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Modelling the thermal regime of perched talus slopes: The Gislá landslide (06/10/2020, Iceland)

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Nicolas Monzie, Skafti Brynjólfsson

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Modelling the thermal regime of perched talus slopes

The Gislá landslide (06/10/2020, Iceland)

Contributors:

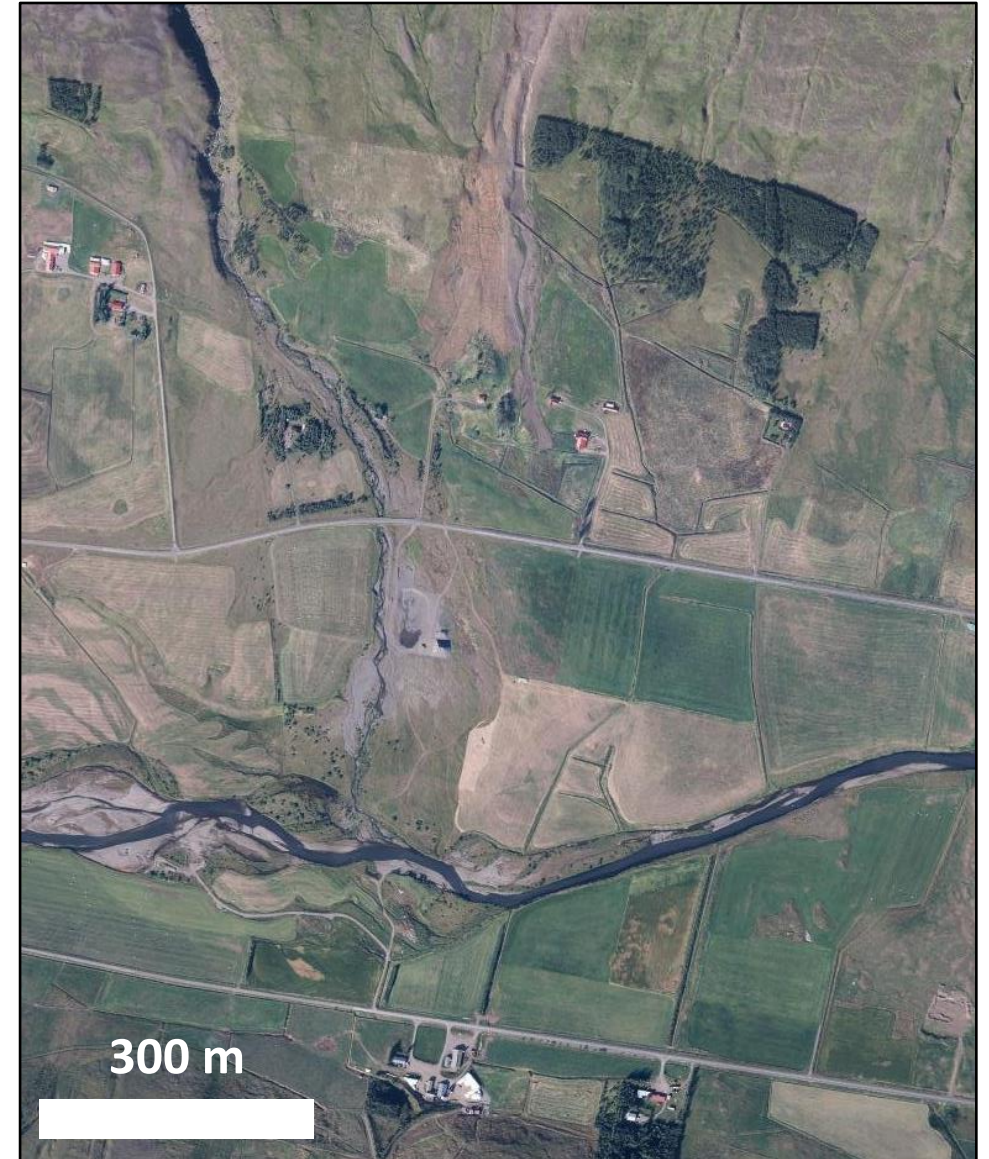
Meven Philippe, Florence Magnin, Jean-Yves Josnin,
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Permafrost landslide hazard

Permafrost degradation can generate **landslides...**

...which represent an **increasing hazard in mountain environments**

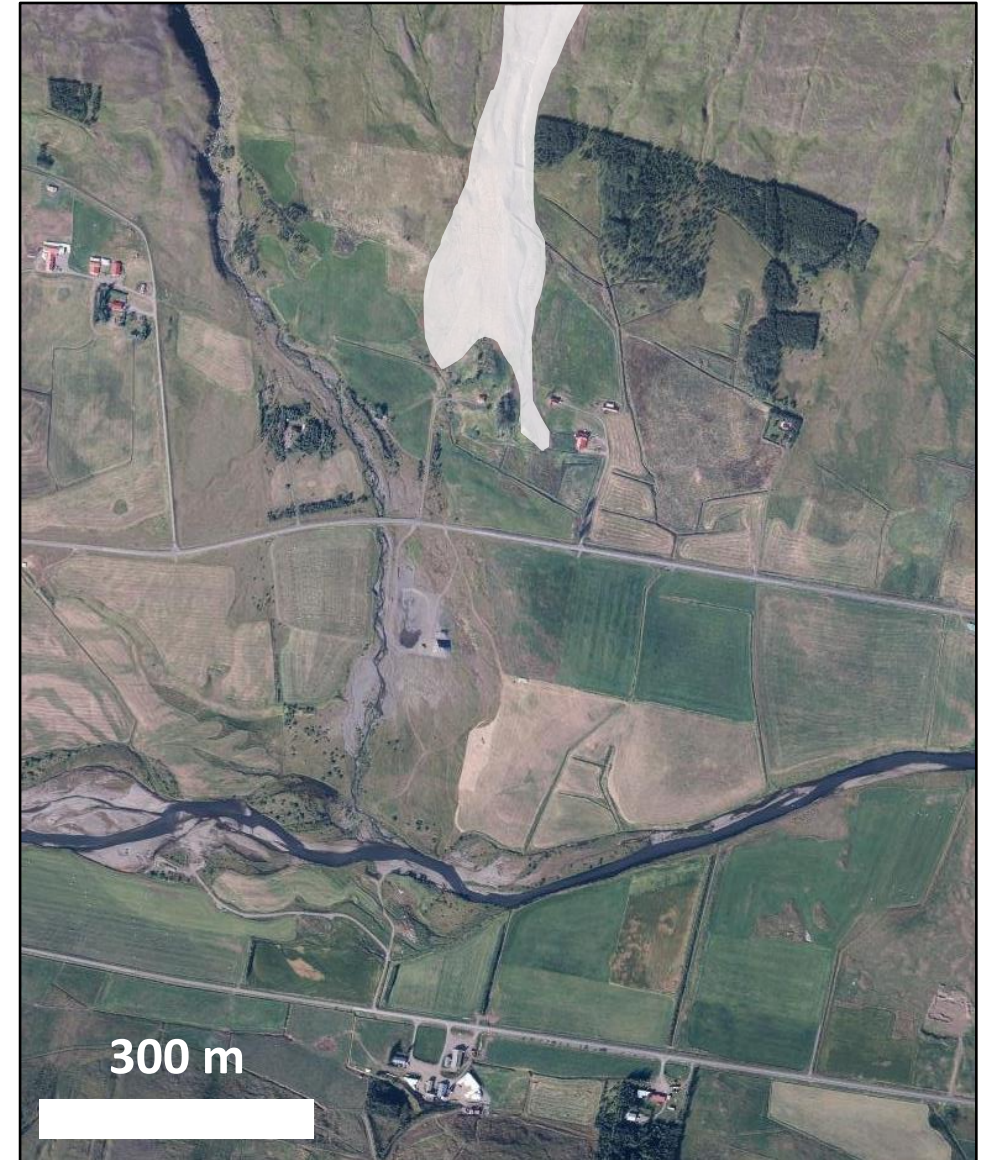


the Gislá landslide (map.is)

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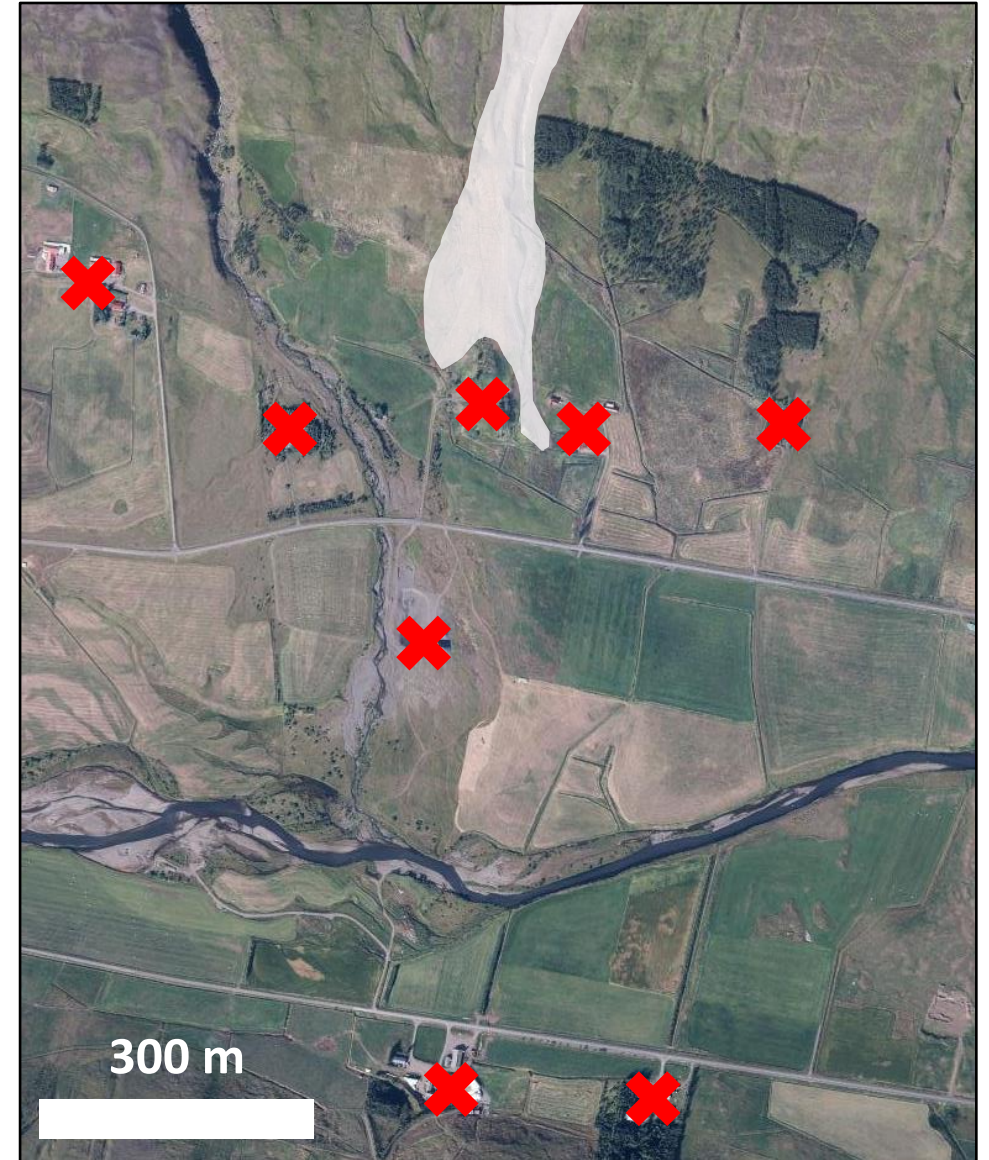


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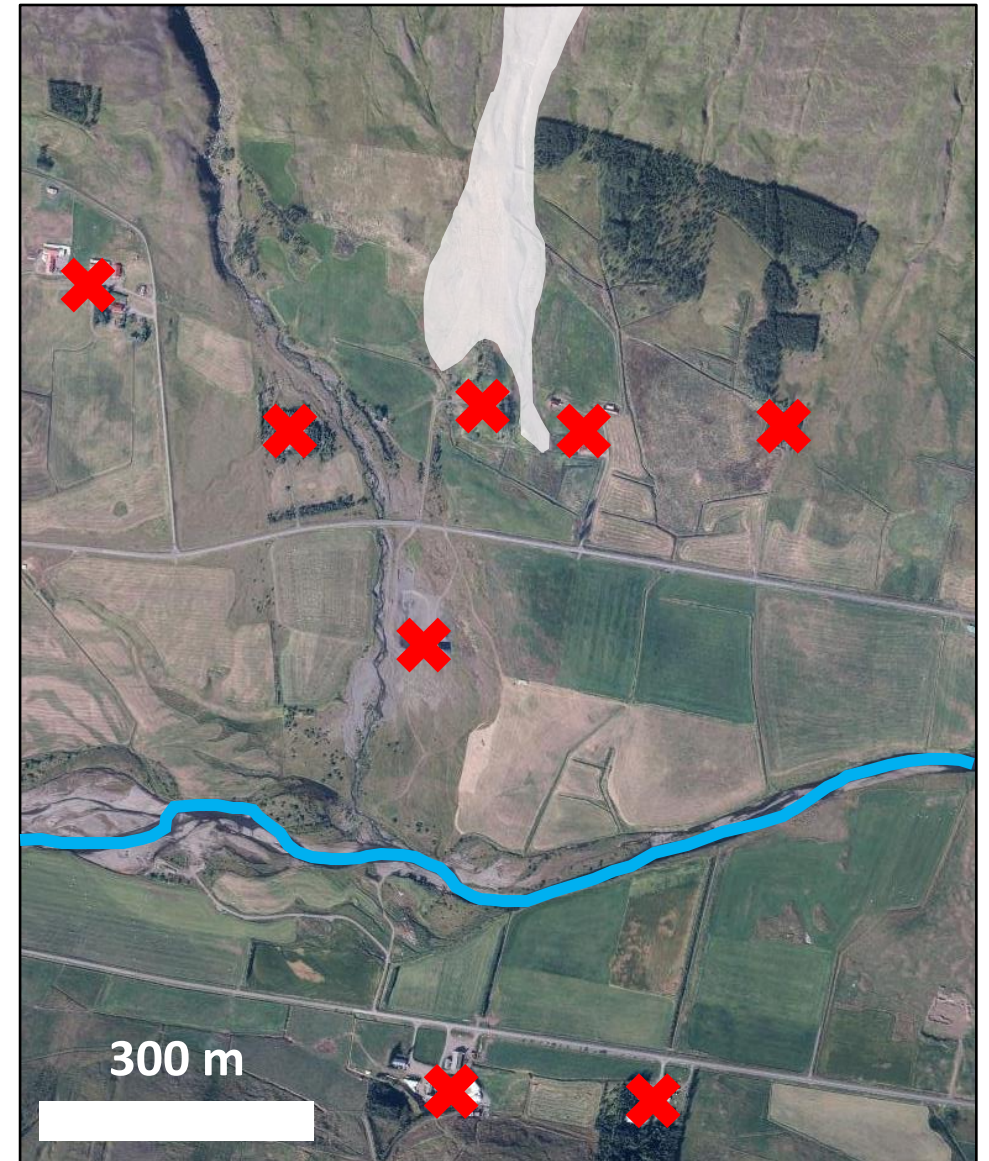


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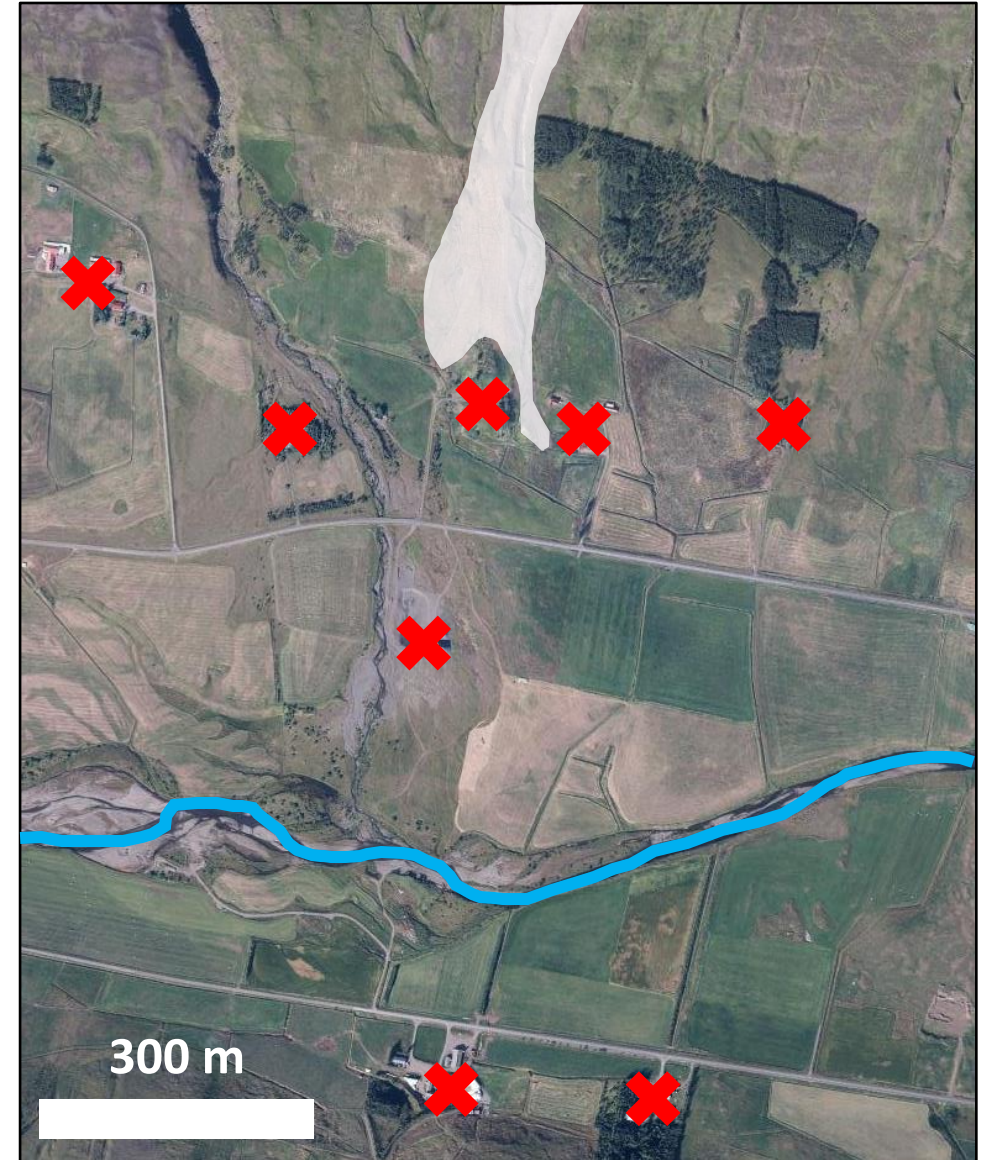
the Gislá landslide (map.is)

Permafrost landslide hazard

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...which represent an **increasing hazard in mountain environments**

→ **predicting permafrost boundaries is crucial for prevention/protection purposes**

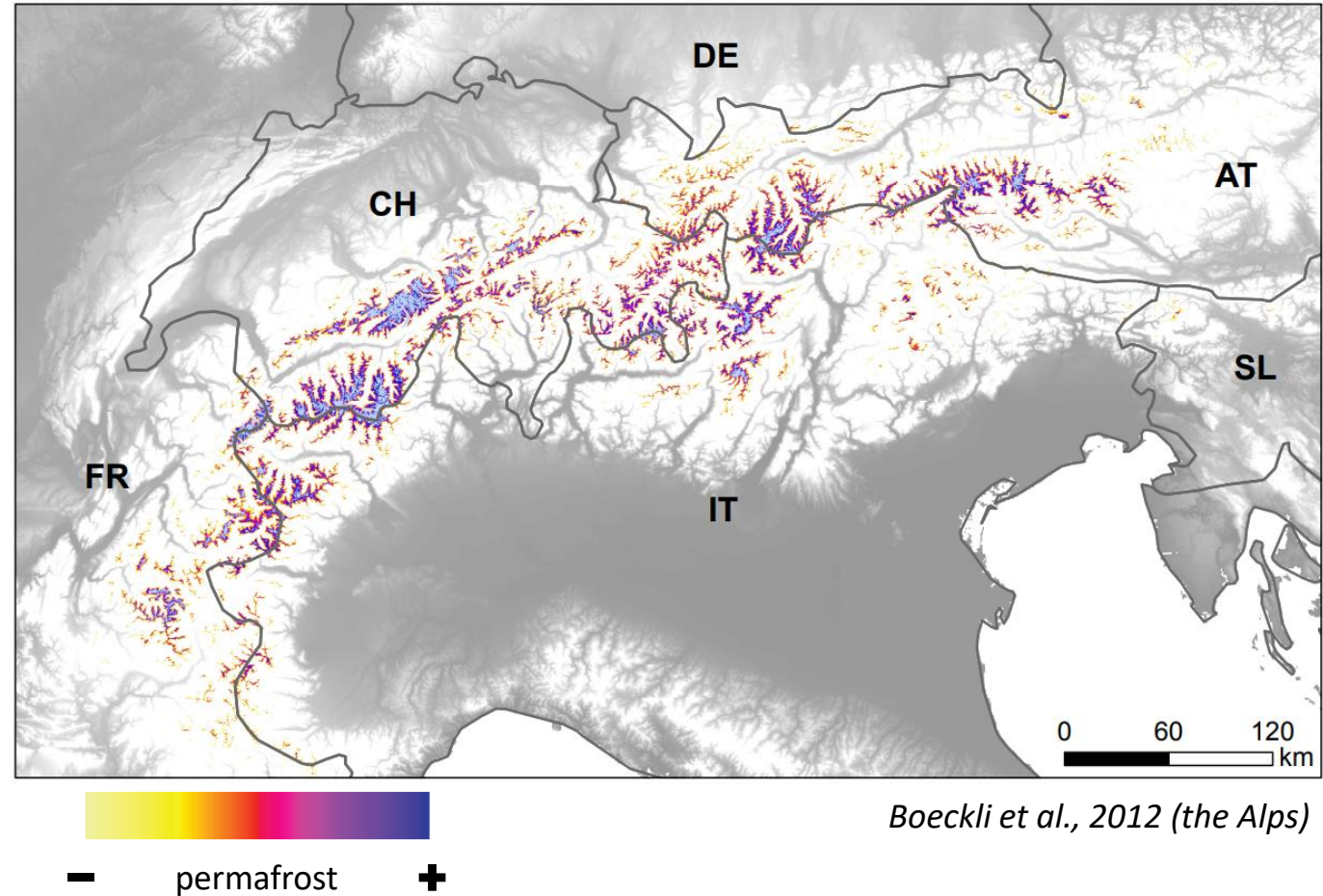


the Gislá landslide (map.is)

Permafrost models

To predict permafrost occurrence:

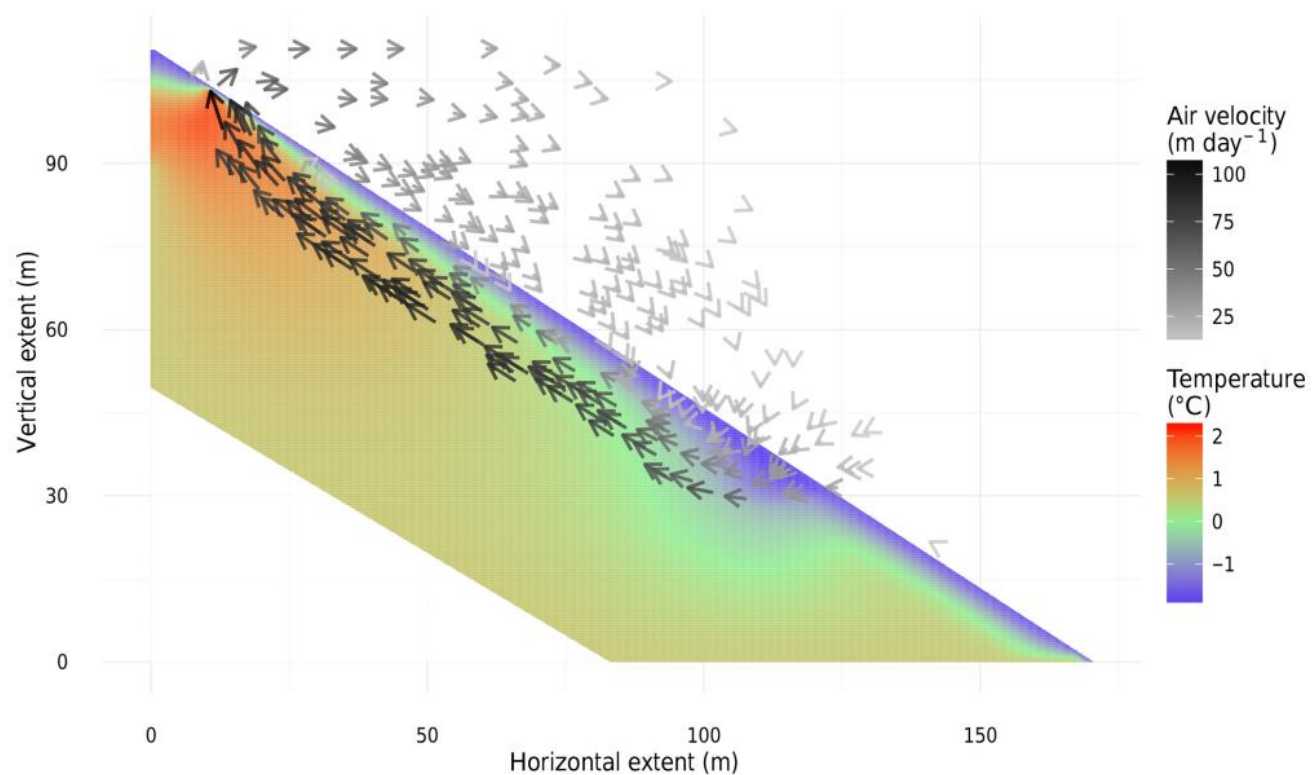
- **statistical models**
 - from **topoclimatic data**
 - **large scale modelling**



Permafrost models

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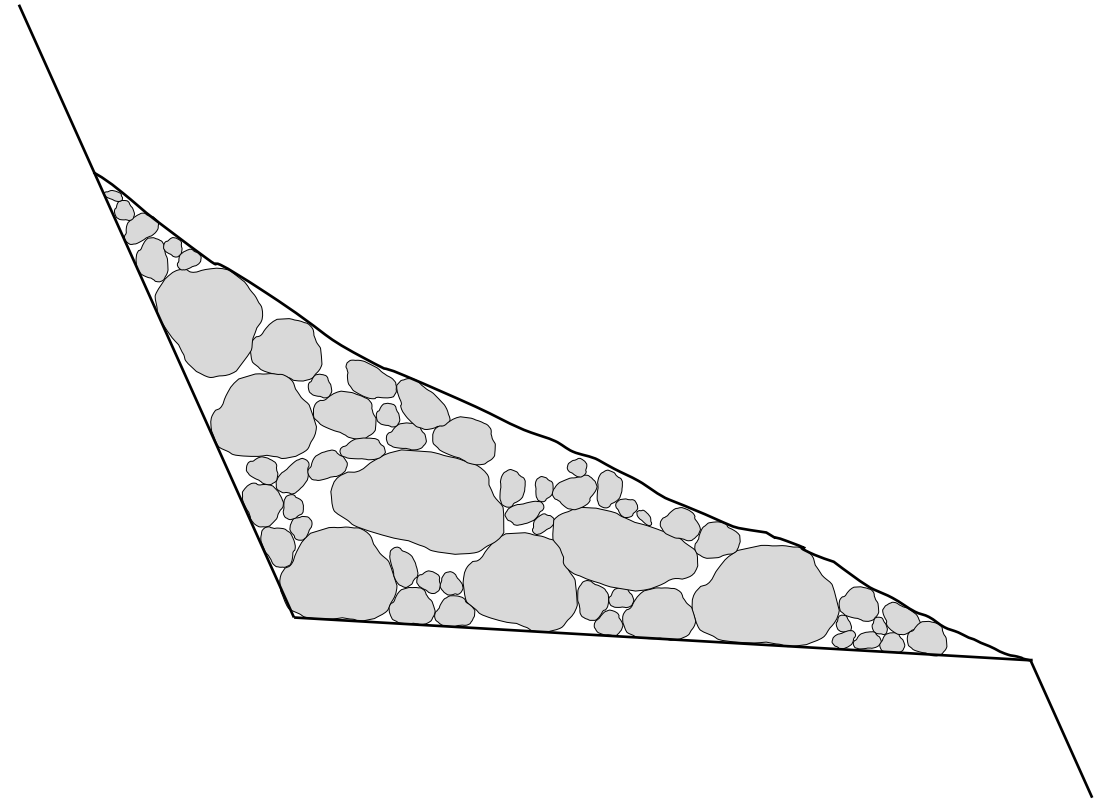
- **statistical models**
 - from **topoclimatic data**
 - **large scale modelling**
- **physic-based models**
 - compute **physical processes**
 - at **site scale**
 - can predict **azonal permafrost**



Wicky et al., 2024 (in a talus slope)

The 'chimney effect'

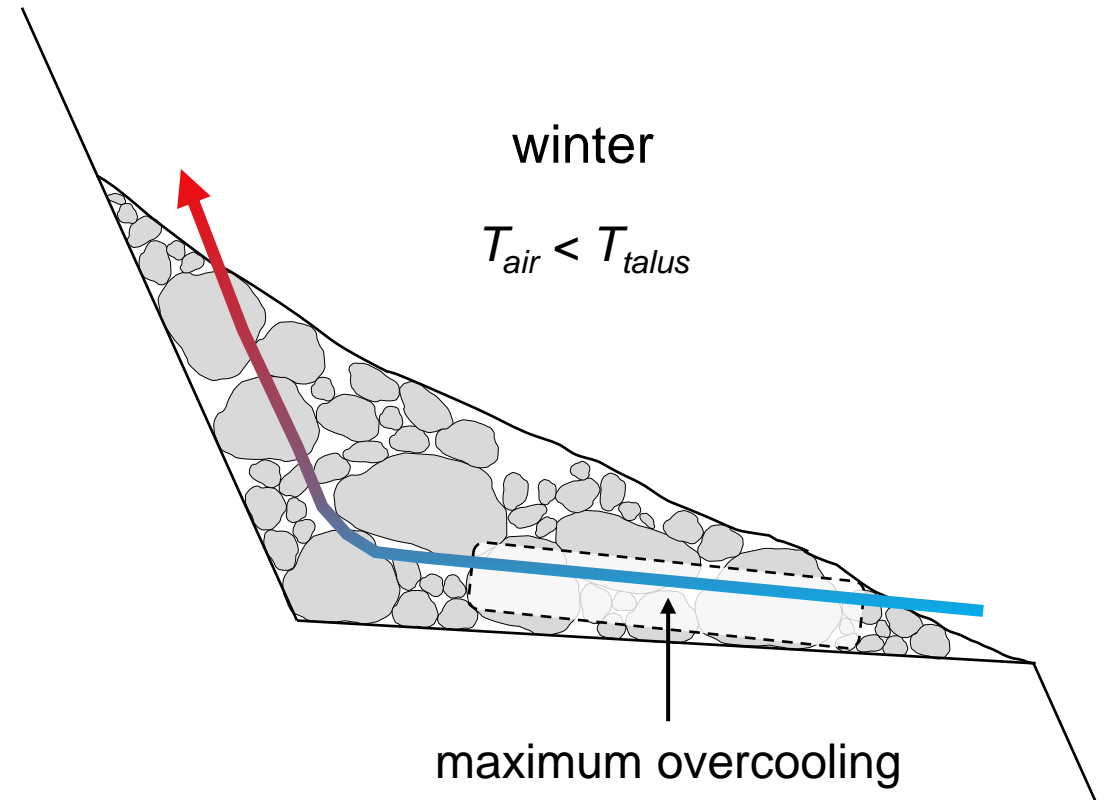
In talus slope, particular air convection can take place - the '**chimney effect**'



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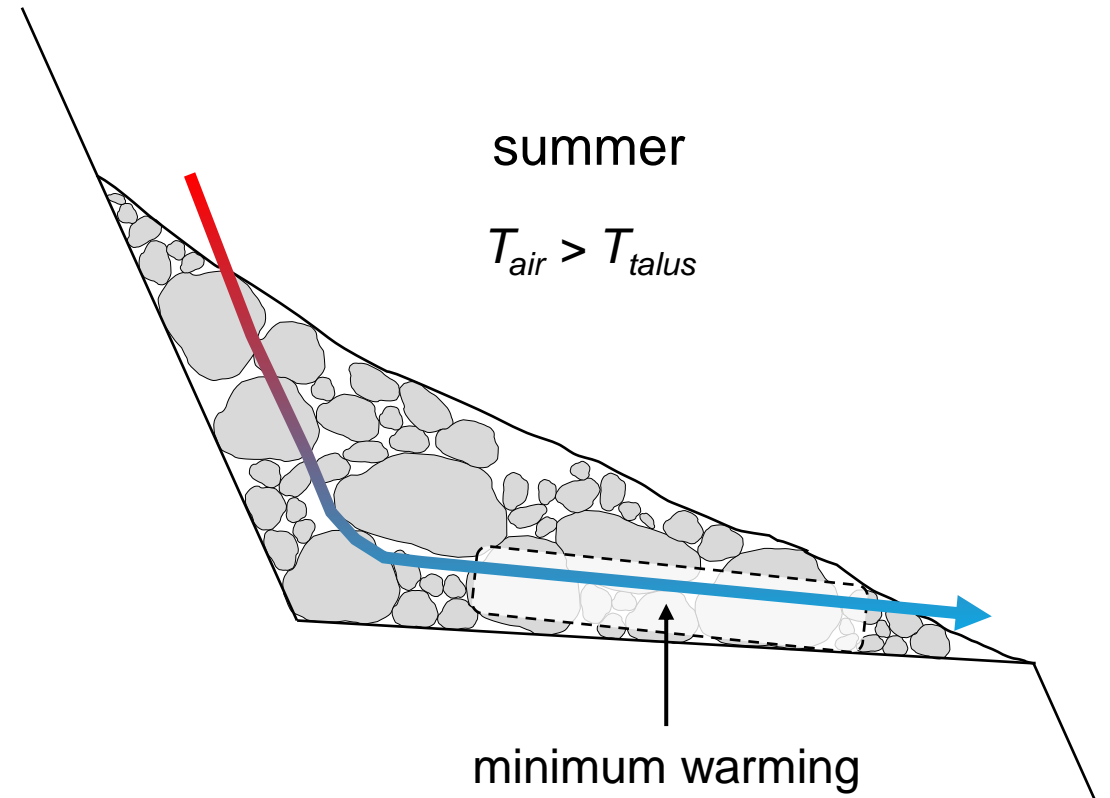
→ **winter:** suction of cold air at the base of the talus



The 'chimney effect'

In talus slope, particular air convection can take place - the '**chimney effect**'

- **winter:** suction of cold air at the base of the talus
- **summer:** gravitational flow of cold air to the base of the talus

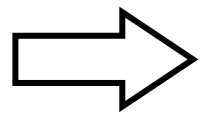


The 'chimney effect'

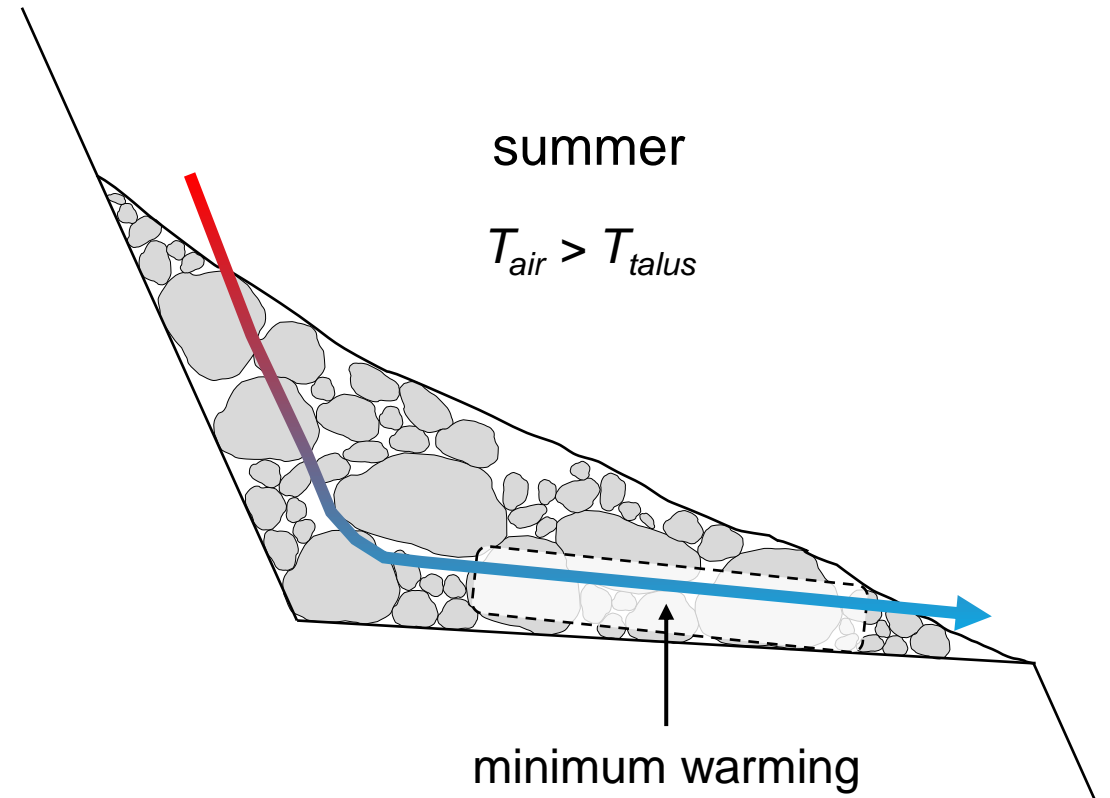
In talus slope, particular air convection can take place - the '**chimney effect**'

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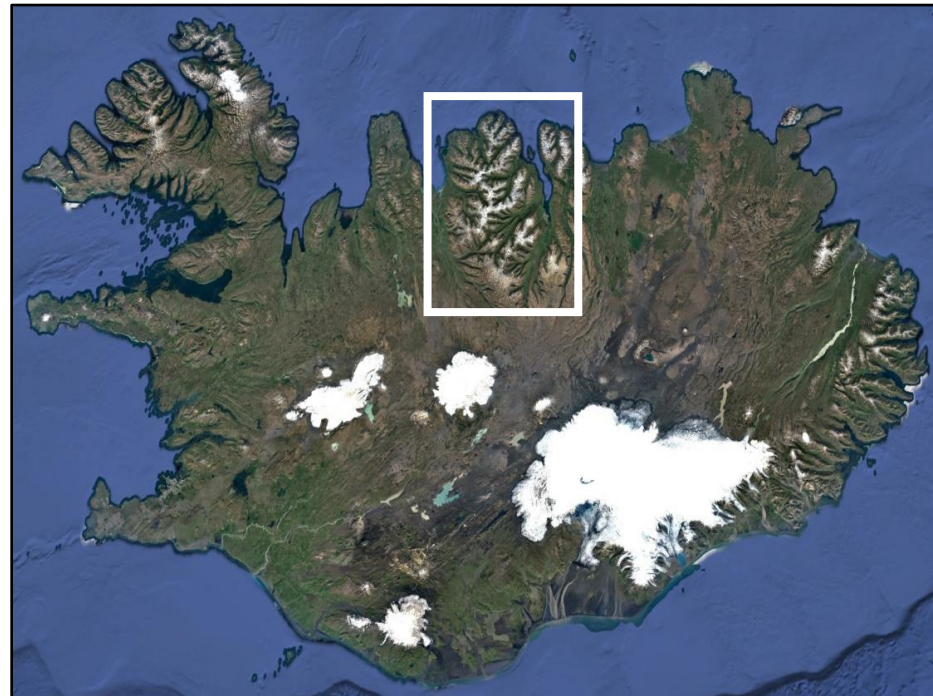
→ **summer:** gravitational flow of cold air to the base of the talus



Thermal dynamics of talus slopes are poorly understood

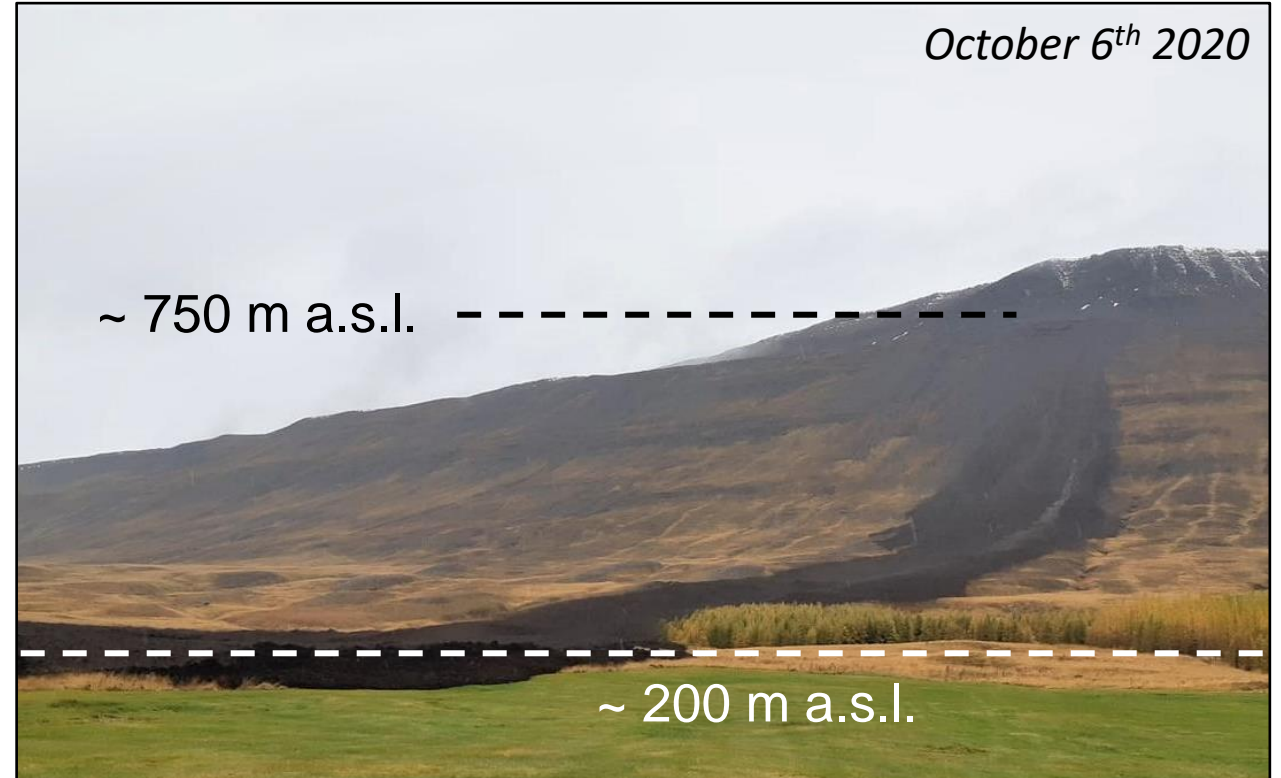


The Gislá landslide (October 6th 2020):



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- source: **perched talus slope**



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- **ice-cemented material** in the deposits (molarads)...



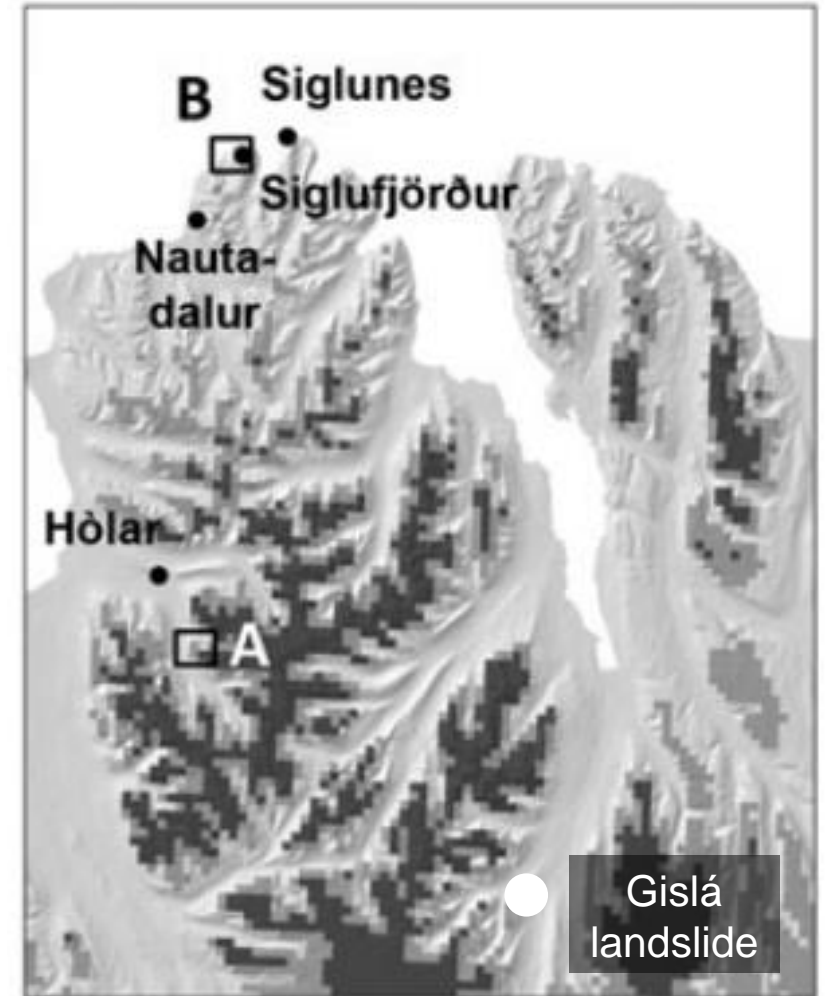
The Gislá landslide (October 6th 2020):

- source: **perched talus slope**
- **ice-cemented material** in the deposits (molards)...
- ... but located **outside of permafrost climatic boundaries**

continuous permafrost



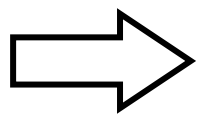
discontinuous permafrost



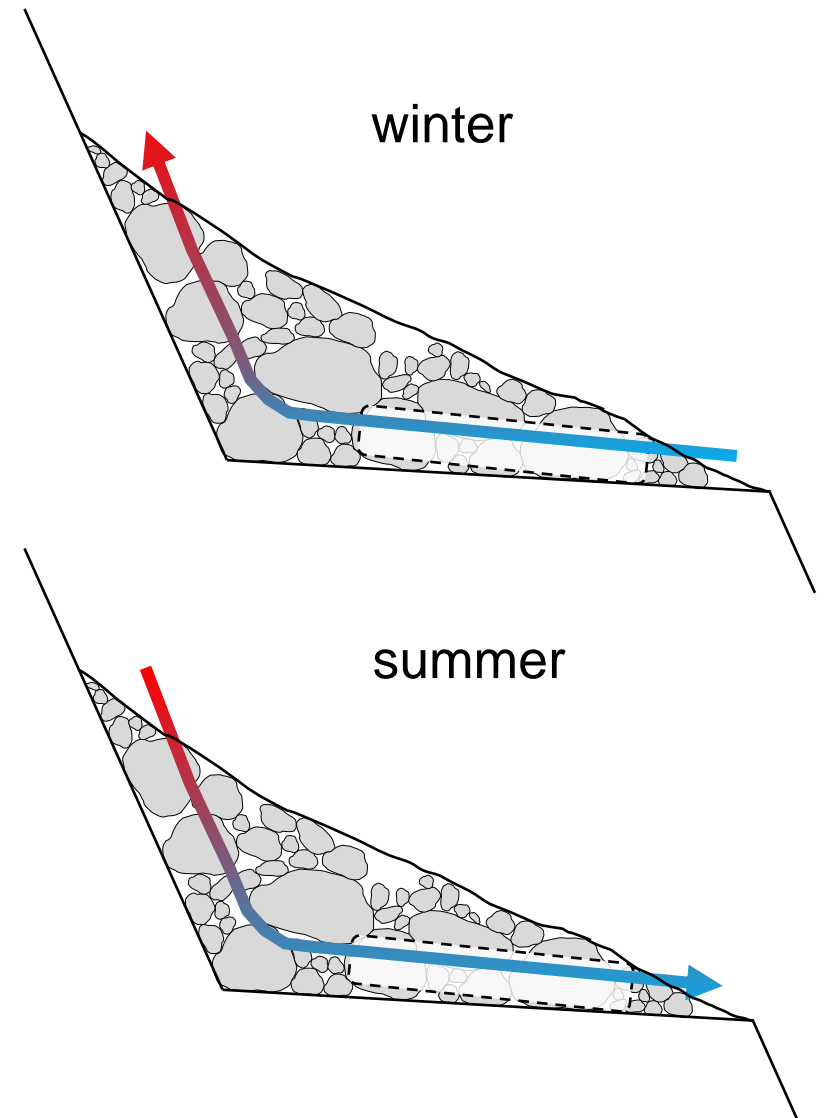
Lilleøren et al. (2013)

The Gislá landslide (October 6th 2020):

- source: **perched talus slope**
- **ice-cemented material** in the deposits (molarads)...
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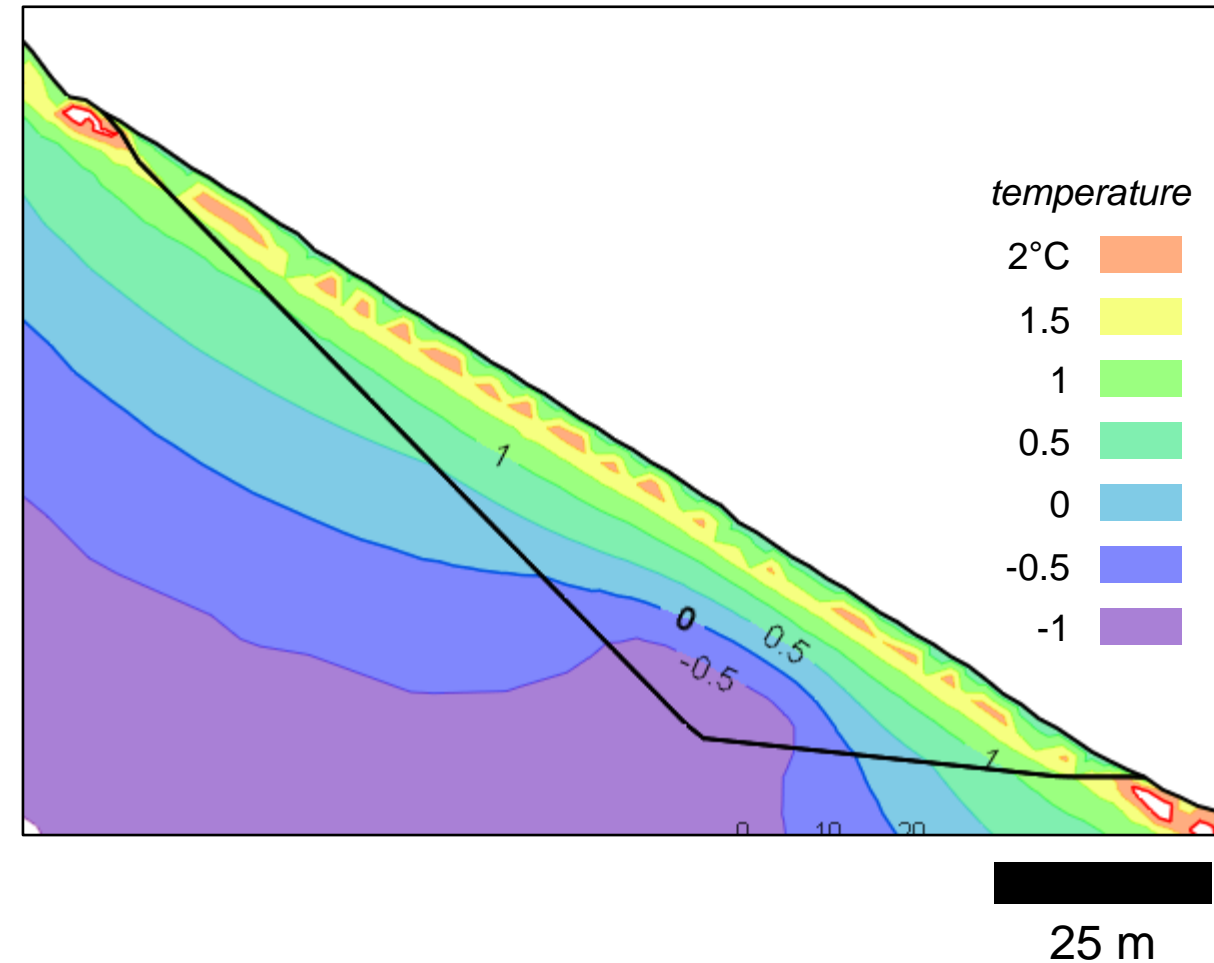
persistence of permafrost due to the chimney effect ?



- 1. Can permafrost persist in the Gislá talus slope until the date of the landslide?**
- 2. What was its thermal state at the date of the landslide?**
- 3. What thermal properties of the Gislá talus slope are required to maintain permafrost?**

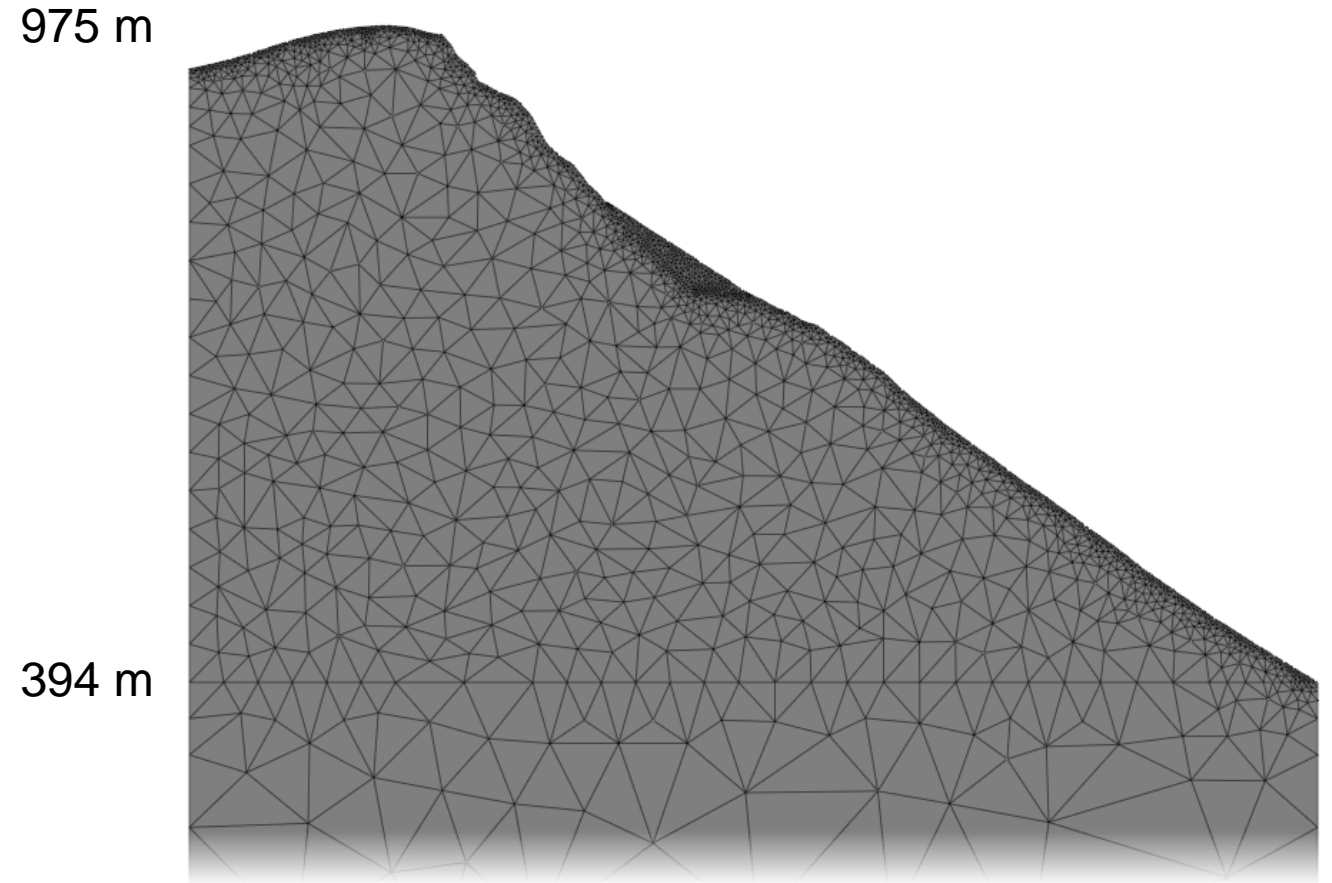
Methods: heat transfer modelling

- computation of **heat transfer equations**
- **Finite-Element Method** (FEFLOW commercial software)
- modelling of the **thermal dynamics from -20,000 to present**
- evaluation of **permafrost conditions at the date of the Gislá landslide**



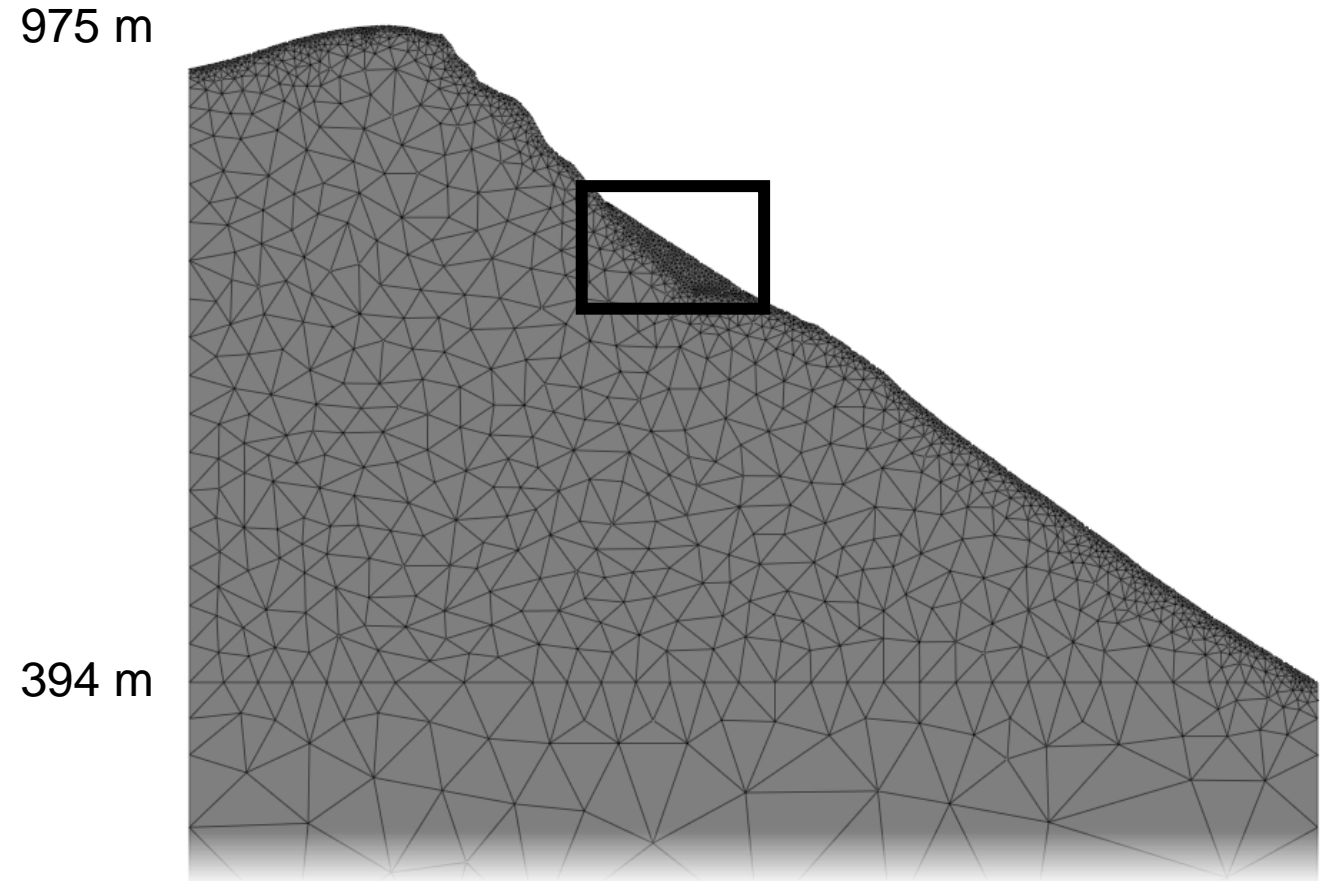
Heat transfer modelling within the Gislá perched talus slope:

1. definition of 2D site geometry



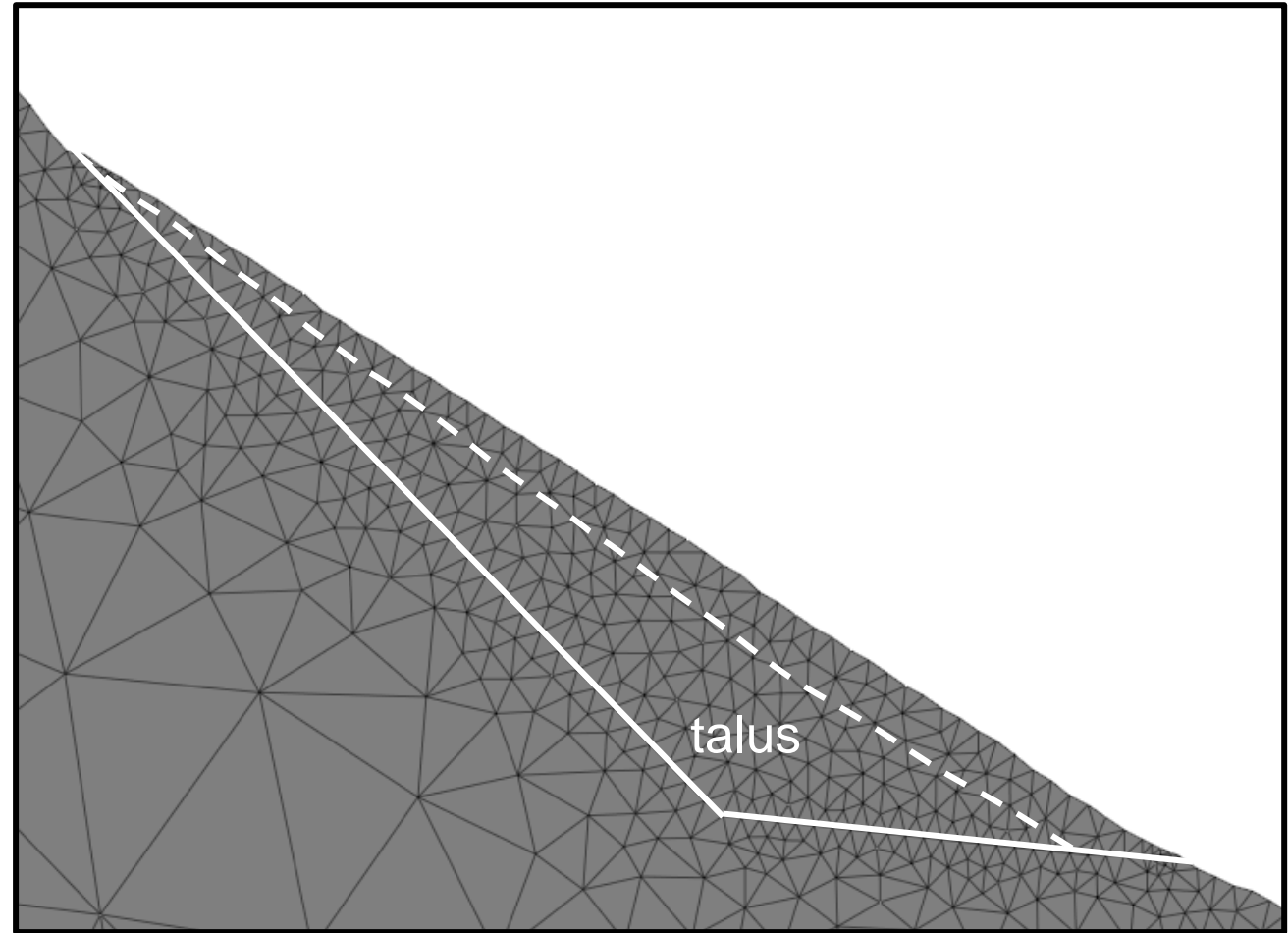
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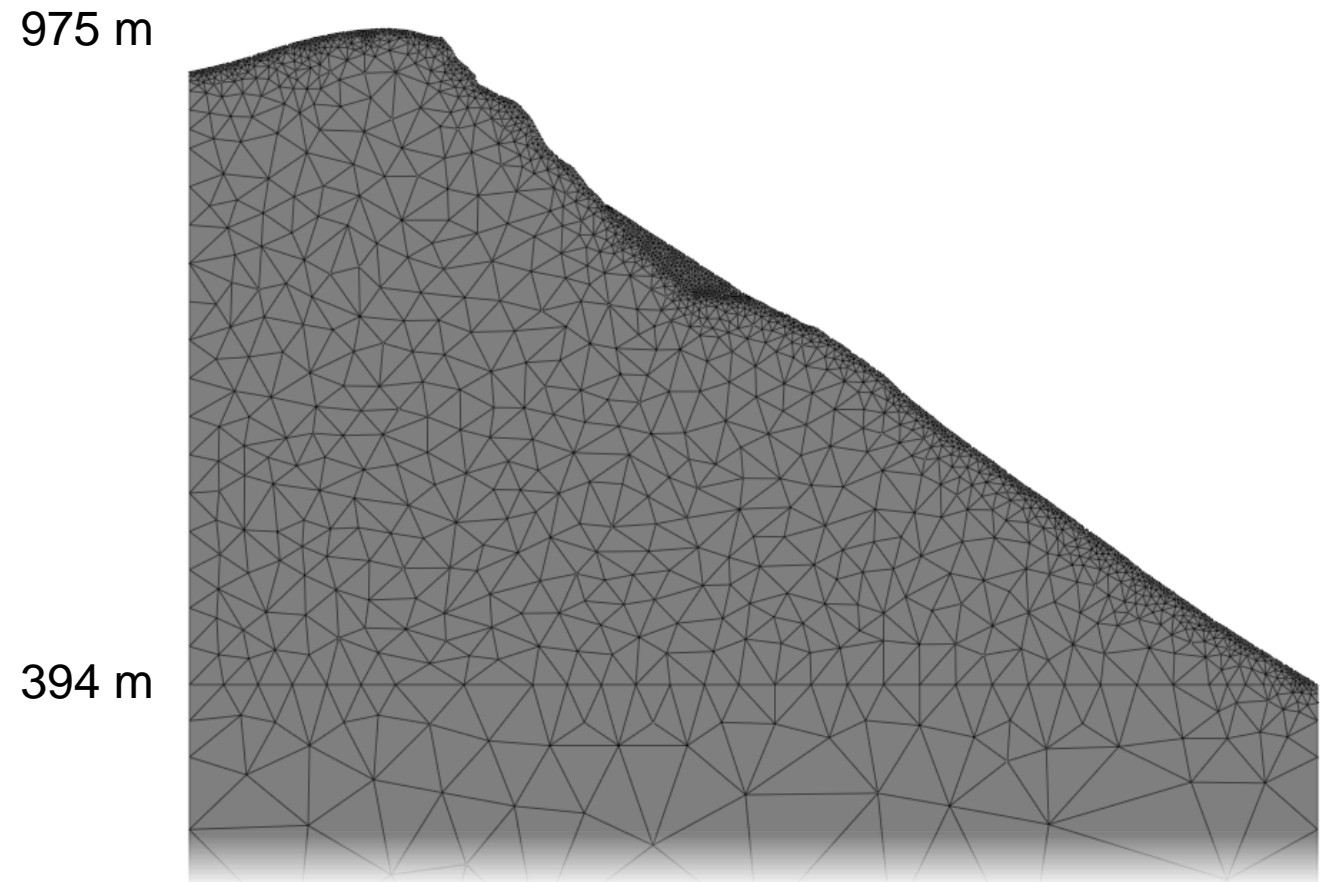
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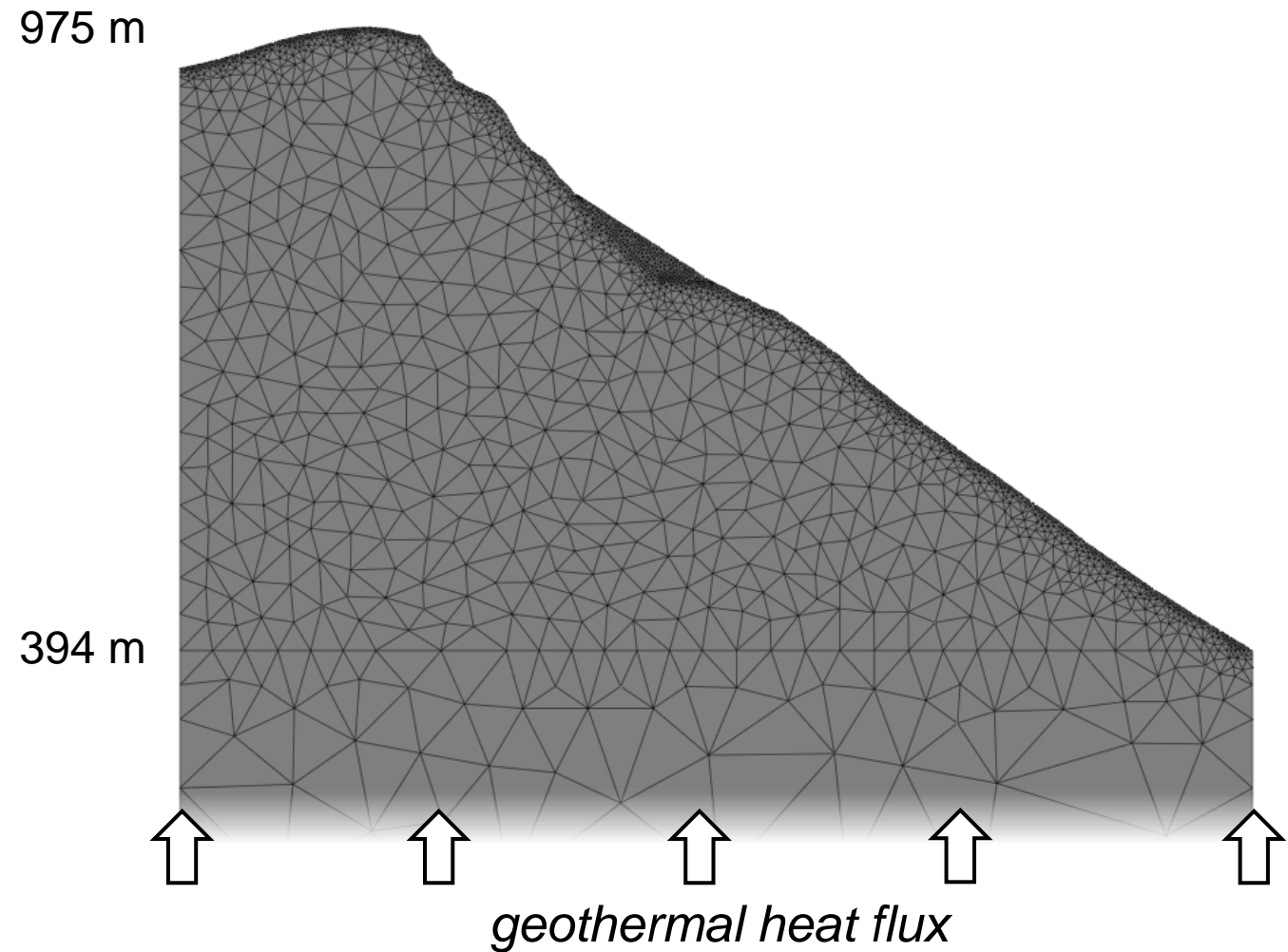
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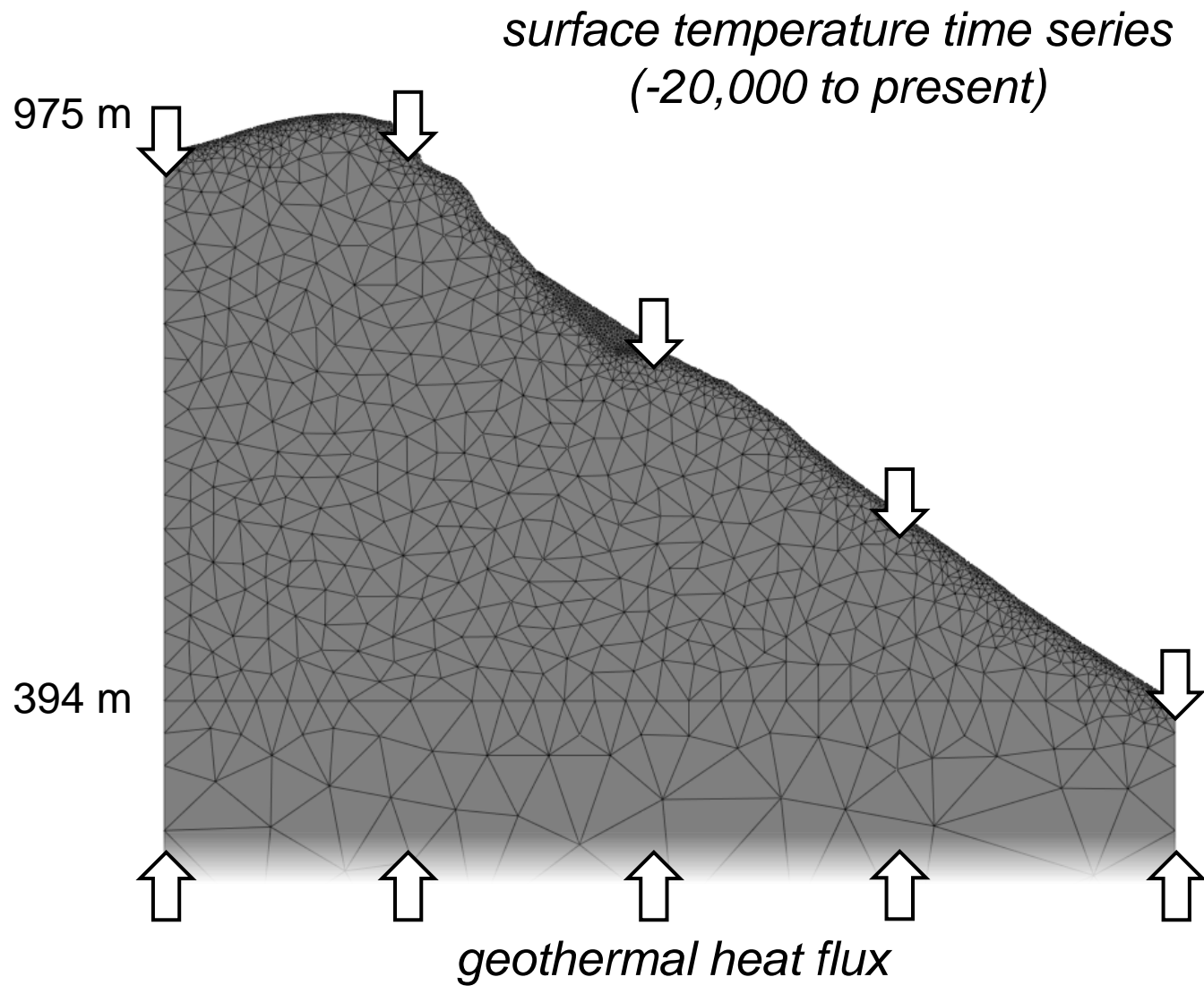
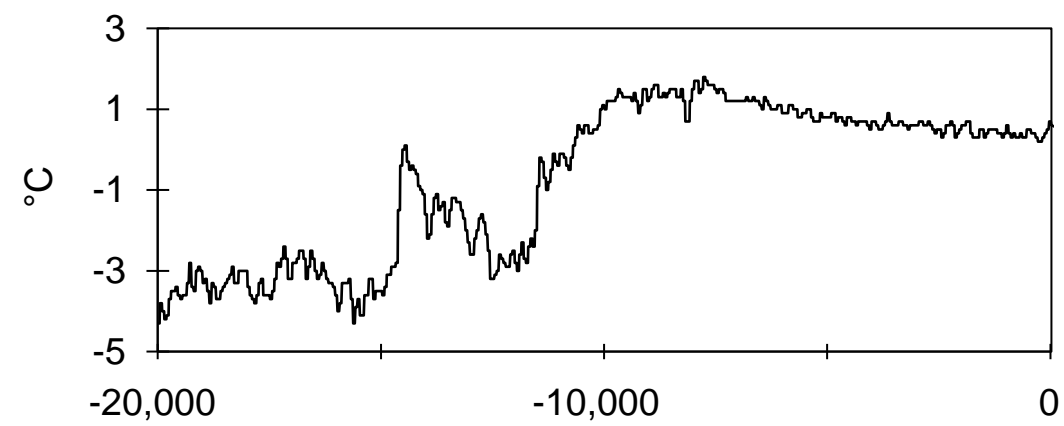
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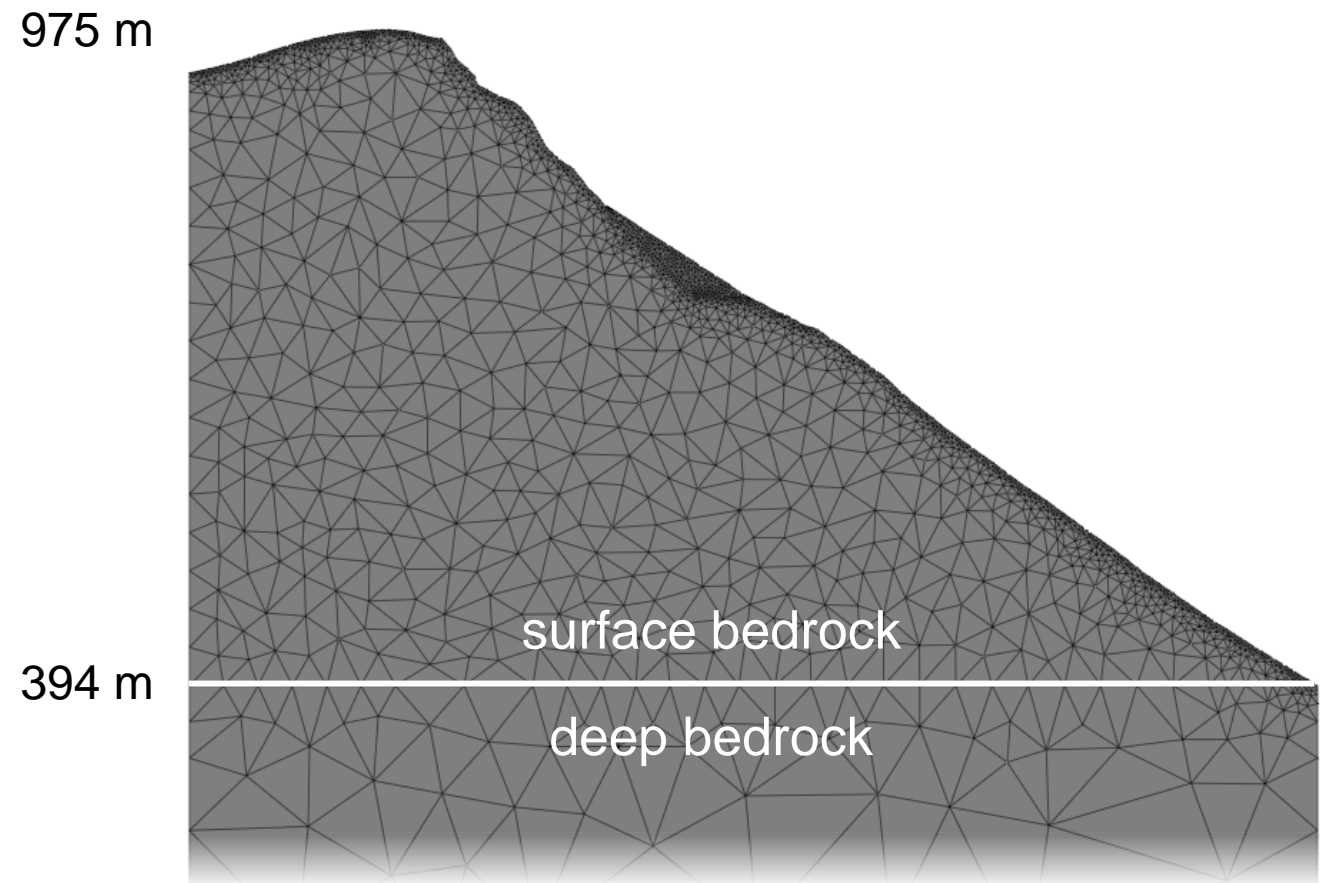
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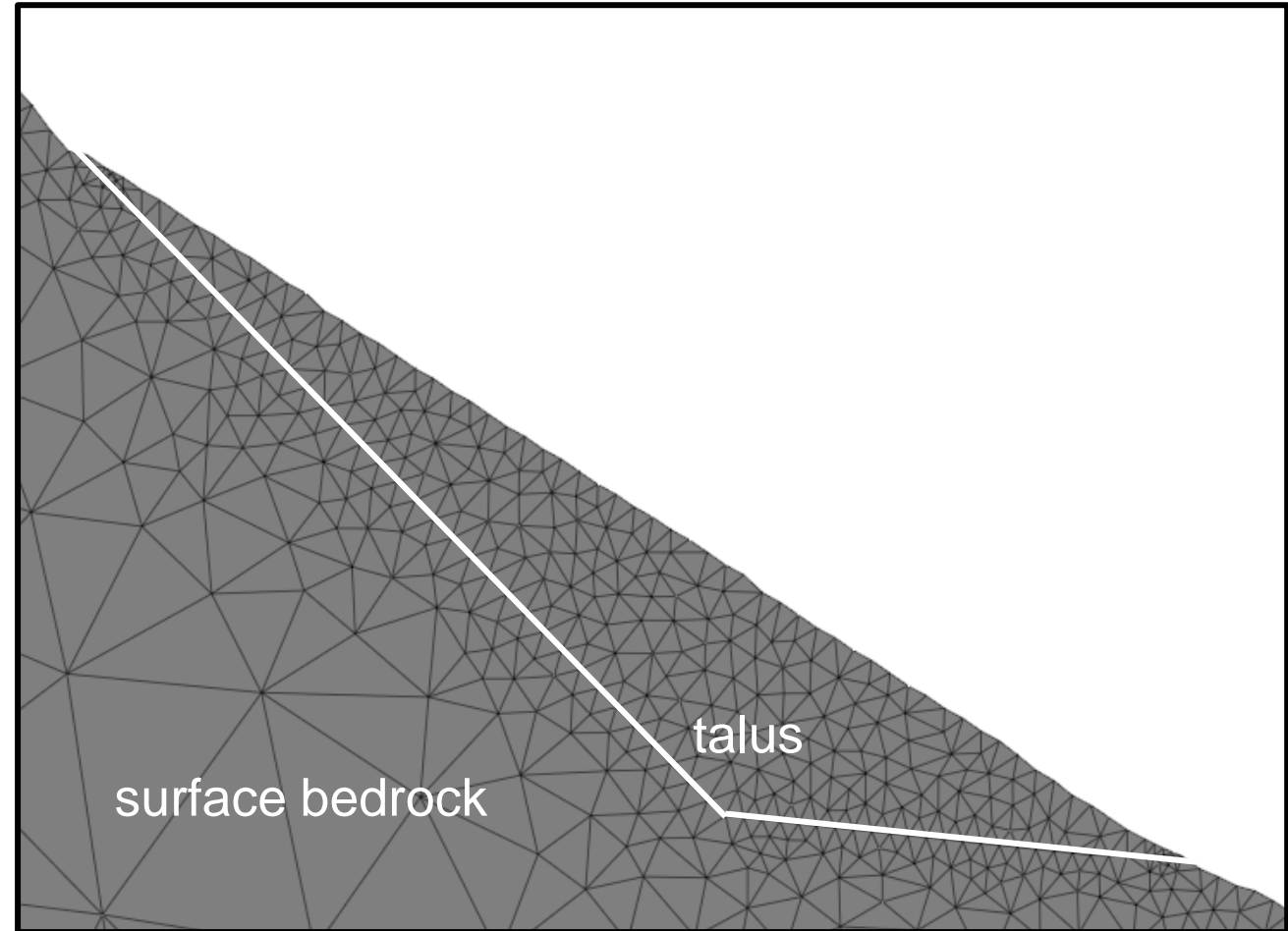
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3. modelling approach:
 - *division in sections*
 - *meshing*



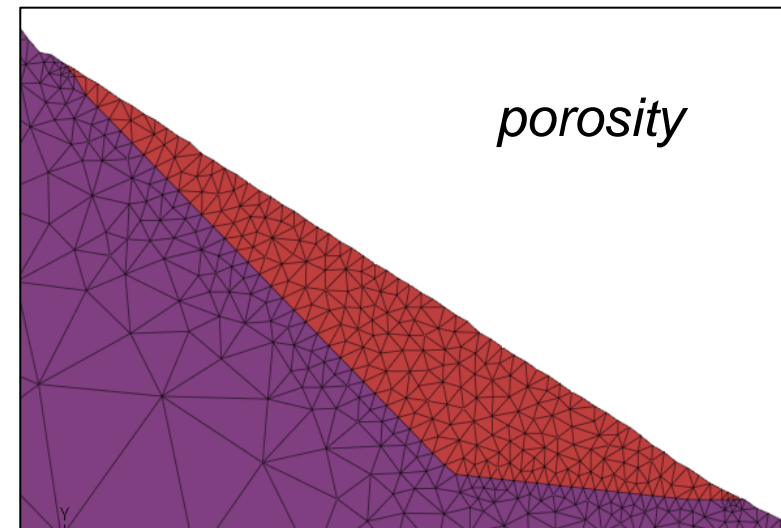
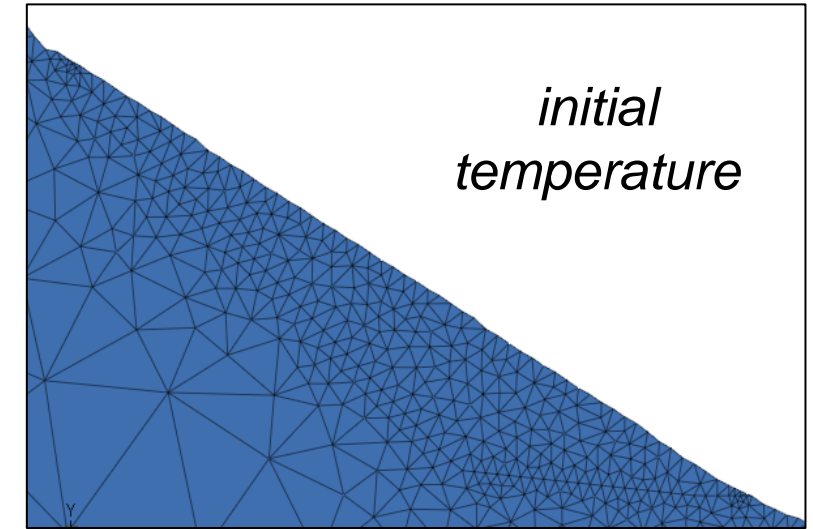
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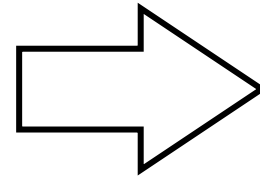
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Heat transfer modelling within the Gislá perched talus slope:

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models are good to go!

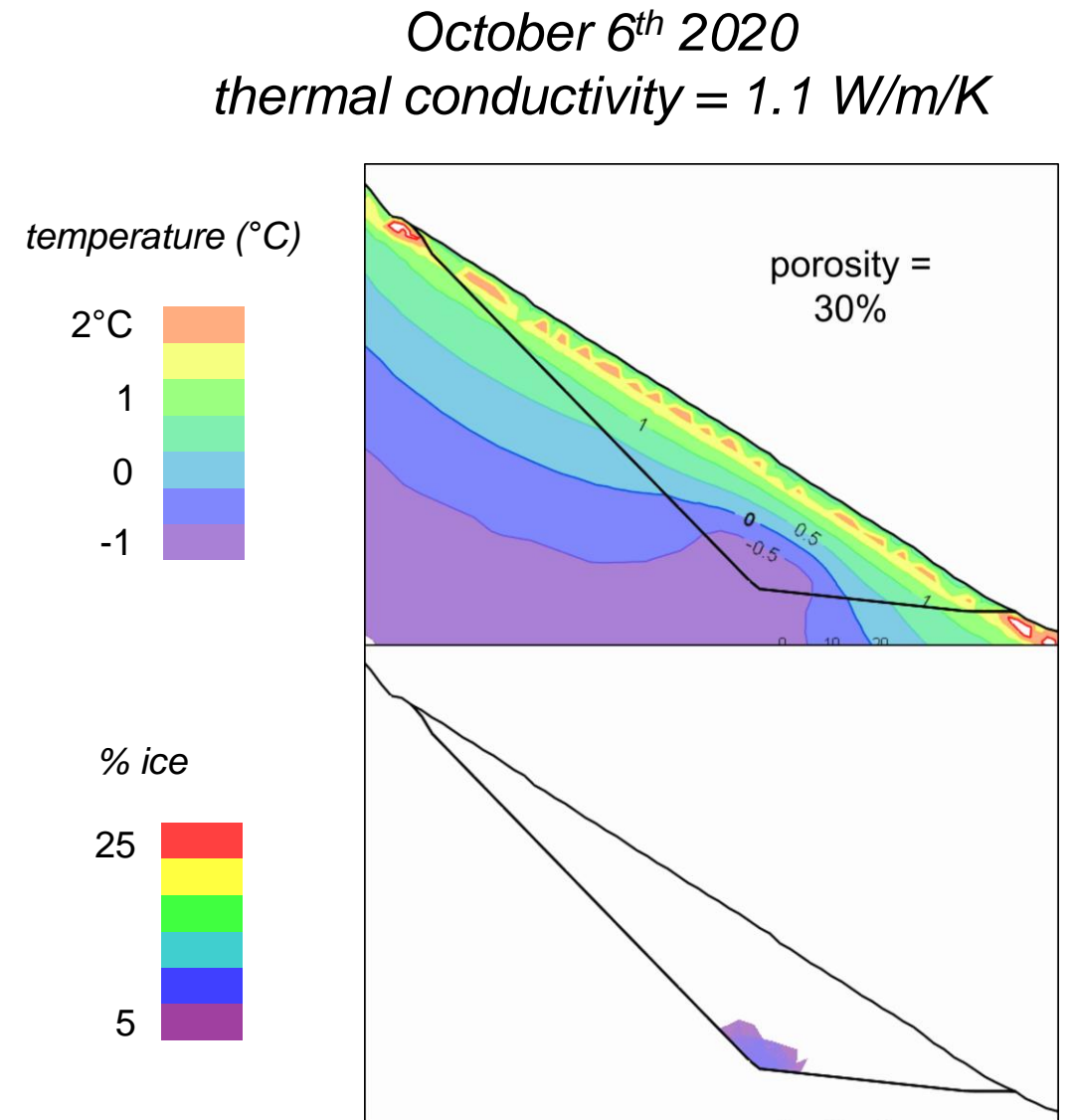


Model sensitivity to porosity/ice content

Final temperature/permafrost conditions mainly depend on:

1. the **porosity** and **initial ice content** of the talus slope

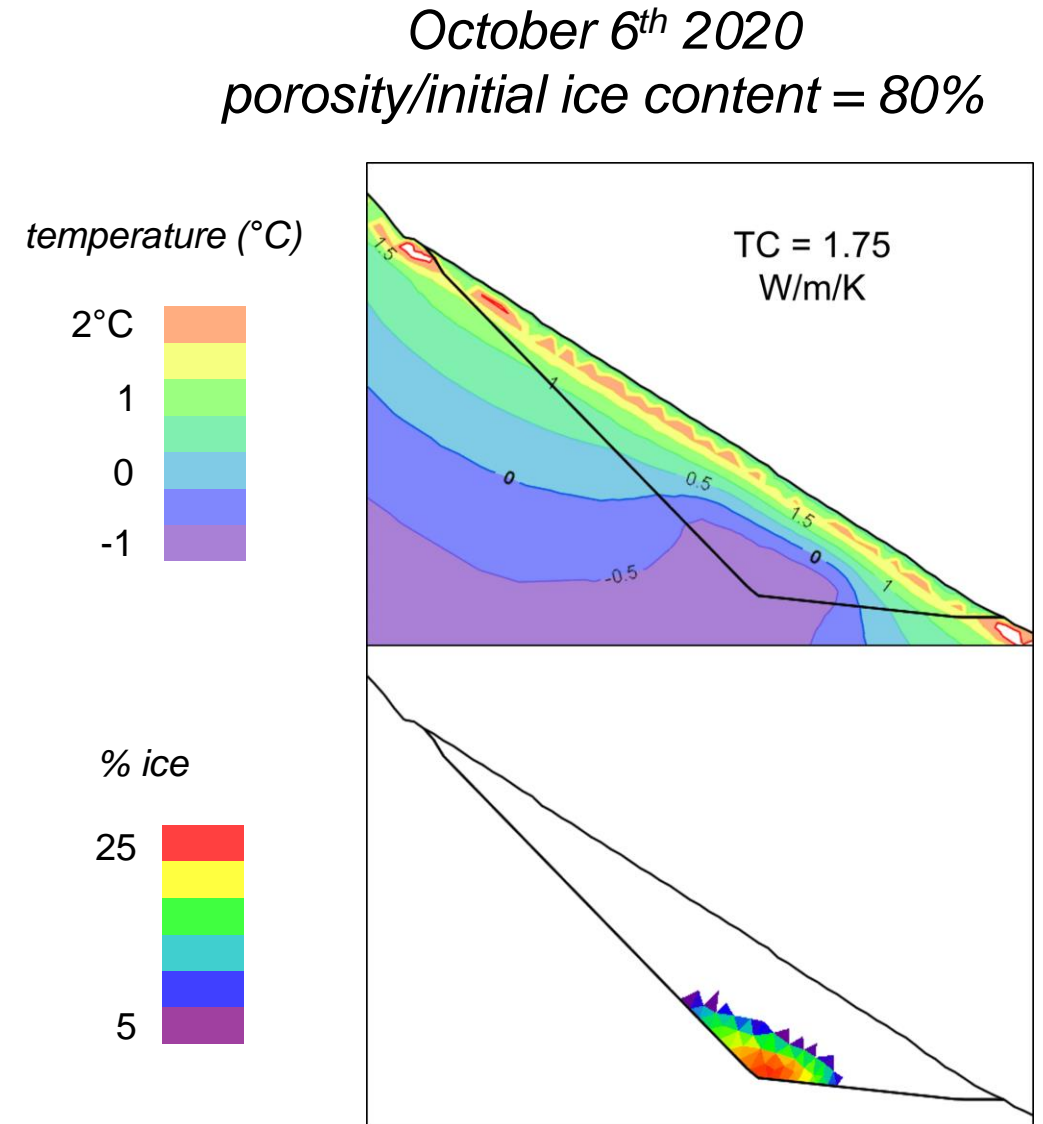
→ **higher porosity/ice content**
= **greater permafrost persistence**



Model sensitivity to the thermal conductivity

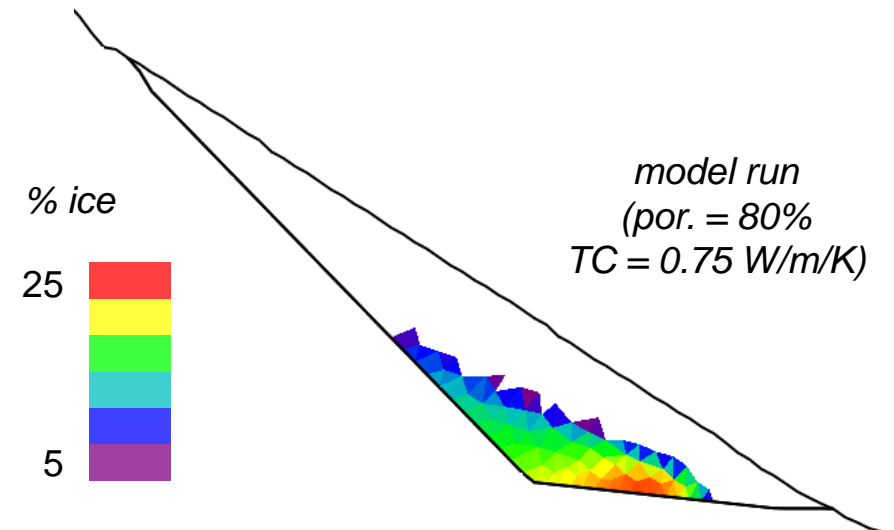
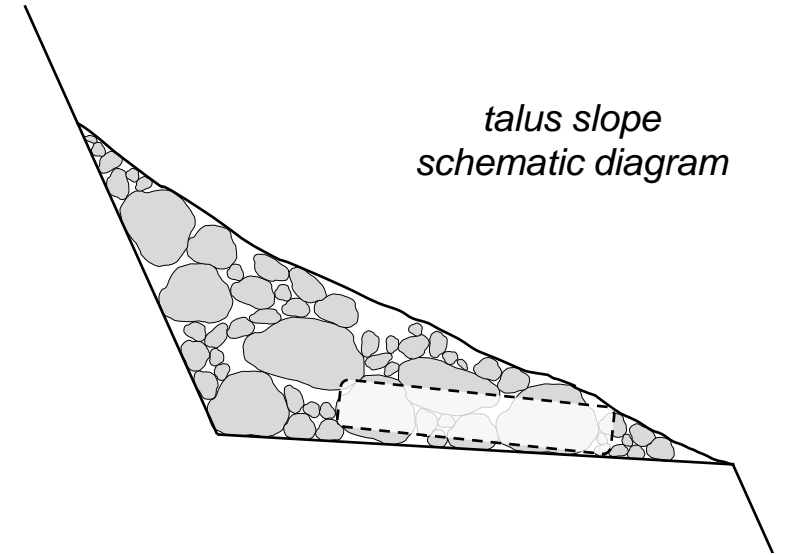
Final temperature/permafrost conditions mainly depend on:

1. the **porosity** and **initial ice content** of the talus slope
→ **higher porosity/ice content**
= **greater permafrost persistence**
2. the **thermal conductivity** of the rock
→ **lower thermal conductivity**
= **greater permafrost persistence**



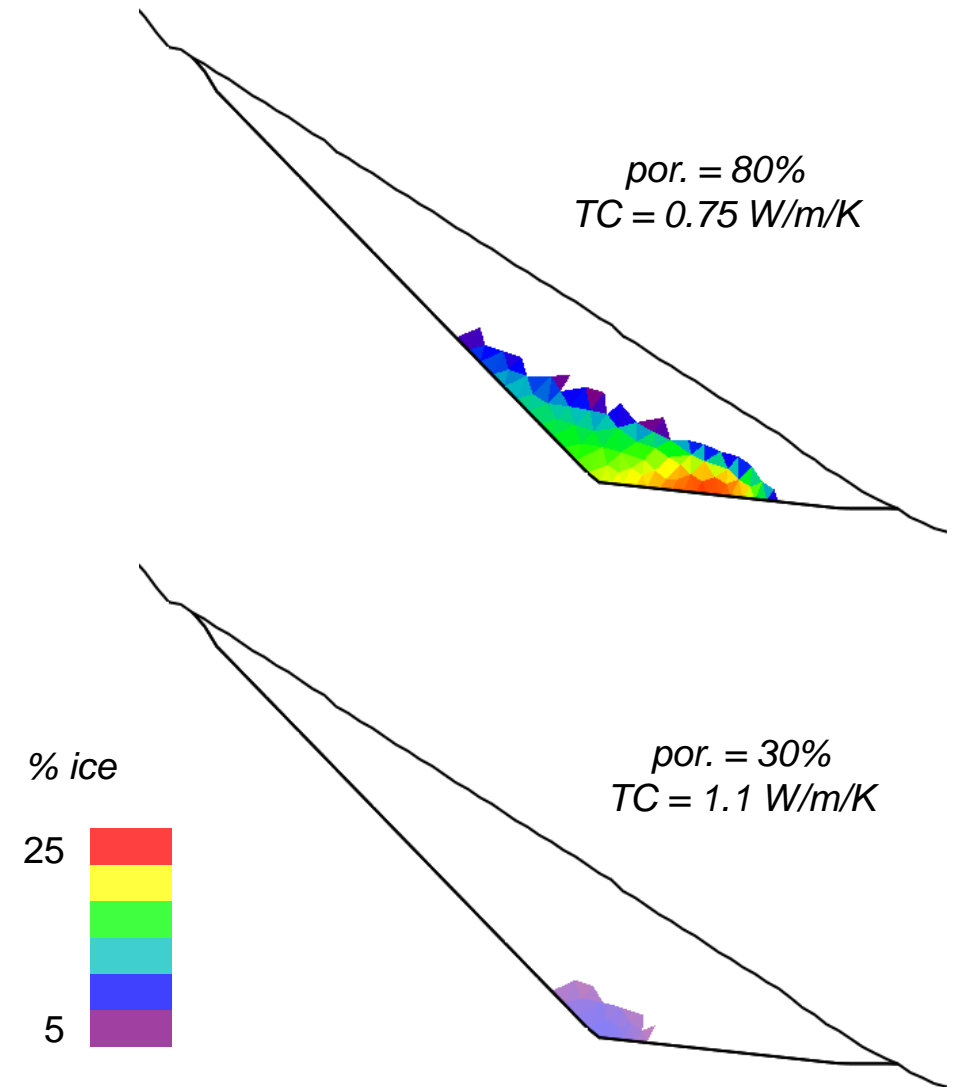
1. Can permafrost persist in the Gislá talus slope until the date of the landslide?

→ Yes - permafrost persists **at the base of the talus**, as expected with a **chimney effect**



2. What was the thermal state of permafrost at the date of the landslide?

- **25% of ice persists** at the base, with the most ice-conservative scenario
- **nearly no ice persists** with the least ice-conservative ones



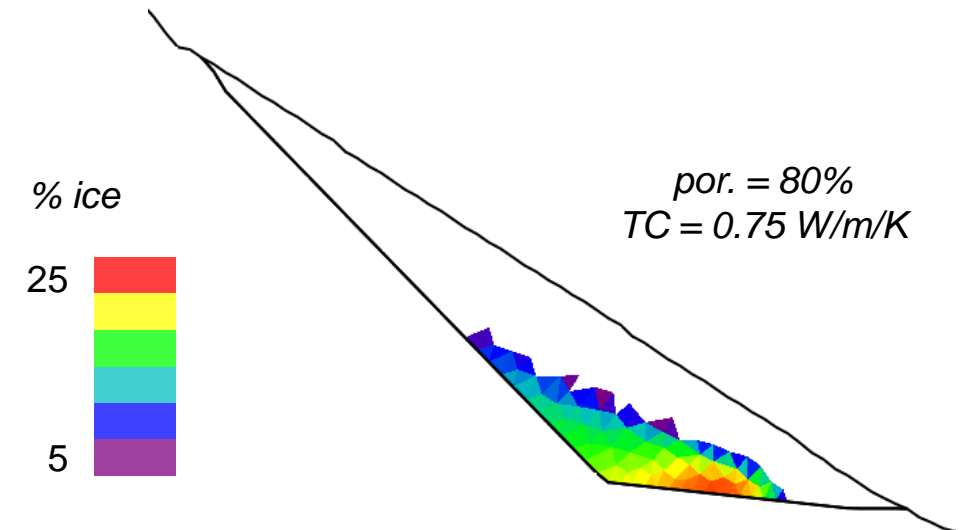
3. What thermal properties of the Gislá talus slope are required to maintain permafrost?

→ **ice-cemented material** in the landslide deposits indicate a **relatively high ice content** (~ 50%)



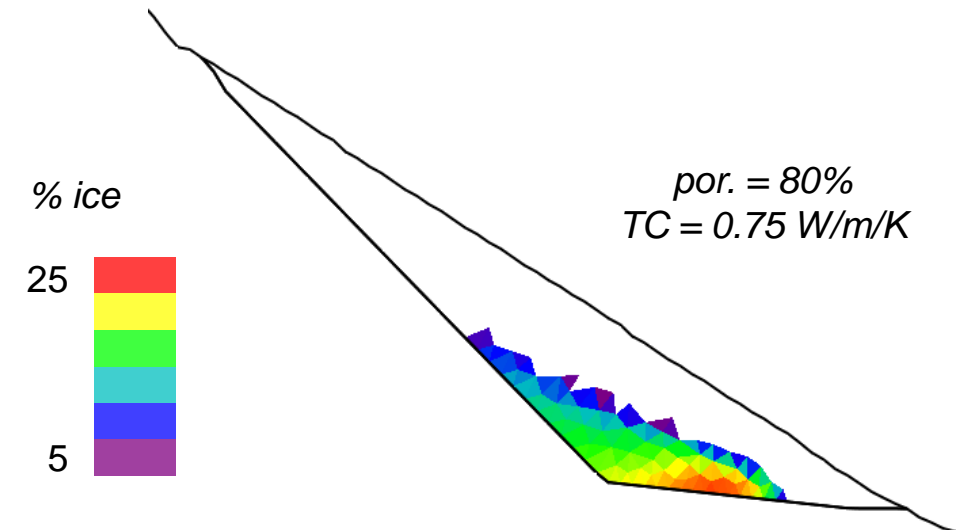
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3. What thermal properties of the Gislá talus slope are required to maintain permafrost?

- **ice-cemented material** in the landslide deposits indicate a **relatively high ice content** (~ 50%)
- the most ice-conservative scenario shows **lower ice content** (25%)
- modelling air convection would **increase the final ice content**



Thank you for your attention!

