Cross-Calibration and Sensitivity Analysis of OSL Rock Surface Exposure Dating Using Cosmogenic Nuclide Ages on an Uinta Mountains Rock Glacier (Utah, USA)

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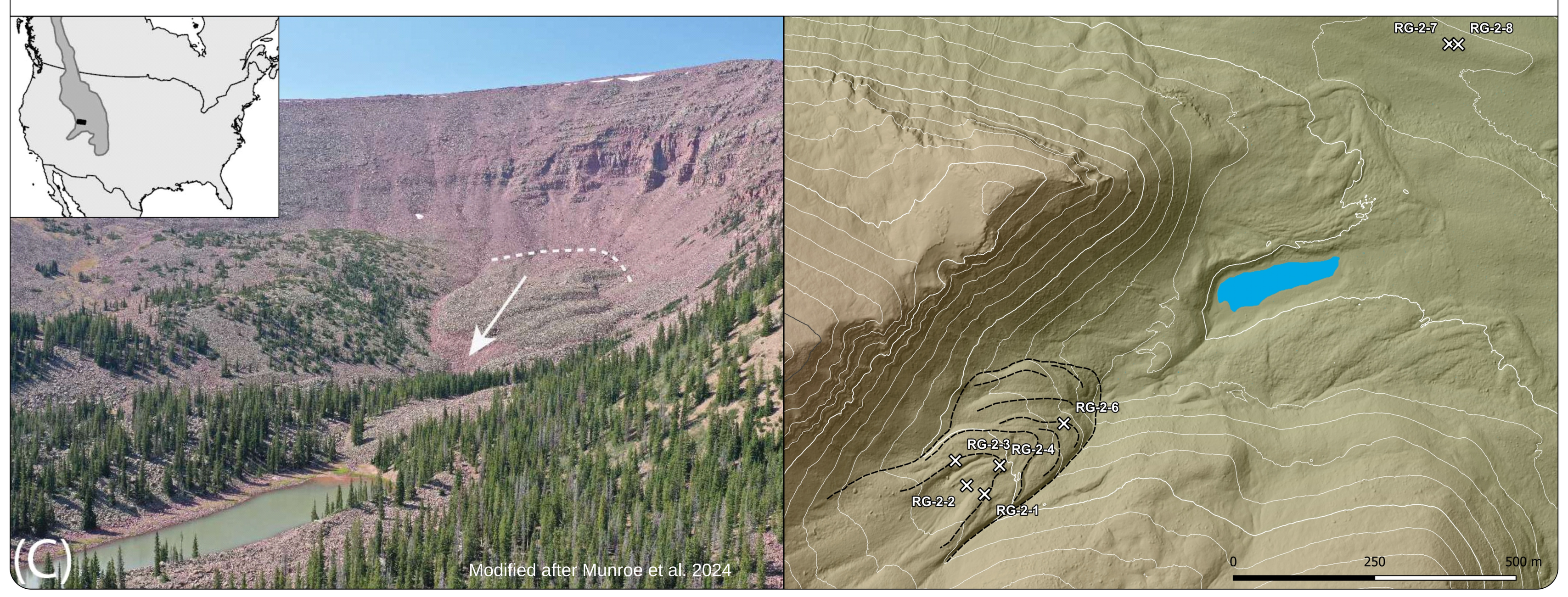
Introduction + Study Site

Rock glaciers are common permafrost features in mountain landscapes around the globe with a geohazard relevance sourcing large amounts of debris [1] while also acting as aquifers storing large amounts of water [2], yet their long-term (i.e. centennial to millennial scale) dynamics remain poorly constrained due to limited dating e orts. Short term observations, via GPS, InSAR, UAVSAR, Lidar or feature tracking, show acceleration of flow rates of rock glaciers in all mountain regions [3].

RG-2 in an active rock glacier in the Uinta Mts (NE Utah, USA, 3 300 m asl) [4-8]. Previously exposure dated boulders using cosmogenic radionuclides (CRN, ^{10}Be) [4] act as independent age control for optically stimulated luminescence rock surface exposure dating (OSL RSeD). We integrate the CRN-ages into our analyses to
(i) investigate the sensitivity of the relevant parameters in the Bleaching With Depth Model, (ii) evaluate the model's underlying assumptions, and (iii) interpret the resulting OSL ages.

Code	SampleID	^{10}Be age (a)	^{10}Be 2σ uncertainty (a)
A	RG-2-1	6780	310
B	RG-2-2	3650	190
	RG-2-2.2		
C	RG-2-3	8130	360
D	RG-2-4	6050	290
E	RG-2-5	1200	100
F	RG-2-6	10000	480
G	RG-2-7	14310	680
H	RG-2-8	14000	600
	RG-2-calB	0.91	

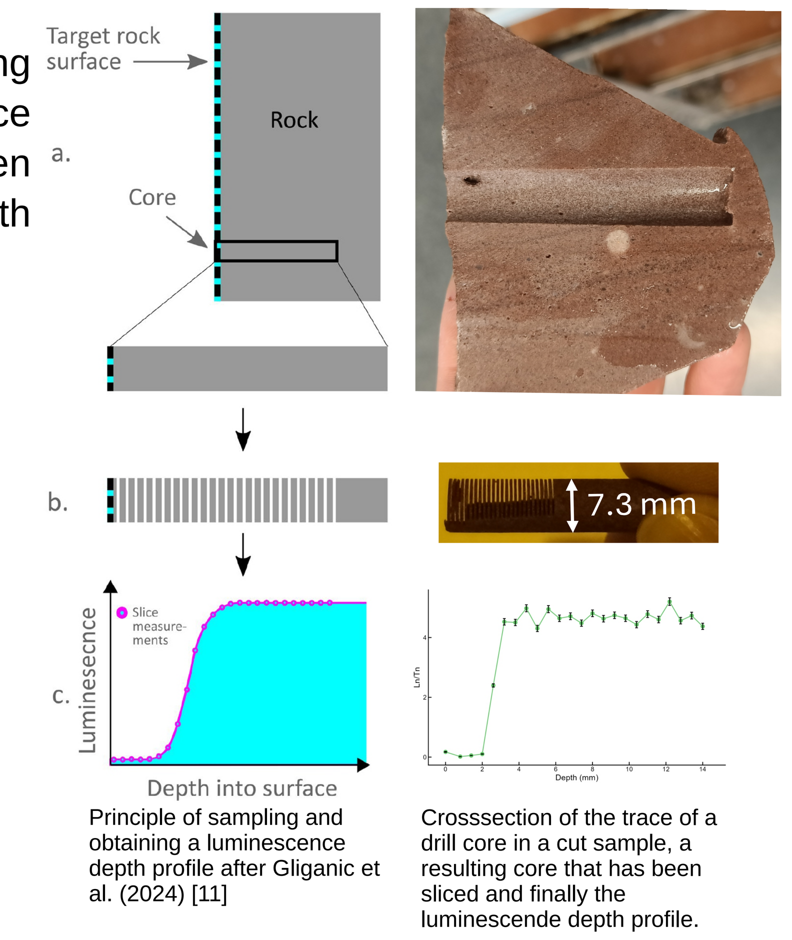


OSL Rock Surface Dating (RSeD)

OSL RSeD is novel method that is under ongoing development. It is based on the loss of luminescence signal as light penetrates the rock. It has been physically described in the Bleaching With Depth Model [9, 10] (first-order kinetics).

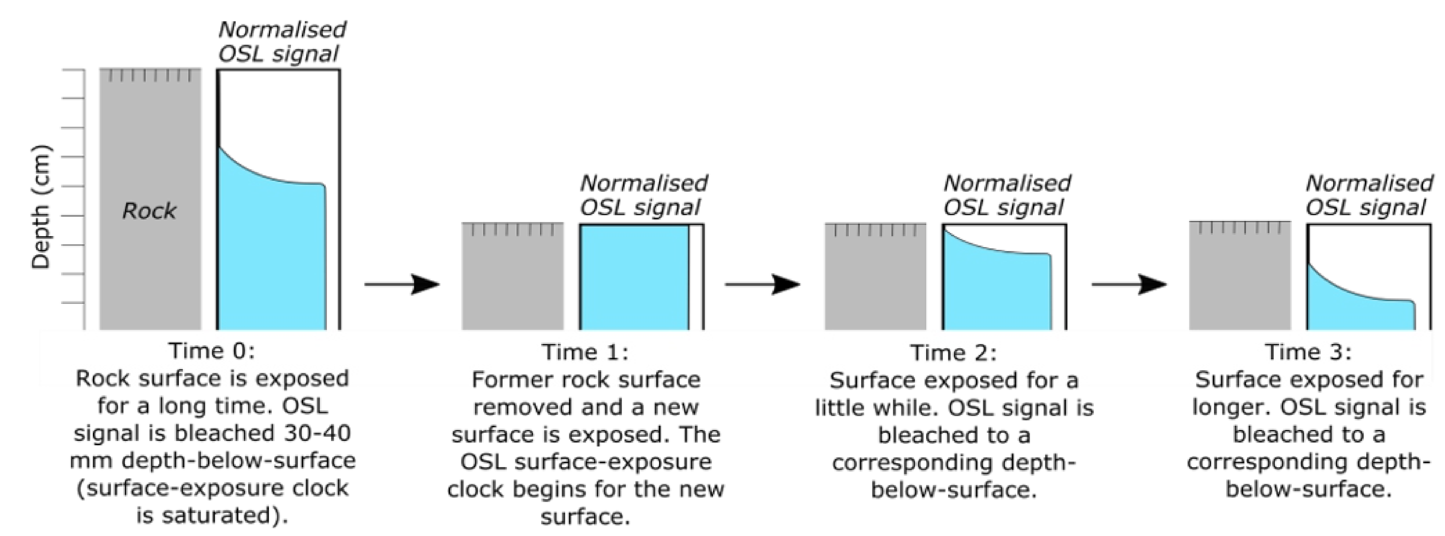
$$L = L_0 e^{-\overline{\sigma\varphi_0} t e^{-\mu x}}$$

L	[1]	Luminescence remaining at depth x
L_0	[1]	Maximum luminescence signal
σ	[cm^2]	Photoionisation cross section
φ_0	[cm^{-2} a^{-1}]	Photon flux at rock surface
$\sigma\varphi_0$	[a^{-1}]	Effective luminescence signal decay rate
t	[a]	Exposure time
μ	[mm^{-1}]	Light attenuation coefficient
x	[mm]	Depth



Principle of sampling and obtaining a luminescence depth profile after Gliganic et al. (2024) [11]

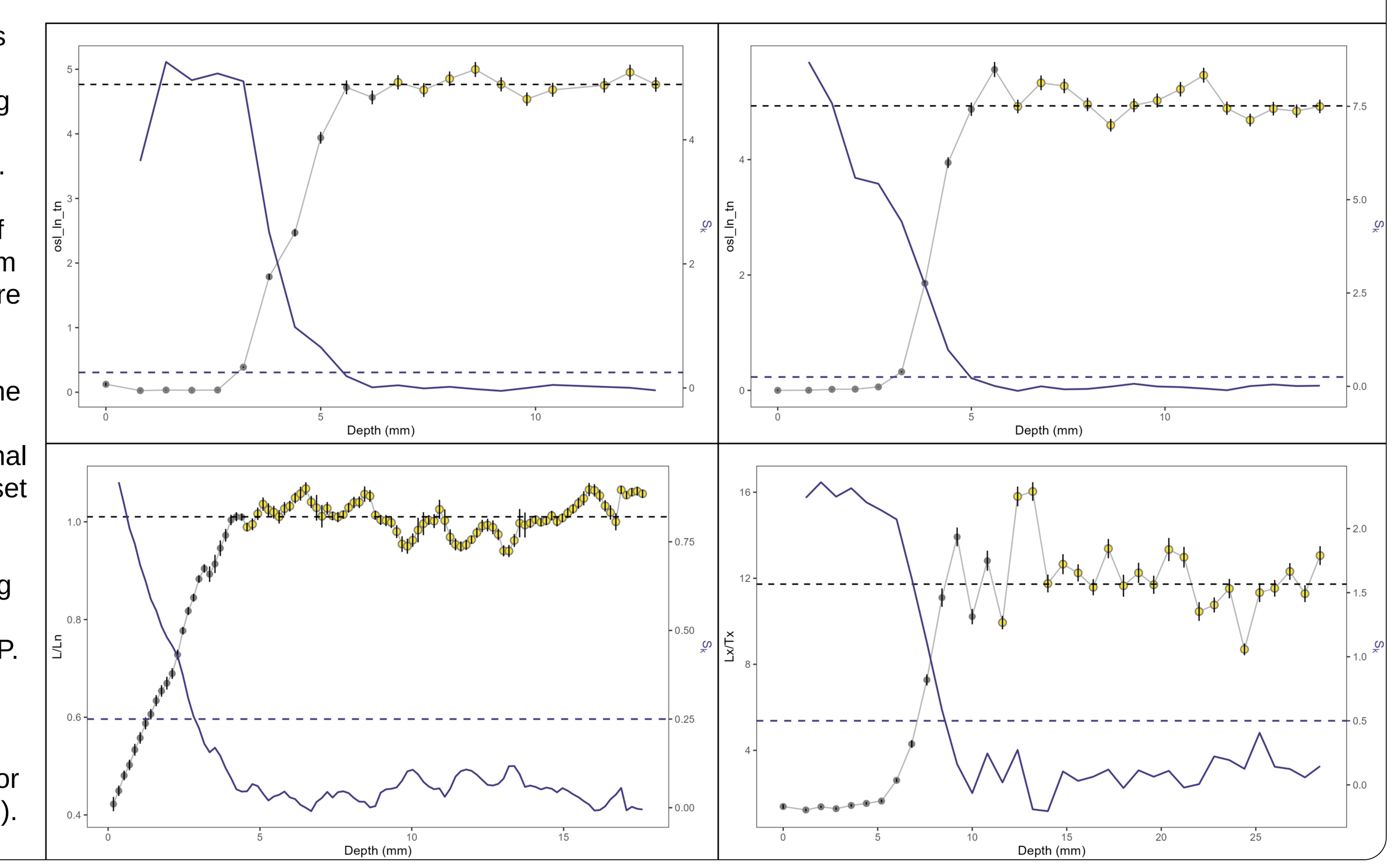
Crosssection of the trace of a drill core in a cut sample, a resulting core that has been sliced and finally the luminescende depth profile.



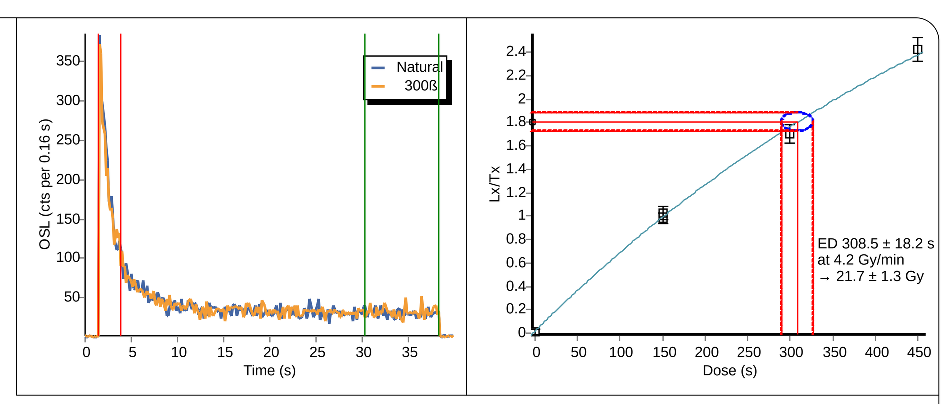
Determination and Normalisation of Saturation Plateaus

The saturation plateau of the OSL depth profile must be normalised to L = 1 for fitting to the first- or general-order kinetic RSD models (see EGU26-22933 at poster board X2.90). The determination and normalisation oh the saturation plateau is not standardised yet as a literature review showed. Therefore, we developed a plateau determination algorithm that is based on sequential analysis change point detection. We take log-ratios of adjacent datapoints and compute the cumulative sum thereof starting at the saturated luminescence signal at the greatest distance from the rock surface. When the cumulative sum exceeds a certain threshold, the median of data points along the plateau is taken as the normalisation factor (NF) and the luminescence signal normalised by dividing by NF.
The algorithm was tested on several natural datasets of the 1D coring and slicing and 2D imaging approach as well as simulated datasets. It will be o ered as a ready-to-use R tool [12].

OSL depth profiles bleached at the surface, increasing until reaching the saturation plateau. The solid blue line shows the trend of the cumulative sum and the point where it crosses the threshold (dashed blue line). Since the change in luminescence signal is gradual, the onset of plateau calculation is delayed depending on the number of datapoints per LDP. Yellow points are flagged for calculation of the normalisation factor (black dashed line).



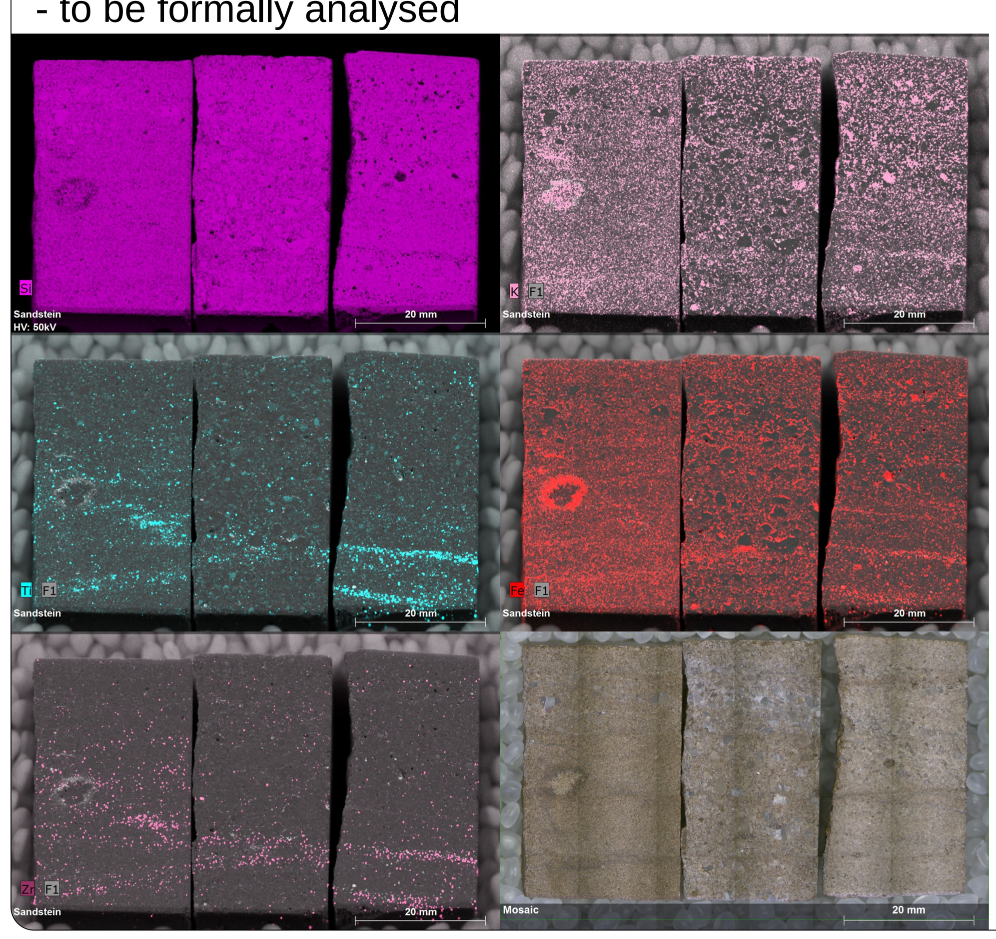
OSL + lithological characteristics of rock

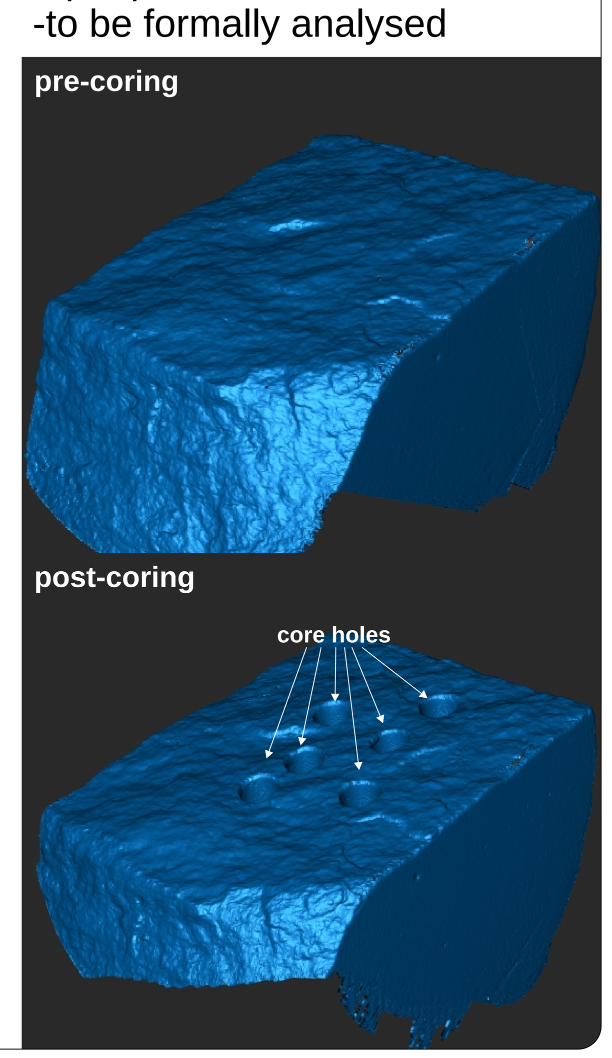


Dose Recovery Test
- Dose recovery ratio 0.83 ± 0.09 (21.7 Gy given dose)
- Recycling ratio: 1.05 ± 0.07
- Recuperation: 0.8 ± 1.0 %

3D laser surface scan
- to estimate surface roughness and depth error on cores and resulting OSL depth profiles
- to be formally analysed

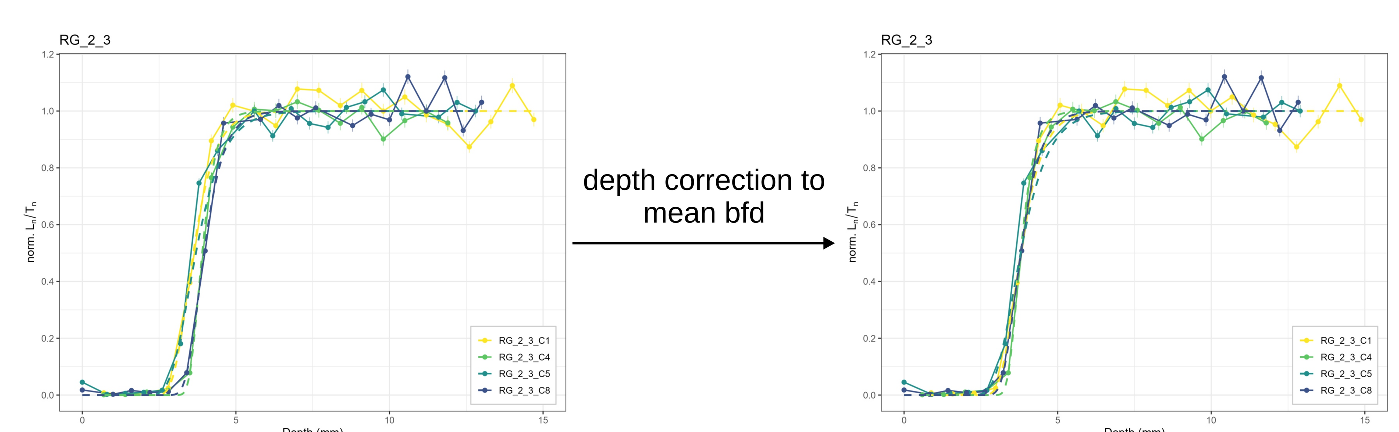
µXRF elemental mapping
- shows layers of di erent opacity → impacts light attenuation coe cient µ
- to be formally analysed





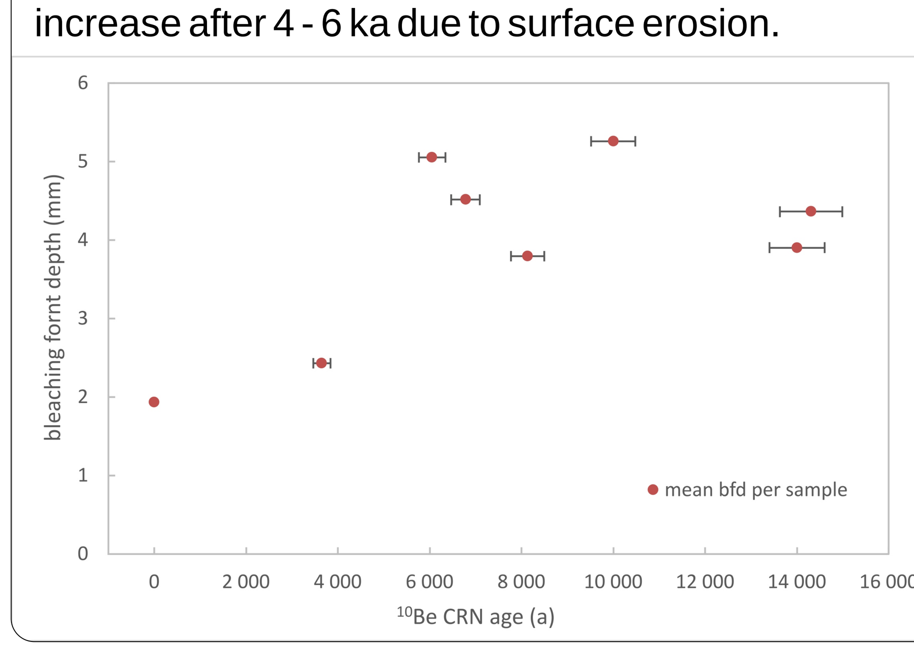
Preliminary Results

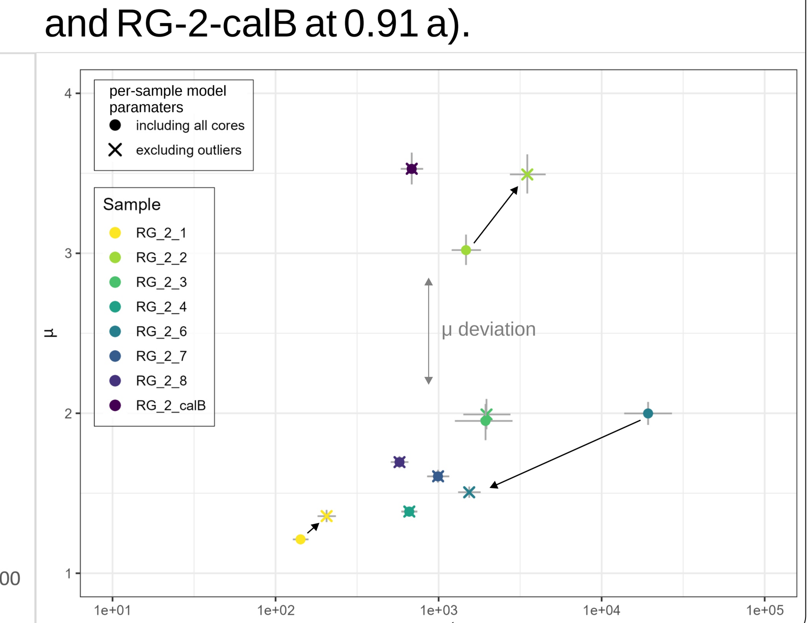
Due to surface roughness of the samples (see 3D laser surface scans), a depth correction of cores is necessary. This is done by (i) calculating the bleaching front depth (bfd) at the depth x of L=0.5 (halfway point to saturation) for each depth profile, (ii) taking the mean of several depth profiles and, (iii) shifting all depth profiles of one sample to the mean bfd.



Deviation in per-sample $\sigma\varphi_0 t$ decreases after removal of outliers. Still two populations of parameter µ persist due to di erent slope of the bleaching front (younger samples RG-2-2 at 3650 ± 190 a and RG-2-calB at 0.91 a).

Plotting the ^{10}Be CRN ages against the mean bleaching front depth of each sample, it does not increase after 4 - 6 ka due to surface erosion.





Conclusion

- RG-2 is a suitable laboratory for assessing parameter sensitivity
- We developed a standardised Saturation Plateau Determination and Normalization algorithm which is in preparation for publication
- depth correction is necessary to increase resolution of per-sample OSL depth profiles and therefore fitting precision
- Bleaching front depth levels out after a certain exposure age due to surface erosion
- Two populations in µ due to di erent slopes of bleaching front
- $\sigma\varphi_0 t$ of samples improves after excluding outliers, but deviates due to strong surface erosion

Outlook

- Investigate µ deviation via
  - Assessing sample darkness
  - Assessing petrography and texture
- Assessing surface roughness and e ect on LDP
- Assessing suitable $\sigma\varphi_0$ and µ for erosion rate calculation
- Obtain **average Holocene erosion rate** for climate setting and lithology of the Uinta Mts

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