Fracture Dynamics In An Unstable, Deglaciating Headwall, Kitzsteinhorn, Austria

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Aim

Processes destabilising recently deglaciated rockwalls, driving cirque headwall retreat, and putting high alpine infrastructure at risk are poorly understood due to a lack of in situ monitoring data.

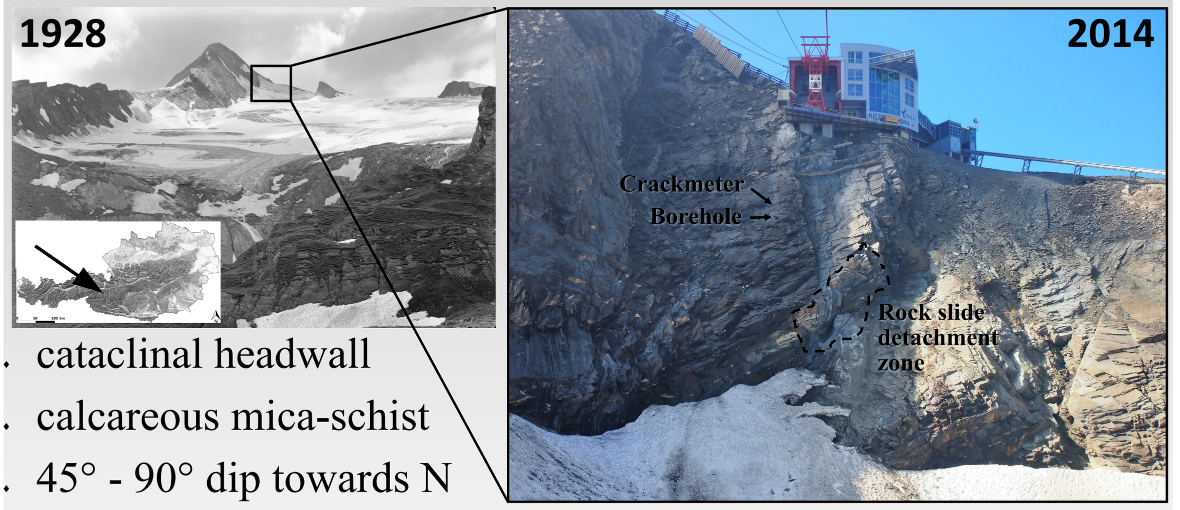
Here we present quantitative data from an unstable, recently deglaciated cirque headwall at the north face of the Kitzsteinhorn (3203 m a.s.l.). Based on 2.5 years of monitoring fracture dynamics, this study aims to **decipher and quantify stability-relevant processes and their temporal occurrence**, and addresses the following research questions:

(i) Are fracture dynamics dominated by **thermo-mechanical expansion/contraction** of the inter-cleft rock mass?

(ii) Do **cryogenic processes**, i.e. freeze-thaw dynamics and ice segregation, affect fracture opening/closing?

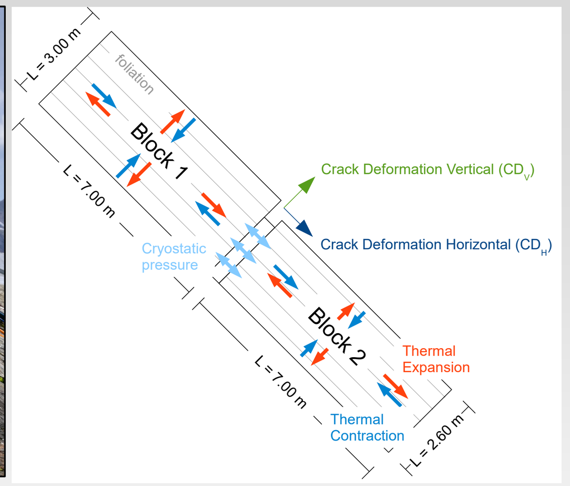
(iii) Can **irreversible crack deformation** patterns and destabilisation be observed?

Study Site



- cataclinal headwall
- calcareous mica-schist
- 45° - 90° dip towards N
- glaciated until the 1980´s
- since then, numerous **rockfalls** as well as a 500 m³ **rock slide** occured, **predominantly in the most recently deglaciated sections**

Methods



Crackmeter measurements

Geokon Model 4420 Vibrating Wire Crackmeters measure horizontal (CD_H) and vertical crack deformation (CD_V) as well as crack top temperature (CTT).

Thermo-mechanical deformation modelling

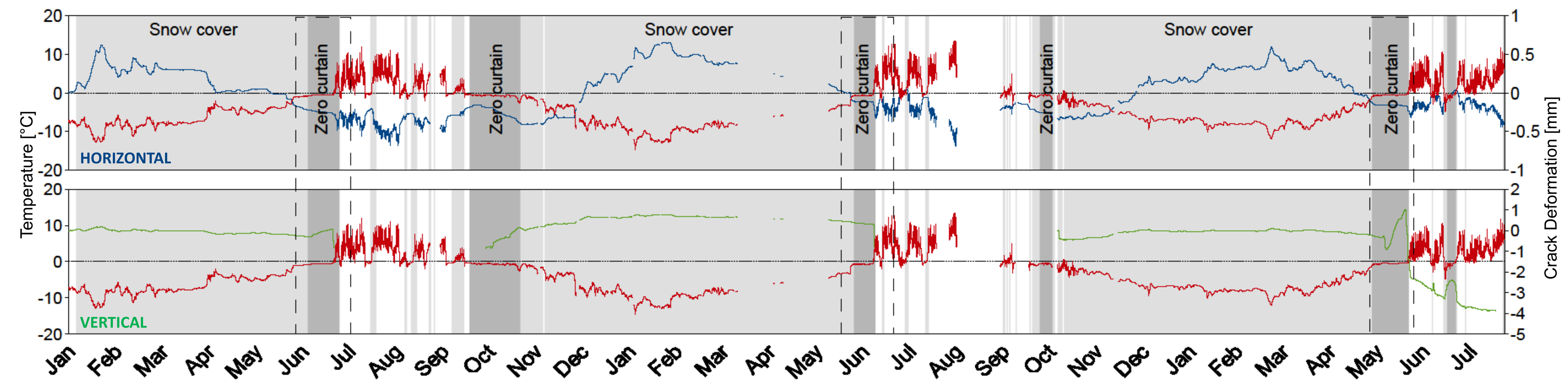
$$\alpha_H = -\Delta CD_H / 2L\, \Delta CTT$$

$$\alpha_V = -\Delta CD_V / L\, \Delta CTT$$

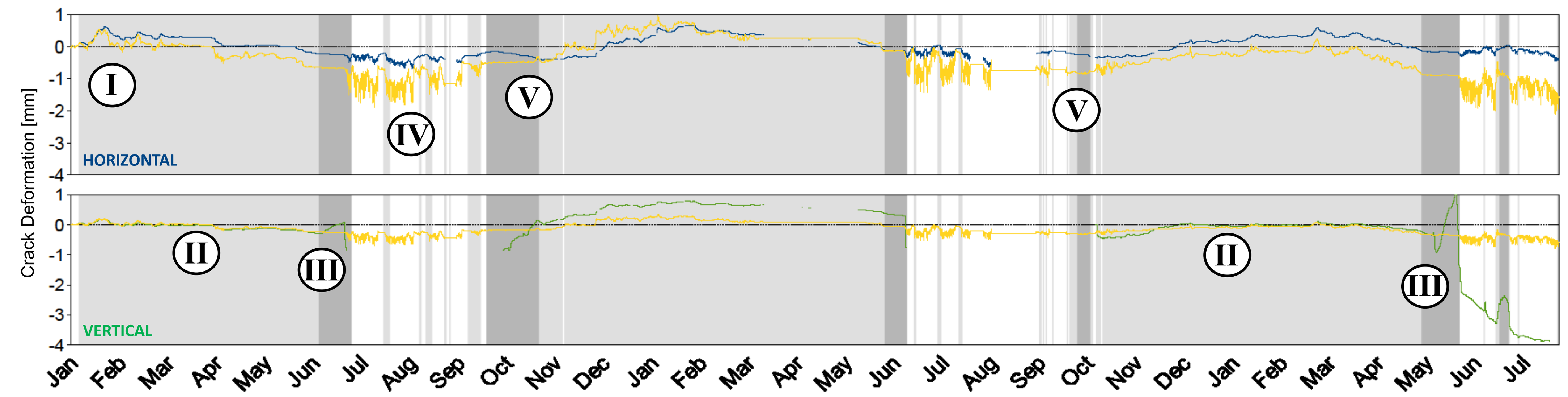
[1,2]

Results & Interpretation

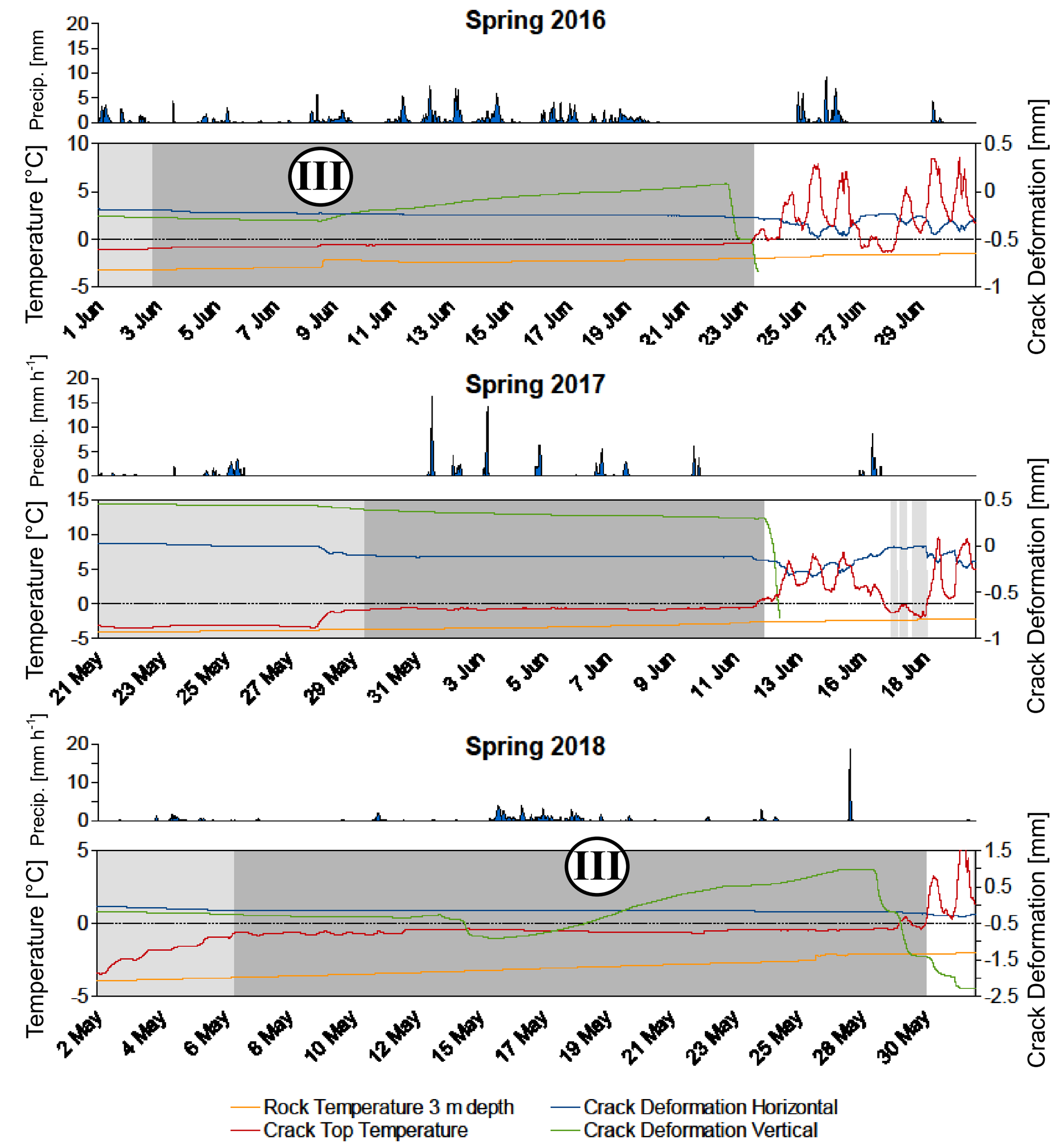
Crack deformation regime

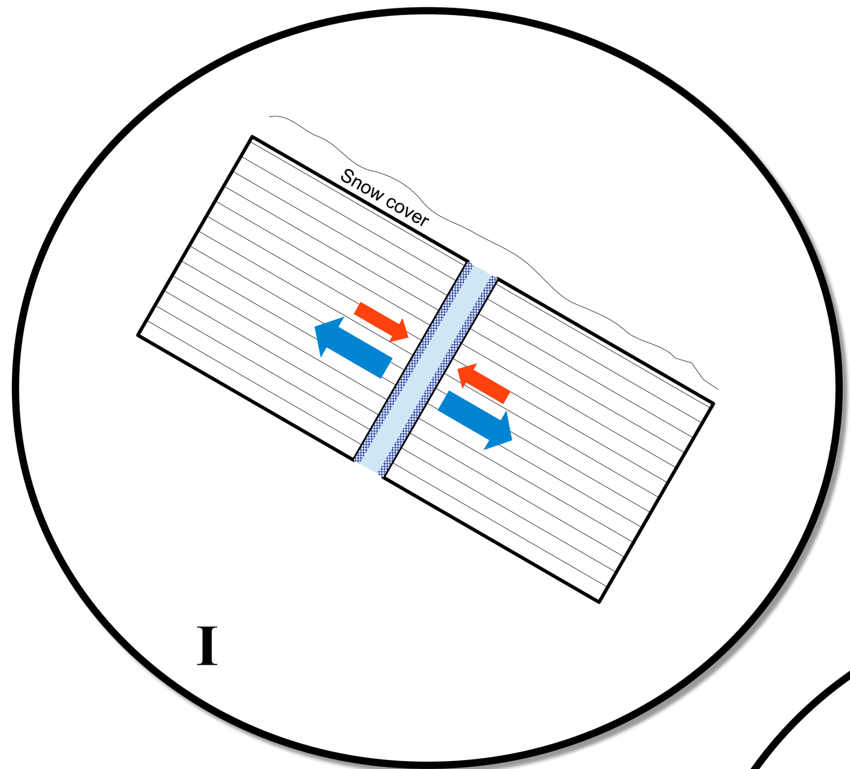


Measured vs modelled, thermo-mechanical deformation



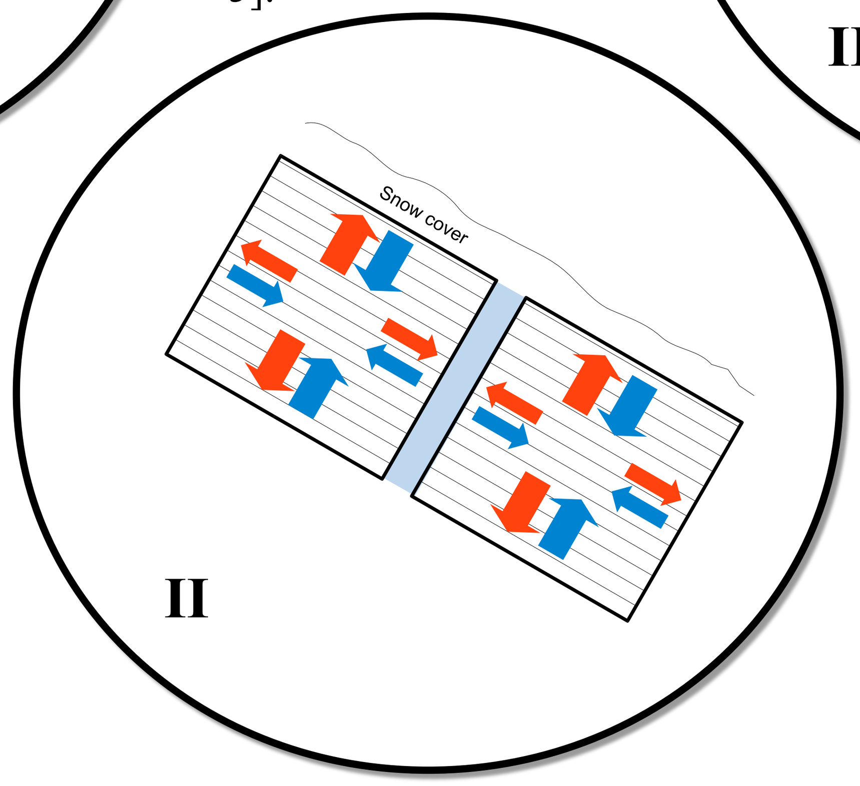
Spring deformation events





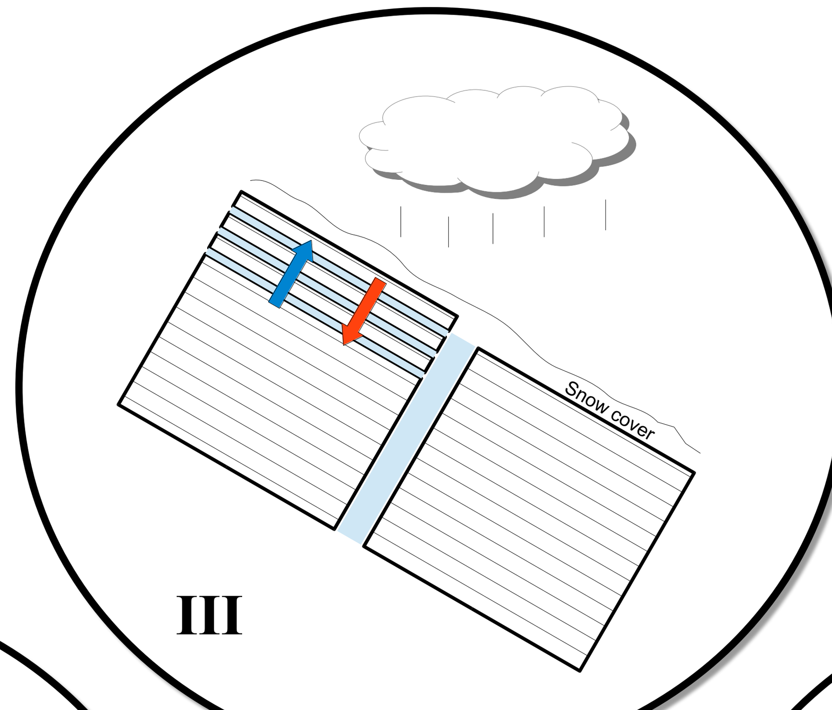
I:

Maximum fracture opening due to thermal contraction of the inter-cleft rock mass providing space for segregation ice growth, which in turn impedes fracture closing.



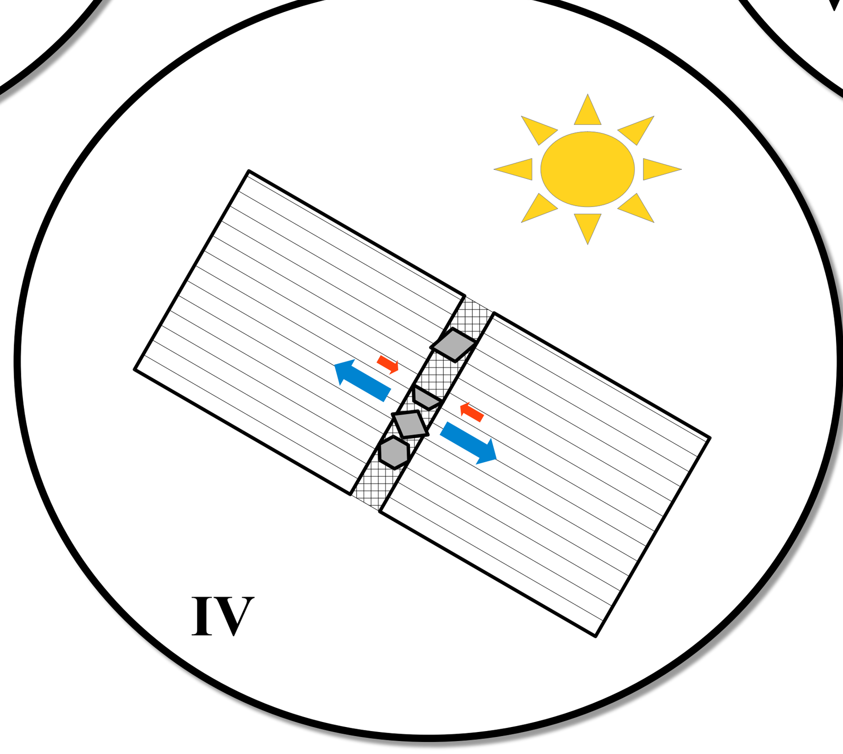
II:

During snow-covered periods, deformations are controlled by thermal expansion and contraction of the inter-cleft rock mass [3, 4, 5].



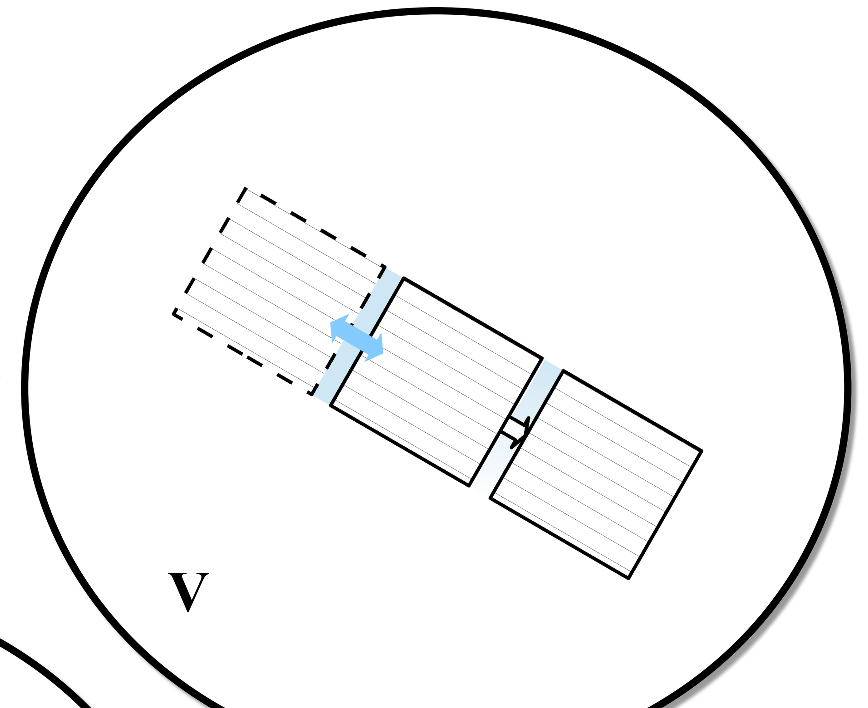
III:

Transient expansion of the upper block due to refreezing meltwater in the foliation-parallel fissures. As soon as snow cover disappears, melting leads to rapid contraction [3, 6]



IV:

Maximum fracture closing during snow-free periods might be impeded e. g. due to wedged rock fragments [1].



V:

Fracture closing instead of an expected, cryogenic opening during autumn zero curtain periods might be caused by the dominance of adjacent fracture dynamics.

Thus monitoring of a whole joint set may highlight the importance of the effects of compound fracture deformation.

Conclusions

(i) Fracture dynamics are **dominated by thermo-mechanical expansion and contraction** of the inter-cleft rock mass during snow-covered and snow-free periods. Thermal expansion coefficients of 7 x 10^{-6} °C^{-1} along and 14 x 10^{-6} °C^{-1} perpendicular to foliation highlight strong **anisotropy** of the calcareous mica-schist.

(ii) Significant **deviations** from the thermo-mechanical deformation regime occur mainly during spring and autumn **zero curtain periods** due to **freeze-thaw action**. Lower magnitude deviations arise in autumn and early winter probably due to **segregation ice growth**. Besides cryogenic processes, other mechanisms may affect fracture dynamics such as wedged rock fragments impeding maximum fracture-closing during snow-free periods.

(iii) Irreversible fracture opening as precursor of high magnitude rock slope instability was not observed. Instead, enhanced cryogenic deformation in spring and autumn may lead to **shallow, lower magnitude rock detachments**.

Our results highlight the importance of **liquid water intake** in combination with **subzero-temperatures** on the destabilisation of glacier headwalls. Randkluft systems may favour intense frost action and ice segregation, serving as important preparatory factors of paraglacial rock slope instability.

References

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