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Impulse Waves Generated By Rockfalls: Run-Up Assessment Along a Lakeshore (Lake Lucerne, Central Switzerland)

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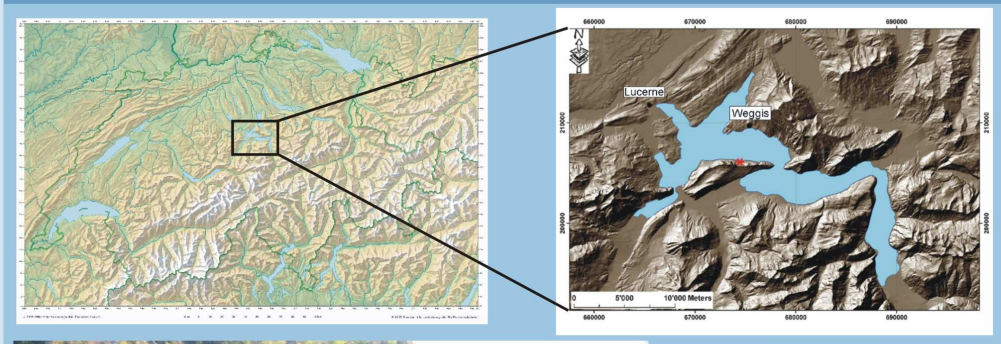
Abstract

The inoperative Obermatt quarry is an up to 160 m high rock face located directly at the lakeside of Lake Lucerne in Central Switzerland. Geologically the study site is situated in the Helvetic nappes and at its base consists of siliceous limestone (Kieselkalk Formation). The upper part of the quarry can be characterized by alternating limestone and weak marly layers (Altmann Member, Drusberg Layer).

Several major rockfall events in the past are documented causing two human casualties in the 1960's, as a consequence of the failure of rock masses in the range of approximately 70'000 m^3 and 100'000 m^3. The most recent rock falls, occurring in 2007, involved volumes in the range of 10'000 - 20'000 m^3. All events generated impulse waves with different heights in the lake, directly in the slope line of the instable rock face. In 2007, the 1-2 m high waves reached the community of Weggis at the opposite lakeside at 3.5 km distance, causing large damage to infrastructure along the entire lake shoreline.

The object of this study was to assess the structural predisposition of potential rock slope instabilities that menace to fail, plunge into the lake and induce impulse waves. The wave propagation and its variability across the lake and along the vulnerable lakeshore were studied. As a consequence from the hazard assessment several monitoring systems and structural measures in the source as well as the potentially affected areas across the lake were evaluated.

Situation / Geological settings



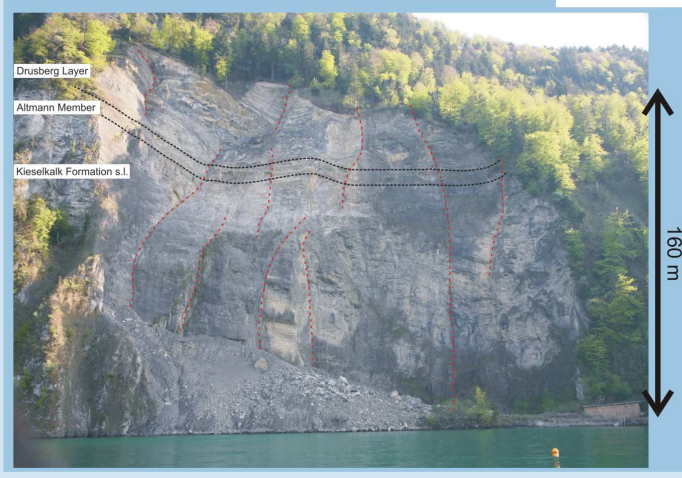


Fig. 1
View from the lake of the Obermatt quarry with the main stratigraphy and the major active tectonic faults.

1. Structural and stability analyses

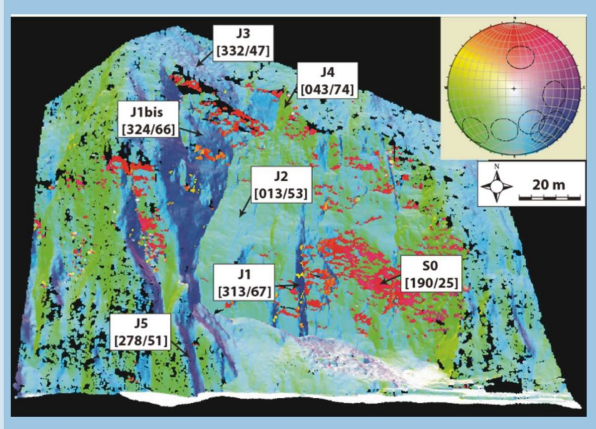


Fig. 2
Point cloud of the quarry using COLTOP-3D, based on High Resolution Digital Elevation Model (HRDEM) and field observation.

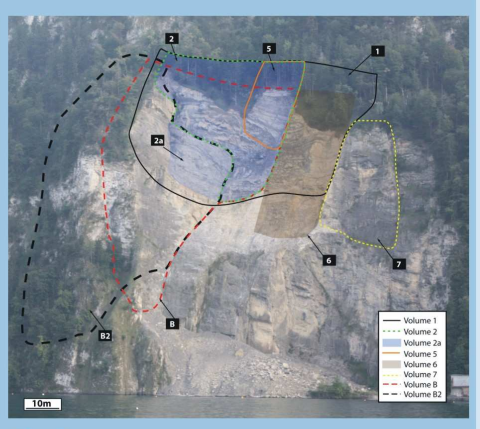


Fig. 3
Eight potentially unstable volumes were identified.

- Determination of discontinuity sets
- Identification of potential failure mechanisms
- Calculation of potential unstable volumes with Sloping Local Base Level
- Safety factor calculation of each potential unstable volume

2. Impulse waves study

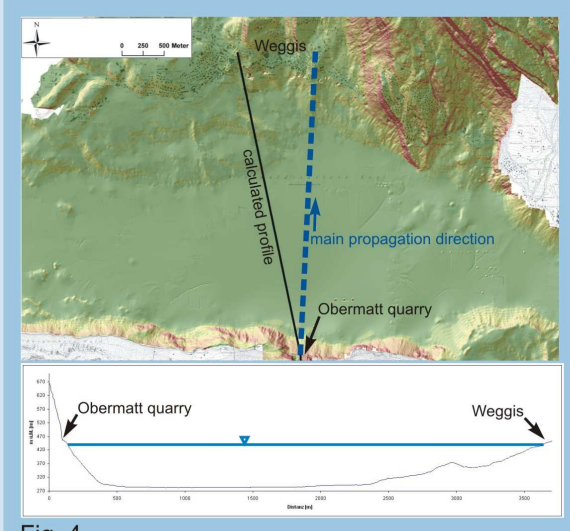


Fig. 4
Calculated profil based on bathymetry data.

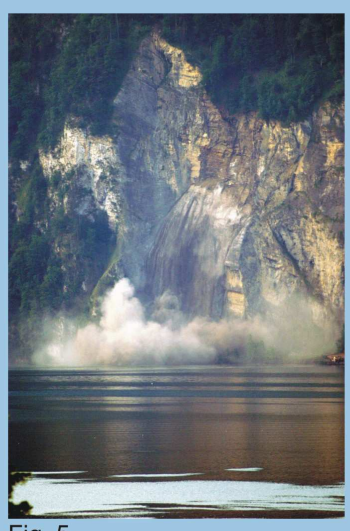


Fig. 5
Rock fall event on the 20th June 2007.

For 3 scenarios: Calculation of wave hight, wave run-up, wave overtopping

	Calculation 1	Calculation 2	Calculation 3
Bulk slide volume [m^3]	20'000	40'000	60'000
Run-up height [m]	7.6	12.4	15.2
Overtopping volume per 1m shoreline [m^3/m]	118	245	331

3. Wave run-up assessment

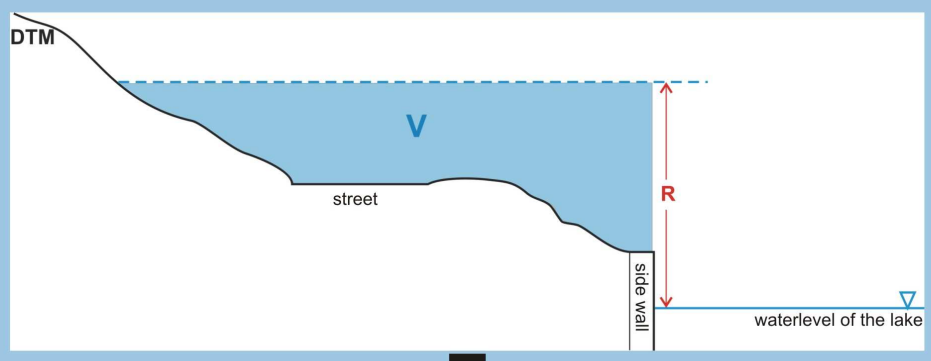


Fig. 6
Mapdetail showing the areas with a wave overtopping impact for calculation 1 and 3.

4. Suggestion of measures

Clearance of the quarry

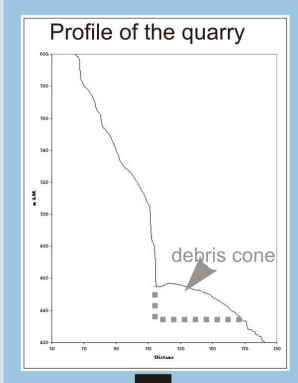


Fig. 7
Actual state of the quarry base.

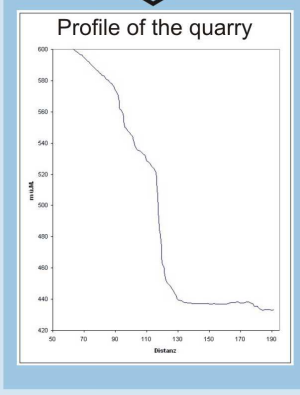


Fig. 8
Cleaned quarry base.