<u>Hope Landslide – January 9th 1965 – Canada's Largest Landslide</u>

Dan Kellar, beingthechange.ca, November 30th 2005

Introduction

According to Sharpe a rockslide is "the downward and usually rapid movement of newly detached segments of the bedrock sliding on bedding, joint, or fault surfaces or any other plane of separation" (Sharpe, 1960, pp 76). On January 9th 1965, in the early hours of the morning, Canada's largest rockslide (landslide) occurred (Clague, 2005). The slide occurred on the southwestern slope of Johnson Peak, in the Cascade Mountains,18 km east of the city of Hope, on the northern side along highway 3 (see figure 1) in southern British Columbia.

Figure 1 (Brideau et al, 2005)

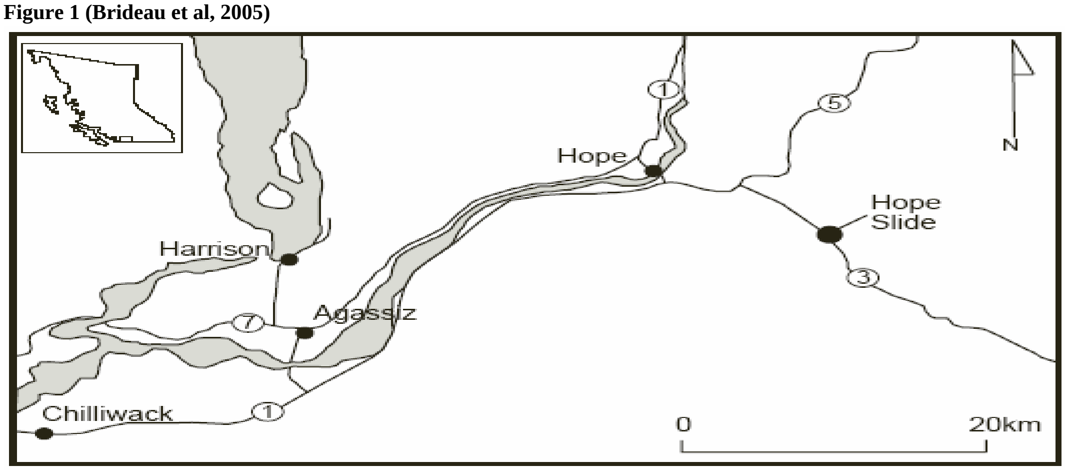

Fig. 1. Location map of the Hope Slide, southern British Columbia, Canada.

There is much debate as to what triggered the slide, with most academics insisting on tectonic activity, while dissenters insisting on something else. What is certain is that the slide killed 4 people as 3 cars were buried (Couture and Evans, 2000), the highway required re-routing, and the eyes of Canadians were opened to the possible dangers of driving alongside and in between mountains. No amount of planning will be able predict all possible slide hazards in such a mountainous region and timing contributed to this hazard becoming an disaster; if the slide occurred earlier in the day, it is possible that no one would have been injured; if it would have happened later, more people could have been directly affected.

Extent of the Hazard Event

The Hope slide is the largest recorded rockslide to have ever occurred in Canada. The south-western slope of Johnson Peak collapsed (figure 2) resulting in the spread of "…47 million cubic metres of debris, 85 metres thick, over a 3 kilometre stretch of the Hope-Princeton highway. The slide occurred in an unpopulated area in early morning hours and resulted in four deaths" (GSB, 1993, pp 1). Clague estimated a shallower depth of debris, measured to be 79m in his study (2005), either way, it can be agreed upon that 79-85m of debris is a massive amount. After running down the slope and spreading laterally, the slide crossed over the road "…ploughed through a lake formed by debris of a previous landslide...Up valley, the splashed material formed a thin extensive sheet. Down valley it was channeled into a stream forming a distinct mud flow for several kilometers" (CGS, 1984, pp 5). Brideau et al. made some general observations about the movement of debris in the Hope Slide:

> Block shape and size were observed to vary as a function of distance from tectonic structures. The central portion of the Hope Slide (away from the tectonic structures) was composed dominantly of large blocks (1–3 joints/m3) with tabular shape….The shape of the 1965 failure event is generally shown as fanning outward at the toe; this morphology is typically associated with rock slides and rock and debris avalanches…The thickest slide deposits are also found at the northern portion of the debris pile. Evidence suggests that the main mass of failed material traveled in a westerly direction as opposed to a southwest direction… The distribution of discontinuity sets suggests that the presence of rock-mass damage related to tectonic activity may have been significant in facilitating release surfaces for the rock-slope failures at the Hope Slide (Brideau et al, 2005, pp245).

From this study we can see that the slide spread laterally as it moved downhill (as expected with rock avalanches) with large blocks in the central portion of the slide, while smaller, more damaged blocks on the outer-edges related to tectonic activity. Whether or not this tectonic activity occurred on the day of the slide is a point of contention.

Figure 2 (Brideau et al, 2005)

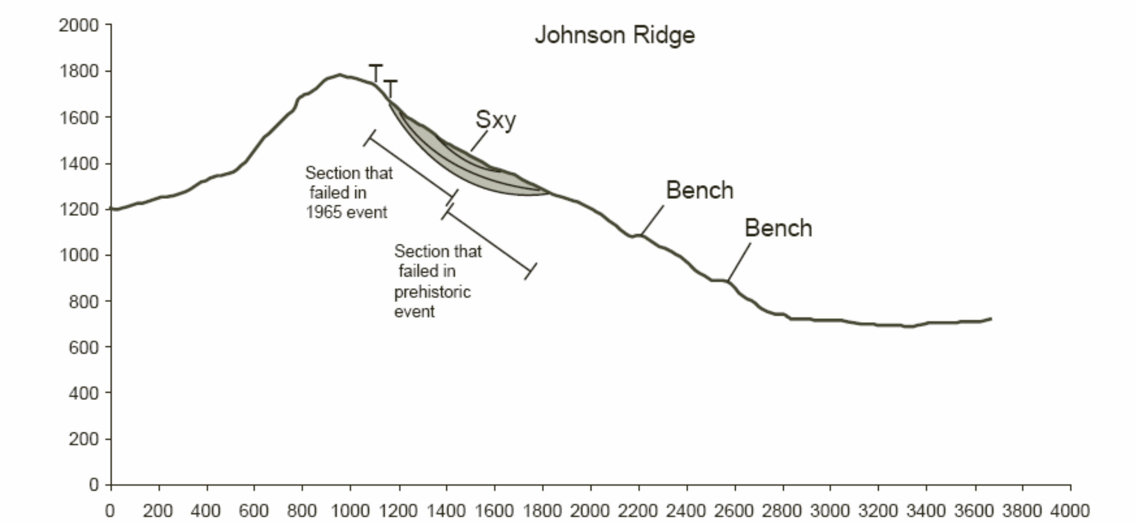

Fig. 14. Cross section through Johnson Ridge showing the location of the expected shear-stress concentration (Sxy) at the Hope Slide based on an analysis performed by Kinakin and Stead (2005).

Cause of the Hazard Event

There are many possible triggers that cause landslides. Seismic and tectonic activity and ground saturation by water are the two most common. The trigger for the Hope slide and the reasons for its massive volumetric size are topics of much controversy. Kent suggested that the slide was fluidized by an upward escape of air after the slide started, but all other reports, and the evidence from the slide does not support this conclusion (CGS, 1984).

Most research indicates that the main triggers for the slide were two earthquakes that occurred earlier on the 9th of January (Evans and Wetmiller, 1989, Evans et al 1989). There is research, however, that concludes that there were no earthquakes and the seismic activity recorded was that of the slide itself: "Seismograms associated with the 1965 Hope slide in British Columbia were re-examined, and it is concluded that these seismograms were the signatures of two rock-slides, and not of hypothetical tectonic earthquake triggers as previously suggested" (Evans et al., 1995, pp 208). Couture and Evans also point out that:

> no seismic or hydrometeorological trigger is discernible for the 1965 events. It is suggested that progressive long-term deformation of the slopes of the southwest flanks of Johnson Peak caused the stability of the slope to deteriorate to a point where the 1965 events occurred. Thus we conclude that the Hope Slide was a catastrophic termination of very long term non-episodic mountain slope deformation. (Couture and Evans, 2002, pp 1)

It is interesting to note that Evans has reports published arguing both sides of the earthquake debate. Another dissenter from the status quo: Clague found that "Failure occurred, without an obvious triggering event, along felsite sheets and joint planes within metavolcanic rocks of the Hozameen Group" (Clague, 2005, pp1). Strong evidence for a seismic trigger comes from Havenith et al. who "reveal a morphological dependency of the seismic slope failure occurrence. They show that seismically triggered slope failures tend to occur in the upper parts of slopes and close to ridge-crests" (Havenith et al, 2003, pp 250). As the slide started near the ridgeline on Johnson Peak this information seems very prevalent. Most evidence leads to the conclusion that earthquakes were the main trigger, and this paper concludes the same. There were, however, numerous secondary triggers that contributed to the failure.

In the study by Brideau et al. it is proposed that the cold temperature could have raised the pore-water pressure due to closure of normal seepage points by the formation of an impermeable frozen zone at the ground surface (Brideau et al., 2005). Hydrothermal heating of the rock is also considered to have weakened the rock by up to half its original strength (Ibid). Pore water pressure is also recognized by Evans et al. as a secondary trigger as they found seepage on the rupture surface which would suggest water pressure may have existed prior to the slide (Evans et al., 1989). In addition to pore water pressure, Evans et al. note that weakness planes exist near or at the margins of felsite sheets, also that the landslide occurred over part of a scar created by a prehistoric rock avalanche of similar size (Ibid). Evans and Wetmiller conclude that the final trigger to the landslide was the earthquake, but the major contributing factor was the incipient instability of the slide mass due to previous earthquakes (Evans and Wetmiller, 1989). Couture and Evans conclude that the event was the culmination of years of deformation (2002). Here the dominant factors contributing to the landslide are years removed from the actual event. The areas' seismic history must be considered when looking for triggers.

It can be seen that there is much debate as to the triggers of the event, but the two earthquakes (3:56am magnitude 3.2, and 6:58am, magnitude 3.1, Evans and Wetmiller, 1989) will be considered here as the primary trigger. Pore-pressure from frozen and swelled pores, weakened rock due to hydrothermal heating, and slope instability due to location (on prehistoric slide scar) and weathering will all be considered as secondary factors. There is no indication that the construction of the road negatively impacted the slope.

Social Impacts

Recognition that Canadian roads and motorists are not impervious to the effects of a landslide was created after the Hope slide. Highway 3 was re-routed further away from the base of Johnson Peak when it was rebuilt. And, with increased research, better road and slide diversion and prevention techniques were researched. The death toll for the slide was 4 people buried in 3 cars; the families of the victims must have been devastated and those driving on the highway at the time that just missed the slide may have taken a new outlook on life. When the highway was re-routed, a pull-off from the highway was created taking people to the location of the buried vehicles. Here a memorial was set up with educational signs to tell people what happened and why.

A common unreported social impact is the prolonged physical and psychological pain that victims (and their families) and those close to the disaster face (Crozier, 1986). The victims of the slide may have been on their way to make a change in the world or simply the area in which they resided. The loss of the victims are not measurable, they merely become statistics, used for directing research in preventing such hazards from becoming disasters in the future.

Economic Impacts

The emergency response and re-routing of the highway are the two direct economic impacts associated with the Hope slide. Indirect costs related to the Hope slide are the Clean-up efforts at the site of the Hope slide and down valley, the life insurance pay-outs to the victims families (if applicable), and the income generating potential of the victims. Companies may miss the expertise that the victims may have afforded them, and may suffer for some time due to the loss. The creation of the highway pull-off also cost time and money but was created to educate and remember.

Environmental Impacts

Direct environmental impacts linked to the Hope slide are as follows: vegetation and animals on the slope and in the path of the landslide were obliterated; the lake at the base of the slide was consumed by the debris, and the ensuing down valley mudslide destroyed much vegetation; large amounts of fine sediments were transported down-valley in streams; the mountain on the other side of the valley also had vegetation destroyed as the landslide impacted upon it (Brideau et al, 2005). An indirect environmental impact is that the road had to be re-routed around the debris which led to further environmental degradation. A long term impact of the slide is that the lake that was consumed was habitat for countless animals. They were either destroyed in the slide or had to find a new home (or perish in the effort). The slope has still not been re-vegetated as the soil that had been present before the slide was mainly removed. New soil has not been deposited, nor has it developed, thus vegetation re-growth is at a minimum.

Mitigation and Management

The Geological Survey Branch of B.C.'s Ministry of Energy and Mines recognizes that areas of B.C. are very susceptible to landslides. They have created a pamphlet which aims to educate people about landslides:

> [B.C.'s] steep, mountainous terrain, its complex geology, its high precipitation, both as rain and snow, its abundance of unconsolidated glacial sediments, and its geographic position astride the earthquake zone that surrounds the Pacific Ocean, all combine to make our province particularly susceptible to landslide activity. In fact, in British Columbia the loss of life and damage to property caused by landslides is greater than losses caused by other natural hazards such as earthquakes and flooding… As our cities, towns, roads and highways steadily encroach onto steeper slopes and mountainsides, landslide hazards become an increasingly serious threat to life and property (GSB, 1993, pp 1).

The government recognizes that development increases the risk of disastrous landslides, yet continues to push forward with building and road construction. After the Hope slide event, a large amount of research was done on the site to determine what caused the event (primarily earthquakes), whether it was an isolated event (no) and where else was susceptible to a similar landslide hazard. In their study, Brideau et al found:

> The location of the Hope Slide was not due to the presence of any single abnormal tectonic feature, but to a concentration of the regional tectonic features that reduced the rock-mass quality by increasing jointing intensity and controlling the attitude of discontinuities and hydrothermal alteration (Brideau et al., 2005, pp 257).

Obviously, much of the area around the Hope slide could fail at any point, depending on a sufficient trigger.

Since the Hope slide, progress has been made in determining the triggers that will cause a slope to fail. Geological mapping technology has increased, which has led to better detection of possible slope hazards and better estimations of the likelihood of landslide occurrence. Using this technology, project planners and developers can better avoid high risk areas. Stabilization techniques such as re-vegetation, drainage improvements, construction of stabilization and diversion structures, as well as many others have been developed to assist in avoiding landslides when original development had not considered them. Warning systems linked to seismographs and slope stability monitors have also been developed. These systems allow for warning to be given to those in the possible path of a landslide. If these systems had been better developed prior to 1965, it is possible that the disaster could have been avoided. Finally, educating the public about the disaster potential involving landslides is an important step in reducing impact. Approximately 2 hours prior to the landslide, highway 3 was closed by an avalanche following an earthquake. If the drivers knew about the earthquake, and knew of the risks, they may have turned back instead of waiting for snow removal crews. Instead they remained stationary and when the second earthquake initiated the rockslide, they were overcome (Evans and Wetmiller, 1989).

Conclusions

The Hope slide of 1965 was Canada's largest recorded slide in terms of volume of material involved. The origin of the slide was clear but perceived to be a low risk. The slide occurred quickly with no warning; this resulted in the involuntary deaths of 4 motorists (3 cars) caught on the road as the slide occurred. Though emergency vehicles were on site within minutes (Evans and Wetmiller, 1989) there was little that could be done for the victims who were buried under 79-85 meters of debris. The dominant attitude towards nature of those who constructed the road did not consider all the associated dangers, or they concluded the dangers to be manageable. The timing of the slide made it a disaster as people happened to be on the road directly in the path of the slide as it happened. Proper monitoring of danger areas is required, and warning systems must be improved so roads that are at risk of landslides may be quickly closed and the population may be warned of the potential hazard. If the dominant attitude remains, it must at least incorporate the quick warning systems that are currently being developed. Economic and social impacts were relatively low as the slide occurred in an uninhabited region, and few people became victims. Environmental impacts, however, where of much higher magnitude as an entire slope with all its flora and fauna was decimated and a lake was fully consumed. The area has not yet, nor will it ever return to its state before the slide, but this is just natural succession. The process of orogeny and denudation will continue long after humans are gone, while we are here, however, we must take care to avoid areas of potential hazard, or in the least take caution while developing in such areas, or else hazards will continue to evolve into disasters.

References

1. Brideau et al. *Influence of tectonic structures on the Hope Slide, British Columbia, Canada.* Engineering Geology, Vol. 80, pp 242– 259, 2005.

2. Clague, J.J. *The Hope Slide.* http://www.sfu.ca/~jclague/hopeslide.htm. Accessed September 30th, 2005.

3. Canadian Geotechnical society (CGS). *37th Canadian Geotechnical Conference*. Conference, 1984.

4. Couture, R. and Evans, S.G. *Canadian Workshop on Geotechnique and Natural Hazards Proceedings IDNDR.* Geological Survey of Canada, 2000.

5. Couture, R. and Evans, S.G. *THE 1965 HOPE SLIDE, BRITISH COLUMBIA; CATASTROPHIC FAILURE OF A SAGGING ROCK SLOPE.* Geological Society of America 2002 Denver Annual Meeting, Paper No. 16-6, 2002

6. Croizer, M.J. *Landslides: causes, consequences & environment*. Croom Helm, England, 1986.

7. Evans S.G. and Wetmiller R.J. *Analysis of the earthquakes associated with the 1965 Hope Landslide and their effects on slope stability at the site.* Canadian Geotechnical Journal, Vol. 26, pp 484-490, 1989.

8. Evans S.G. et al. *Joint Patterns at the Headscarp of the 1965 Hope Slide.* Geological Survey of Canada, 1989.

9. Evans, S.G et al. *Seismic signatures of landslides: the 1990 Brenda Mine collapse and the 1965 Hope rockslides.* International Journal of Rock Mechanics and Mining Science & Geomechanics Abstracts, Vol. 32, no. 5, Page 208, 1995.

10. Geological Survey Branch (GSB). *Landslides in B.C.* Ministry of Energy and Mines, 1993.

11. Havenith, H.B. et al. *Seismic triggering of landslides. Part B: Simulation of dynamic failure processes.* Natural Hazards and Earth System Sciences Vol. 3, pp 663–682, 2003.

12. Sharpe, C.F.S. *Landslides and related Phenomena: A Study of Mass-Movements of soil and rock.* Columbia University Press, New York, 1960.