

THE TEMPORAL PACE OF LANDSLIDE MOVEMENT DETERMINED FROM GROWTH ASYMMETRY IN *TSUGA CANADENSIS*, BOWMAN CREEK, MOHAWK RIVER WATERSHED, NY

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Landsliding in New York State is a widespread problem, and there are a number of historic events in Schenectady County and in the Mohawk drainage basin. This study investigates the timing of slumping at Bowman Creek, which is a small tributary that empties into Schoharie Creek at Burtonsville. We are interested in this slumping because this process is potentially one of the main ways that large volumes of sediment is mobilized in the watershed. The lowermost part of the slope failed during a torrential rainfall event in July 2008. In fact, this high-volume rainfall event caused tremendous damage to the infrastructure in Bowman Creek and Chaughtanooga Creek (Wolf Hollow), and these two areas are of particular concern to the County.

The Bowman Creek slide (N 42.80306, W -74.25895) is incised at its base by Bowman Creek, which is a small brook that flows west into Schoharie Creek near Burtonsville, New York. The slump on Bowman Creek is ~27 meters high, over 53 meters horizontal along the base. It is entirely on private property. For this study, *Tsuga canadensis* (Eastern Hemlock) was cored, as they are abundant and have extremely good, long annual records, and they produce clear distinct annual rings. Other trees on the hillslope are *Fagus grandifolia* (American Beech), *Acer saccharum* (Sugar Maple), and *Betula alleghaniensis* (Yellow Birch), and *Tsuga canadensis* (Eastern Hemlock). *Pinus strobus* (White Pine) also occurs on the slopes of Bowman Creek, but not directly on the slump.

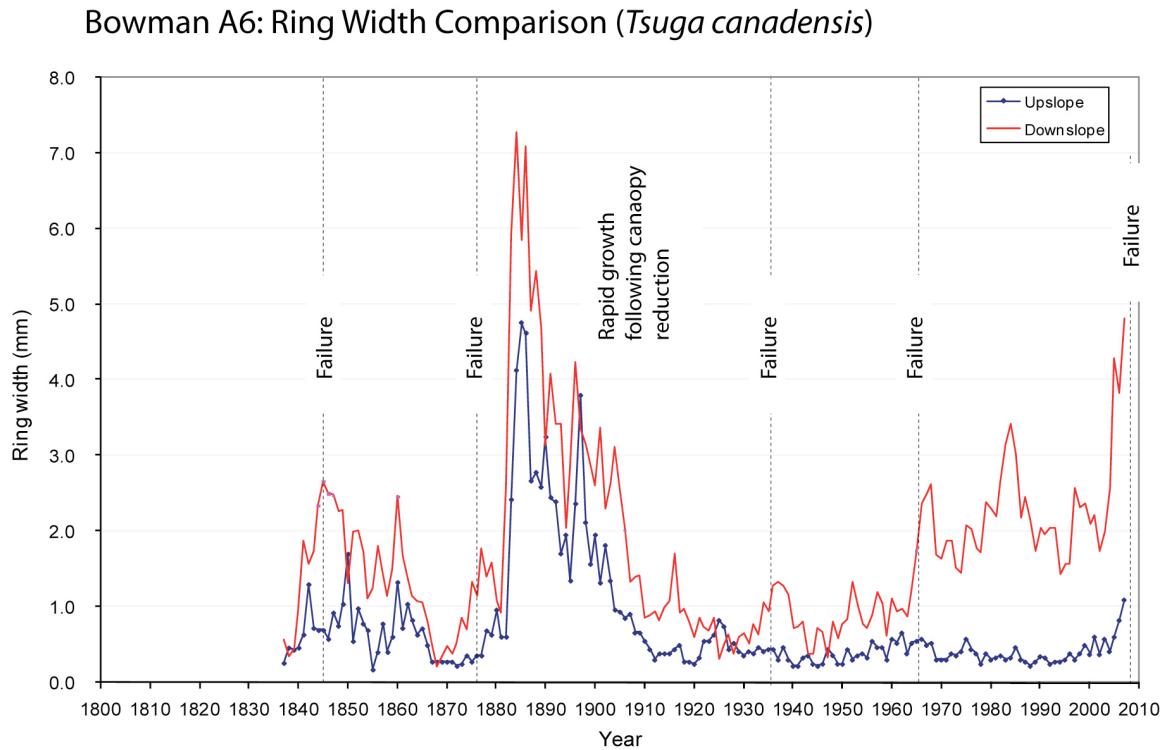
Dendrogeomorphology is the study of tree rings as they relate to the geomorphic

processes of the substrate that the tree is growing on (Stoffel and Bollscheiler, 2008). This method is helpful for assessing mass movement on landslides and slumps. Stress in a tree can be distinguished in the growth of tree rings in a tree core by the size and color of the rings because trees respond to the tilting and root disturbances. Conifers that grow on a slope add more growth to the downslope side of the tree to compensate and force straightening (Bollscheiler and Stoffel 2008). Eccentric growth of the trunk occurs after mass movement and tilting, and growth adjustment results in an easily detectable change within the rings. Reaction wood is easily distinguishable from normal annual rings, because it is darker than uninterrupted tree growth because the cell walls are thicker and the wood is rich in lignin. The rings on the opposite side correspond with the reaction wood by growing smaller (very tightly), and they may even be lighter in color.

Methods. Tilted *Tsuga canadensis* were cored on the crown, body, and toe of the slump. Cores were taken with an 18" increment borer. Upon extraction, cores were slid into a plastic sleeve in the field, and then mounted in a grooved plywood board with wood glue. They were sanded progressively with 60, 100, 150, and 220 grit, and finished with a linen cloth. Individual cores were scanned on a 17" flatbed high-resolution scanner (Epson Expression 10000 XL). The cores were generally scanned at 600 DPI (or greater), with an adjacent metric ruler. The resulting images were cropped in Adobe Photoshop, and then imported into Adobe Illustrator.

In Illustrator, cores were enlarged and individual annual years were measured, and the length was determined and calibrated against the millimeter ruler. For all the trees with successful downslope and corresponding upslope data, three plots were made showing

the annual growth ring width, the ring width ratio, and the ring difference throughout time. Here we only show plots of upslope and downslope ring plots. When these two diverge, the tree has grown eccentrically.



*Figure 1: Plot showing tree rings in sample A6, a slice from a *Tsuga canadensis* that was felled as a result of the 2008 slip event. Red (upper) is the ring width plot of the downslope side and blue (lower) is the plot of the upslope side of the tree.*

Results. Eccentric growth of tilted trees on the Bowman slide are related to ground movement that is likely both creep as well as sharp dislocations related to slip events.

Tree-ring records from the Bowman slump indicate that the movement history of this hillslope is complex. Tilted trees across the entire slump all show movement with reaction wood on the downslope side of the tree throughout their growth history.

All tilted trees studied show eccentric growth in their rings between 1970 and 1990. This result is a clear indication that there was mobilization over the entire slump at some

point during this entire 20-year interval. For brevity, we show the record of a single tree (A6), but our conclusions are based on 11 complete records that are discussed in detail in Bucci, 2009 (see also condensed summary from the upper slope in Figure 2).

Tree A6 from the lower part of the Bowman Creek slip is one of the best records from the study as it shows an excellent record of progressive, decades-long movement on the slump (see Fig. 1). One of the most impressive aspects of this record is that some of the most eccentric growth and most prominent reaction wood is during a three year period of 2005-07. The slip and failure of this

block occurred in July 2008 (and the toppling of the tree). Therefore reaction wood and the largest eccentric growth of this tree for three years *before* the ground actually failed in an event and killed the tree. One possible explanation is that ground motion occurred for several years, and that trees begin to react to internal ground movement before an actual slip occurs. One implication is that rapid eccentric growth of trees on a slope may be used to predict future failure.

If there is progressive movement in the form of rapid creep, the results from trees on the upper part of the slump are interesting and worthy of note. The three successful cores from tilted trees at the top of the slump all showed rapid growth on the ring width comparison graphs from the past five years (see Fig. 2). Like tree A6, this result is important because there have not been any obvious slip events with ground breakage on the upper part of the slump in the past decade. The tree rings would suggest that slip on the upper part is imminent if the same pattern occurs as is seen in A6. Note that the summer of 2008 event only affected the bottom block in the slump (A). It is quite possible that the tree ring records (C) show that there is current ground movement (rapid creep) and this rapid ring growth may be a predictor that there is internal ground deformation, and that that uppermost part of slump could fail at any time.

Implications and conclusions

This active slow-moving slump shows a record of 175 yr of deformation and tree tilting and as such it is ideally suited to reveal subtle clues as to the relationship between ground movement and precipitation. There are clearly periods of ring asymmetry that is inferred to relate to enhanced slip and this study serves as a starting point for developing a regional evaluation of the historic significance of landslides.

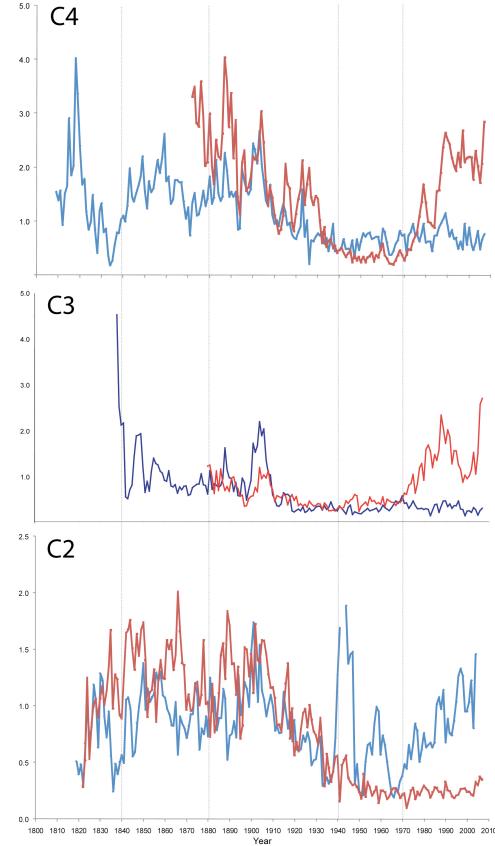


Figure 2: Ring-width asymmetry for the three trees on the upper part of the slump. All three show a pronounced asymmetry in the last few years, but this trend started in c. 1970.

Eccentric growth indicates that this landslide is actively moving. Slip in 2008 is part of that current phase of movement, and the highly eccentric growth of A6 suggest ground motion and slip started 3 yr before failure in 2008. Therefore, one likely possibility is that deformation and ground motion in this instance first occurred as accelerated creep, and that motion precedes failure. If this model is correct, slip on upper of the slope (C) is imminent because all trees successfully evaluated on that part of the hillslope show rapid and wildly eccentric growth in the past few years.

Movement at the base is complex and trees show a number of different responses to movement over time, which is likely related to differences in the size and complexity of slide blocks. Tree growth and eccentricity patterns

on the upper part of the slope is much more simple in comparison. This pattern likely reflects the fact that the upper block responds to only a single separation point or slip surface.

Rapid and dramatic growth from c. 1880 to 1910 is inferred to be release from suppression growth that likely responded to the formation of a canopy gap. Maximum growth occurred 1880-82. If this gap was formed by trees felled in a slip event, similar to what happened in 2008, then our best estimate of the timing of that slip is 1873-1880 based on ring asymmetry in A2 and A6. There are several alternate hypothesis as to how a canopy gap could have formed, logging is foremost among them.

We suspect that trees respond to disturbance rapidly, but then growth is followed by a long period of recovery that appears to last for more than a decade. Eccentric growth can precede slip (A6), and that growth is eccentric for some time after slip in the recovery phase. As such, assignment of slip or significant ground movement from asymmetry requires the evaluation and synthesis of many individual trees. In doing this, we recognize the following key periods of slip:

- 2005-P appears to be a period of enhanced instability. This is obviously manifested by the small volume slip in 2008, but wildly eccentric growth of trees on the upper part of the slope suggest instability that is the most dramatic that many of these trees have experienced in over 175 yr.
- 1970-76 tilting and slip was pervasive and acted progressively upslope over 6 yr. this period corresponds to a well-known extremely wet period in this area. Much of the slope appears to have been mobilized in this interval, and this is similar in timing to movement of comparable features in the Plotterkill Preserve (c. 15 km east).
- 1942-1946 appears to be a single, short-lived event that is also recognized in the Plotterkill Preserve (Bucci and Garver, 2009).

- 1873-1880 may have been when a slip occurred that caused a canopy gap recorded in rapid growth from c. 1880 to 1910.
- 1828-1833 may have been a time of instability on the slope. A single tree (B4) shows eccentric growth and reaction wood. As we would expect, old events are more difficult to decipher because the record is less robust.

References

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