Forest Sciences

Prince Rupert Forest Region

Extension Note # 35

April, 1999

Tsunamis on Troitsa Lake British Columbia

Research Issue Groups:

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Picture yourself on a sandy beach contained in a small bay at the end of a long narrow lake bounded by steep mountains—Troitsa Lake, on the edge of the coastal mountains west of Tweedsmuir Park (Figure 1).

Suddenly on a calm, rainy misty day a sharp swell enters the bay; not an abnormally large storm-size wave. Seconds later, water is sucked from the bay leaving boats and debris stranded. With a tremendous roar a large wave returns tearing boats from their moorings, smashing into the shore carrying debris 20 meters over the beach and up into the forest surrounding the bay. The water subsides but the lake remains unsettled, with many progressively smaller waves pulsing back and forth throughout the day.

What phenomenon has just occurred? A terrified onlooker with presence of mind would have long since climbed to higher ground to wait out this unusual event. What had just taken place on Troitsa Lake was a tsunami. We generally think of tsunamis occurring on the Pacific Ocean, triggered by earthquakes, volcanic

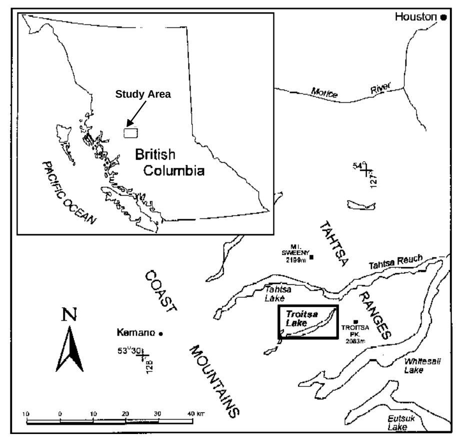

FIGURE 1. Location of Troitsa Lake

eruptions or by underwater landslides. Tsunami waves when approaching shallow water or the shore can build to terrifying heights.

What occurred at Troitsa Lake on the morning of October 6, 1998 and unsettled the lake for 4 hours was triggered by a large underwater landslide that occurred off the steep slope of a fan-delta. The visible portion of the landslide measures 400 m by 60 m along the edge of a fan-delta surface. This visible face is the head scarp and upper slump block of a large landslide that extends down the steep face of the delta to depth in Troitsa Lake (Figure 2).

Bag 5000, Smithers, BC V0J 2N0 847-7500 (FAX 847-7217)

An estimated three million cubic meters of materials moved in the event. A displacement wave 1.5 m high hit the opposite side of the lake one kilometer away. Groups of large trees matted together were rafted by the wave up to one km across the lake. A backwash wave two m in height crashed back over the head scarp carrying debris up to 150 m inland over the delta surface. The north end of Troitsa Lake (10 km from the landslide) experienced an initial sharp swell about 60 cm in height; bays and shallows where then sucked empty. About 10 minutes later, a large return wave 1.5 to 2 m high crashed through the shallow bay, tearing sunken logs and debris from the bay floor and hurling the debris on to the beach and into the forest surrounding the bay. Boats and floating wharves were ripped from their moorings. A log jam at the head of Troitsa River was also dislodged and sent down the river.

The large fan-delta on Troitsa Lake where the failure occurred is forested with big spruce and subalpine fir. It covers an area of 100 ha and extends for a distance of 1,600 m along the water's edge (Figure 3). The most actively aggrading portion of the fan edge extends over a distance of 700 m. Sediment source for the fan-delta originates in a steep-gradient watershed (13.5 km^2) containing recently exposed glacial materials. Glaciers ring the upper elevations of the valley. The fan-delta has a slope of 6 degrees from its apex to the lake shore. This fan has experienced many episodes of dynamic processes, as attested by the many distributary creeks on its surface, and by the layers of cobbles, gravels and sand. Materials at depth are unknown but probably include complex layers of interstratified muds, sands and gravels. Fan-deltas similar to Troitsa's grow in size through sediments deposited during spring freshets and floods. Materials perched underwater on the steeply sloping face are generally highly unstable.

FIGURE 2. Floating debris at the landslide head scarp. Scarp extends 2 metres above the lake surface.

Fan-deltas are common along the side-walls of coastal fjords and also on steep-sided, long, narrow, fjord-type lakes in mountainous areas of British Columbia. The geomorphology of fan-deltas has been studied and described in coastal fjords but not in freshwater lakes. However, the processes are similar. Fan-deltas have developed over the last 8,000 to 12,000 years, commencing with the high-energy, sediment-laden meltwater during deglaciation of fjord-side drainage basins. Considerable variation exists in fan-delta architecture. Some systems build large cone-shaped fans with the apex of the fan close to the

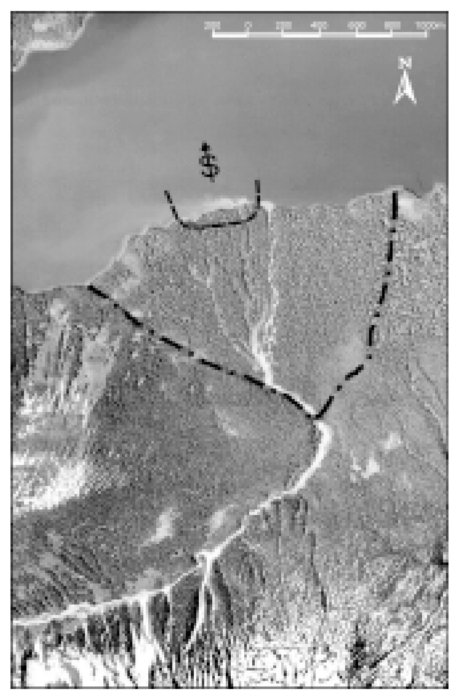

FIGURE 3. Troitsa Lake fan-delta with landslide location indicated.

shoreline while others aggrade to form alluvial fans or deltaic plains (Figure 4a). River floods continue to supply sediment and in the case of the Troitsa delta resulted in the aggradation of sediments over the delta through multiple distributary channels. Although occurring under water, slope failures can be visualized on a steep fan-cone as a slide trough and debris lobe similar to a debris slide or flow. The presence of crescent-shaped slide scarps and blocky debris ridges on the face of a fan-delta suggests the occurrence of a retrogressive rotational type of landslide movement (Figure 4b).

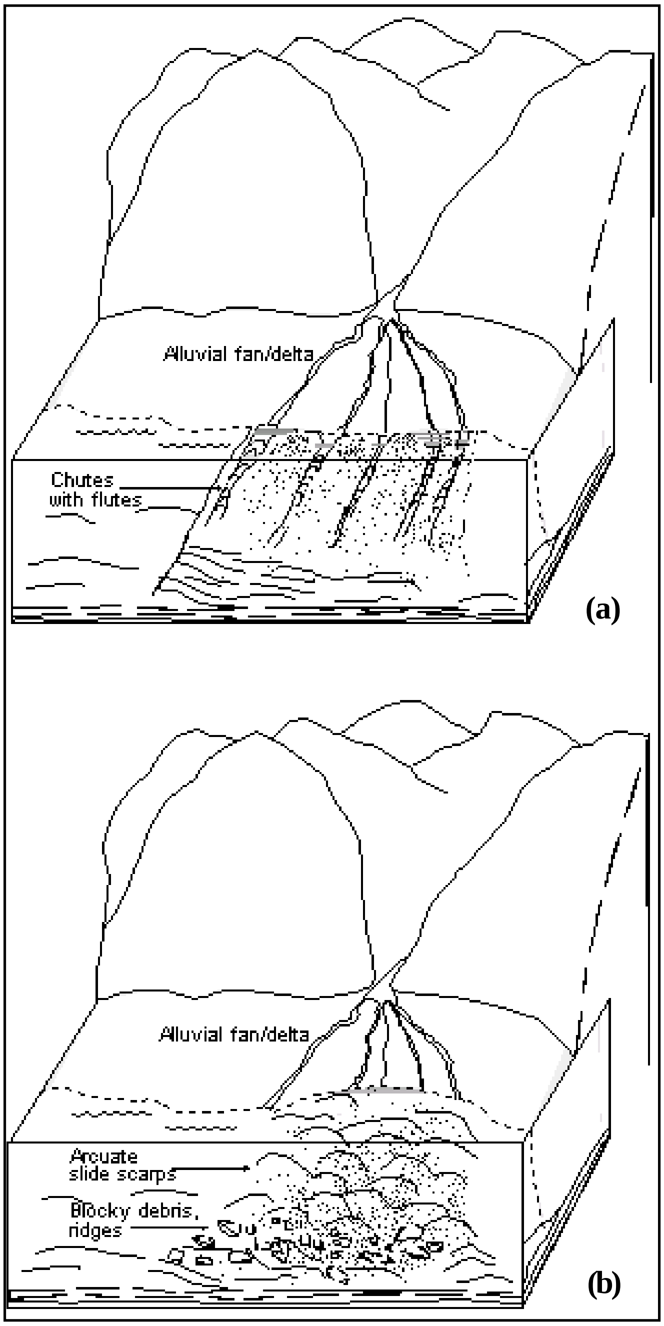

FIGURE 4. Schematic representations of the Troitsa Lake fan-delta before (a) and after (b) the landslide.

The Trotisa Lake fan-delta at first glance appears as a relatively flat, unassumingly stable landform—but evidence of a historic failure is exposed at the headscarp of the present landslide. Imbedded in the head scarp is a row of trees all protruding at the same level perpendicular to the scarp (Figure 5). New trees fallen in the water from the erosion created by the backwash are similarly placed, suggesting the imbedded trees are from a landslide-triggered tsunami. Radio carbon dating of one of the imbedded tree logs provided a date in the order of 650 years B.P. Possibly the time since the last landslide-triggered tsunami on Trotisa Lake.

Implications For Forest Land Management

Recreation:

Tsunamis on lakes are thought to be relatively uncommon. This may in part be due to poor documentation for remote areas. But they do occur. The likelihood of experiencing a tsunami may be very low, but high-class recreational opportunities draw individuals to fjord-type lakes. What can a person do if caught in a tsunami event caused by a landslide? Being aware and recognizing what is happening is the first step. Close to the landslide, large waves can swamp or capsize small watercraft. At a distance from the event, tsunami waves on open water may only cause a slight or undetectable swell. A typical tsunami builds when entering a shallow or confined area with an initial swell or wave, then a drawdown of water, followed by a much larger return wave. The size of wave will vary depending on the size of the landslide, and the depth and configuration of the lake. The only safe option to avoid return waves is to escape to higher ground.

Forest Development:

Fan-deltas are very productive forest sites. However, the delta face and slope into deep lakes or fjords are often highly unstable. The evidence of landslide activity is often concealed because landslide features are covered by water. Large fan-deltas are tempting sites for waterfront development because of their relatively flat terrain.

On coastal fjords, development on fan-deltas has caused destructive failures and tsunamis (Kitimat April 27, 1975 and Bute Inlet March 3, 1989). Many such failures remain poorly documented, occurring in remote areas. Working with equipment or the placement of structures close to the fan-delta water edge can cause disastrous slope failures. These sites must be avoided or a detailed investigation of the fan or fan-delta must be carried out to ensure stability and safety of the sites.

Research Opportunity:

The instability of fans and fan-deltas in freshwater fjord-type lakes is mentioned briefly in published literature, but little documentation exists of known sites and landslide-tsunami events in British Columbia. Surveys to identify fan-deltas and sites of historic landslides should be undertaken to determine the extent of potential hazards from landslide-tsunami in British Columbia's fjord-type lakes. The Troitsa Lake landslide-tsunami provides a unique opportunity to investigate and document fan-delta development, landslide frequency and magnitude, and tsunami wave generation in a confined fjord-type lake. Such information could aid in the development of predictive models to link landslide type and size to tsunami-wave size and to hazard prediction for fjord-type lakes.

Contact:
Jim Schwab**, R.P.F., P.Geo.**
Research Geomorphologist
Prince Rupert Forest Region

FIGURE 5. Trees imbedded in the landslide headscarp—evidence of a historic failure.

Suggested Reading

Prior, D.P. and B.D. Bornhold 1990. The underwater development of Holocene fan deltas. Special Publications International Association Sedimentology 10:75-90.

Bornhold, B.D. and J.R. Harper. 1998. Engineering geology of the coastal and nearshore Canadian Cordillera. *In* D.P. Moore and O. Hungr (editors). Engineering geology a golobal view from the Pacific Rim. Eight International IAEG congress. Blanka Rotterdam. 1:63-75