting ring growth. Disease, damage, or climatic factors could have caused the formation of narrow rings, but not for nearly 70 years. Rather, the onset and duration of narrow ring growth of the oldest study trees suggest that the rate of brackish flows into the wetland increased dramatically in the early 1890s and remained high until at least the late 1950s. As expected, other trees that started to grow after the onset of mining also formed unusually narrow rings during the entire interval of injection mining.

### B. After the Period of Injection-Mining

A twenty year sequence of unusually wide rings began about 1960 or shortly thereafter (fig. 1), indicating that conditions for tree growth improved strikingly and quickly. The onset of this "growth release" in wetland pines coincides with closure of the eastern part of the brine field in 1957 and the discontinuance of surface-water injection practices in the western part of the brine field a year or two later. Continued pumping of brine and the absence of injected waters reduced flow to the bedrock fractures and thus reduced the flow of brackish springs as far north as the wetland. Flow patterns of the precipitation-driven freshwater springs were not altered, however, resulting in the progressive drying of waterlogged soils during summer and, thus, creating favorable conditions for tree growth. In other words the site during summer was probably more like an upland than a wetland. If this interpretation is correct, wetland trees that started to grow after 1960 would be expected to have very wide rings rather than the narrow rings typical of trees established during the interval of injection mining, and indeed this was the finding.

### C. Since the Cessation of Mining

The growth of some trees declined during the early 1980s, apparently as the result of regional drought. However, instead of recovering from drought when conditions improved in following years, many trees continued to grow even more poorly from the late 1980s to the present (fig. 1). Some trees died during the mid 1990s and others show signs of poor health suggesting that they too may soon die. Although it might appear that the demise of trees is due simply to overwatering, this does not seem to be the case. Chemical analysis indicates that affected trees contain unusually high concentrations of chloride in rings that formed during the early to mid 1990s. Moreover, affected trees grow closest to the brackish springs, those intermediate in distance show mild symptoms, and those most distant appear healthy.

The cessation of brine withdrawals in 1988 reestablished flow to bedrock fractures in the mining area and to the brackish springs. Thus, the growth of trees again slowed as saturated soil conditions persisted longer into the growing season. Unlike irrigation of the wetland from lost injected waters, however, the new flows contained larger amounts of salt derived from the collapsed bedrock above the brine cavities. The demise of wetland trees seemingly is related more to this change in water quality than to the quantity of increased flows. To strengthen this contention, chloride was measured in the oldest trees in rings that formed before, during, and after mining. As expected, chloride concentrations were low in rings that formed before the onset of mining, higher in rings that formed during the 1890-1960 period of injection mining, lower again thereafter during the 1960-1986 period, and highest following the cessation of mining.

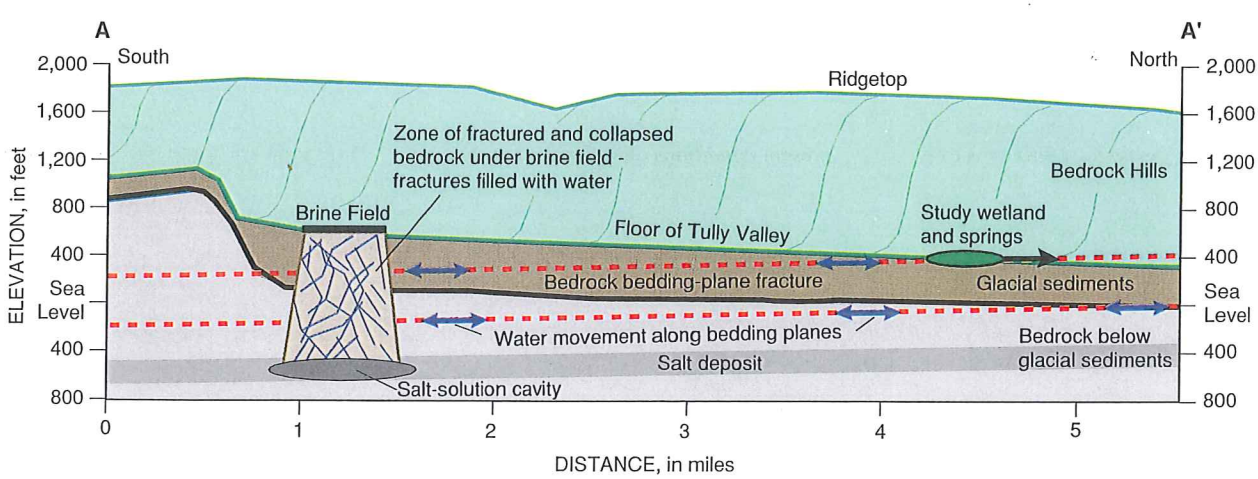


**Figure 3.** Schematic cross-section of the Tully Valley showing bedrock and bedding-plane fractures that provide a flowpath from the south to the north.

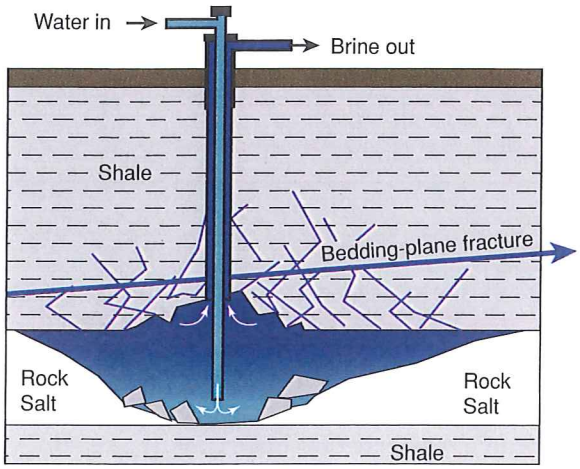


**Figure 4.** Solution-salt mining
The solution mining of salt in the late 19th century began with drilling a hole down to the salt layer, and the installation of two steel casings into the hole. Fresh water was pumped down the inside casing where the water dissolved the rock salt and produced a brine (salt water). The brine was "lifted" and later pumped up to land surface in the outside casing. As large amounts of rock salt were dissolved, the unsupported shale rock above the salt cavity began to break and fall into the salt cavern. As the cavern became larger, the shale bedrock continued to break and slowly fill the cavern with broken rock, which eventually caused subsidence at land surface. Initially, the subsidence was small and gradual, and generally unnoticed. Later, as the cavities became larger, the land-surface subsidence was greater and more noticeable.

## CONCLUSIONS

Tree rings preserve evidence of three distinct episodes of hydrologic change within the wetland during the past century, at a location where no previous effects of salt mining had been reported. This study is one example of the U.S. Geological Survey's use of tree rings to investigate hydrologic conditions during both the past and present. For more information regarding additional tree-ring studies, please contact a Survey representative from ol,ne of the two addresses listed below.

*T.M. Yanosky and W.M. Kappel*

## Additional Reading

Kappel, W.M., Sherwood, D.A., and Johnston, W.H., 1996, Hydrogeology of the Tully Valley and characterization of mudboil activity, Onondaga County, New York: U.S. Geological Survey Water-Resources Investigations Report 96-4043, 71 p.

Phipps, R.L., 1985, Collecting, preparing, crossdating, and measuring tree increment cores: U.S. Geological Survey Water-Resources Investigations Report 85-4148, 48 p.

Yanosky, T.M., and Kappel, W.M., 1997, Effects of solution mining of salt on wetland hydrology as inferred from tree rings: Water Resources Research, v. 33, p. 457-470.

## For More Information:

Subdistrict Chief
U.S. Geological Survey
903 Hanshaw Road
Ithaca, New York 14850

Chief, Branch of Regional Research
U.S. Geological Survey
National Center, Mail Stop 432
Reston, Virginia 20192

This fact sheet and related information can be found on the World Wide Web at: http://ny.usgs.gov

Additional earth science information can be obtained by accessing the USGS"Home Page" on the World Wide Web at: http://water.usgs.gov