Evidence and Impacts

It’s difficult today to escape the sensational discussion of climate change. It’s on the news, in popular novels, science books, on the radio and talk shows. Earth day this year revealed several commentaries by famous talking heads telling us of the impacts of our actions on climate, species, floods and storms. Famous actors are helpfully pointing out how we might live more modestly. One talk show host lauded another for handing out climate change packs to her audience but noted that it might not offset the damage done by that same host a previous year when she handed out automobiles!

Showmanship, hyperbole and misinformation notwithstanding, the public itself seems to have reached one of Gladwell’s tipping points on climate change and accepted it as an item of faith. I would be encouraged if the swing was based on an understanding of evidence rather than simply a matter of faith. To my knowledge, the average Joe has no additional information today than they had in October less than a year ago, and yet public opinion has changed radically. In BC, the tipping point has probably come from several sources including general media, the now-famous Al Gore movie and the impressive storm in November 2006.

The November storm is not, in and of itself, evidence of climate change; no single event can be such. However, it certainly is consistent with climate change scenarios, and if the modellers are reasonably accurate in their predictions, we should be concerned with our ability to deal with such events. The storm has given us the unique opportunity to gather evidence on potential impacts of such storms, and our ability to adapt. See the request for partnerships in this issue. If you are interested in wading through the evidence for your own knowledge, click the photograph on this page to take you to the New Scientist web site where they tackle the questions around what is real and what is not.

I’m pleased to bring you, in this issue, a summary of a recent paper that examines the role of landslides of different magnitudes in the formation of the coastal landscape. The full manuscript is published in the August issue of Geomorphology.

Comments on any of the articles, or the newsletter can be sent to me at: richard.guthrie@gov.bc.ca

Past issues of Island Geoscience are here: http://www.for.gov.bc.ca/hfd/LIBRARY/Island_Geoscience.htm

Many thanks for your continued interest, and enjoy the summer field season!

Rick.

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One of many blocked roads following the November 2006 storm on Vancouver Island.
In 1960, Wolman and Miller first proposed to measure the relative work done by geomorphic events differing in magnitude and to establish which of these event magnitudes were ultimately landscape-forming. In the case of rivers, they determined, based on observations that moderate-sized events accounted for the largest portion of work done in a fluvial landscape (Figure 1). They argued that high magnitude events, despite their visible impacts, occurred too infrequently to have effective control on geomorphic design, and those smaller more frequent events were similarly ineffective because they lacked power to sufficiently alter the terrain.

In contrast to rivers, landslides are discontinuous in time and space, exceptional by nature, and arbitrary in magnitude. Consequently, despite implied extrapolations of the Wolman Miller paradigm, the role of different sized landslides in forming the landscape has not formally established in the four and a half decades since.

Recently, complete inventories allow us to analyze landslide data in aggregate, and small landslides may be compared to the rarer larger events to determine which does the most work.

Work, is defined as it was for rivers: the product of frequency and magnitude (Figure 1). Fundamentally, work may be further characterized as the change from potential to kinetic energy through time (Caine, 1976):

\[ \Delta E = mg(\Delta h) \]  \hspace{1cm} (1)

where \( E \) is energy in joules, \( m \) is the landslide mass, \( g \) is the gravitational constant, and \( \Delta h \) is the change in elevation in a given time interval.

It can be shown that total landslide area relates directly to both \( m \) (Guthrie and Evans 2004) and \( \Delta h \) (Caine, 1976). Total area was therefore used as a proxy for work.

Figure 1 (from Guthrie and Evans, 2007). A simplified diagram of the Wolman-Miller (1960) paradigm. In continuous natural phenomenon (river rates, wind speeds and so forth) a stress is applied to transportable medium (sediment for example). As the stress increases, the magnitude of material that may be transported increases. However, the frequency distribution of the event size is log normally distributed and consequently the most work (a product of frequency and magnitude) is done by moderate-sized events given by the work peak on the graph.

Over 12,000 landslides were considered from both California and coastal British Columbia. In each case, the probability of an event of size \( x \) was multiplied by the area of that event to obtain the work done by each landslide size (grouped into logarithmic bins) in the landscape. Some of the results are shown in Figure 2.

The data strongly corroborate the original concept put forward for rivers in Figure 1 (Wolman and Miller, 1960). When analyzed in aggregate landslide inventories demonstrate that the magnitude of geomorphically effective landslides, those doing the most work, peaks shortly after the magnitude of landslides with the highest probability of occurrence.
A precise definition of moderate size remains thus far unresolved. The magnitudes of geomorphically effective landslides differ, for example, between coastal BC and California by 10 times. Moderate size should therefore be defined by the work peak (Figures 1 and 2). There will be a range in magnitude of work peaks based on the physiographic, climatic, and geotechnical properties of individual landscapes.

![Figure 2](adapted from Guthrie and Evans, 2007). Probability distribution of landslides compared to work done by events of size $x$ observed for landslides from the 1994 Northridge earthquake, California ($n=11,036$). Work is defined as Probability$\times$Area and then scaled to fit the graph. Similar results were evident in British Columbia.

Further analysis suggests that even when measured against the largest landslides worldwide, it is the moderate events that are doing the most work forming the landscape.

A difficulty remains, however, in reconciling the notion of geomorphic work with the impact of the largest events on the local landscape in which they occur. At some point a single event of sufficient magnitude would be resolvable above the background noise of the various processes active within a system and would persist in the landscape sufficiently long to be quantifiable as individually formative. It is at this point that a landslide may be, at least geomorphologically, regarded as catastrophic. A good example is the Frank Slide (Figure 3), which dominates the features of Turtle Mountain, and which exceeds the ability of local processes to return the landscape into one determined by more moderate sized events.

![Figure 3](Frank Slide at Turtle Mountain. Large landslides have to occur somewhere and may dominate the local landscape, become landscape forming, despite their relatively low global contribution to morphology. In order to determine when landslides become catastrophic, a measure of the persistence time in that landscape is needed.

A model of landslide persistence was determined using the time series landslide inventories and larger landslides were estimated using known ages and geomorphic indicators of persistence (see Guthrie and Evans, 2007 for details).

The results (Figure 4) provide an estimation of landslide persistence over nearly six orders of magnitude. Two distinct groups are indicated: debris slides and debris flows are shallow failures involving unconsolidated surficial material, and rock slides and rock avalanches where the initial failure occurs in bedrock.

![Figure 4](from Guthrie and Evans, 2007). Persistence times for debris slides, debris flows, rock slides and rock avalanches.)
Based on the results, persistence of the Frank Slide may be estimated. At 2.7 km$^2$, Frank Slide has a global probability of about $3.14 \times 10^{-9}$ yr$^{-1}$ km$^{-2}$ of mountainous terrain worldwide (Guthrie and Evans, 2007). On average, a landslide equivalent in magnitude to the Frank Slide occurs somewhere in the world every 8.6 years. The persistence of such an event (Figure 4) is estimated at approximately 8,000 years.

The degree to which a large landslide overwhelms a system is dependent on the frequency-magnitude characteristics of the landslides associated with the work-peak (Figure 2) and their persistence in the same system (Figure 4).

The extent to which an event is individually formative (catastrophic) is given by the persistence ratio (PF):

$$PF = \frac{P_E}{P_{WP}}$$  \hspace{1cm} (2)

When PF $\geq 10$, the extreme event is individually formative and can be considered catastrophic. At PF values below 5 an individual event begins to merge with the background noise of the system, as it tends toward the magnitude of the work peak.

References

This article is a short version of a paper recently published in Geomorphology (see references). For full details please see the following site: http://www.sciencedirect.com/science/journal/0169555X

Winter 2006/2007

In November 16$^{th}$ of 2006, the west coast of Southern BC was struck by a major storm that caused millions of dollars in damage. Whatever didn’t go in November was preconditioned for another event in January 2007. We are in the process of trying to accumulate data for the winter storms.

We are also looking for partners to share in the costs of gathering imagery for this year. If you are interested in having access to 2007 imagery for all of Vancouver Island as well as the results of change detection (what changed on the imagery from the previous year) and can contribute to the project as a funding partner, please contact Rick Guthrie at 250-751-3138, or by Email at richard.guthrie@gov.bc.ca. Funding partners will get credit in the reports.

In the meantime, here are a few images of some of the results of the storm.

Deep channel scour and subsequent deposition. Unusual to Vancouver Island, several debris flows were initiated in-channel as the tractive force of water entrained sediment and scoured deep channels into the hillside.

Channelized debris flows were common and in many cases removed material to bedrock.
Deposition zones of debris flows varied from sites that were simply buried to those that removed everything in their path before burial. This stream is a tributary to the Gordon River.

Gravel deposited in Robertson River. Log jams in nearby tributaries caused water to bury several holes of a local golf course in mud.

Debris flow onto private property in the Beauforts. In addition to the deposit here, the landowner experienced several centimetres of overland flow across large portions of his land, and a debris flow reached his mill.

Over one hundred landslides clustered south of Nitnat Lake north east to Cowichan Lake suggest that even within the regional influence, there were storm cells of concentrated activity.
Introducing:

Pat Lapcevic is currently the Ministry of Environment's Vancouver Island Region (including the Gulf Islands), Regional Hydrogeologist. Her responsibilities include overseeing the region’s observation well network, working with water stewardship groups and local government to further groundwater protection, providing groundwater expertise to MOE and other agencies and working on technical projects such as the vulnerability mapping of Vancouver Island, assessing possible impacts of climate change on coastal aquifers and a survey of groundwater geochemistry of the Gulf Islands.

Prior to joining the Ministry in 2005, she worked for 15 years for Environment Canada, focussed on understanding groundwater flow and contaminant transport in fractured rock, and 4 years for the Grand River Conservation Authority in Ontario, where she worked on a number of issues related to groundwater/surface water interaction within a large-river watershed.

Pat lives on Gabriola Island with her husband and 3-year-old son.

Carnation Creek Workshop:

Get in the field with the CWRA! The BC Branch is organizing a two day field based workshop presenting historic and on-going geomorphology and biology based research in Carnation Creek. The workshop will be held on Monday Sept 24th – Wednesday Sept 26th, 2007.

Speakers on both days will include seasoned professional geoscientists, biologists, and current graduate. The workshop is intended for professionals in geosciences, biology, water resources, forestry, and those interested in learning about one of the most important research sites on the west coast. Tours will include field time in both Carnation Creek, and the nearby Carmanah forest, one of the last great old growth locations on the west coast.

Mark your pages! Registration will begin here: Carnation Creek. Contact Channa Pelpola at cpelpola@jacqueswhitford.com or 604-412-2971 for more information.

Next issue:

Geomorphology and Salmon! - RHG