Quaternary legacies to managing urban geohazards in Canada

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ABSTRACT
A proper appreciation of risks posed by geologic hazards requires a thorough understanding of geomorphic processes and Quaternary history. The main processes responsible for the landscape and geology of British Columbia and that continue to shape the landscape are earthquakes, volcanism, glaciation, rivers, and mass wasting. Engineering geologists who understand these processes and how they operate, both singly and in tandem, possess an essential context for assessing the vulnerability of people and built structures in developed environments to geologic hazards. This understanding allows an engineering geologist to identify geologic nuances that are commonly overlooked, yet are causes of disasters. It is these nuances that I explore and illustrate with examples in this presentation.

The first example is large landslides in glacial-lake sediments. Thick lacustrine sediments are common in valleys in interior British Columbia. Most of these sediments were deposited during three periods – at the end of the penultimate Pleistocene glaciation, probably about 50-60 ka ago; early during the last glaciation (ca. 25-20 ka years ago); and late (12-11 ka years ago) during the last glaciation. Sediments deposited during these three periods are superficially similar – both comprise mainly horizontally layered non-plastic silt and, locally, sand – and can be difficult to distinguish, but they pose different hazards. The older two sediment sequences were overridden by up to 2 km of glacier ice and commonly are pre-sheared. Large failures (e.g. Ashcroft, 1886; Attachie, 1973) occur along gently inclined to nearly horizontal shear planes or along sand or coarse silt layers where pore pressures may become elevated. The youngest lacustrine sediments have not overridden and sheared by glaciers and commonly are less compacted than the older sediments. Although they too can fail on inclined slopes, most of these failures occur along shallow bedding planes. The landslides are smaller and typically are fluidized flows.

The second example involves the interpretation of linear scarps that are common on high mountain slopes and ridges throughout western Canada. Some workers have interpreted these scarps to be faults produced by postglacial earthquakes. Indeed, their length (up to 2 km) and seeming disregard for topography (some cross ridges) appear do demand such an interpretation. However, in nearly all cases, careful geomorphic interpretation and trenching of sediments that have accumulated in swales adjacent to the scarps, demonstrate that the features are gravitational in origin (sackung, or “sagging slopes”) and thus carry no implications for earthquake hazard. The linearity of the more problematic examples is explained by slow, deep-seated gravitational movements along gouge zones localized along Tertiary faults.

The third example involves interpretation of hazard and risk on debris flow fans and snow avalanche cones. Many large fans in western Canada are relict, “paraglacial” features that were active during early postglacial time when sediment supply was greater than today. Questions arise as to the level of activity on these fans today. Surface vegetation on such fans provide valuable clues about the likelihood that a debris flow will occur in the present climate regime. Equally important is the vegetation in the source areas of the fans and on slopes above avalanche cones. A continuing risk may be signaled by subtle differences in conifer stand age and in the present of pioneering trees and shrubs in strips oriented downslope.

Training in geomorphology and Quaternary geology also allows engineering geologists to identify tell-tale traces of past catastrophes. Minor lineaments may be the traces of large earthquakes; thin sand layers record tsunamis; or sheared rock in drill core delineate the sole of a large landslide. A vastly improved understanding of seismic hazards and risk in the Pacific Northwest came after Holocene fault scarps that cannot be seen on aerial photographs were identified on LIDAR imagery. Quaternary stratigraphy and geomorphology are useful in most hazards investigations, but they are particularly valuable in urban environments, where the potential for subsurface investigations is commonly limited by private land ownership. Classic geotechnical engineering, based entirely or largely on material properties and drainage and done without a thorough understanding of local and regional geology may result in incomplete or even potentially erroneous risk assessments.