Geophysical survey of a terminal moraine in Fjaerland, Norway: looking for ice after a major debris flow in 2004.

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Mass movements of all kinds threaten human life, and water is often a major component, either as the trigger, or in the dynamics. The May 2004 debris flow in Fjærland, Western Norway, developed from a failure of a glacial moraine ridge, causing sudden drainage of the lake behind and possibly also a lake trapped within the Flatbre glacier. This event is a unique opportunity to learn more about such glacial hazard and an impressive example of the downstream damages such floods debris flows may generate. The total height drop of the debris flow was 1000 m, and the run-out about 3000 m. The movement ended in a fan of huge boulders, and fine material and muddy waters inundated the fields of three nearby farms, fortunately without causing any casualty. Due to the extensive collected data set, mass dynamics can now be studied, which is important for later mitigation of similar events, i.e., where a volume of water is released at high altitude, flowing towards narrow valleys filled with glacial deposits and alluvial material. But it is also important to understand why this event happened in the first place.

The moraine ridge at the Flatbre glacier is a perfectly shaped terminal moraine, which is approximately 650 m long, shaped like an arch and is about 25-50 m high. The slope is up to 33º downstream and 35º upstream. The Flatbre till deposit contains a large fraction of sand, a considerable amount of boulders due to the steep terrain, and little clay. Whether the moraine ridge is ice-cored is important in the evaluation of the dam stability. Its elevation (1000 m.a.s.l) is well below the normal permafrost limit (1450 m.a.s.l) in similar mountain ranges in Norway. But the moraine is in contact with the glacier the whole year, as well as with the icy water in the lake, so there is a good chance that the moraine is ice cored. In addition, the topography makes the moraine exposed to cold winds coming down from the largest European glacier (Josterdalsbreen). The melting of an ice core would strongly reduce the safety factor of the dam. The porosity increases, and the material gets wet and unstable. If the moraine is, or has been partly ice cored, an incipient melting process may have start internal erosion (piping), weakening it. The downstream foot of the moraine is indeed wet all year round, suggesting such piping. The lower part of the crest, where the breach was formed, could possibly be the result of such melting and internal erosion causing set-

tlement and leading to overtopping, which in turn accelerates the erosion. The failure became more severe in May 2004, probably due to a combination of a larger amount of water early in the spring (early melting) and advanced internal erosion. In order to check the internal structure of the moraine, a short geophysical campaign took place in September 2006 (3 days), consisting of resistivity, GPR and seismic measurements. All techniques worked well, providing useful information, even for the seismic expected to be the poorest method. Preliminary results will be presented. So far, there is no evidence of ice, at least at the penetrated depths (20-30 m). On the contrary, the moraine is quite wet, characterized by low resistivity in opposition to icy material closer to the glacier. The GPR detected some clear reflectors (water table?) and the seismic velocities correspond to wet moraine material. A more detailed interpretation is on-going.