# Aspect and Topographic Controls on Weathering and Permeability in the Montane Critical Zone


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## Introduction

+ Critical zone evolution hinges on the ability of landscapes to transmit meteoric water through the subsurface, as oxygen- and carbon-dioxide-rich water is a crucial driver in the transformation of rock into soil.

+ Previous studies suggest that groundwater flow and critical zone evolution are dependent on slope aspect, as different aspects receive varying amounts of solar radiation.

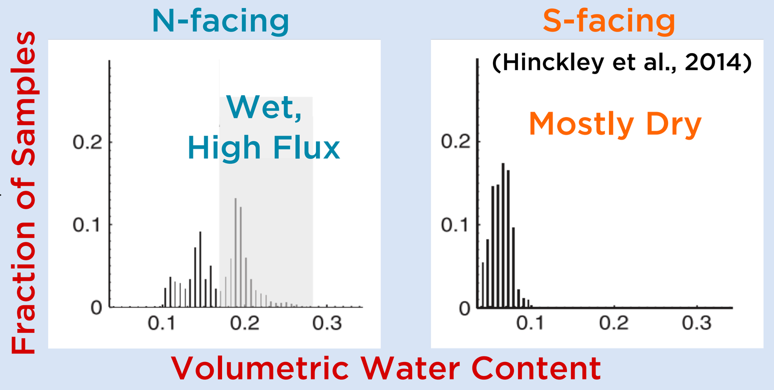
+ The movement of groundwater has far-reaching ecological effects that include the health and diversity of vegetation and the biogeochemical cycling of nitrogen and carbon.


### How does slope aspect affect...

**+ Groundwater Flow?**

North-facing slopes:
+ High GW flux in spring melt
+ Matrix flow

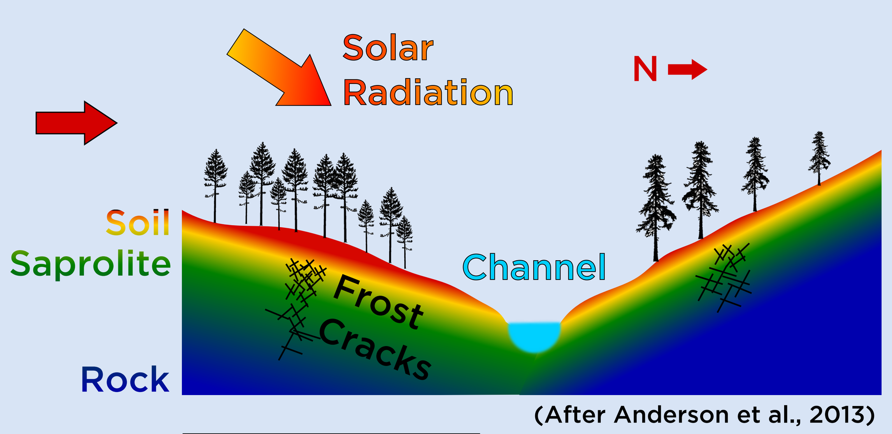
South-facing slopes:
+ Dry year-round
+ Preferential flow




**+ Weathering?**

North-facing slopes:
+ Colder temp.
+ Deeper frost damage
+ More persistent saturation
+ Thicker saprolite

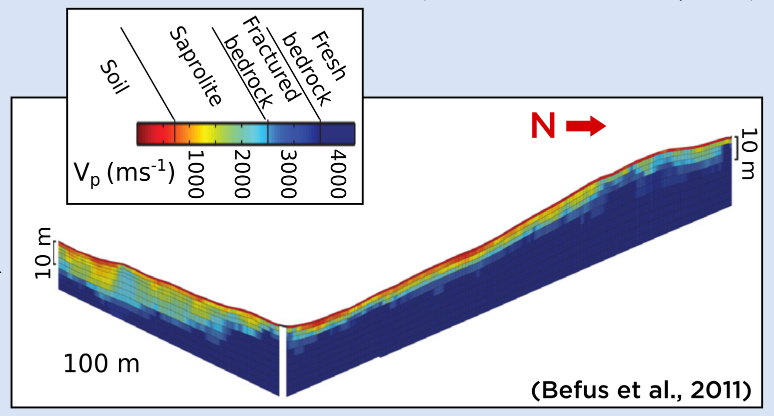
South-facing slopes:
+ Warmer temp.
+ Shallower frost damage
+ Less saturated
+ Thinner saprolite




**+ Bedrock Depth?**

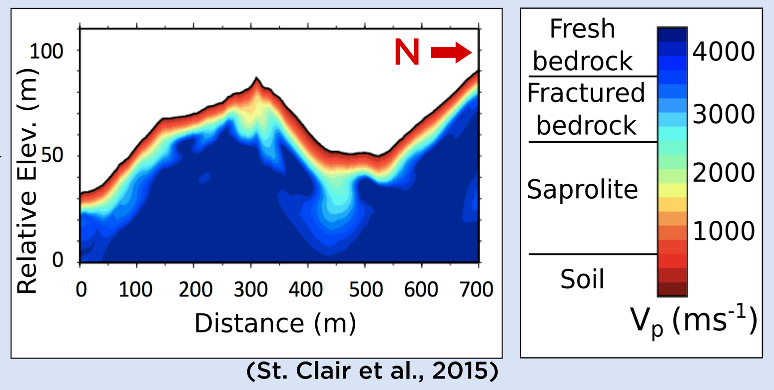
North-facing slopes:
+ 10-15 m to bedrock

South-facing slopes:
+ <10 m to bedrock



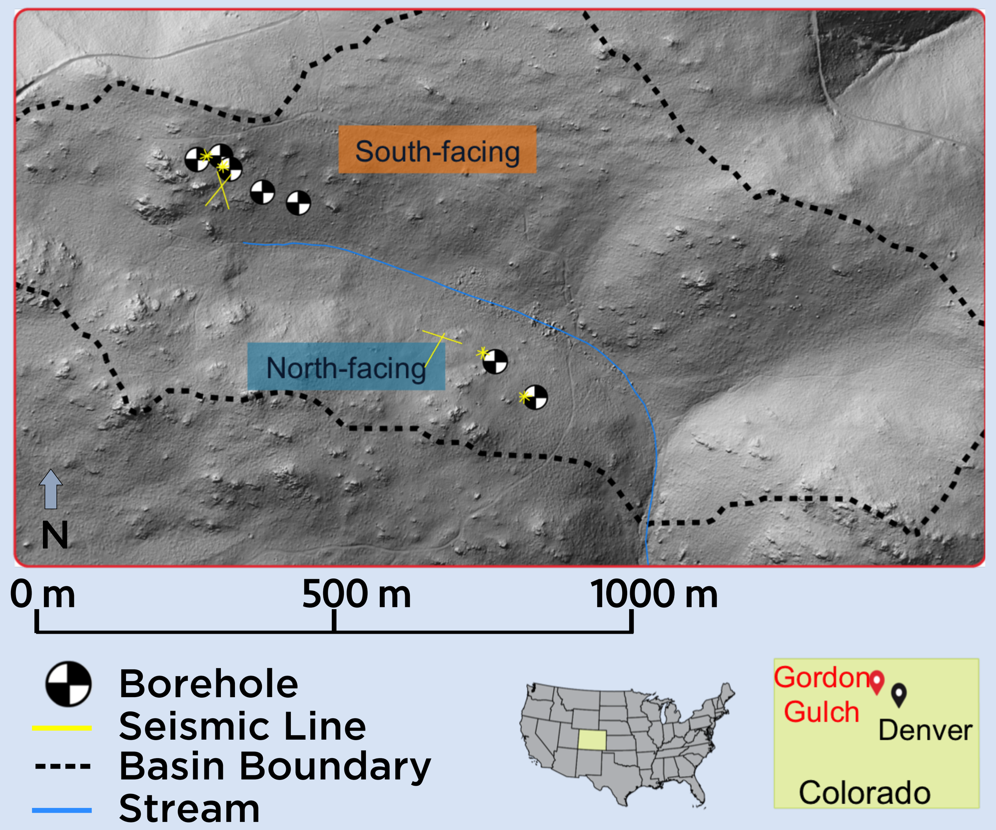

**But Wait!**

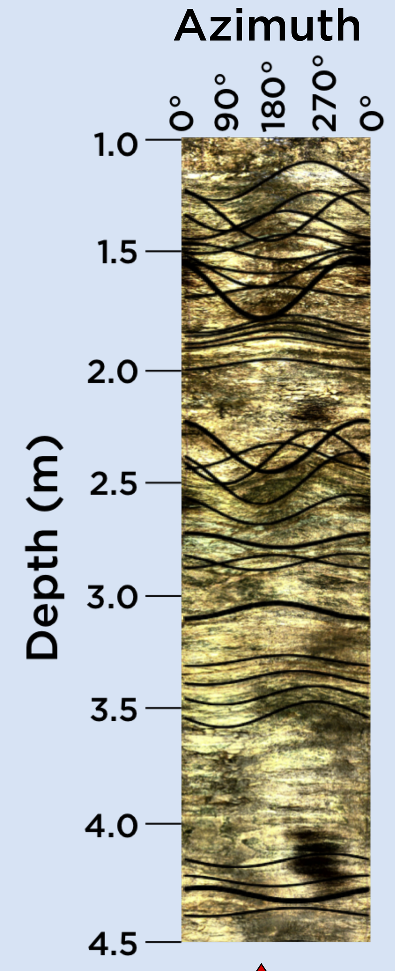
Seismic observations by St. Clair et al. (2015) demonstrate that saprolite thickness is consistent with slope aspect, and instead depends more on regional stress, which controls the distribution of open fractures that can act as groundwater conduits.




**The goal of this study is to use borehole and surface geophysical techniques to investigate the controls of slope aspect and regional stress on the weathering of saprolite and groundwater flow.**

## Methods



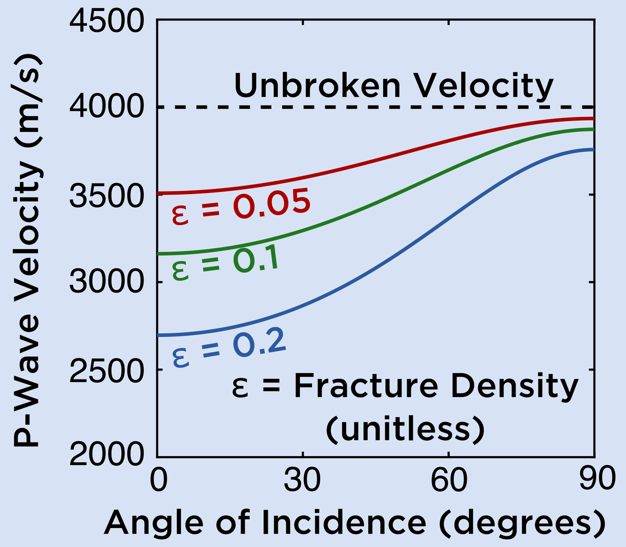




+ This study was conducted in Gordon Gulch, a field area within the Boulder Creek Critical Zone Observatory.

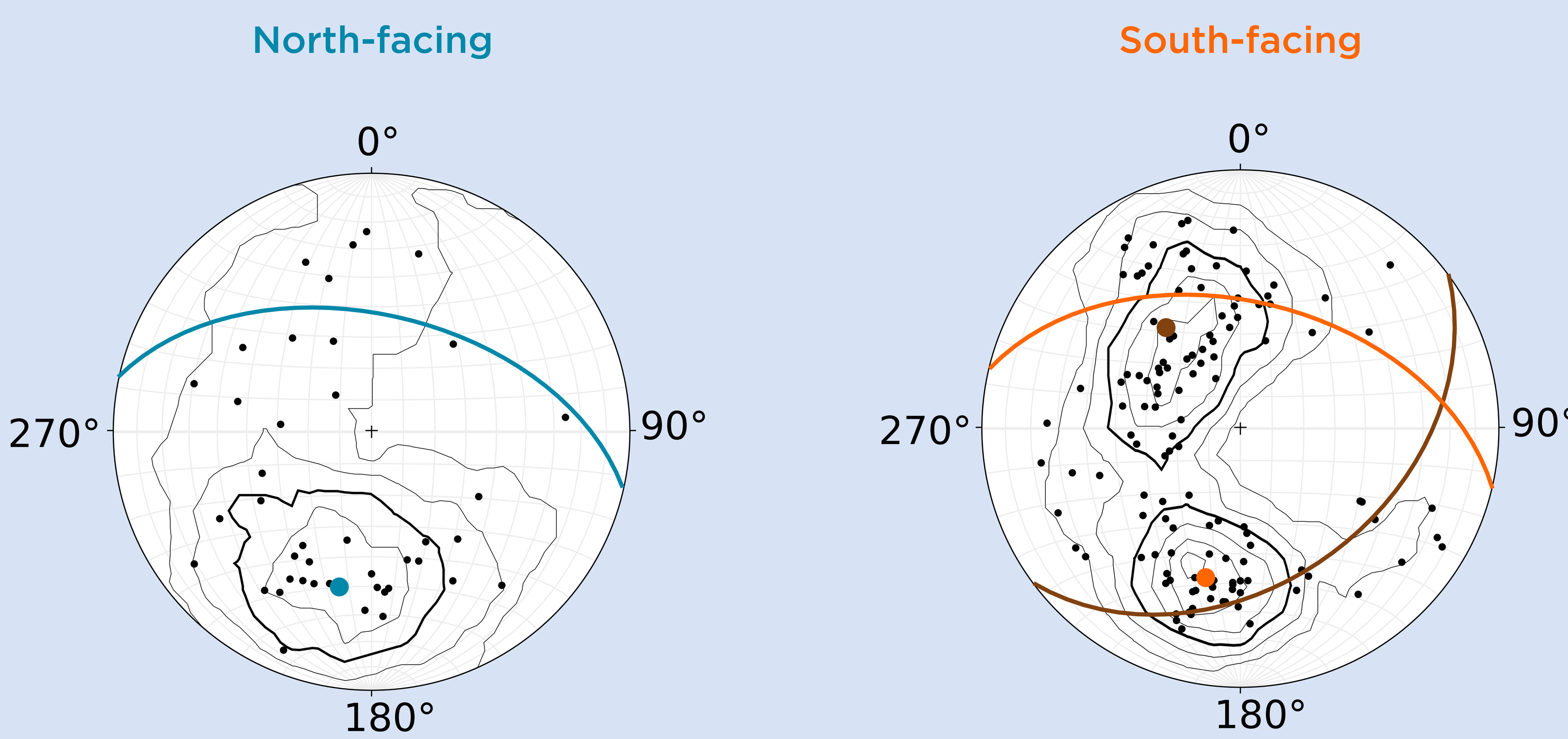
+ We conducted two short and one long seismic survey on each hillslope.

+ We drilled seven boreholes and counted fractures in each hole with an Optical Televiewer.

+ We compare seismic velocity with density and orientation of fractures. In fractured material, compressional (P) wave velocity depends on fracture density and orientation.

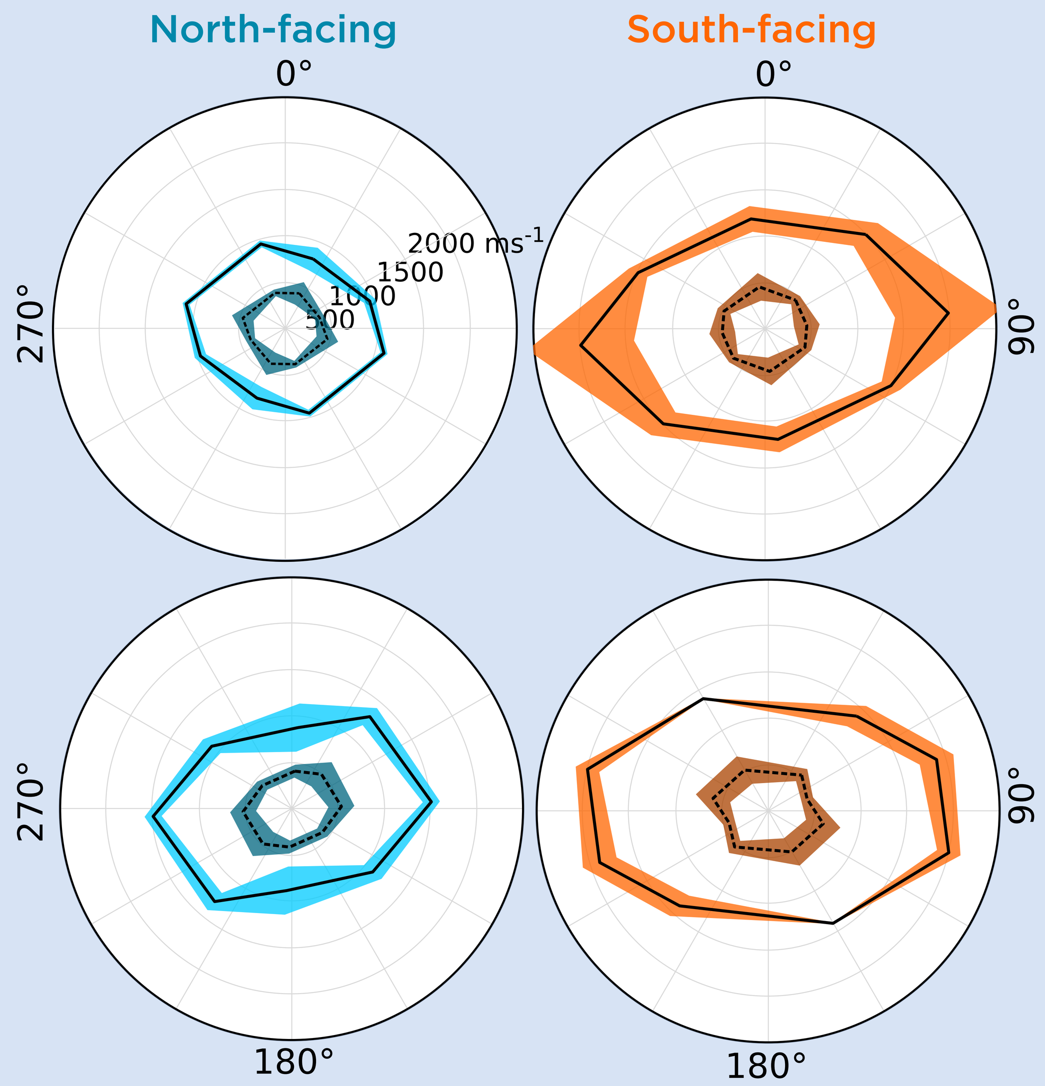



## Borehole Results




+ Fractures on the north- and south-facing slope trend in the same direction. Points represent poles to planes of fractures; dark contours identify significant fracture orientations; colored arcs and points represent mean strike and dip of significant fractures.

## Seismic Results




+ Seismic velocity vs. polar direction on north- and south-facing slopes: dotted black lines are mean soil velocity; solid black lines are mean saprolite velocity; shaded regions are one std. deviation.

+South-facing saprolite velocities are anisotropic relative to north-facing saprolite. Soil velocities are isotropic.

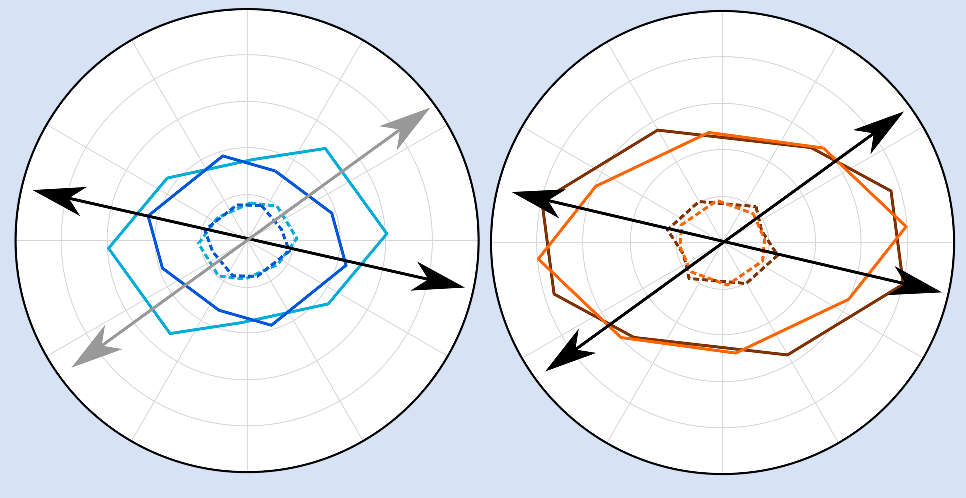
**Bedrock Velocity**

| Direction | N-facing | S-facing |
|---|---|---|
| Cross-Valley | 4600 $ms^{-1}$ | 4400 $ms^{-1}$ |
| Down-Valley | 3700 $ms^{-1}$ | 4300 $ms^{-1}$ |

**Depth**

| Layer | N-facing | S-facing |
|---|---|---|
| Saprolite | 2 m | 2 m |
| Bedrock | 8-9 m | 9-11 m |

+ Bedrock and saprolite depths do not vary significantly with slope aspect.



+ Mean fracture directions observed in borehole analysis correlate with fastest direction of seismic velocity.

## Conclusions

+ Fracture orientation is consistent across hillslopes, suggesting it is controlled by regional stress.

+ Saprolite velocity varies with hillslope:
  + North-facing slopes are slower and likely more weathered
  + South-facing slopes are faster and more anisotropic

+ Groundwater flow is likely matrix-driven on north-facing slopes and fracture-driven on south-facing slopes.


ACKNOWLEDGMENTS

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