Effects of mica-rich rocks on the failure criterion of ice-filled permafrost rock joints

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Background

Rock slope failures in high mountains poses great hazards to human lives, buildings and infrastructure directly or indirectly by secondary geohazards i.e., flooding or debris flows[1,2]. The added strength of ice in permafrost rocks allow steeper slopes than similar ice-free rock slopes. During thawing, the strength of permafrost rock joints decreases, causing destabilization and potentially large rock slope failures[3,4].

Aim

The cohesion of the rock volume in three localities in Europe with high rock fall hazard, Ramnanosi and Nordnesfjellet in Norway and Matterhorn in Switzerland, is partly controlled by the presence of ice in rock joints.

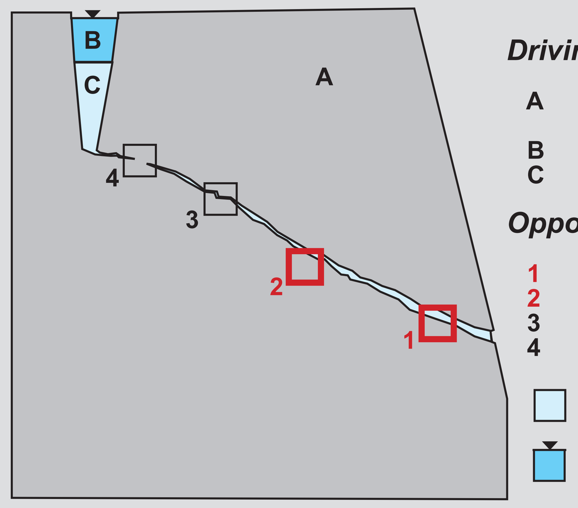


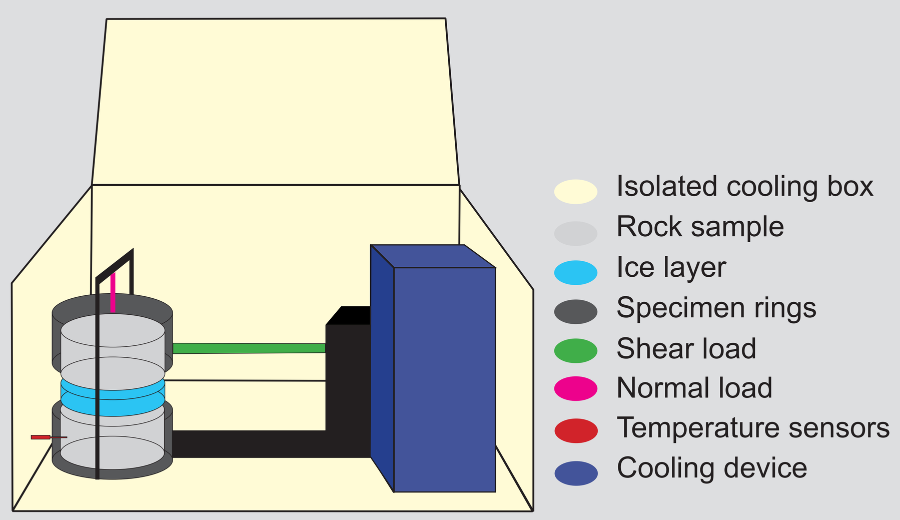
Figure based on Krautblatter et.al (2013)[5].

The aim of this study is to:

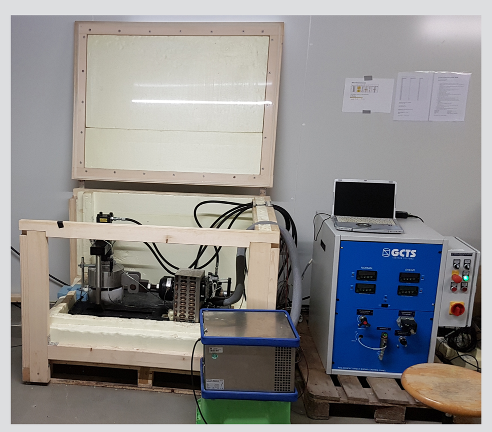
- Test validity of the permafrost failure criterion presented in Mamot et al., 2018 for mica-rich rocks

Methods

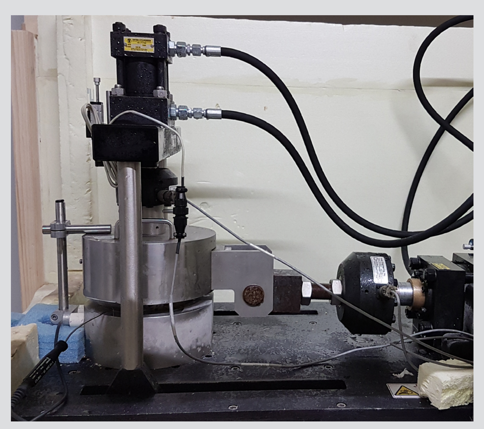
The samples sliding surface were ground with a grinding powder to ensure reproducibility of the initial roughness. A direct shear machine, developed at Technical University of Munich, was used to conduct 36 tests on rock-ice-rock sandwich samples. A mean shear strain rate of $9.16 \pm 5.9 \times 10^{-4}$ s^{-1} was applied, while a constant normal stress equivalent to 4 or 15 meter overburden was maintained. The temperature was constant and controlled at -10°C, -6°C and -2°C.



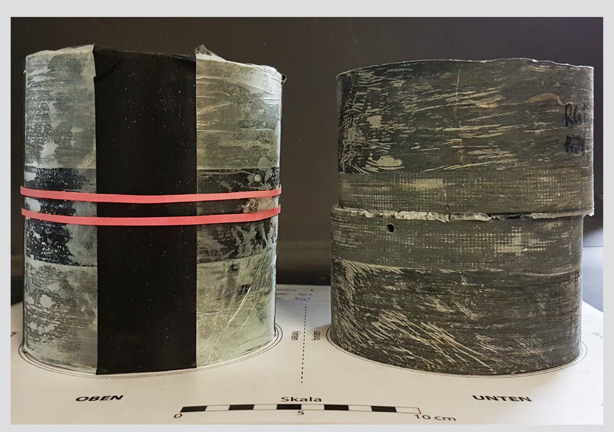
Schematic shear machine setup.



Shear machine setup.



Shear cylinders enclosing a sandwich sample.



Prepared and sheared sandwich sample.

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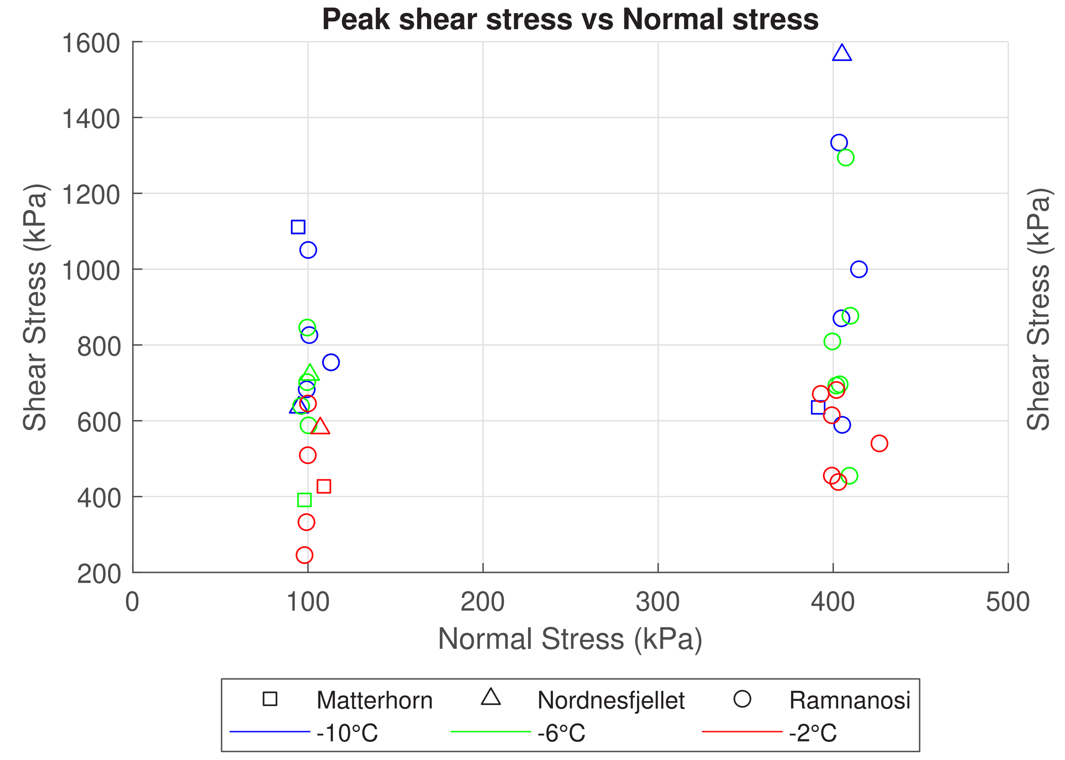
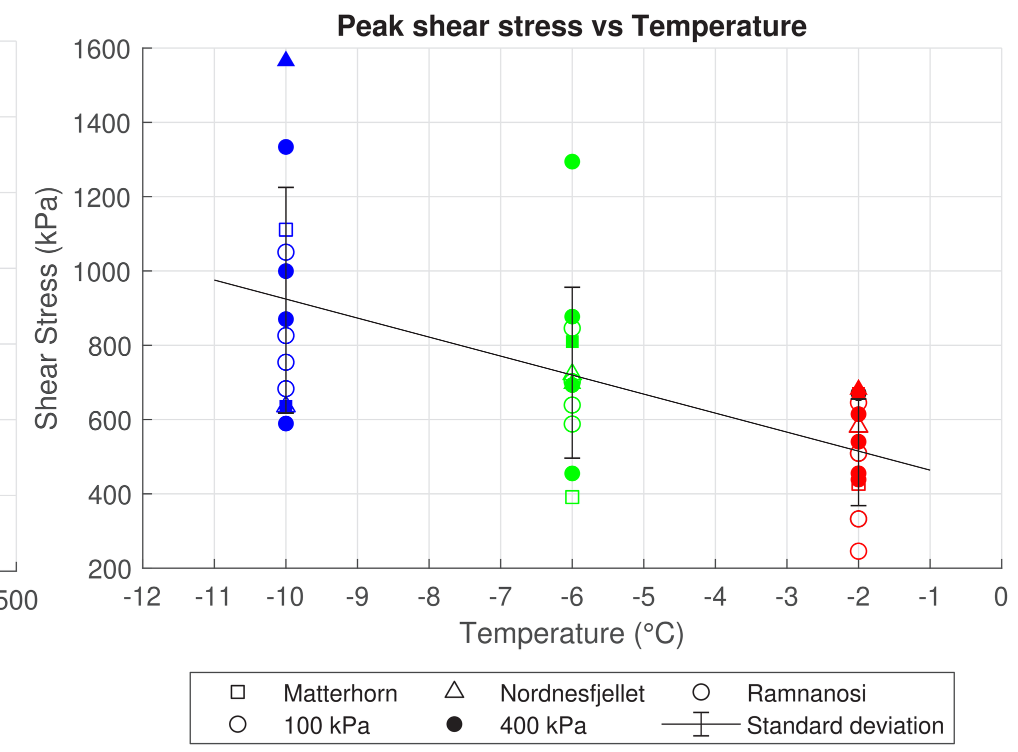
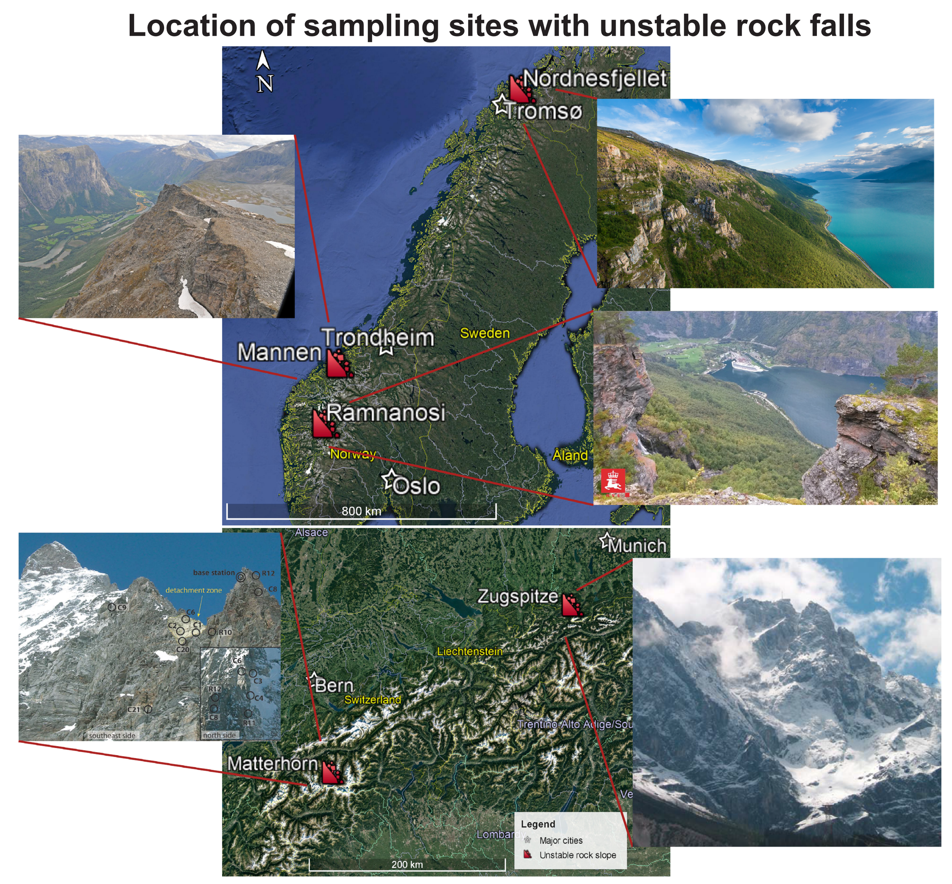
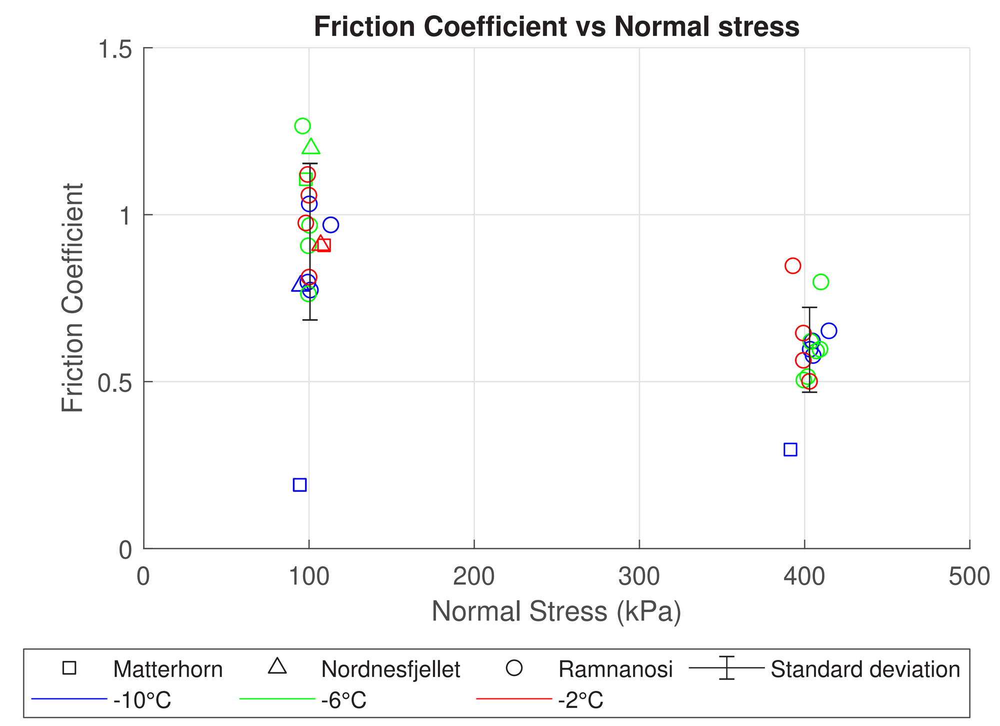
Results

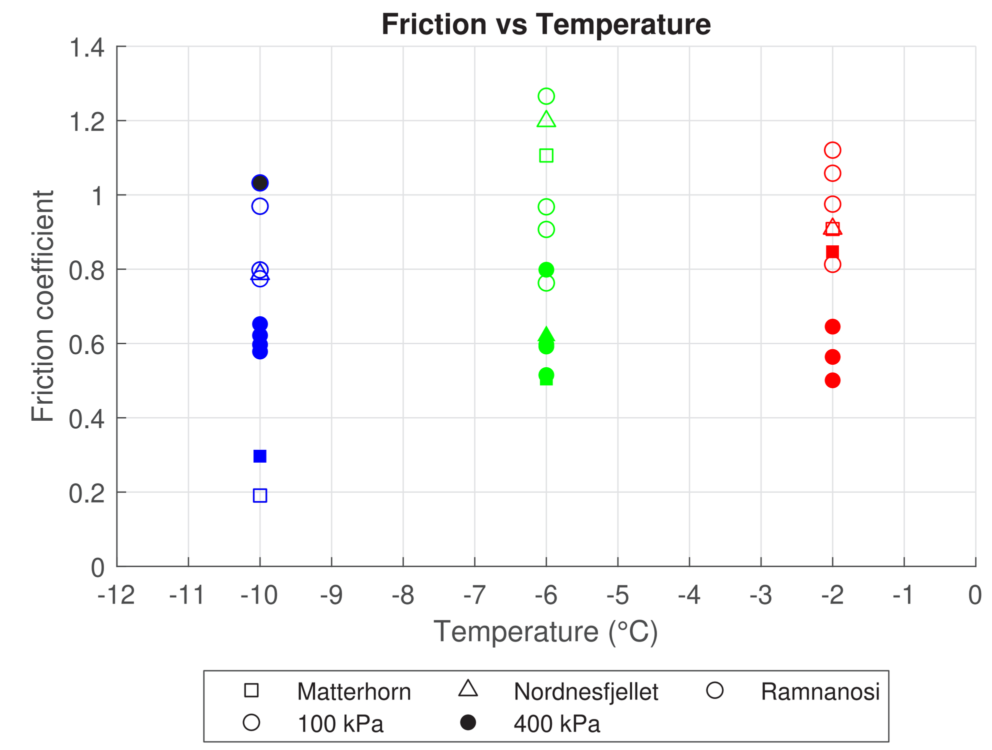
- 36 shear experiments were conducted on three kinds of ice-filled rock-rock interfaces at three temperatures and two normal forces.
- Peak shear stress depends strongly on temperature.
- Friction during sliding depends slightly on normal load and temperature.

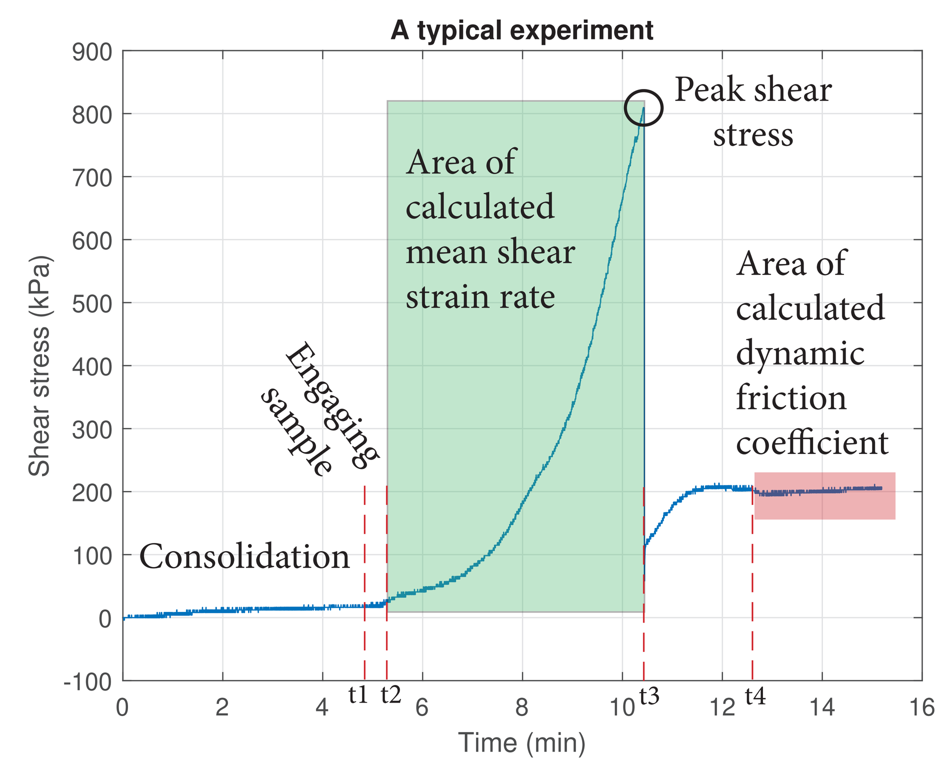


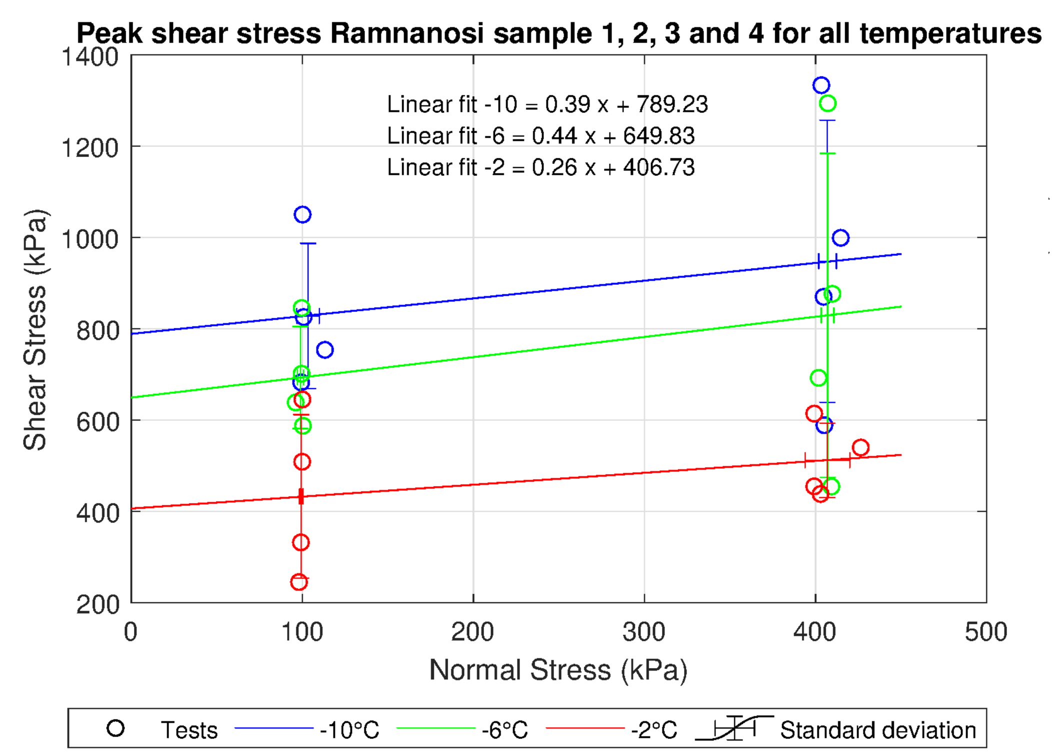


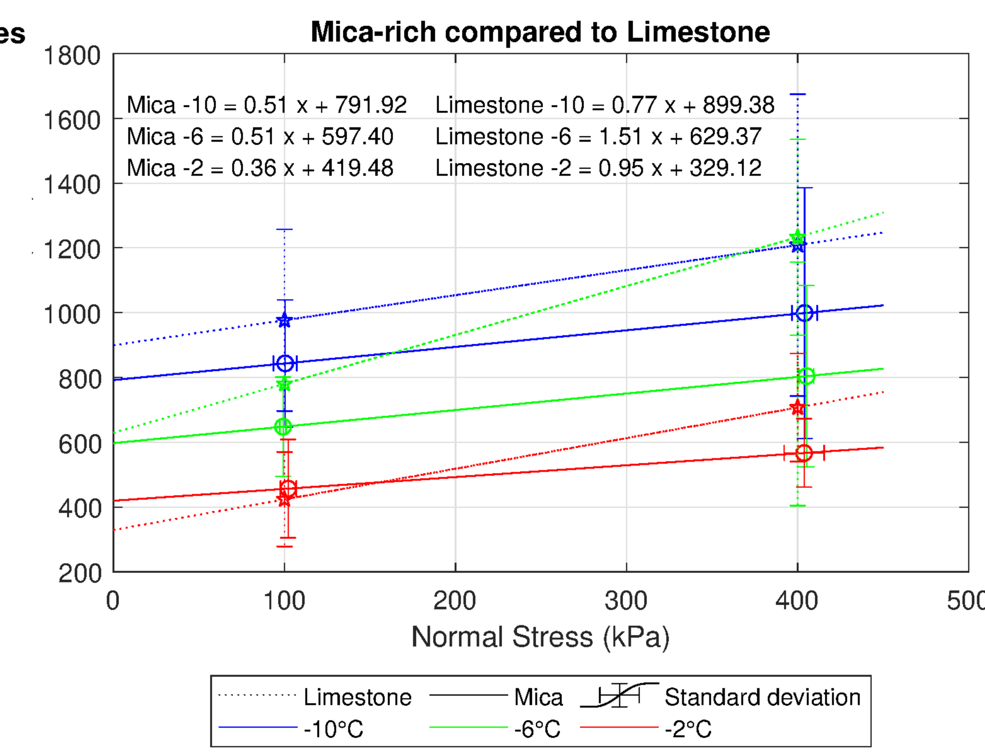












Discussion and conclusion

- Temperature has the strongest effect on the shear strength of an ice-filled joint with higher shear strength at lower temperature: this effect can be interpreted by the creep of ice at the highest temperatures. Conversely, the internal friction angle is close to 0.5, it does not change significantly with temperature.
- The dynamic friction coefficient is lower at higher normal stress. This effect could be interpreted by the formation of melt pockets due to shear heating at higher normal stress.
- The internal friction angle of ice-filled joints in mica-rich rocks (0.5 ± 0.1) is significantly smaller than that for limestone (1.1 ± 0.4). This effect may be explained by the low friction against mica minerals.
- Our data provide a new criterion for failure of ice-filled joints in mica-rich rocks.

References:

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Photography encouraged