Subglacial bedrock topography of an active mountain glacier in a high Alpine setting – insights from high resolution 3D cosmic-muon radiography of the Eiger glacier (Bern, Central Alps, Switzerland)

David Mair[1], Akitaka Ariga[2], Tomoko Ariga[2], Alessandro Lechmann[1], Ryuichi Nishiyama[2], Paola Scampoli[2,3], Mykhailo Vladymyrov[2], Antonio Ereditato[2] and Fritz Schlunegger[1]

[1] Institute of Geological Sciences, University of Bern, Baltzerstrasse 1+3, CH-3012 Bern, Switzerland (david.mair@geo.unibe.ch), [2]Albert Einstein Center for Fundamental Physics, Laboratory for High-Energy Physics, University of Bern, Sidlerstrasse 5, CH-3012, Bern, Switzerland, [3]Dipartimento di Fisica "E. Pancini", Università di Napoli Federico II, Via Cintia, I-80126, Napoli, Italy

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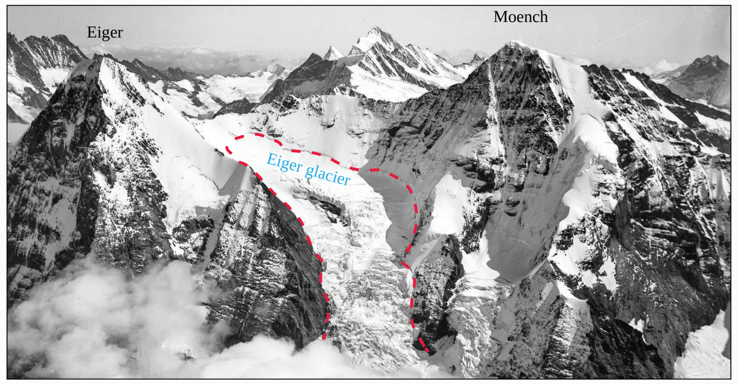
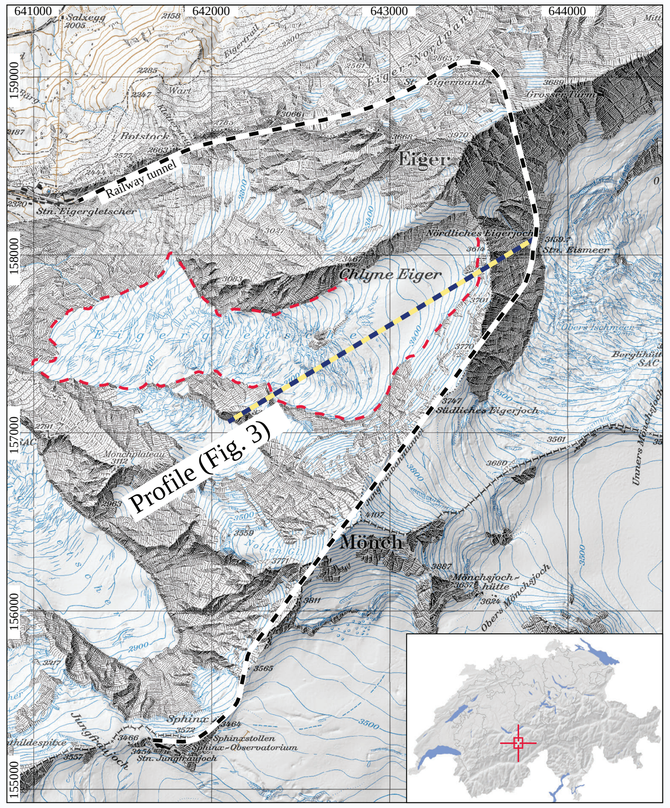
1. Overview and Motivation

The Eiger glacier, on the western flank of the Eiger (Bern, Central Swiss Alps) at 3700 m a.s.l., stretches over 2.6 km to the current elevation at 2300 m a.s.l. A concave cirque is bordered by >40° steep flanks. The middle reach hosts a bedrock ridge where glacier diffluence occurs. The lower region of the glacier is characterized by several transverse crevasses. A basal till and lateral margins border the ice flow along the lowermost reach.

While subglacial erosion in the cirque has probably been accomplished by plucking and abrasion, sub glacial melt water might have sculpted bedrock farther downslope where the ice flow is constrained by bedrock. Overdeepening of some tens of meters is expected in the upper reach of the glacier, which is quite common in cirques (Cook & Swift, 2012).

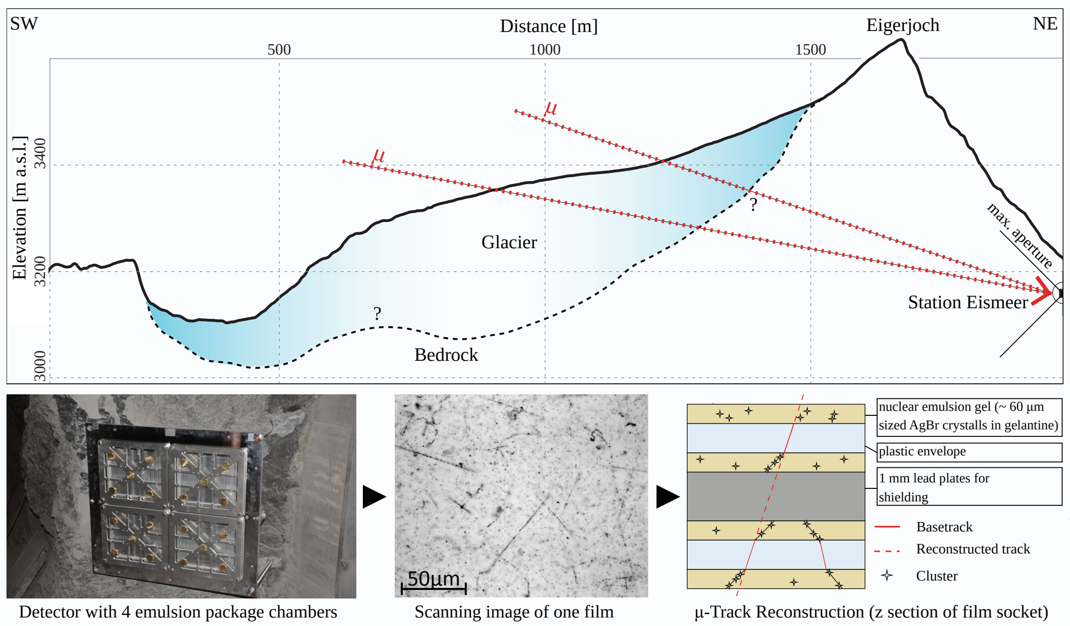


◄ Fig. 1: Aerial picture of the Eiger galcier (highlited) among the Eiger and Moench peaks.



▲ Fig. 2: Map outlining the targeted glacier on the western flank of the Eiger (Basemap: Topographic map of Switzerland 25% transparent on Hillshade on DEM with 2m resolution, © Federal Office of Topography, swisstopo, 2015).

2. Experimental Setup



▲ Fig. 3: Top: Profile through the Eiger glacier demonstrating the principle of the experiment. Bottom: Schmeatic illustration of the data accquisition.

- To test the ideas outlined in (1), we perform a muon tomography using nuclear emulsion films.
- The goal is a 3D image of the base of the glacier.
- The **Muon flux** after crossing the glacier and rock over time (~100 days) can be measured with **angular resolution** up to **~10 mrad**.
- The absorption rate of cosmic-ray muons can be used to reconstruct the base of the glacier
- The tracks are tranformed into **directional intensities** for inversion.
- For more methodological details, please refer to contributions by Nishiyama et al. (2016) and Lechmann et al. (2016).

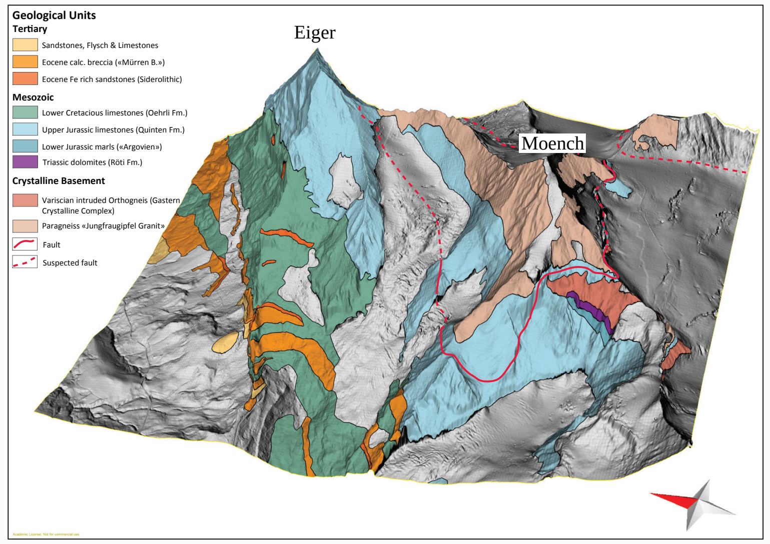
3. Geological modelling in 3D

Why?

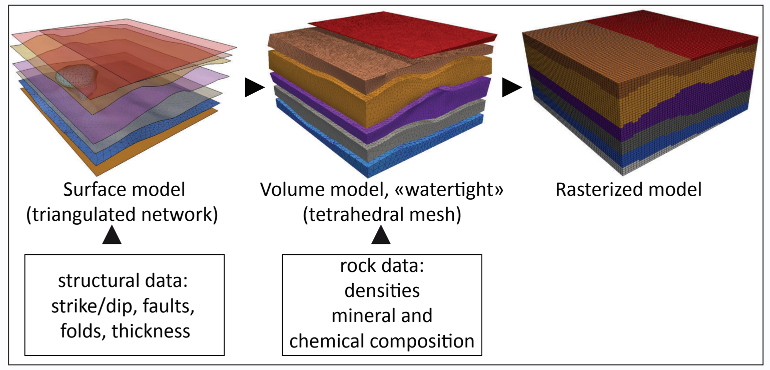
- Muon intesity is a function of energy, therefore energy loss by crossing matter is given by:

  $-\frac{dE}{d\varrho} = a(E) + b(E) * E$, where $\varrho = \int_0^L \rho(l)dl$ («opacity»[gcm^{-2}]),

  E is the Energy, *ρ* the density and *L* the length of and *l* the coordinate along the particle path. The *a* term is energy loss due to **ionisation**, while *b* is for **Bremsstrahlung**, **nuclear interactions** and **e⁻ e⁺ pair production** (Lesparre et al., 2010).
- The main energy loss (expressed by *a* and *b*) is due to the **bulk density** of the material, with an additional minor dependance on the average **‹Z/A› ratio** (Lesparre et al., 2010). This has to be accounted for in every location (K.A. Olive et al., 2015).
- Therefore a state of the art **3D geological model** of the mountain is required to account for spatial density- and composition-variations.
- An accurate «best guess» model will be used for further analyzing glacial erosion processes.



▲ Fig. 4: 3D Visualization of the simplified geological map for the study area (Basemap: DEM with 2m resolution, © Federal Office of Topography, swisstopo, 2015)



▲ Fig. 5: Proposed workflow for the desired model with necessary input with standard software illustrated by an example from Zehner et al. (2016), modified.

How?

- Geol. unit surfaces and faults built from maps, profiles and own field data is used.
- Conversion of the surface model to a **solid mesh without gaps**.
- Attributing **density** (detemined by He Pycnometry and Suspension method) and **minerological** and **chemical** data (from XRD-, XRF-analysis and Raman spectroscopy)
- Result: **3D rasterized grid** that will be used for the inversion of the muon data.

4. Conclusions and Outlook

- The result`s resolution depends on the bedrock density distribution. To avoid errors, lab data uncertainties should be **< 1%**.
- To adress this, a 3D model is required for calculate density lengths with adequately low uncertaintis.
- Data from the prototype experiment is **currently analised**, first results expected for **end of 2016**.

References

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