Quantifying post-glacial erosion at the Gorner glacier, Switzerland, using OSL and ^{10}Be surface exposure dating.

Joanne Elkadi[1*], Benjamin Lehmann[1,3], Georgina King[1], Olivia Steinemann[2], Susan Ivy-Ochs[2], Marcus Christl[2], Frédéric Herman[1]

*joanne.elkadi@unil.ch
[1]Institute of Earth Surface Dynamics, University of Lausanne, Switzerland
[2]Laboratory of Ion Beam Physics, ETH Zurich, Switzerland
[3]Centro de Estudios Avanzados en Zonas Aridas (CEAZA), ULS, Chile

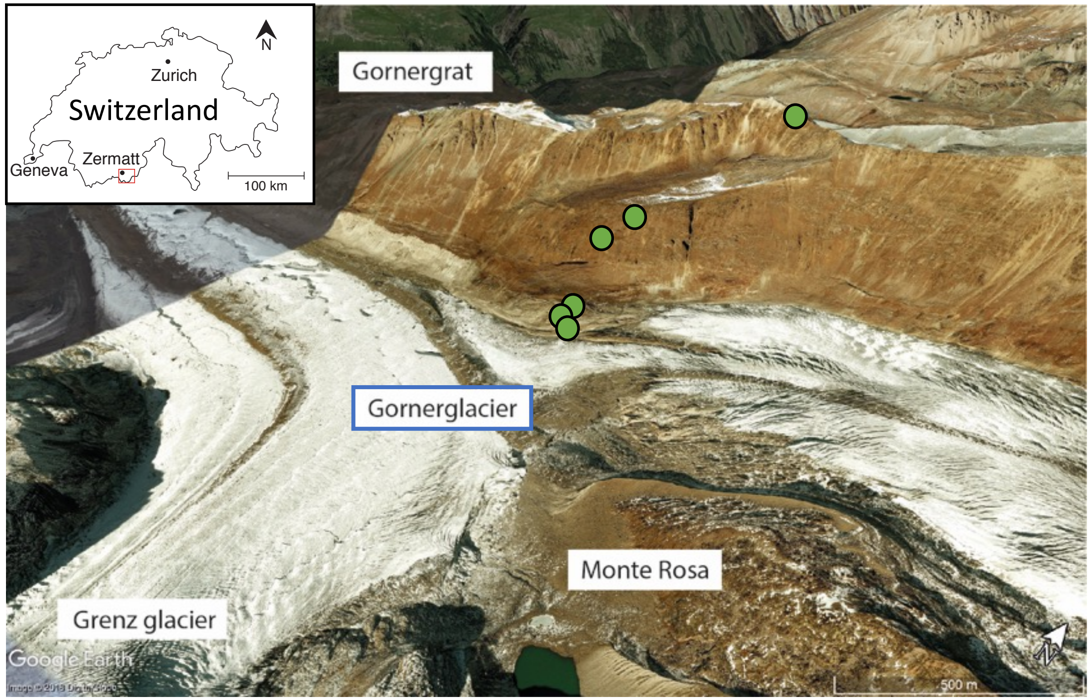
Introduction

Surface erosion contributes significantly to the long-term evolution of Alpine landscapes.

However, little is known regarding erosion rates across interglacial periods and on timescales of the order 10^1-10^4 yr.

In this study, we combine two methods of surface exposure dating to investigate bedrock erosion rates across this time period.

Study Site



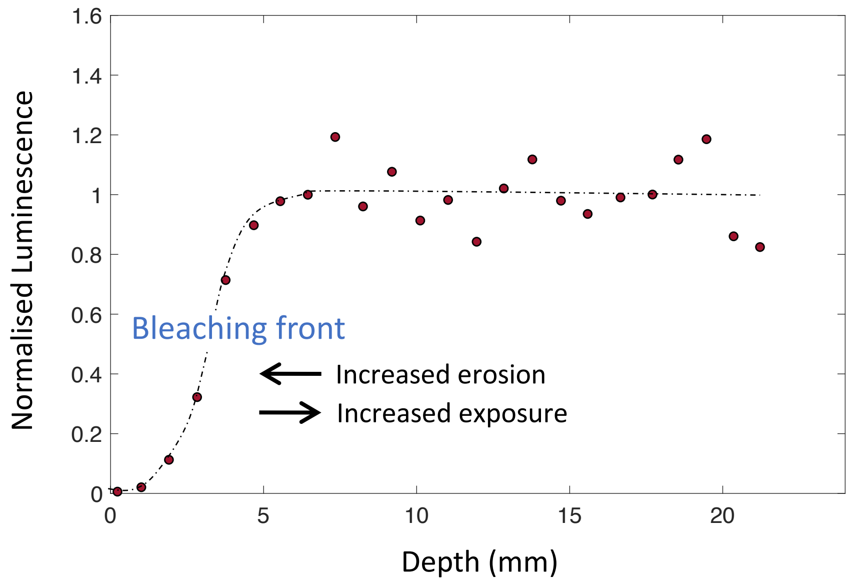
- Gorner glacier, near Zermatt, in Switzerland.
- Second largest glacial system in the European Alps.
- Collected bedrock samples from 6 sites down a vertical transect adjacent to the glacier.
- Applied two surface exposure dating methods:
  1. Beryllium-10 (^{10}Be) cosmogenic nuclide
  2. Optically Stimulated Luminescence (OSL)

Methods

OSL Surface Exposure Dating ≠ Conventional Luminescence Dating

- Not dating sediments, but rather using OSL for the exposure history of rocks.
- Still working off the principle that in a luminescence measurement, the intensity of the light measured is an indication of the population of electrons in traps.
  - In the diagram on the right, each dot represents the luminescence measured at that particular depth.
- Natural exposure to sunlight empties traps at the surface, termed "bleaching".
- Depth of bleaching is influenced by exposure and erosion.
  - For surfaces that have experienced minimal erosion, the depth of bleaching can be directly translated into an exposure age.

Example OSL surface exposure dating result



Methods

1) Constraining the OSL surface exposure dating model:

- The model used (Sohbati et al. 2011) contains two unknown parameters that define the rate at which the bleaching front propagates within the rock.

- Constraining these two parameters ($\overline{\sigma\varphi}$ and μ) is one of the biggest challenges in OSL surface exposure dating.
    - They vary greatly across different locations, minerals and lithologies.

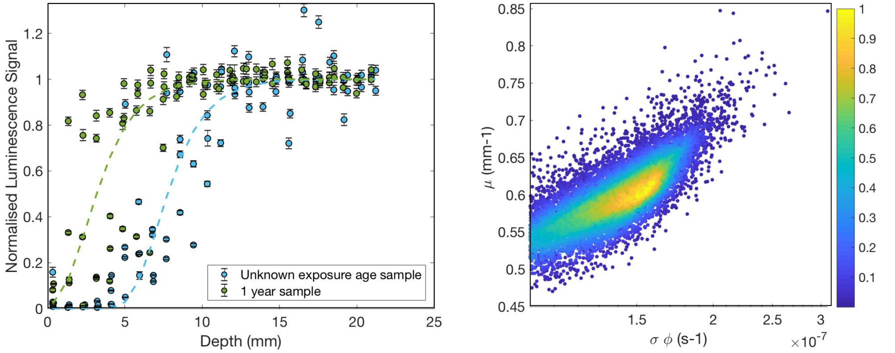
- A common method is through the calibration from a surface with an independently known exposure age.

- In this study, we exposed fresh surfaces at each site for one year.

  → The luminescence signal formed within the year of exposure were used for the calibration.

- We then solved for these parameters by testing random pairs of values, and calculating the median of those which had a high likelihood of fitting the measured data.

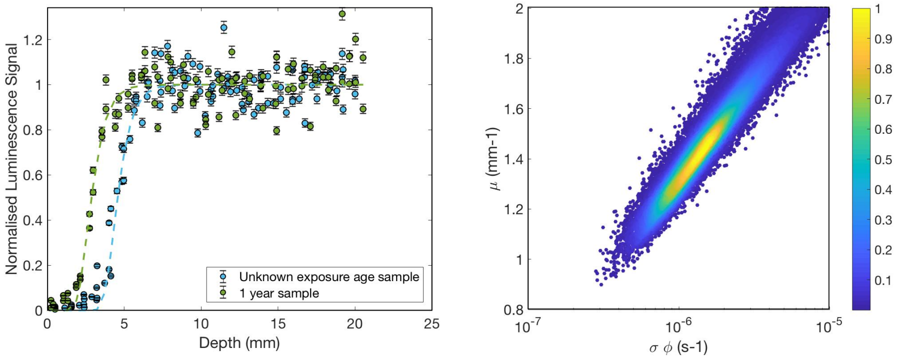
GG17-02



Lithology: Schist

$\overline{\sigma\varphi}$ = 1.38e^{-7} s^{-1}, μ =0.6 mm^{-1}

GG17-06



Lithology: Gneiss

$\overline{\sigma\varphi}$ = 1.69e^{-6} s^{-1}, μ =1.53 mm^{-1}

Methods

2) Estimating erosion rates:

- Combine two methods of surface exposure dating (following Lehmann et al., 2019).
  - Both influenced by exposure and surface erosion:

Cosmogenic nuclide dating

↑ exposure = ↑ concentration of nuclides
↑ erosion = ↓concentration of nuclides

Optically Stimulated Luminescence

↑ exposure = ↑ depth of bleaching
↑ erosion = ↓depth of bleaching

Inversion model

Assumption: erosion follows a step function.

Step 1: Generate pairs of erosion rates ($\dot{\varepsilon}$) and erosion onset times (t_s).

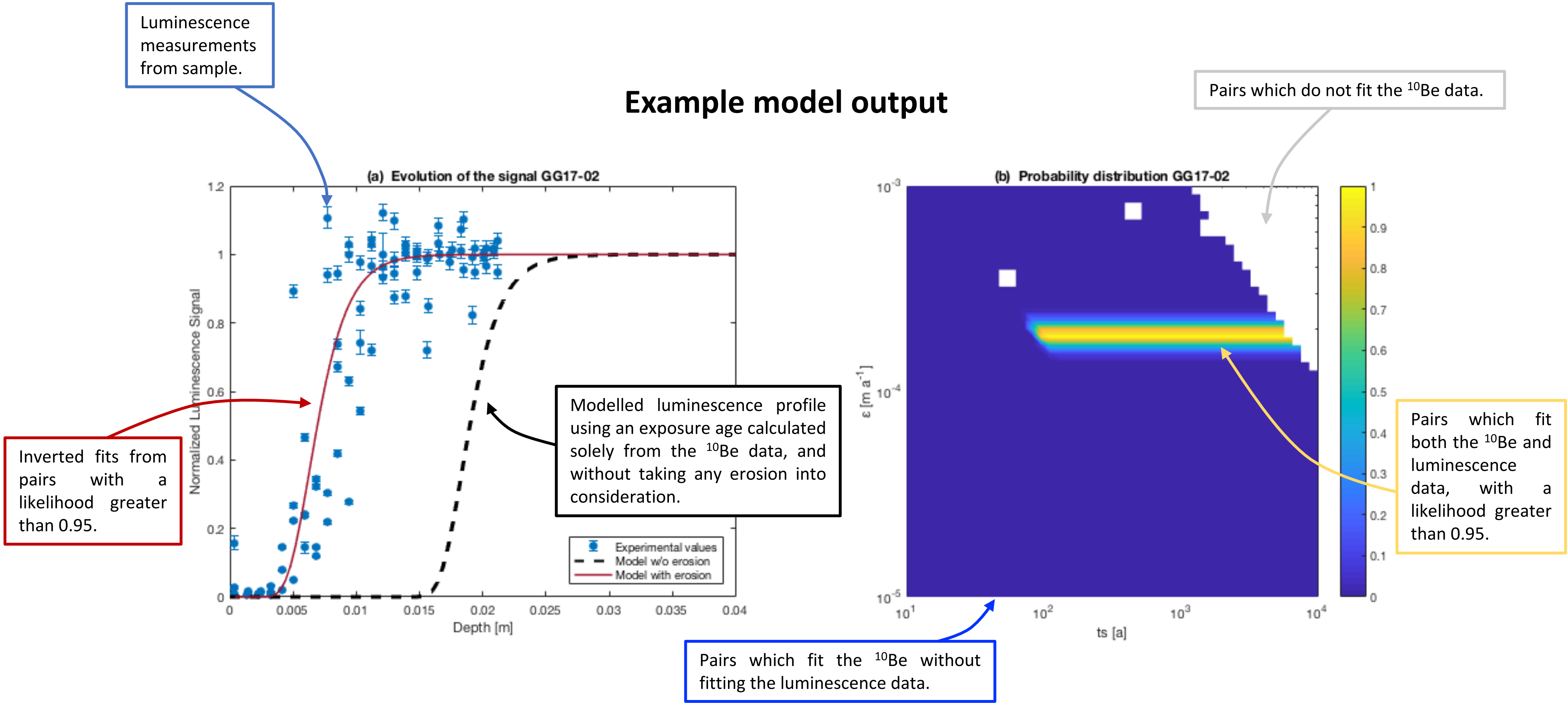
Step 2: Find which pairs are able to predict the cosmogenic nuclide data.

Step 3: Of the pairs which pass Step 2, find the pairs which are able to predict the luminescence data.

Step 4: Of the pairs which have passed both Step 2 and Step 3, find those which have a likelihood greater than 0.95.

Results

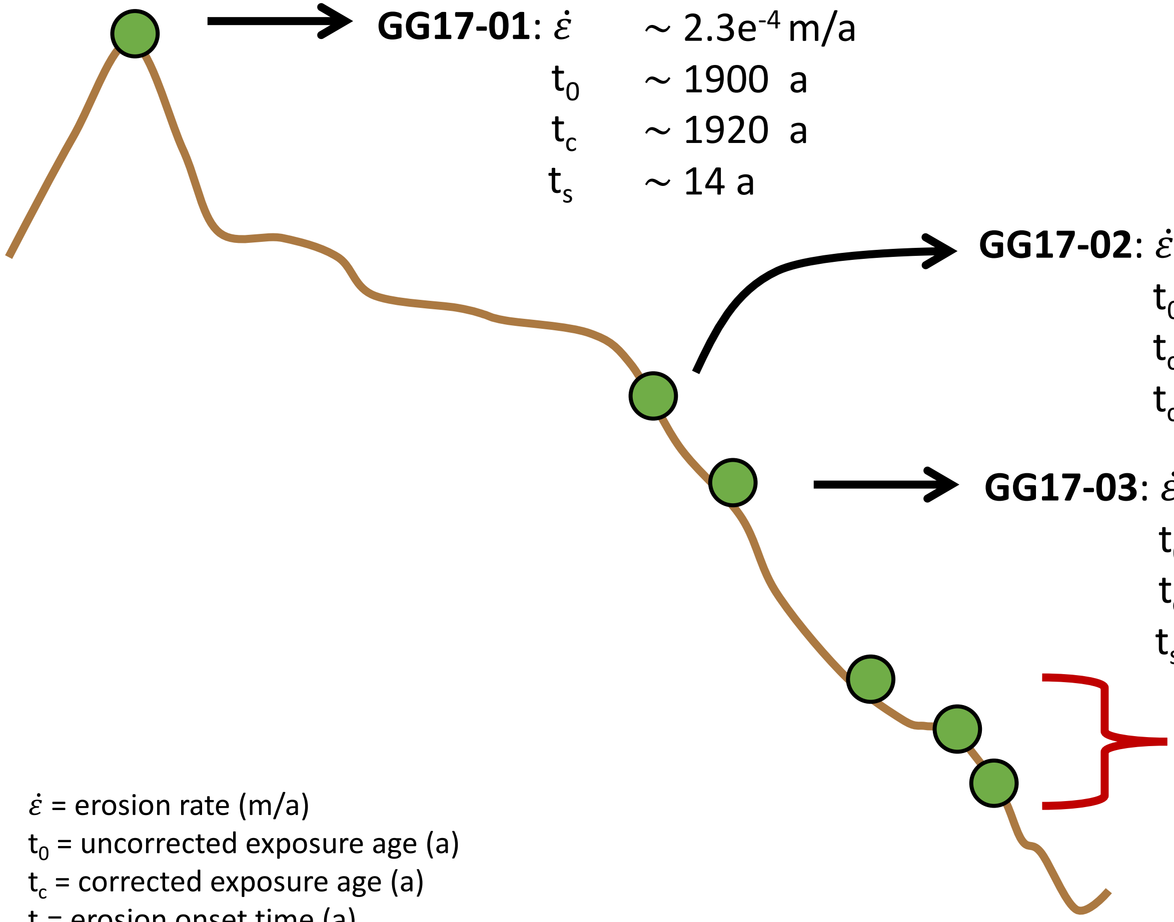
Example model output



Tested 2.5 x 10^3 pairs of $\dot{\varepsilon}$ and t_s in log space

Discussion

Schematic representation of sample sites



GG17-01: $\dot{\varepsilon}$ ~ $2.3e^{-4}$ m/a
t_0 ~ 1900 a
t_c ~ 1920 a
t_s ~ 14 a

GG17-02: $\dot{\varepsilon}$ ~ $1.8e^{-4}$ m/a
t_0 ~ 11 700 a
t_{cmin} ~ 12 100 a for t_s ~ 110 a
t_{cmax} ~ 94 000 a for t_s ~ 6500 a

GG17-03: $\dot{\varepsilon}$ ~ $1.4e^{-5}$ m/a
t_0 ~ 12 200 a
t_c ~ 12 300 a
t_s ~ 180 a

The ^{10}Be concentrations suggest inheritance.

$\dot{\varepsilon}$ = erosion rate (m/a)
t_0 = uncorrected exposure age (a)
t_c = corrected exposure age (a)
t_s= erosion onset time (a)

Conclusion

- The results thus far suggest low erosion rates, which do not significantly alter the ^{10}Be exposure age.

- The ^{10}Be concentrations for the lower three samples in the vertical transect are affected by inheritance.
  - → Old photographs and geological maps will be used to constrain the exposure ages instead.

- Once the final results for all sites have been produced, we will attempt to model the Gorner glacier's ice retreat.

Thank you for taking the time to read this under these tricky circumstances, and please feel free to get in touch should you have any questions at joanne.elkadi@unil.ch