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BORN-AGAIN GULLY: THE REESTABLISHMENT OF THE MILLER BROOK GULLY, NORTHERN VERMONT

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ABSTRACT

Glacial sediments influence many surficial processes in the northeastern United States, especially landsliding and gullying. Such mass wasting is particularly common in river valleys where slopes are steep and lake clays are common. At the Miller Brook gully the glacial sediments, from the bottom up, are 1) till with a clay matrix 2) sands and gravel from near glacial runoff 3) glaciolacustrine inter-bedded clays and fine sands and 4) capping sands and gravels. Such common stratigraphies and the associated mass wasting can have significant impacts on land use in glaciated landscapes.

The exact date of gully initiation is unknown. Time series aerial photographs from the 1940s to the 1970s suggest that the gully became active in the late 1960s or early 1970s. The gully eroded due to a hydraulic conductivity difference between the sands and gravels (high) and the overlying glaciolacustrine sediments (low). Such a difference in hydraulic conductivity focused groundwater in the sands and gravels and formed a piping network that surfaced on the adjacent hillslope. In several places the pipe's roof collapsed and provided windows to the stratigraphy and the pipe. By 1998 the gully expanded to 50 m x 8 m x 2.5 m. The landowner wanted the erosion to stop and in the summer of 2001 the north bank was intentionally collapsed to fill in the gully. Since the piping network was not affected, new roof collapses were observed in the fall of 2001.

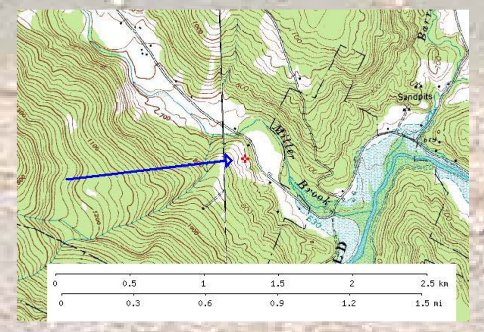
Since 2001, the gully has continued to expand; however, the gully axis is at a different orientation and is eroding naturally deposited glacial sediments, not just the fill. An August 2004 survey of the gully suggests an additional 830 m^3 of erosion, approximately equal to the original volume of the gully. The erosion rate since 2001 (~280 m^3/y) is almost an order of magnitude higher than the estimated erosion rate from initiation until 2001 (~30 m^3/y). Using the volume of an adjacent stable gully that bottoms on till as an analog, we estimate that the active gully has at least several more decades before it stabilizes. This study suggests that in order to stabilize gullies in glacial sediments, one must correctly identify the erosion processes; otherwise the resulting erosion rates could be as much as an order of magnitude greater than the natural erosion rates.

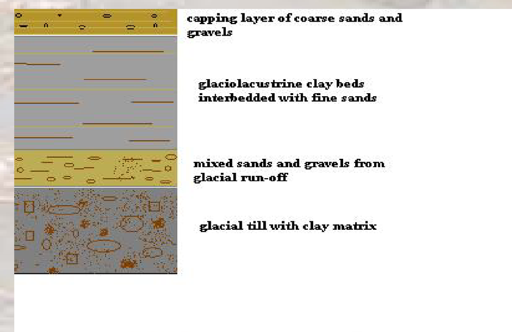
INTRODUCTION

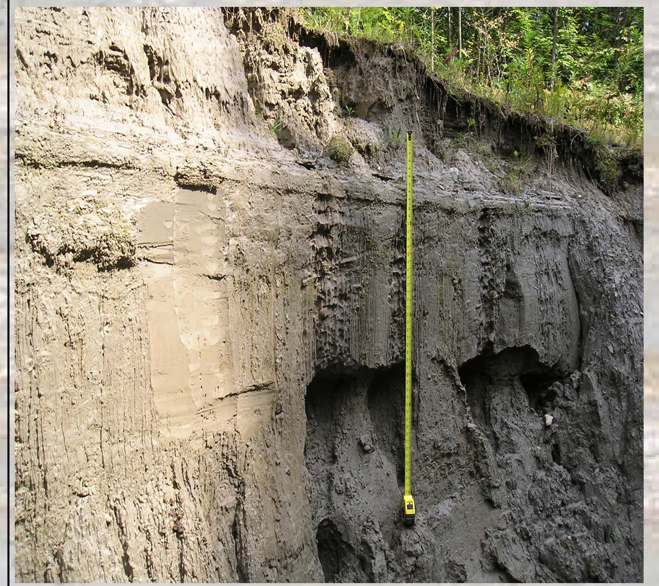
Setting
- Located on a steeply sloping terrace riser of Miller Brook near Stowe, Vermont
- Sediments deposited in glacial lake

Stratigraphy (from top down)
- Capping layers of sand and gravel probably associated with lowering lake levels
- Massive clays interbedded with thin layers of fine sands deposited into glacial lake
- Sand and gravel beds deposited at glacial front

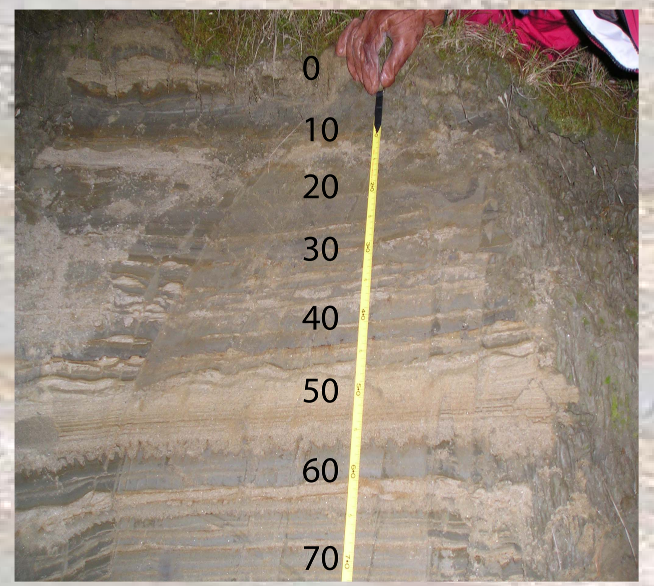
Adjacent gully
- Provides a natural analogue
- Bottoms on till
- Stable slopes with mature trees
- Alluvial fan with mature A-horizon







Lacustrine sediments capped by sands and gravels

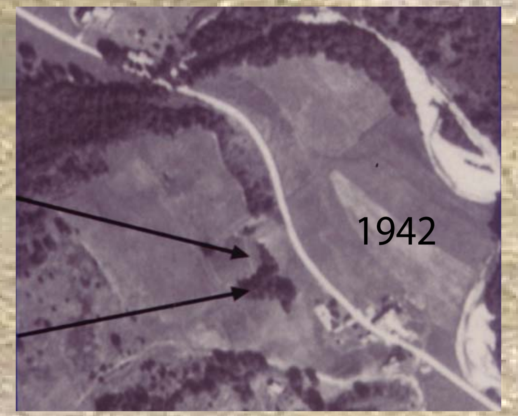


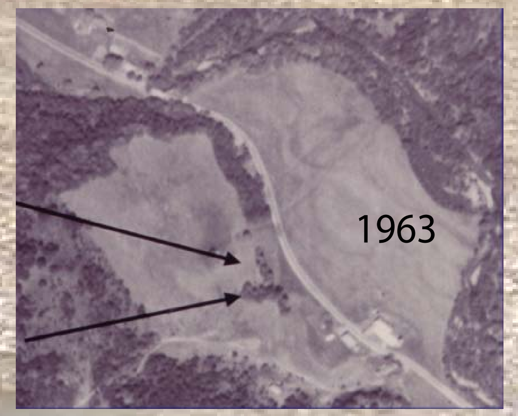
Lacustrine fine sand and clay interbeds
Scale is in 10 cm intervals

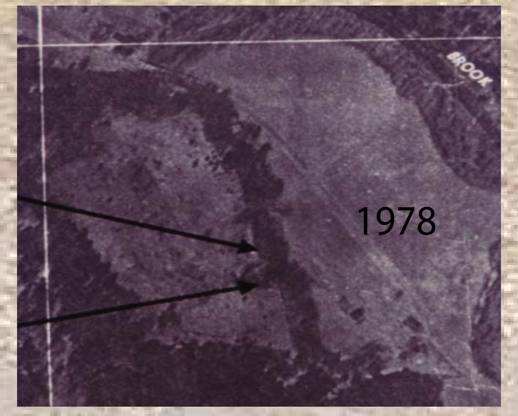
Lacustrine clays overlying till

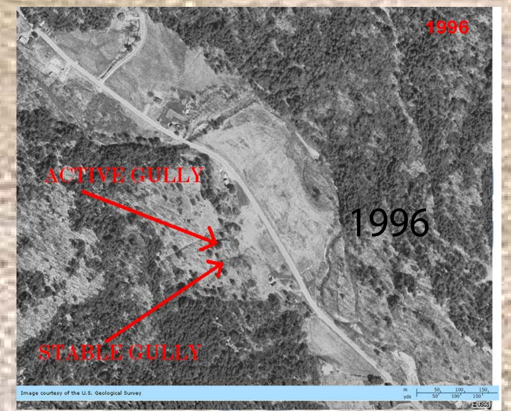
HISTORY

- Hillslope above gully has been extensively logged in the past (town records from 1856)
- Logging ceased in the late 1970s and commenced again in 2000 to 2001
- Gully became active sometime in the late 1960s to early 1970s
- Road moved from base of hillslope sometime between 1963 and 1978 (because of alluvial fan activity?)
- Stable gully that bottoms on till is ~100 m south of active gully







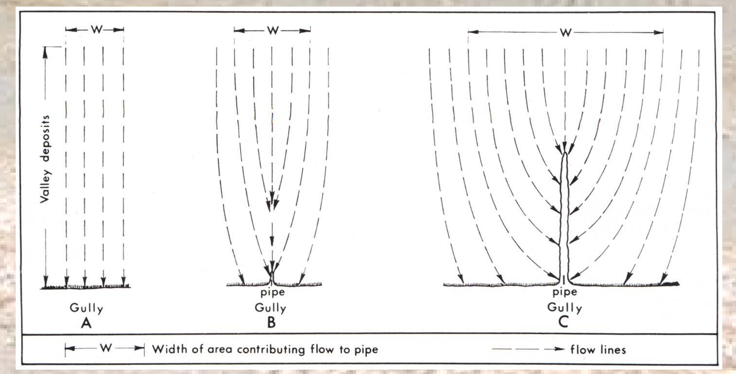


Top arrow in each photograph shows location of active gully
Bottom arrow in each photograph shows location of stable gully

Gully Processes: Piping and Mass Wasting

Piping

- Sands and gravels have high hydraulic conductivities (10^{-1} to 10^{-3} cm sec^{-1})
- Glaciolacustrine sands and clays have low hydraulic conductivities (10^{-3} to 10^{-7} cm sec^{-1})
- Sapping erodes sand (high hydraulic material) to form a pipe
- Pipe focuses water into and expands pipe network
- Eventually pipe cannot support overlying sediment and collapses forming a window



From (Selby, 1993)

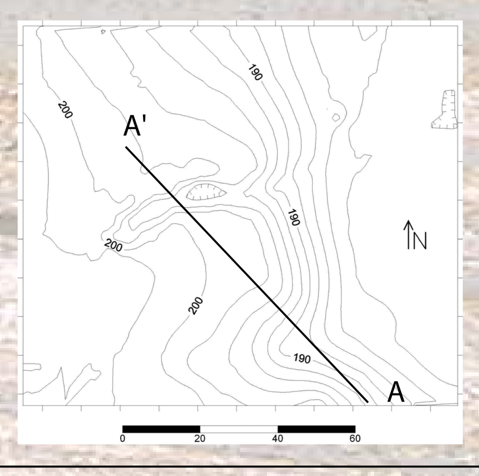
Collapsed pipe at bottom of gully

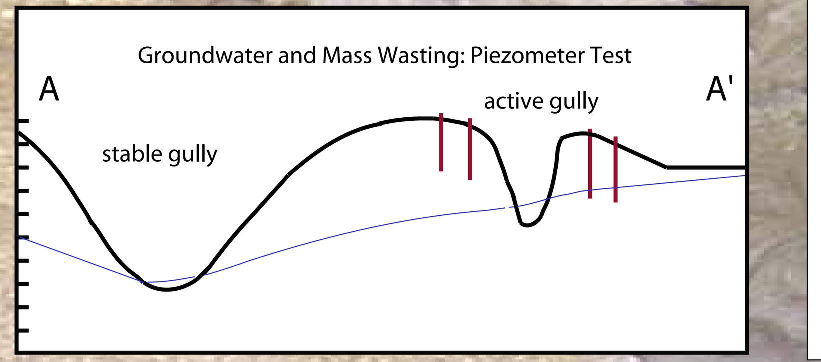
Intact pipe outlet on hillslope

Window to piping network

Mass Wasting

- gravitational slump and toppling dominate gully expansion
- erosion continues in asymmetrical pattern
  - toppling on north side results in vertical walls
  - slumping on south side results in slope angles near angle of repose
- asymmetry result of saturation and high pore pressures on the north slope and a low watertable and drier sediments on south slope



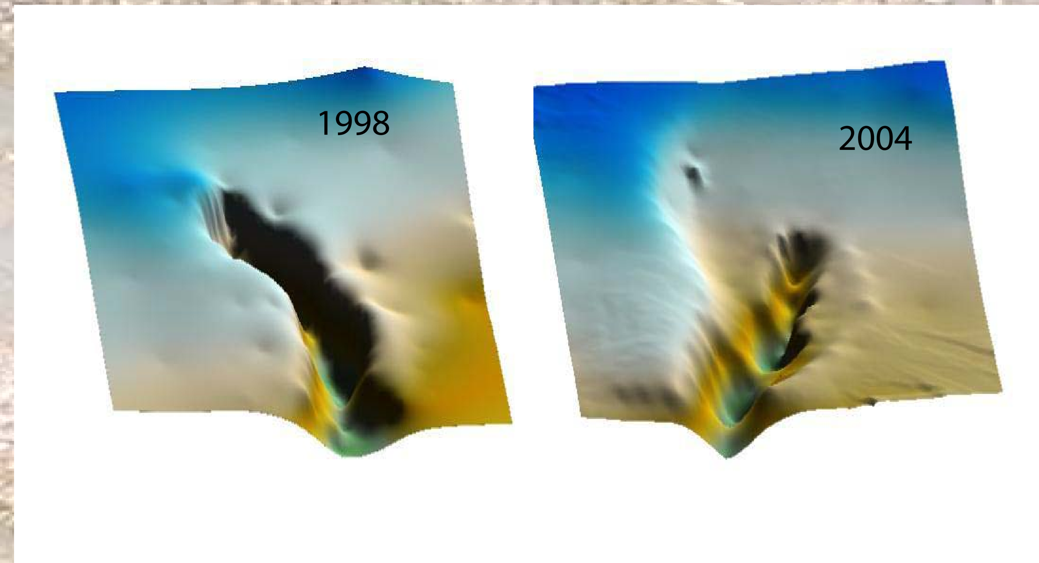


Asymmetrical gully erosion: Toppling on north side

Slumping on south side of gully

Gully Activity

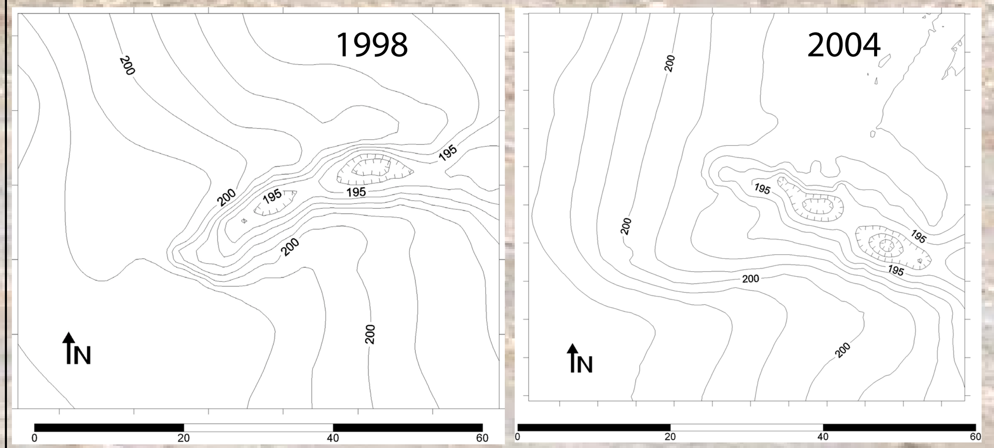
- Gully is active mostly during spring when water table is high
- Gully is also active during intense summer thunderstorms
- Clay can hold moisture and activity (slumping) can continue past rainy period
- Gully headward erosion is due to sapping



Three-dimensional perspectives of active gully in 1998 and in 2004. Notice the gully is currently cutting headward along a new axis.

FAILED REMEDIATION

- Summer 2001 north bank was collapsed to fill in gully
- Piping network remained intact and roof collapses continued with windows by fall 2001
- Reestablished gully is near original volume (2004)
- BUT it is expanding in a new direction!



EROSION RATES AND SEDIMENT VOLUMES

- Total sediment eroded by 1998 was ~1000 m^3
- Estimated erosion rate from initiation until 1998 was ~ 30 m^3 per year
- Total sediment volume eroded since 2001 is ~830 m^3
- Erosion rate since 2001 is approximately 280 m^3 per year (10x increase)
- Adjacent stable gully has over 2500 m^3 of missing sediment
- Active gully could take between one and several decades to become stable

CONCLUSIONS

- Gullies in glacial lake sediments can erode from the bottom up through piping and pipe collapse
- Stabilizing gullies in glacial sediments requires understanding of erosional processes
- The Miller Brook gully is expanding in a new direction
- Based on the adjacent stable gully, the active gully will be active for up to several more decades

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