Remote rock mass characterization

TERRA summer school – Module 2

Mateusz Janiszewski, D.Sc (Tech.)

Lauri Uotinen, D.Sc. (Tech.)

Aalto University
School of Engineering

TERRA

2023

Learning goals

By the end of the course, you will be able to:

- understand the principles and techniques of rock mass characterization, photogrammetry, and laser scanning
- plan data aqcusition and collect photogrammetric data
- process 3D models in photogrammetric software
- measure rock mass properties from 3D point clouds

Introduction

What is rock mass?

- a volume of natural rock in situ
- characterized by rock material properties and the network of discontinuities
- discontinous
- heterogeneous and anisotropic properties

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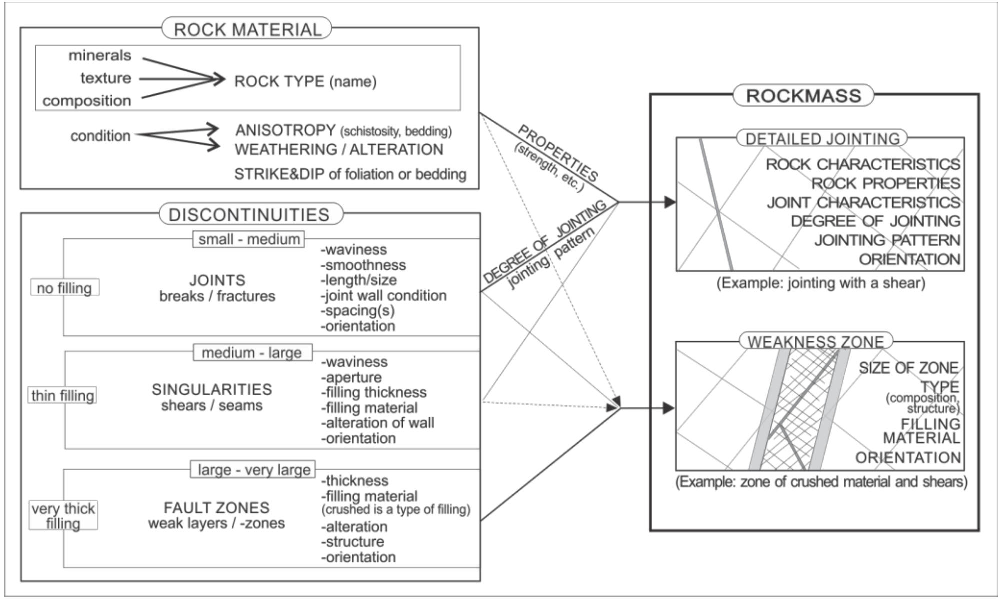
Why is rock mass important in engineering?

- Rock mass characteristics heavily influence the stability and safety of engineering structures
- Understanding the rock mass helps in predicting its response to external forces (loads, stresses) and environmental conditions (water)

Characterizing the rock mass

- Rock mass characterization involves assessing
  - ➢ rock material
  - ➢ **discontinuities and their properties**



https://rockmass.net/rock-properties/

- crucial in the design and implementation of safe and efficient engineering projects

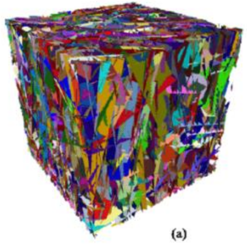
Palmström, 2000

Rock mass model formulation

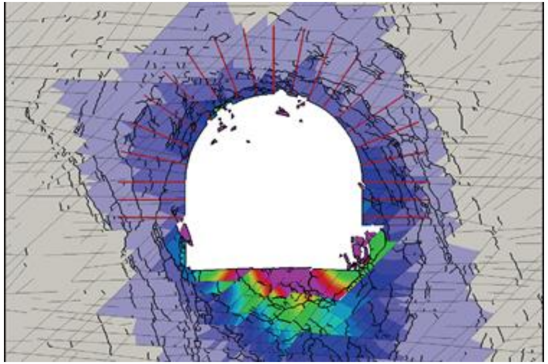
Fracture properties

Intact rock properties

Fracture sets



Rock mass model

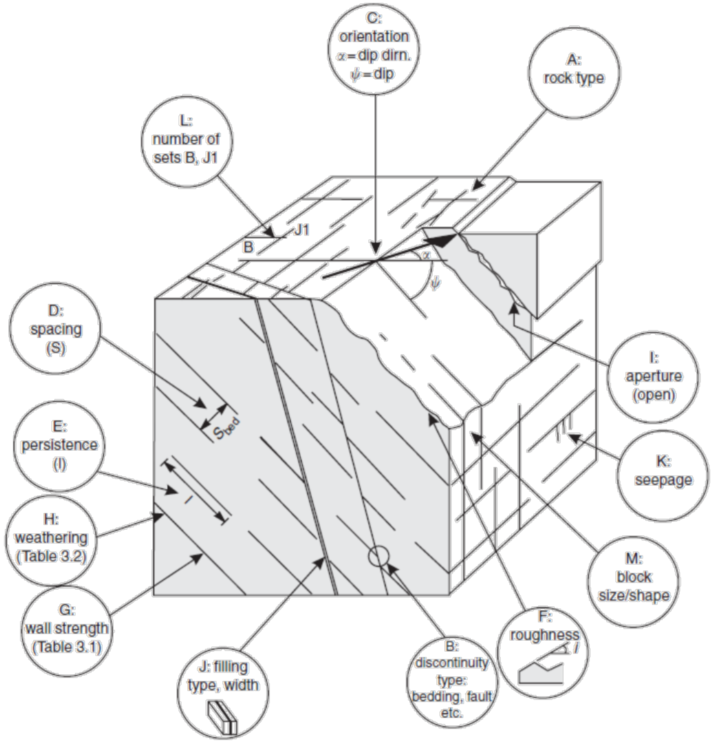


Fracture network model

Numerical model

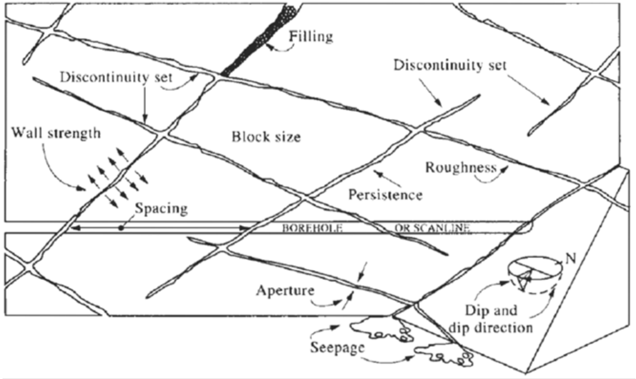
Discontinuities in rock masses

- Fractures in rock masses: joints, faults, shear zones, and bedding planes
- impact rock mass behavior under load and fluid flow

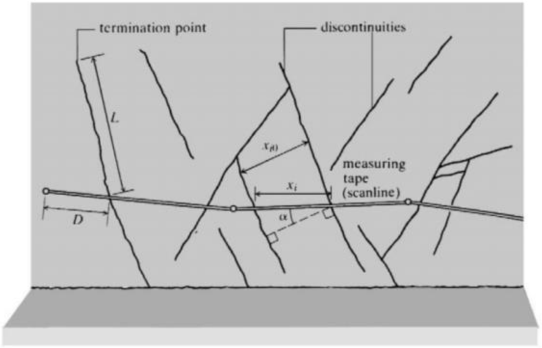


Traditional fracture mapping method

- Mapping exposures
- Contact method: surface measurement -> Need access to rock mass surface
- Spot vs. lineal vs. areal mapping
- e.g. scanline survey
- Major flaws: time constraint and bias



Hudson and Harrison, 1997



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What can go wrong?

Norway, 2019

- classic wedge failure
- large detachment surface
- other detachment surface is a near vertical joint
- not detected in the rock mass characterization process

Emergence of automated mapping

Past

Traditional manual mapping

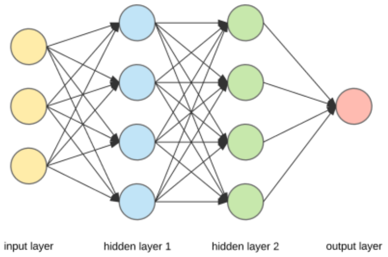
Now

Digital mapping

(manual or semi-automated)

Future

Fully automated mapping



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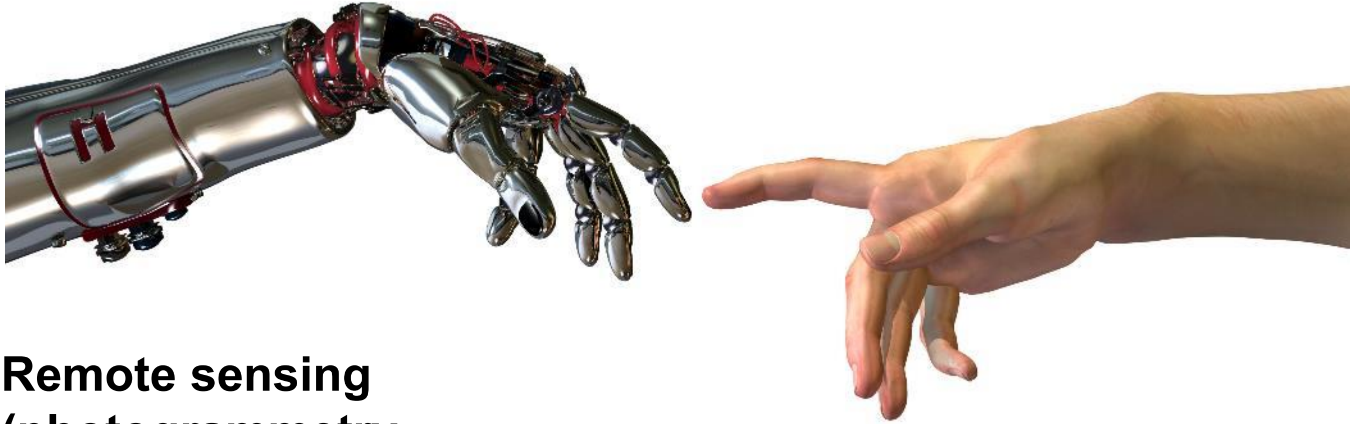
Current technology enables remote rock mass characterization



Remote sensing (photogrammetry, laser scanning)
3D data processing

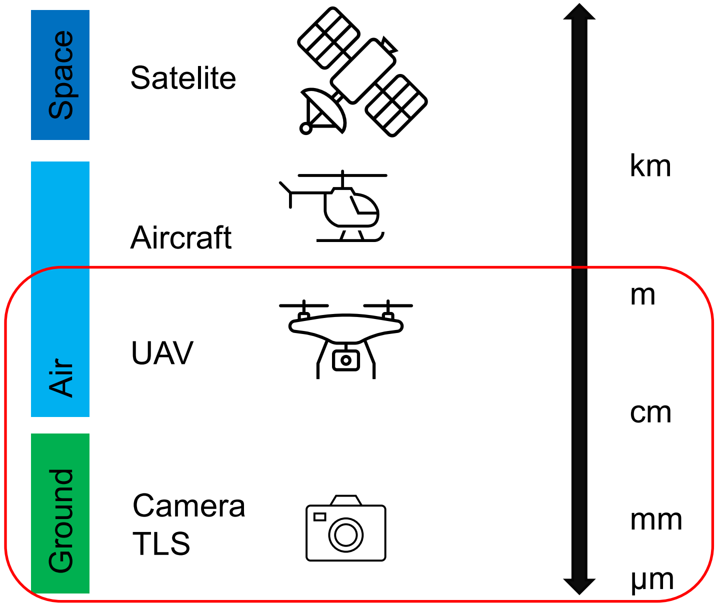
Remote sensing methods

“Detection and monitoring of the physical characteristics of an area by measuring its reflected and emitted radiation at a distance” USGS

SAR interferometry

Aerial Photographs
Airborne Photogrammetry
Airborne LiDAR
Thermal imaging
Hyperspectral imaging

Terrestrial laser scanning (TLS)
Close-range photogrammetry



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Structure from Motion (SfM) photogrammetry

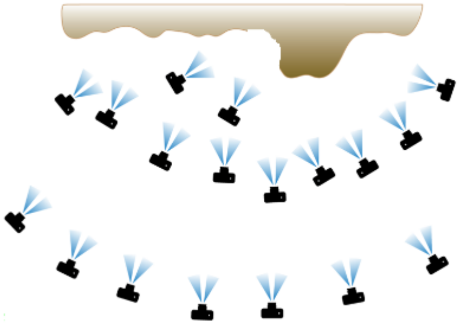
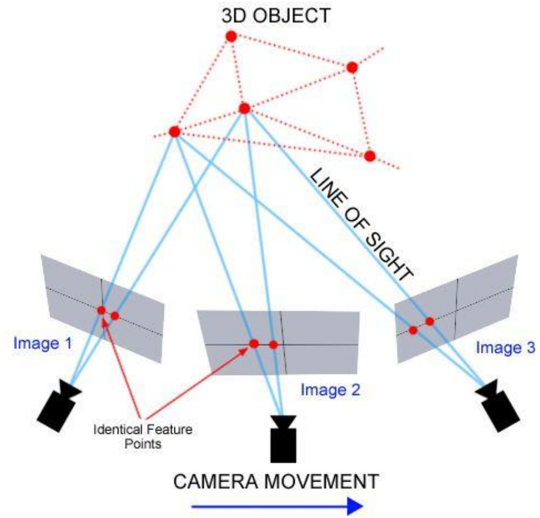


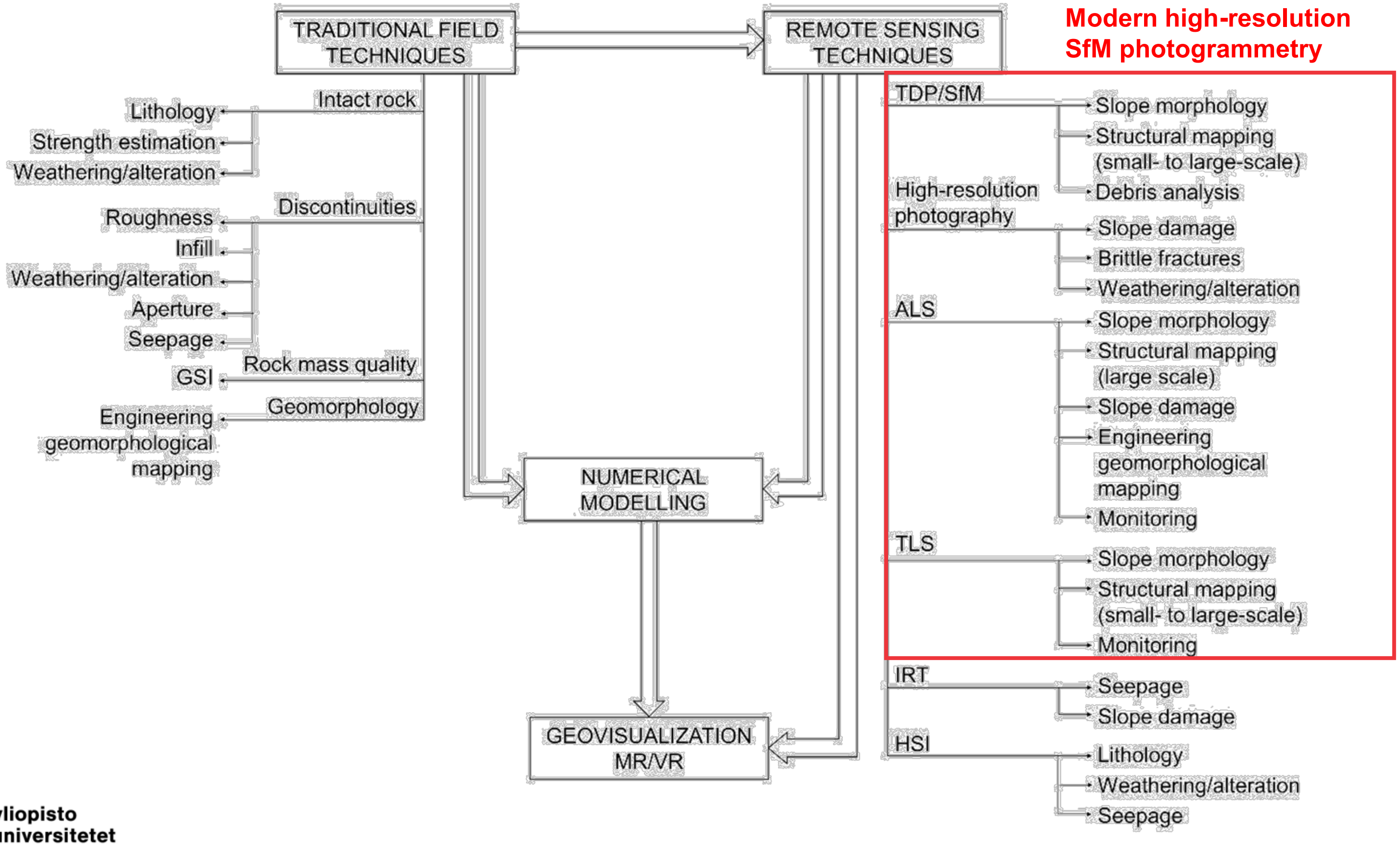
Image acquisition



SfM algorithm

Digital surface model

Slope characterization example



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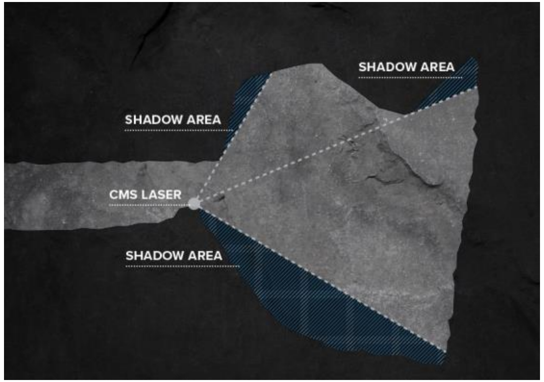
Stead, et al., 2019. Application of Remote Sensing to the Investigation of Rock Slopes: Experience Gained and Lessons Learned. *ISPRS Int. J. Geo-Inf.*, *8*, 296.

Stope mapping example

Stope scanning

- Restricted access to dangerous areas
- CMS unable to provide accurate measurement of all surfaces
- UAV scanning as a viable and safe method for restricted areas



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UAVs are now ready to be used underground

AUTONOMOUS REMOTE MAPPING

Source: www.emesent.io

SAFETY FLEXIBILITY

Source: www.Inkonova.se

CONFINED SPACE ACCESSIBILITY

Source: www.flyability.com

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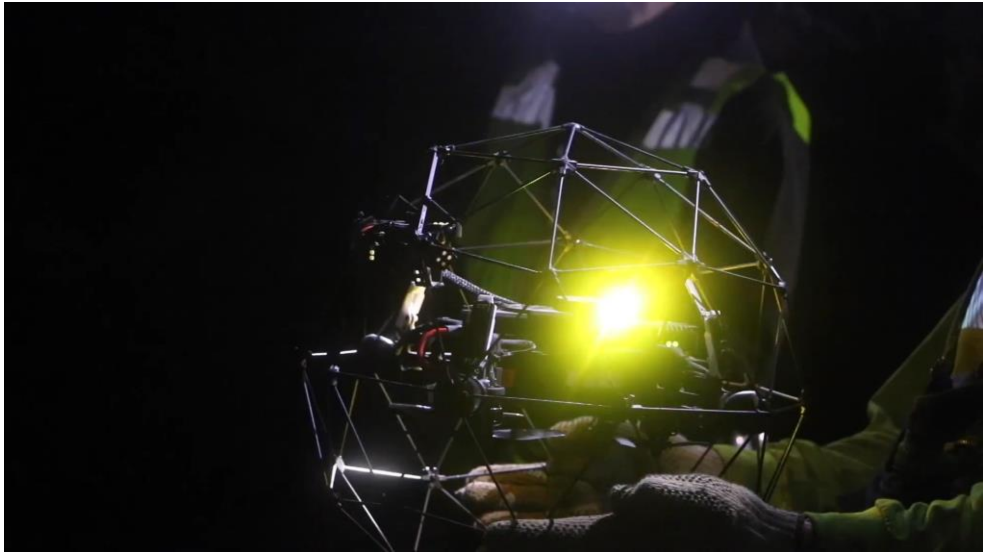
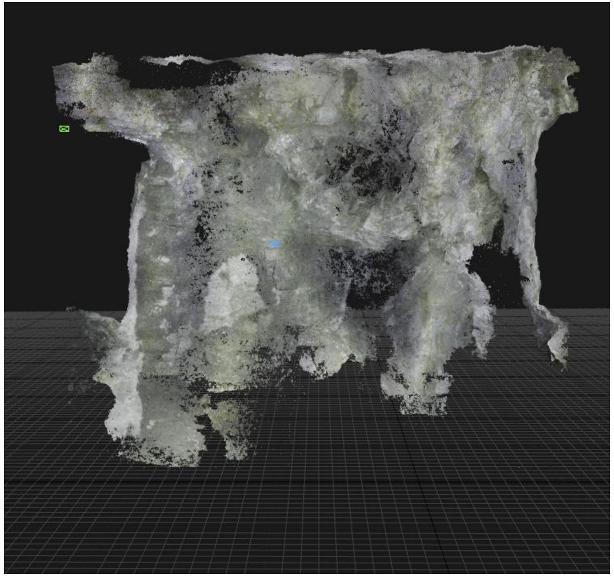
Stope mapping with a drone

- Golden Sunlight Mine in Montana, USA (Barrick Gold Corp.)
- Open dataset https://info.flyability.com/photogrammetry-dataset
- Stope dim. 10 x 30 x 100 m
- 4 flights (~35 min total flight time)
- 4K ultra high definition movie -> 2105 frames extracted

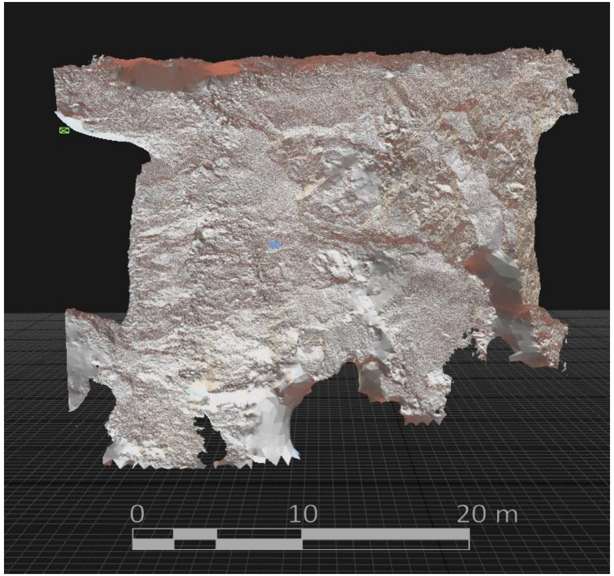


Source: https://youtu.be/e8UVLwRfRdg

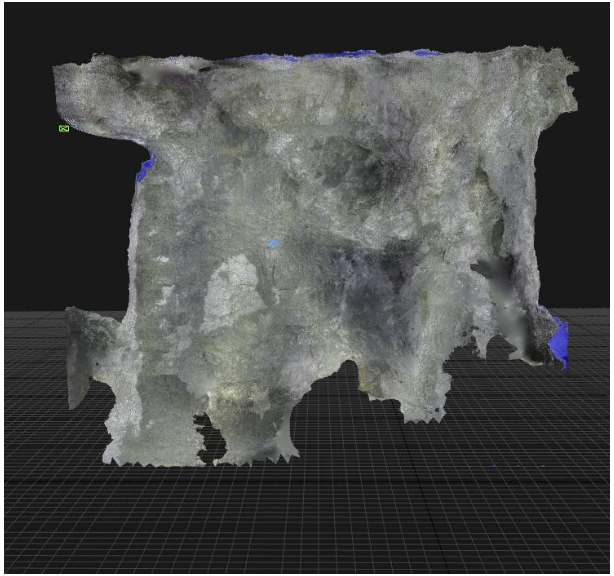
Images were processed to reconstruct the stope model



Point cloud



Mesh

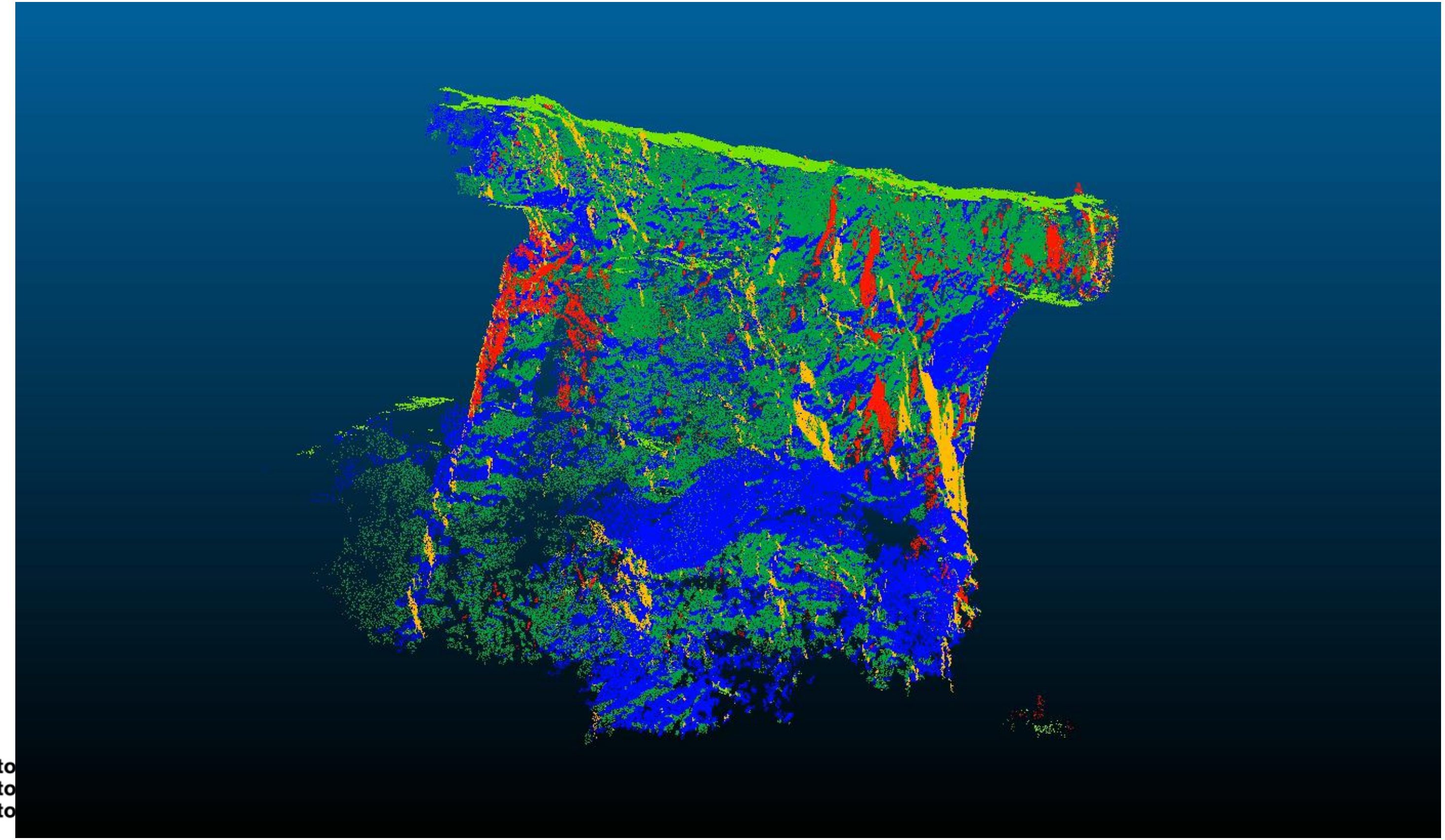


Textured mesh

Textured stope model enables revisitng for remote inspection and visualisation

A?

Discontinuity extracted semi-automatically



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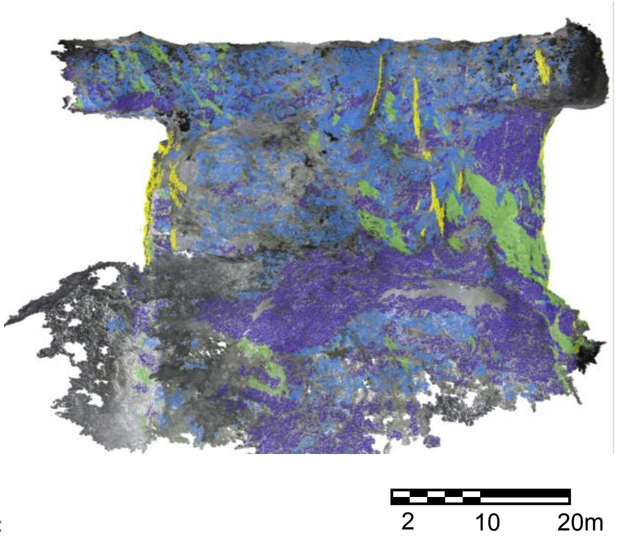
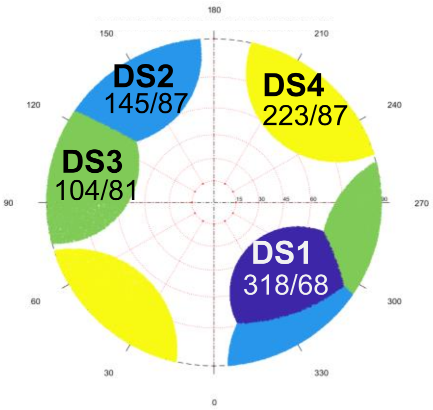
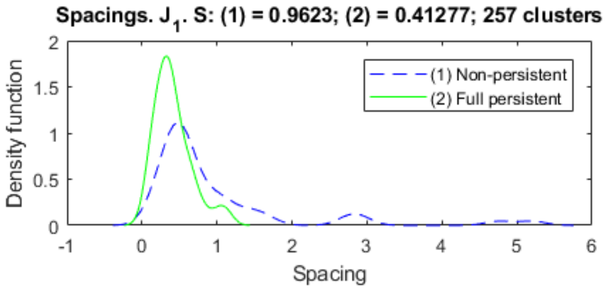
Mapping results

- point density of 33.1 points per cm^2
- semi-automatic method: discontinuity set extractor software ->4 discontinuity sets extracted



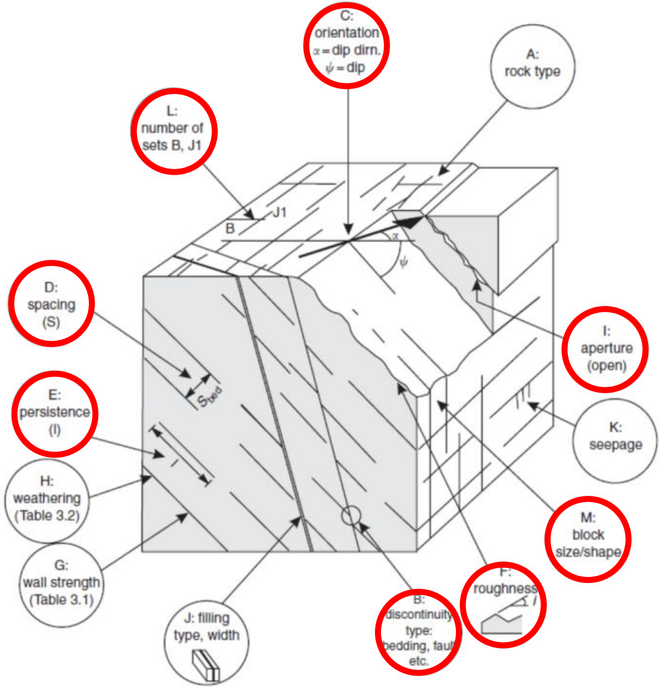




Summary

Remote rock mass characterization

- remote sensing technologies: **LiDAR** and **photogrammetry**
- high-resolution, accurate **3D models of rock mass surfaces**
- enable **detailed analysis of discontinuities** -> orientation and other geometrical properties
- analyze rock mass features over **large areas**
- **stastistical distribution** of parameters
- provides **unbiased data** from **inaccessible or dangerous locations**



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