Wilberforce Earthquake: Preliminary findings of the landslide and ground deformation rapid aerial reconnaissance survey

Introduction:

A helicopter reconnaissance by GNS staff members was undertaken on the 8th and 9th January to assess areas of ground damage associated with the 6th January, M6.0 Wilberforce earthquake. GeoNet located the earthquake in the Upper Wilberforce River catchment, 30 km west of Arthur's Pass, at a depth of approximately 5 km. The earthquake caused moderate to very strong ground shaking intensity near the epicentre and within the central Southern Alps (Figure 1). The depth and ground shaking intensities were close to the threshold for triggering earthquake induced landslides with a further possibility that fault rupture could have occurred close to the epicentre.

It was therefore agreed that a GeoNet response was required to:

- determine whether any ground surface evidence of fault rupture could be observed close to the earthquake epicentre, and
- establish the nature, extent and location of any landslides triggered by the earthquake.

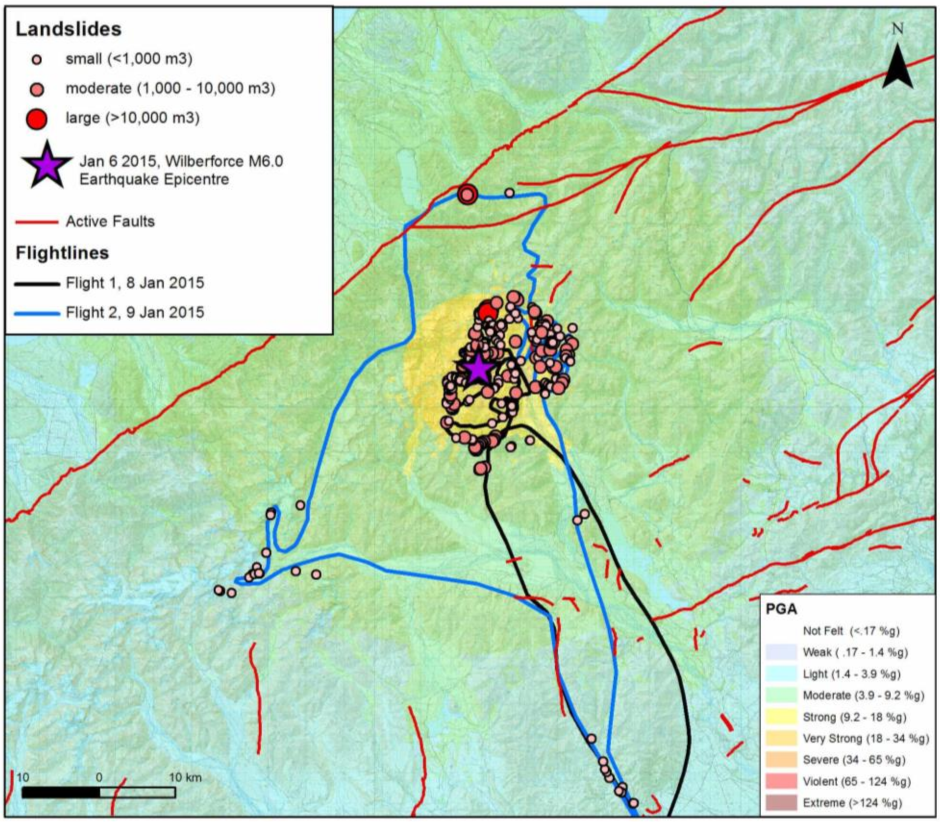

Figure 1 Map of rapid response aerial reconnaissance flight routes and landslide locations in relation to the predicted shaking intensity (%g) and the Jan 6 M6.0 Wilberforce Earthquake epicentre.

Survey extent:

Two helicopter flights were flown from the local town of Methven (30 km west of Ashburton) on the 8th and 9th of January. The flight route on the 8th January focused on the area close to the main epicentre and subsequent aftershock sequence. The route followed the Rakaia River, into the Wilberforce River catchment and incorporated a detailed fly through of each western tributary catchment to the west of the Wilberforce between Moa and Griffiths Streams. The return flight to Methven included the lower reach of the Mathias River and the Upper Ashburton River Valley.

On the 9th January a wider area was covered, in an attempt to delimit the spatial extent of landsliding, by flying up the Rakaia River to the headwaters and over the Whitcombe Pass to the western side of the Main Divide. The flight then included sections of the Whitcombe River Valley, Toharoha River Valley and the Arahura River Valley. The flight then returned to the east of the Main Divide via Brownings Pass, and the Upper Wilberforce the tributaries on the eastern side of the Wilberforce catchment were inspected. The flight paths are shown in Figure 1.

During both flights the weather conditions were fine and clear over the study area.

Geological and geomorphological setting:

The epicentral area (10 km radius) is alpine high country in greywacke and schist terrain. Slopes are often steep (>30º) and particularly on the eastern side of the divide are either bare or have a non-woody vegetation cover (alpine grasses and small shrubs).

Limitations:

The results of the study are limited by its nature as a reconnaissance level activity. Landslides have been recorded where they were observed along the flight path, but the flights paths did not cover the entire area of interest, so at best the observations represent a minimum. Given the remote location of the earthquake and the lack of impact on the built environment there are no plans to conduct a more rigorous landslide survey in the area.

Fault rupture potential:

The most likely location for surface rupture was predicted to be near the confluence of the upper Wilberforce River with a tributary called the Unknown Stream. The area was flown and photographed in detail during the reconnaissance survey but no evidence of a surface rupture of the fault was observed.

Landslide observations:

The landscape in the area of the epicentre is typically very active, with evidence of on-going slope processes including mass movements forming significant features in the landscape. This made identifying which landslides had been triggered by the Wilberforce earthquake more complex. New failures were considered to be sites with fresh rock exposures in the source area, recognisable debris fans void of vegetation and with freshly exposed run-out deposit still in the vicinity of the failure. In some cases, debris had been transported over snow making identification straightforward. Photos taken by a tramper from the upper sections of Wilberforce River during the earthquake and subsequent aftershocks show the dust created by the many small to moderate rockfalls(Figure 3).

In the area of strong shaking (9.2-18% g), approximately 200 km^2, a minimum of 200 individual landslides have been observed giving a minimum density of 1 landslide per km^2 (Figure 1). In the area of moderate shaking (3.9-9.25 g), approximately 2500 km^2, less than 50 landslides were observed giving a minimum density of one landslide per 50 km^2 (Figure 1). Based on these observations a shaking intensity of 0.1g appears to be the threshold for causing landslide densities of greater than one per km^2 in this environment (geology, geomorphology, vegetation, topography).

Many small to moderate rockfalls and a several rock avalanches were observed on the steep slopes close to the earthquake epicentre. The largest rock avalanche was observed in the upper reaches of Griffiths Stream near the Main Divide at an elevation of approximately 1500 m and about 7 km from the epicentre. In this location a series of large rock avalanches had occurred from an exposed rock outcrop and the failure debris formed a large debris fan (or lobe?) within the drainage line (Figure 4). The volume of the largest failure was estimated to be greater than 140,000 m^3.

Figure 2. Confluence of the Upper Wilberforce River (looking upstream), Unknown Stream and Griffiths Stream

Figure 3. Photos taken immediately after the earthquake looking down the Wilberforce river Valley above the confluence with the Unknown Stream, illustrating the dust generated from the multiple small to medium sized rockfalls.

Figure 4. Large rock avalanche in the upper reaches of Griffiths Stream.

The highest density of landsliding was observed on very steep, high elevation rock outcrops between the earthquake epicentre and the Main Divide. The landslides comprised mostly rock falls and rock / debris avalanches which occurred above the snow line and as a consequence provided clear evidence of rockfall source areas, rock and debris run-out and a rock debris talus (e.g. Figure 5). In many locations multiple rock falls could be observed converging within a single drainage channel leading to the development of large rock debris fan features (Figure 6).

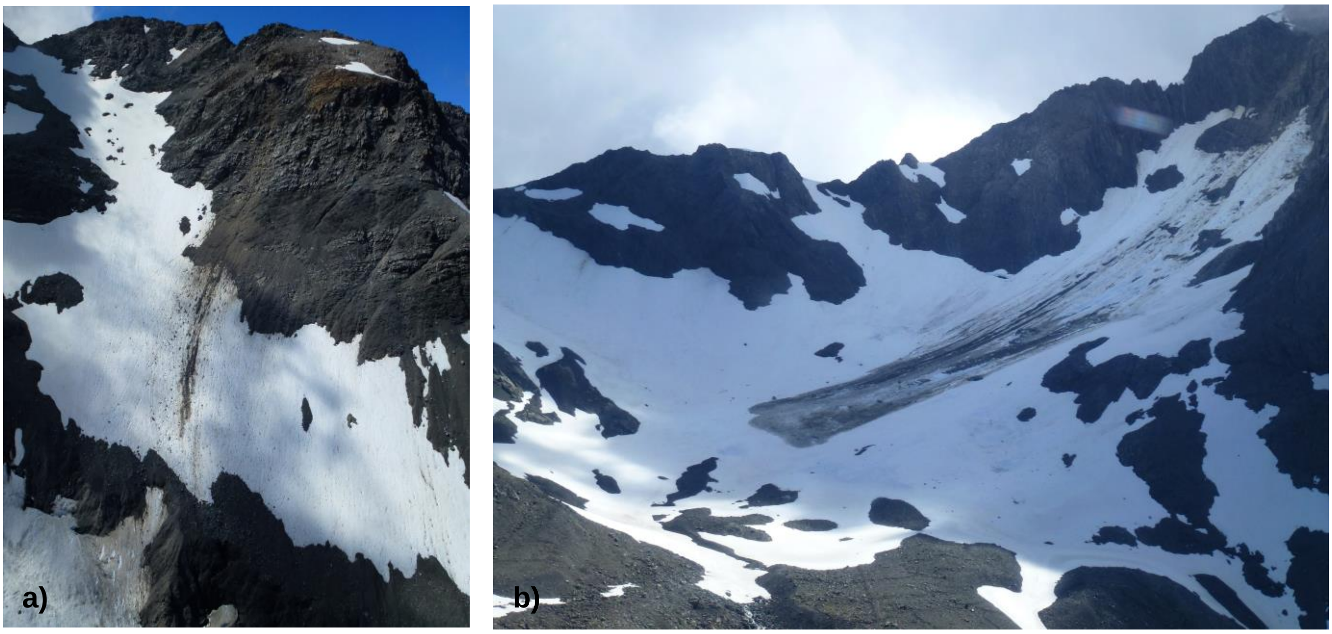

Figure 5 a) A typical rock fall failure in the Unknown Stream Tributary, b). A typical rock avalanche comprising a source area, debris track and deposition over snow in the Unknown Stream.

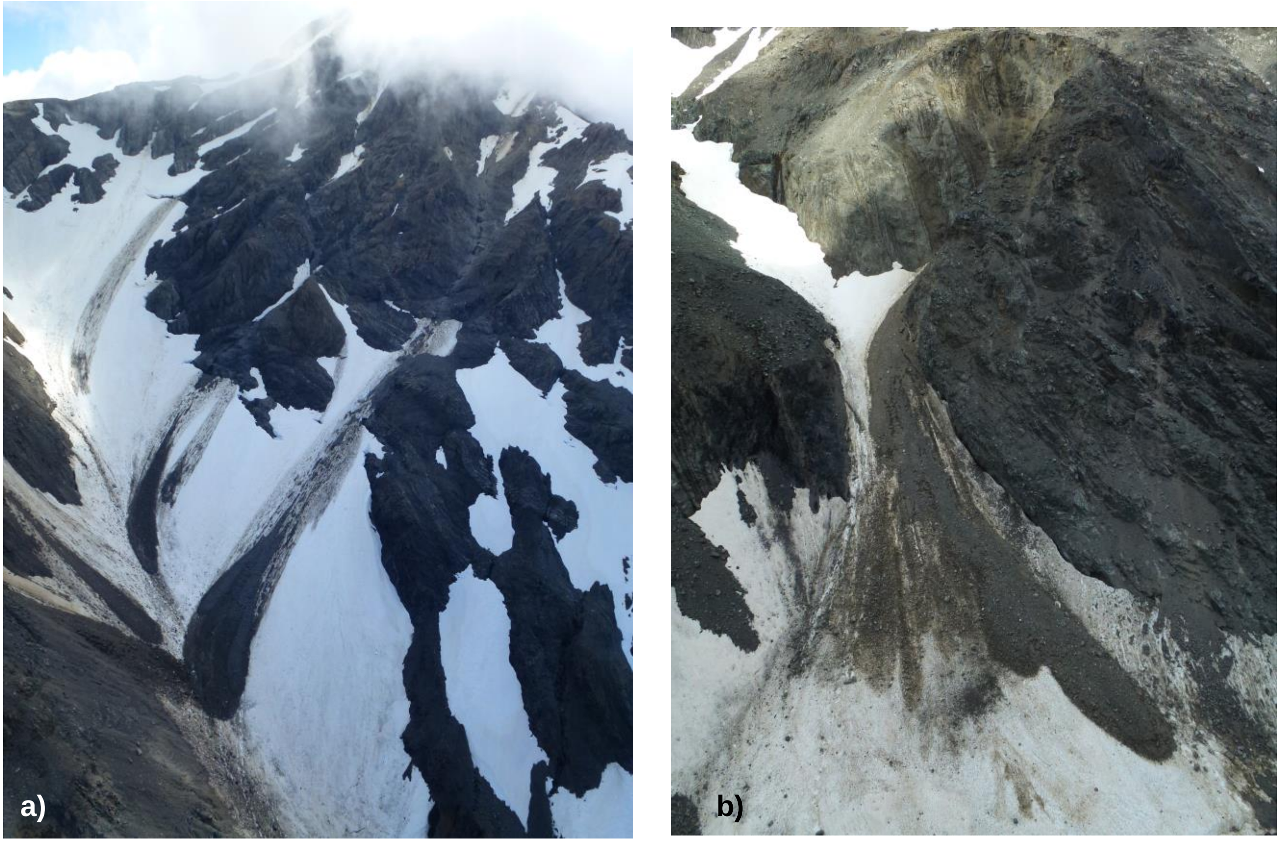

Figure 6. a) Multiple rockfalls and talus accumulation within the drainage channel. b) Rock and debris avalanche

Similar localised rock falls were observed in the eastern tributaries of the Wilberforce River (e.g. Figure 7). Whilst the failures were very similar in size, the density of failures observed appeared to be lower.

Figure 7. Local rockfall failures from the upper slopes of Burnet Stream (debris on snow cover).

One large landslide was observed on the western side of the Main Divide and was reported on the 6th January to have temporarily blocked the Arahura River, at the downstream end of Second Gorge (Figure 8). Two other smaller failures also occurred at the same site but did not affect the river. The site was included in the aerial reconnaissance and at the time of the visit was no longer blocking the river flow (it was still impeding the flow because there was a small lake formed upstream). The landslide occurred from a 60 m high hillside adjacent to the river channel composed of glacial alluvial gravels, glacial moraine deposits. The volume of the largest failure was estimated to be about 25,000 m^3.The presence of adjacent old landslide headscarps and re-vegetated scars along with undulating topography on the opposite channel bank (landslide deposits) indicate that landslides have occurred at this site before which were also likely to have blocked the river (Figure 8).

Figure 8. Large landslide triggered by the Wilberforce earthquake that temporarily blocked the Arahura River, in the lower reaches of Second Gorge (centre). The two other landslides were also triggered by the earthquake but did not affect the river. Part of a larger older failure is visible in the lower right corner and old landslide deposits on the bar opposite.

Conclusions

1) No fault rupture of the ground surface was observed as a result of this shallow (5 km) magnitude 6, earthquake.

2) The ground shaking threshold for landslide densities greater than one per km^2 in this environment appears to be 0.1g.

3) The landslide of greatest concern, which temporarily dammed the Arahura River occurred in the area of moderate shaking (3.9-9.2% g)