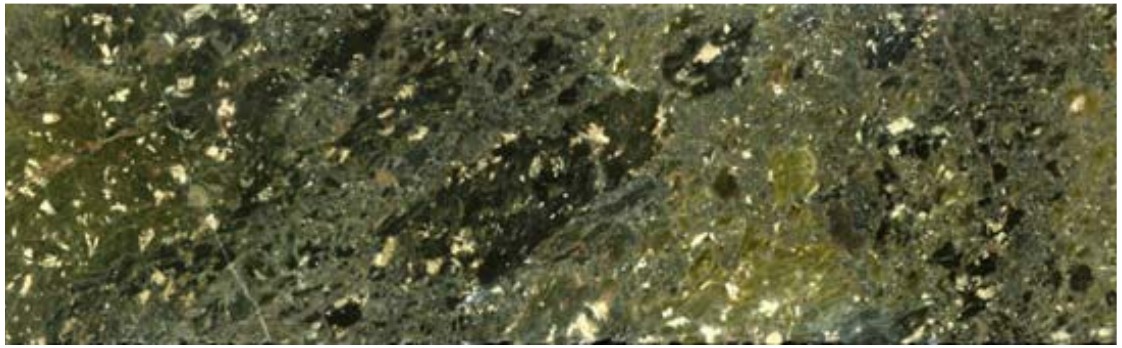
Machine-learning image analysis on phenocrysts to reconstruct lithostratigraphy in mineralised terrains:

An example with dacites in the Mt Read Volcanics



Martin Jutzeler, Yasin Dagasan, Rebecca Carey

Datarock.

CODES
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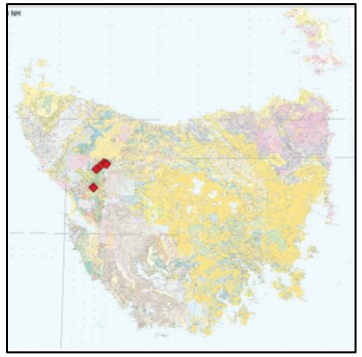
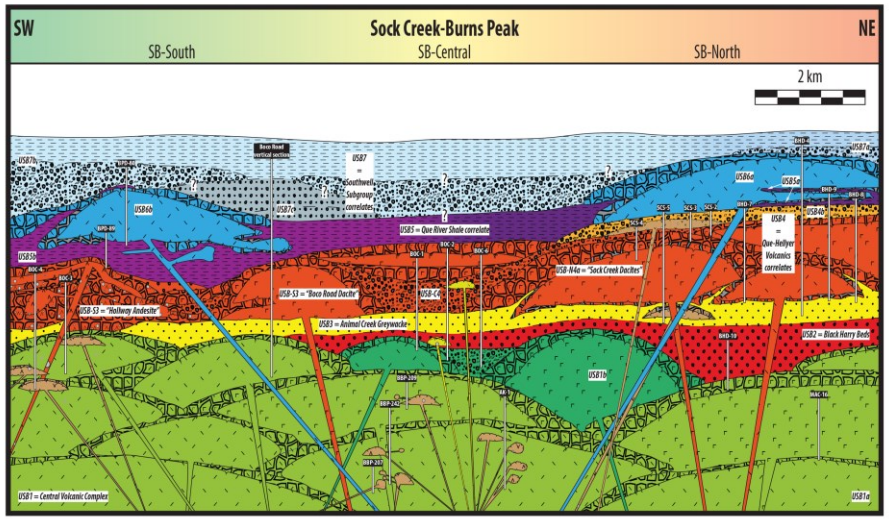
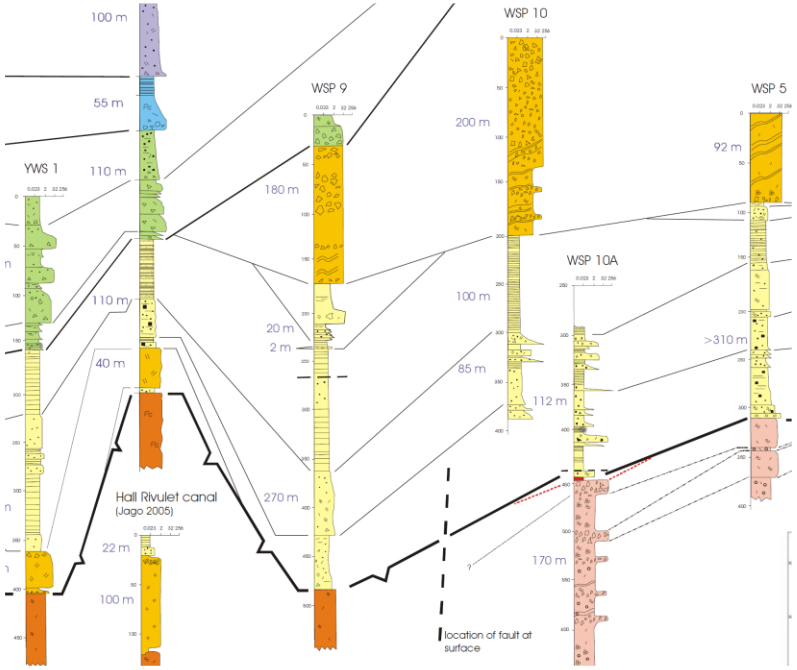
Mt Read Volcanics dacites



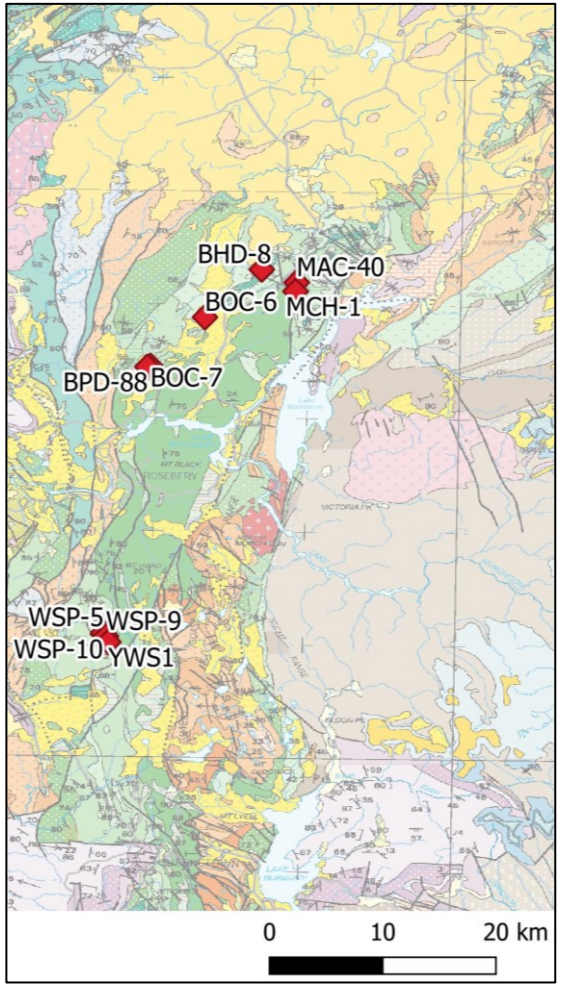
- Extensive coherent and brecciated **feldspar-phyric dacitic** horizons
- *Interpreted as prospective horizons*
  - Equivalent of the mixed Sequence of the **Que-Helley Volcanics ?**
  - Correlative between **Rosebery and White Spur area ?**



Interpreted correlatives between in the Que-Hellyer Volcanics (Fonseca 2016)



Interpreted correlatives between Rosebery and White Spur (Jago 2005)



Automated quantification of crystal size distribution (CSD) allows for fingerprinting coherent textures

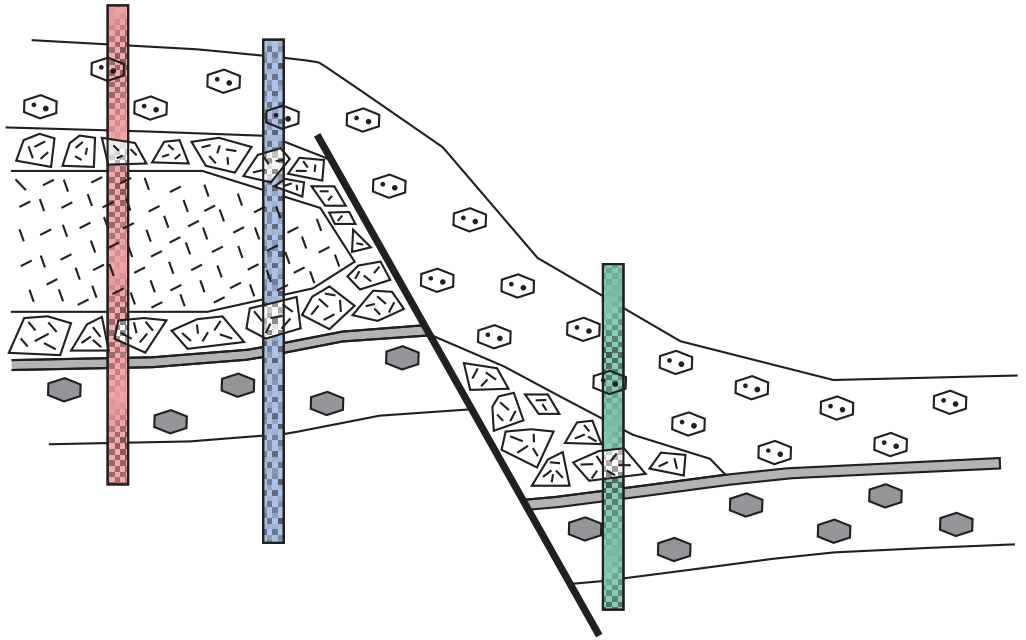
Phenocrysts can be used as a signature in coherent and coarse clastic facies

A novel technique

- Phenocryst (feldspar) content in volcanic rocks
- Machine learning automation
- Assumes homogeneous crystal content in coherent bodies

Direct application for stratigraphic correlations in:

- Poorly exposed / buried formations
- Up to moderately altered formation
- Complexly tectonised formations



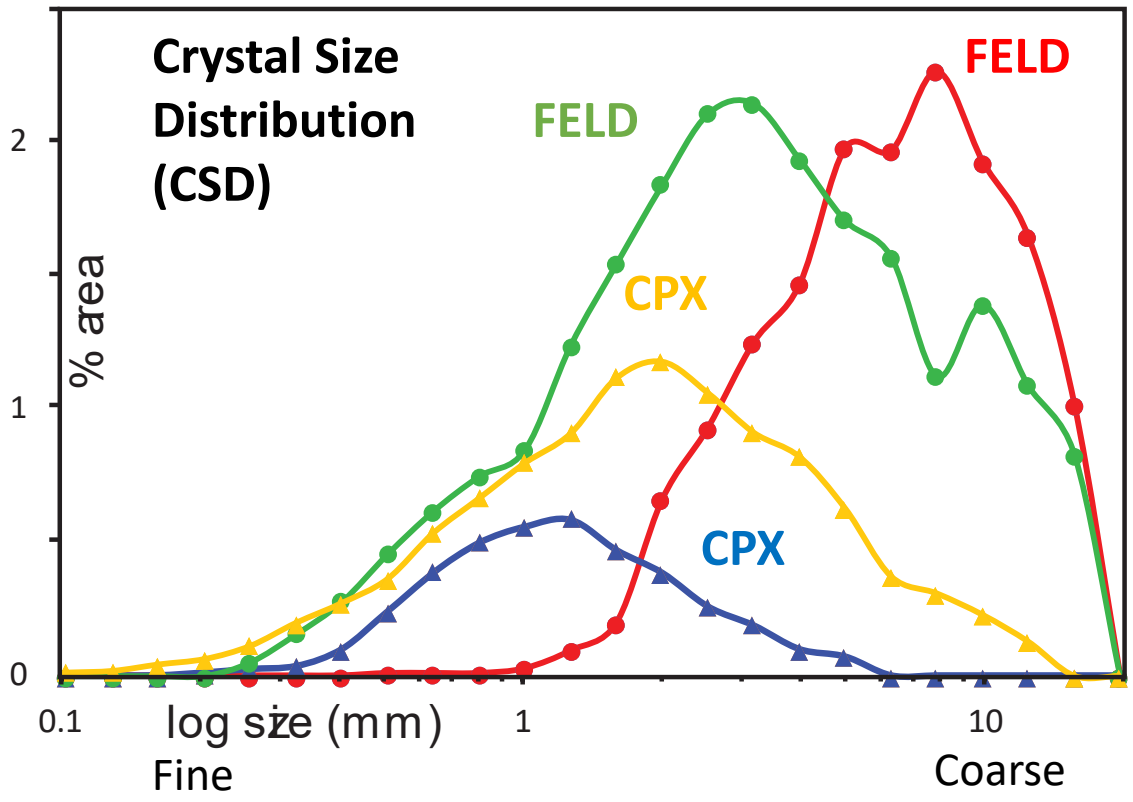
Technique is complementary to:

- Outcrop/Core description
- Bulk rock and crystal geochemistry

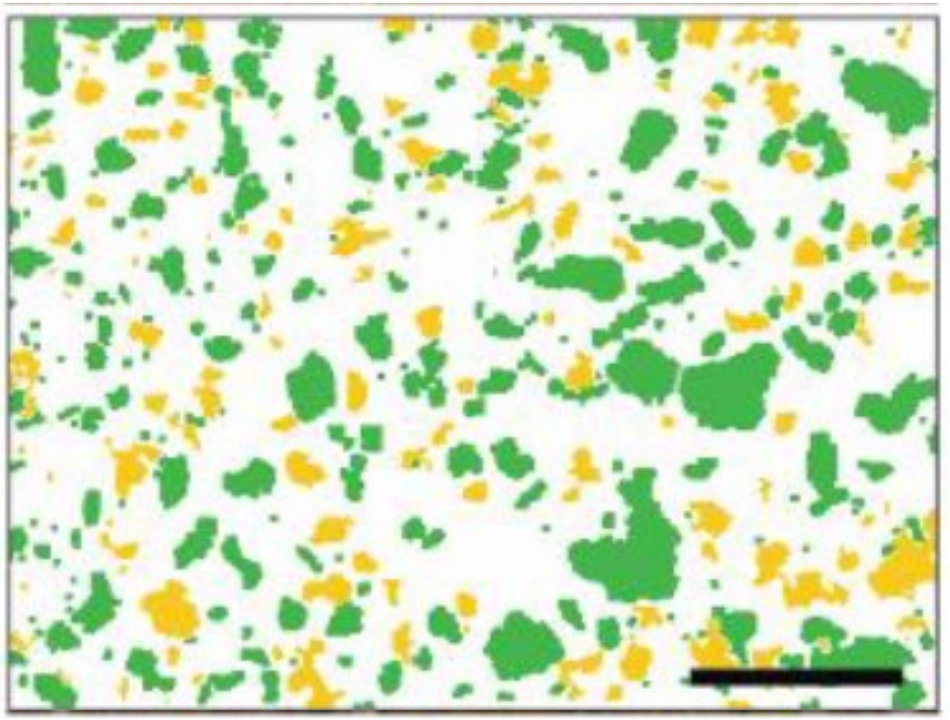
Application to Mt Read Volcanics

- Correlations in prospective dacites

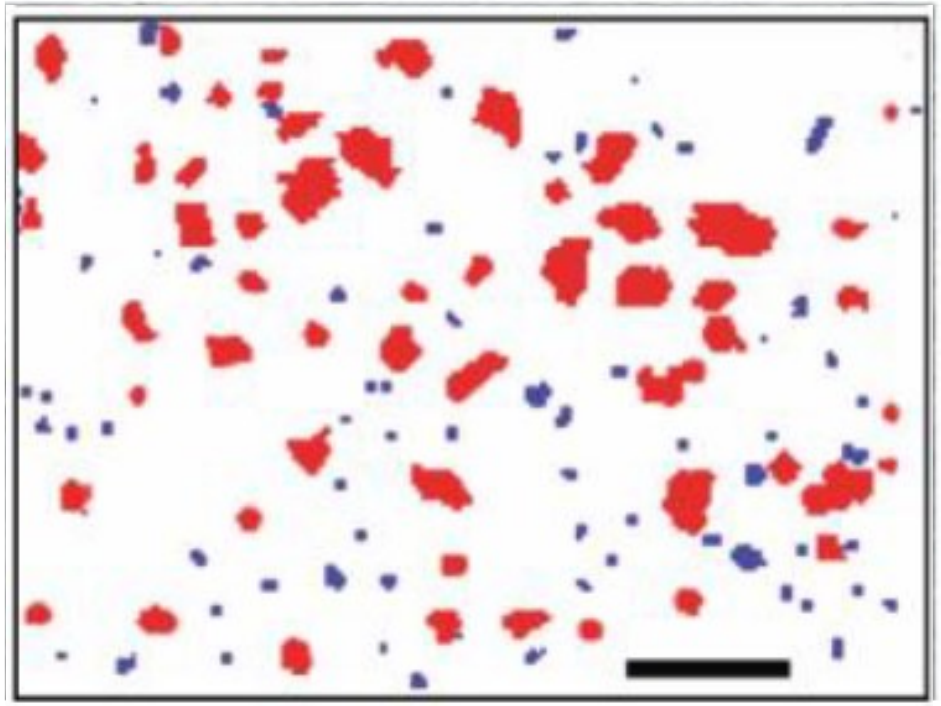
- ***How different are these two basalts?***
- ***Can we quantify how different they are?***



FELD
CPX

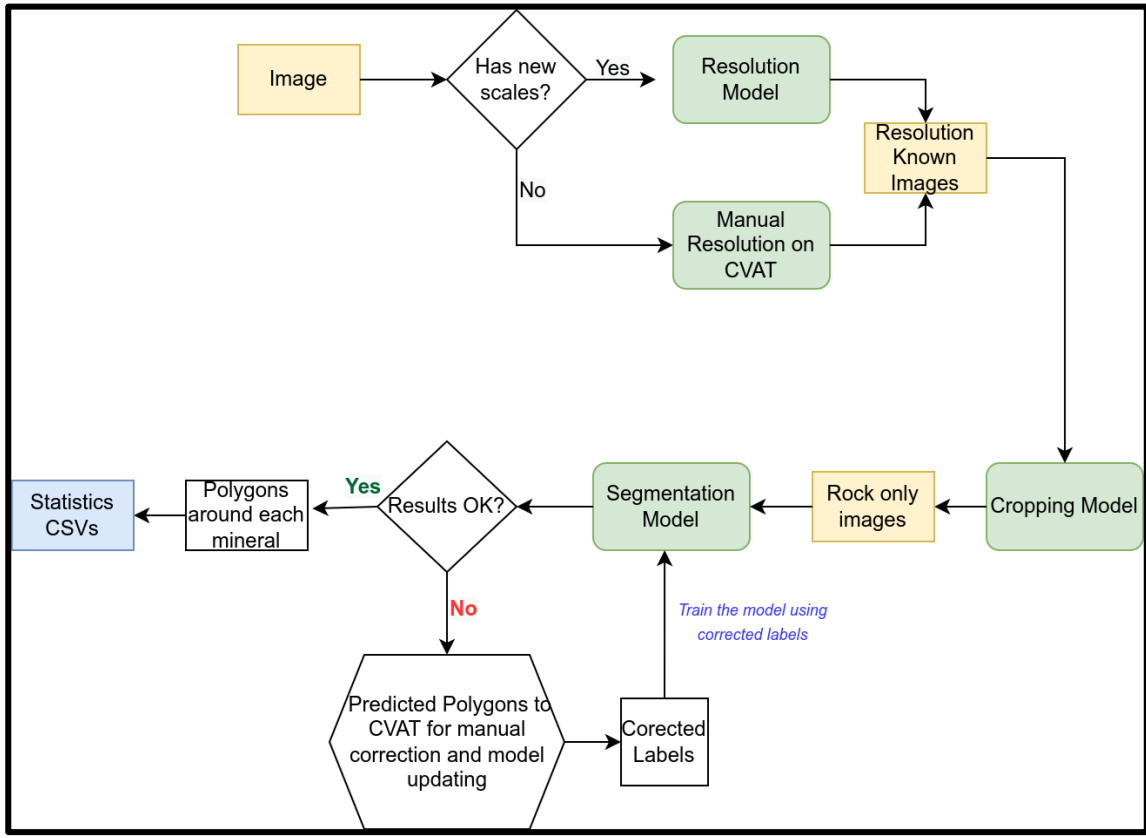


FELD
CPX



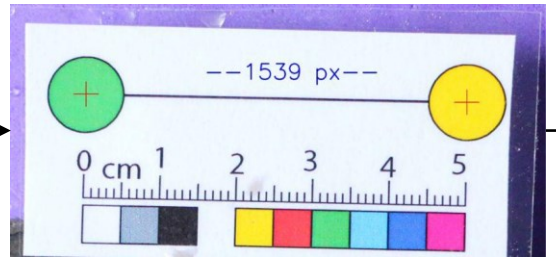
Inference Workflow

Comprises 3 Deep Learning Instance Segmentation Models



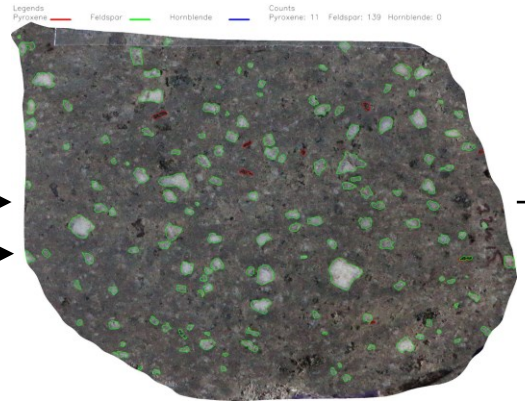
Input Image

Resolution Model



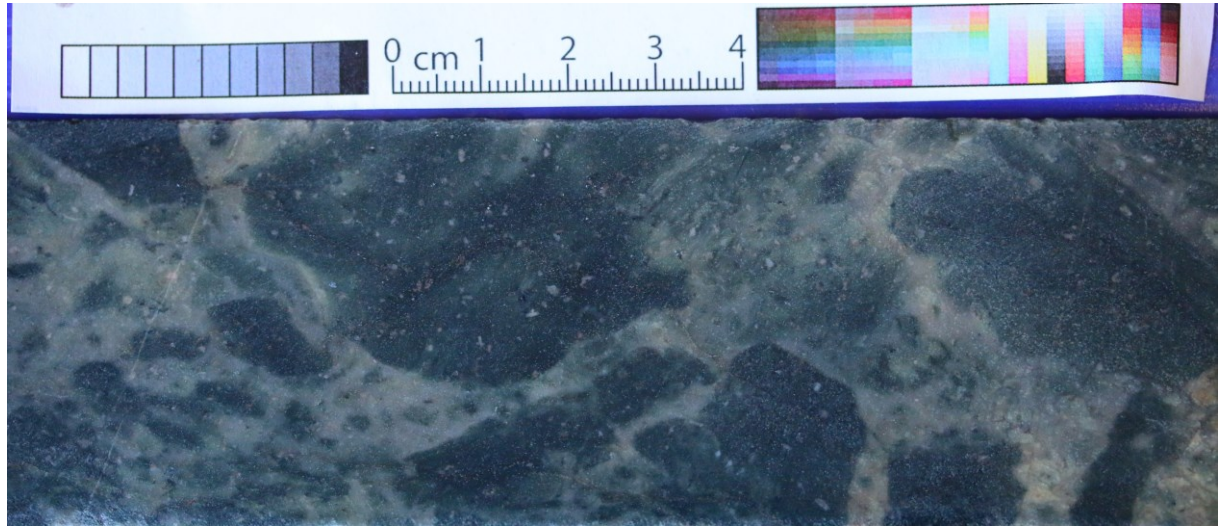
Cropping Model

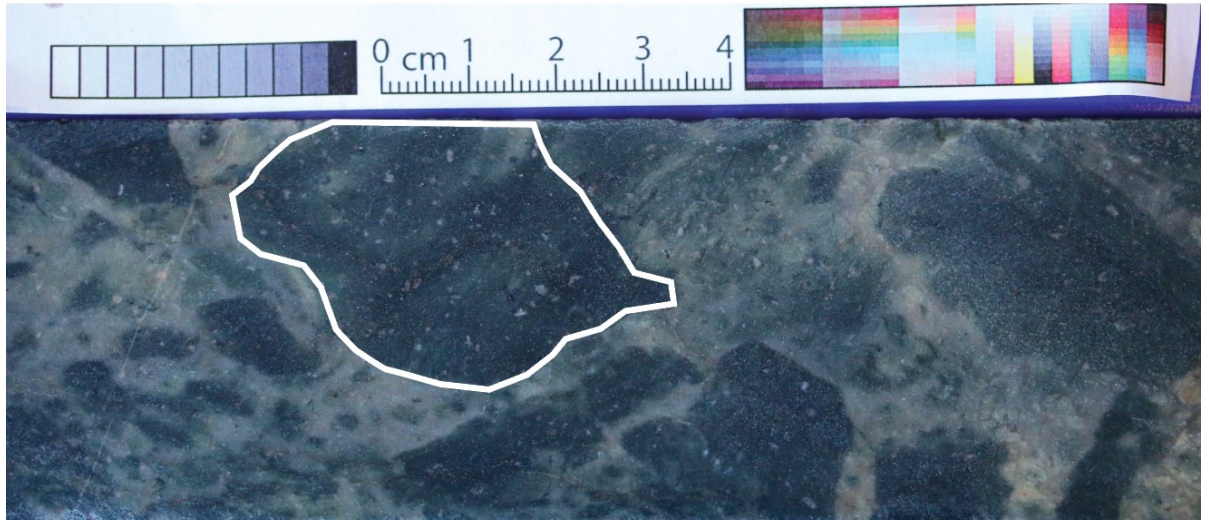
Segmentation Model



CSVs with Aggregated and individual statistics

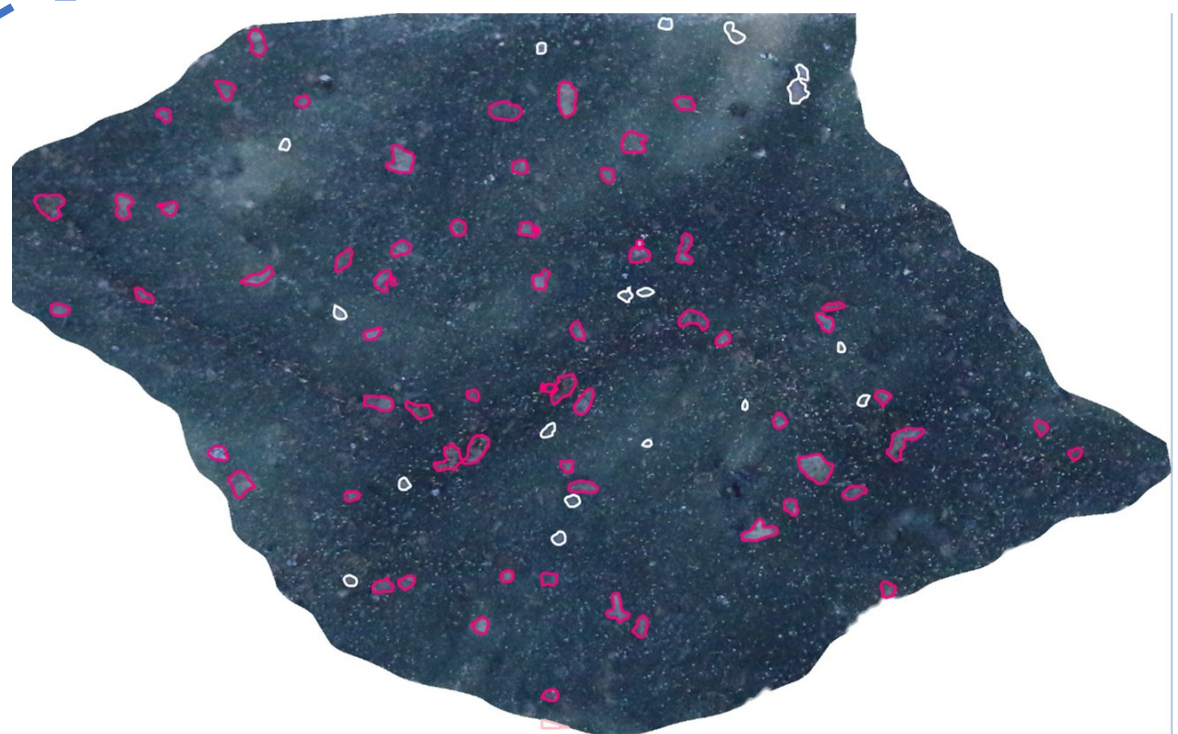
Image selection & analysis workflow



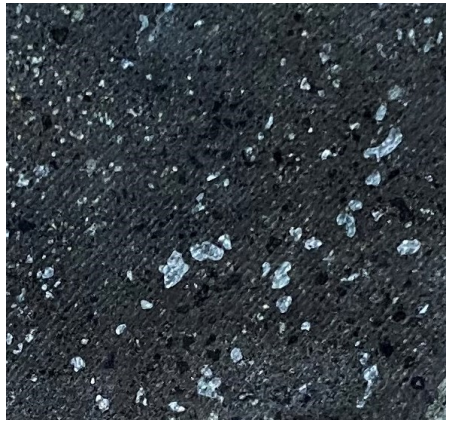
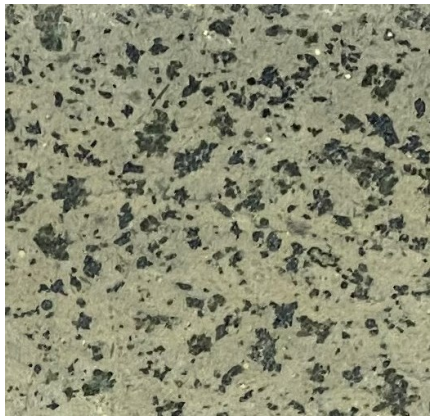
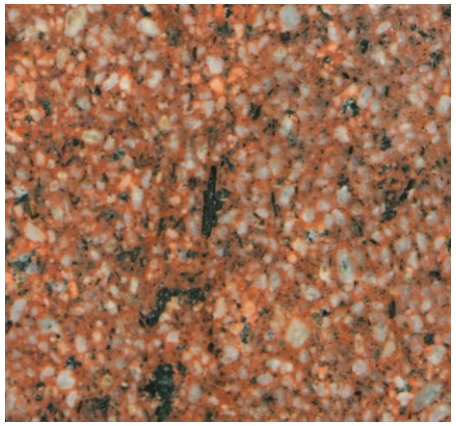
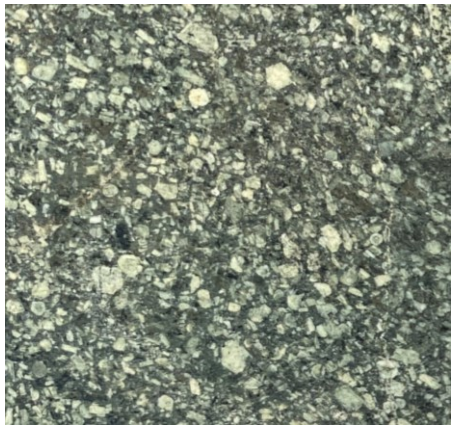
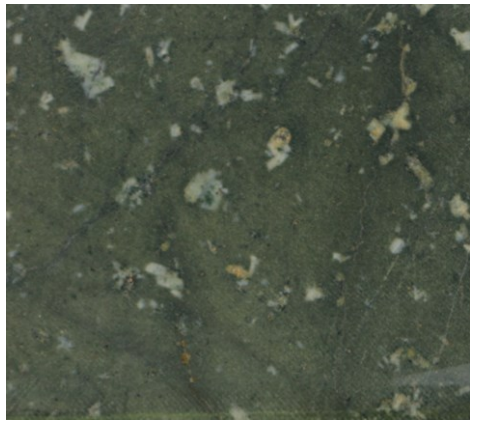


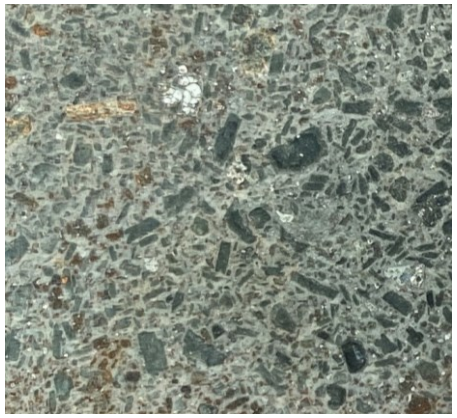
1 → 2

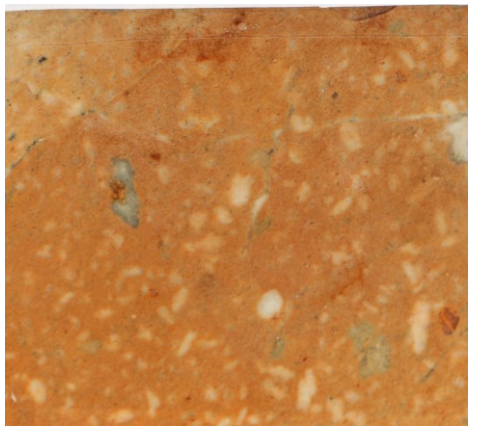
3 → 4

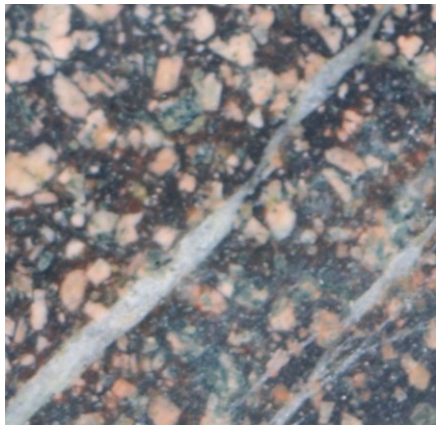


Several tens of rocks were used to teach the ML code

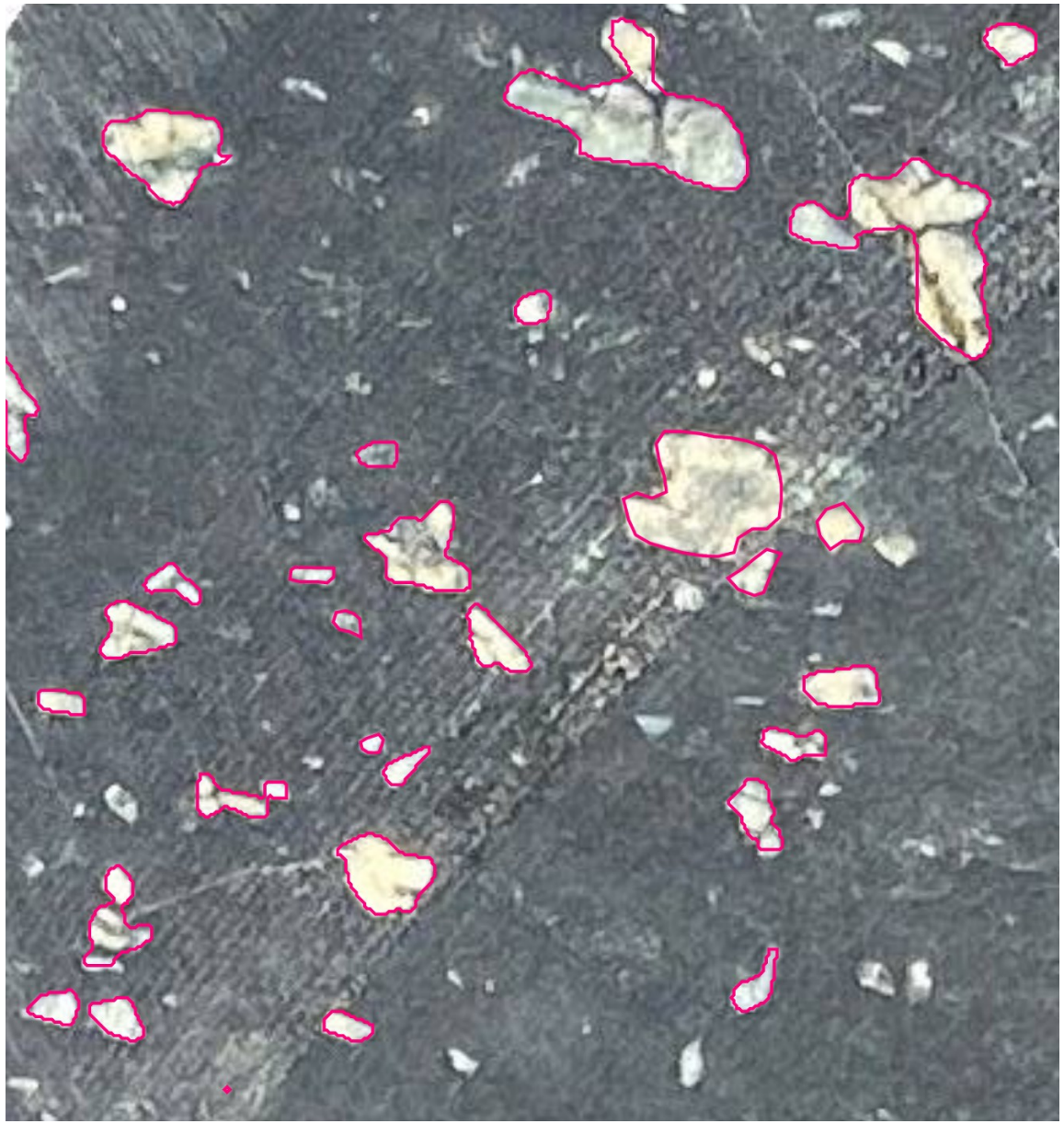






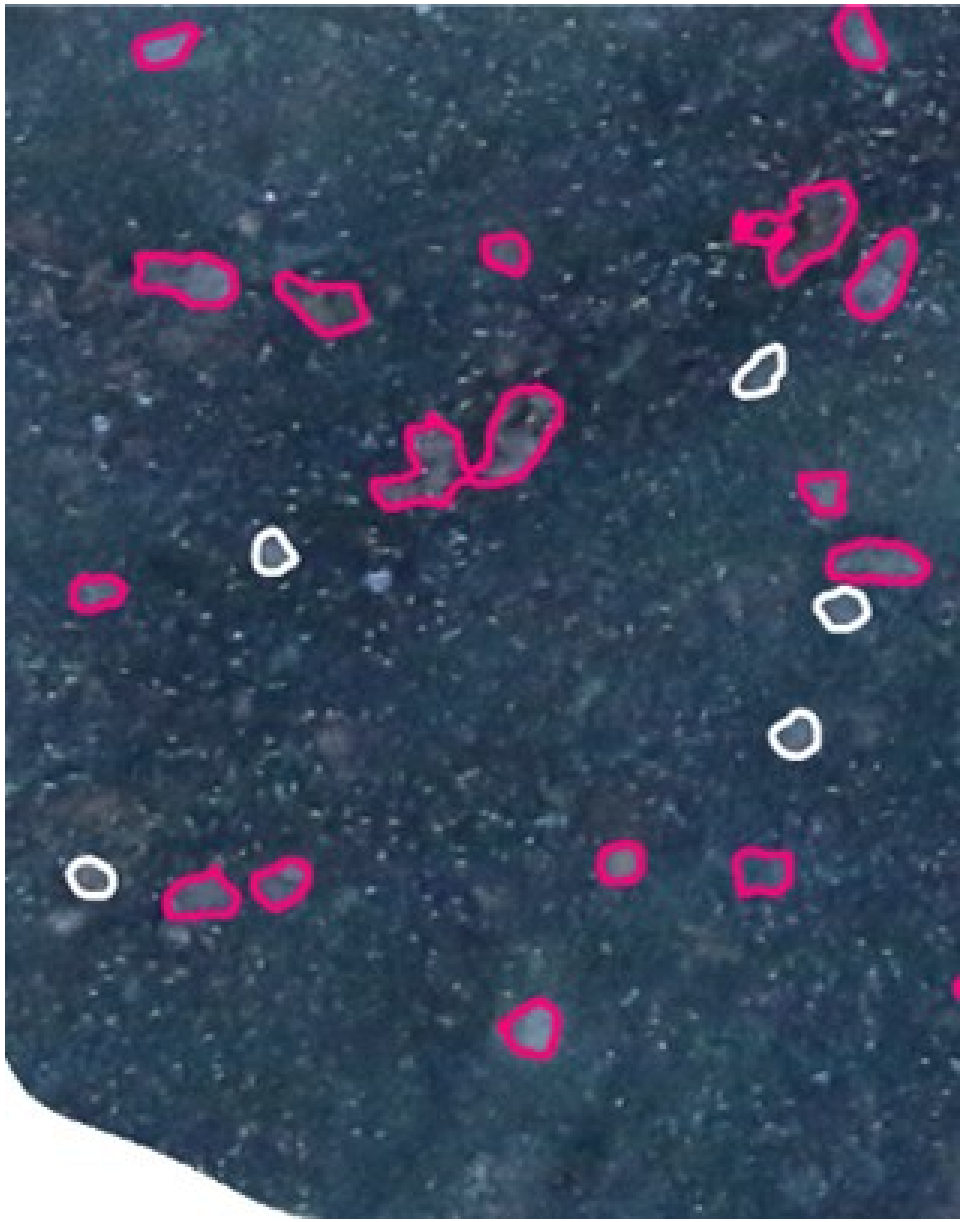





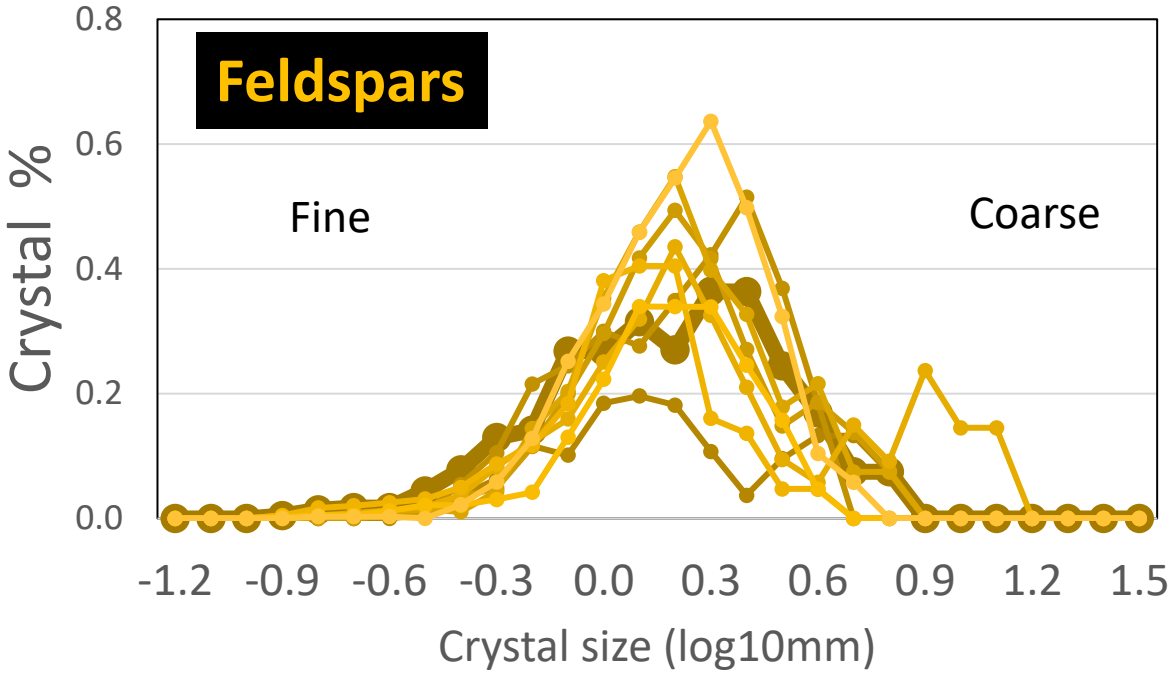




High resolution, high accuracy Machine Learning segmentation





Test on multiple slices of a same fresh rock

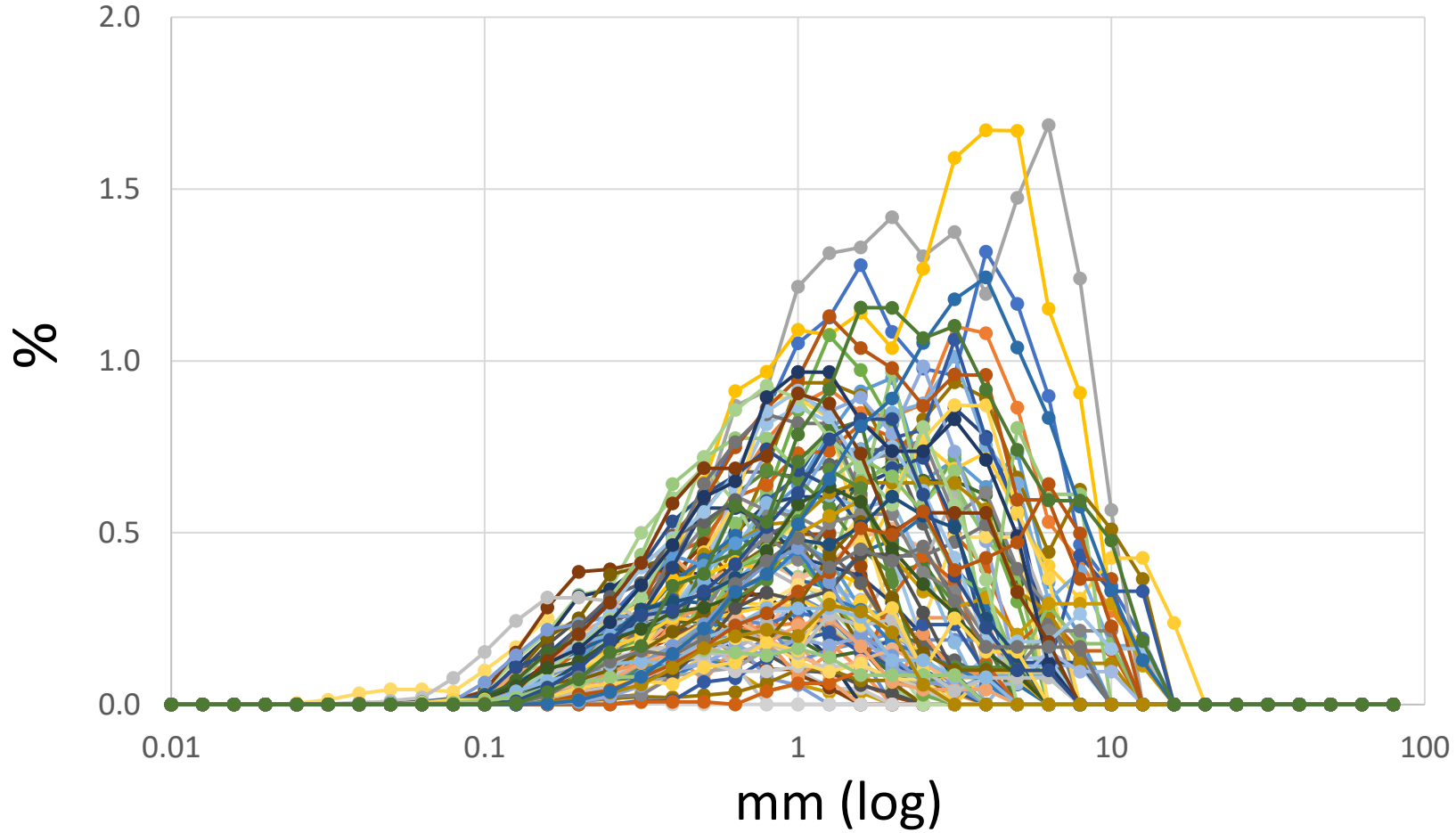


- *Feldspars segmented down to 0.6 mm diameter*
- *Consistent main mode*
- *Variation of CSD in some samples*

- *Best sorting parameters:*
  - ***Mean/mode crystal area***
  - ***Total crystal %***
  - ***Aspect ratio***

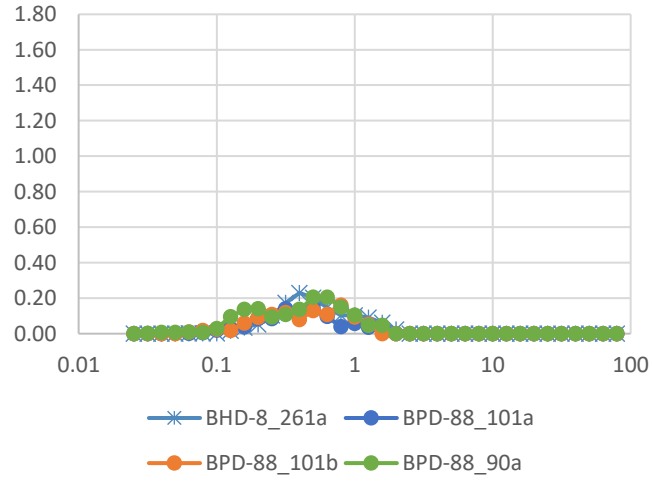
Application to Tasmanian dacites – *a needle in a haystack?*

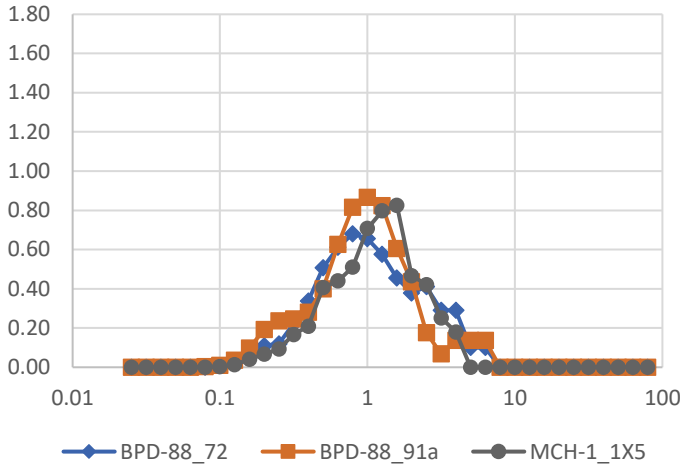
- 10 Holes in Que Hellyer and Rosebery-White Spur areas
- 102 selected samples
- Random and targeted sampling

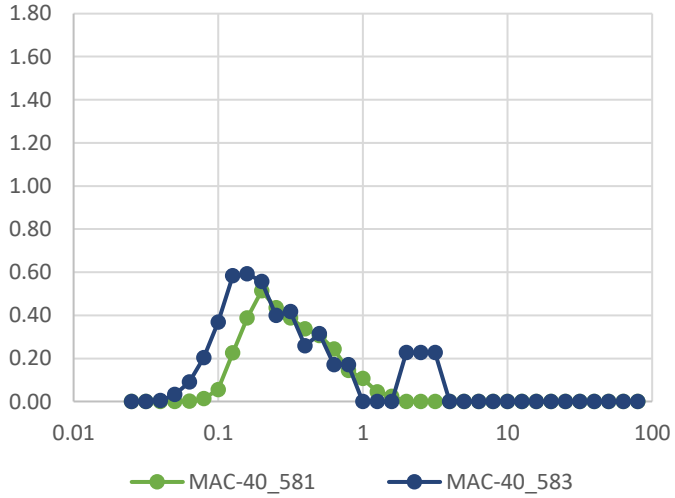


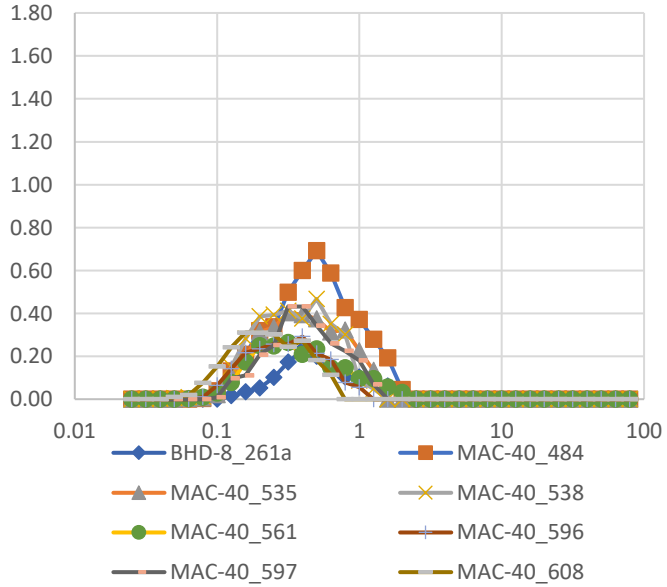
Que-Hellyer

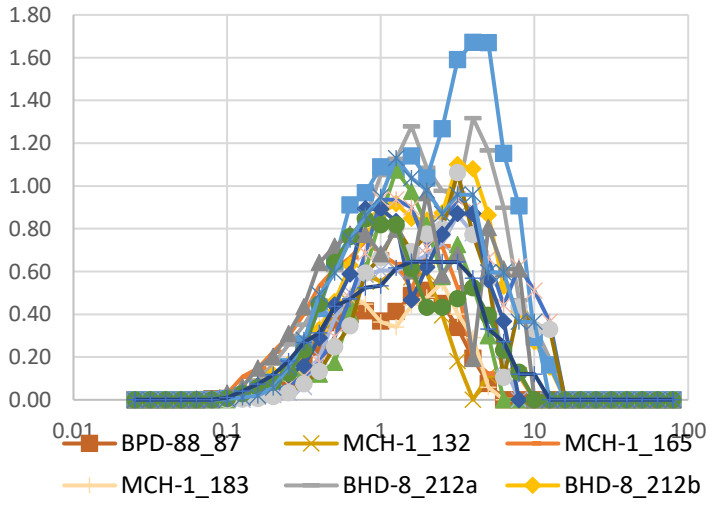
- Multiple CSD populations = Multiple dacitic bodies

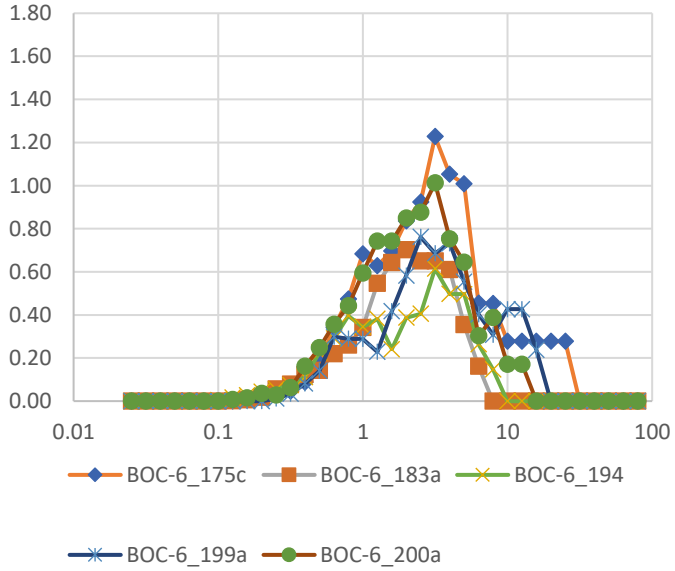






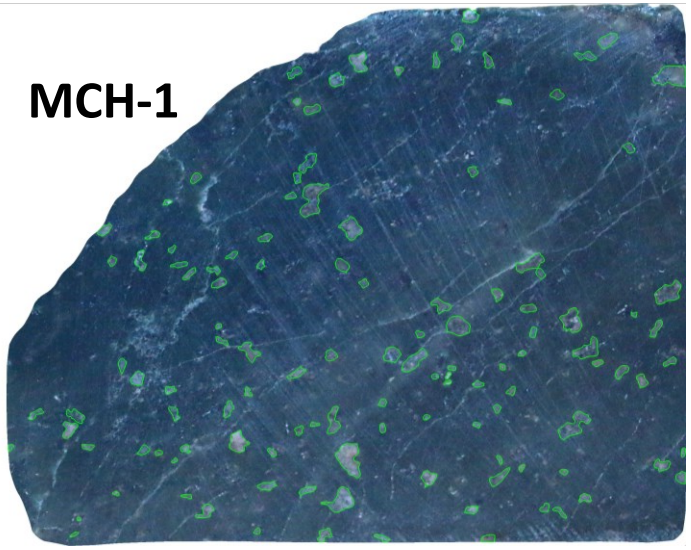


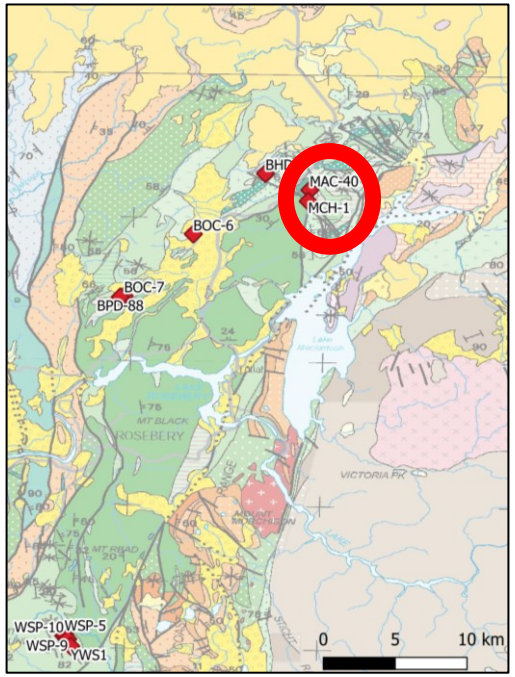


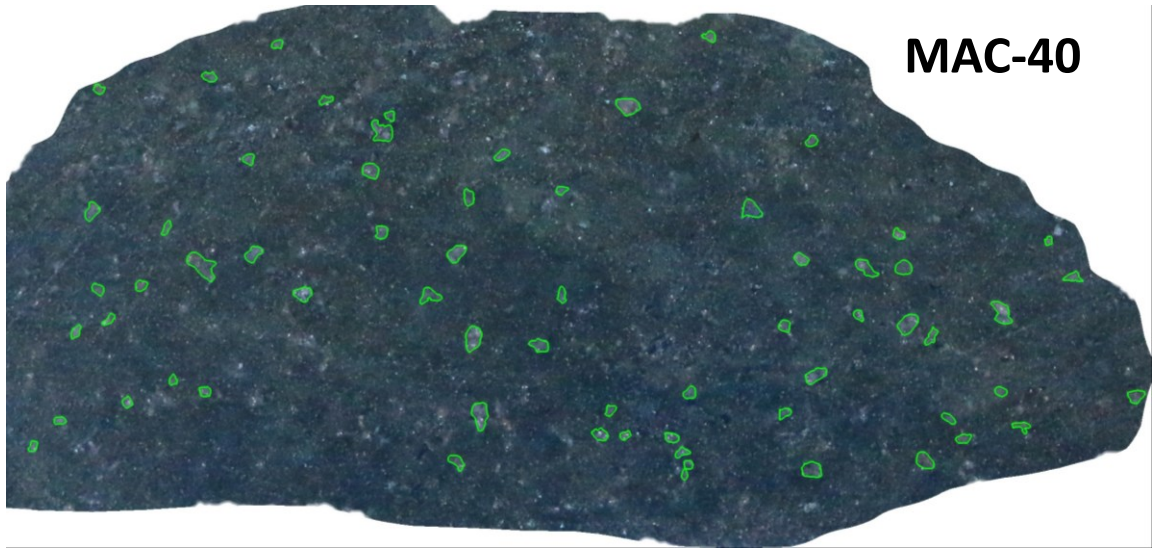


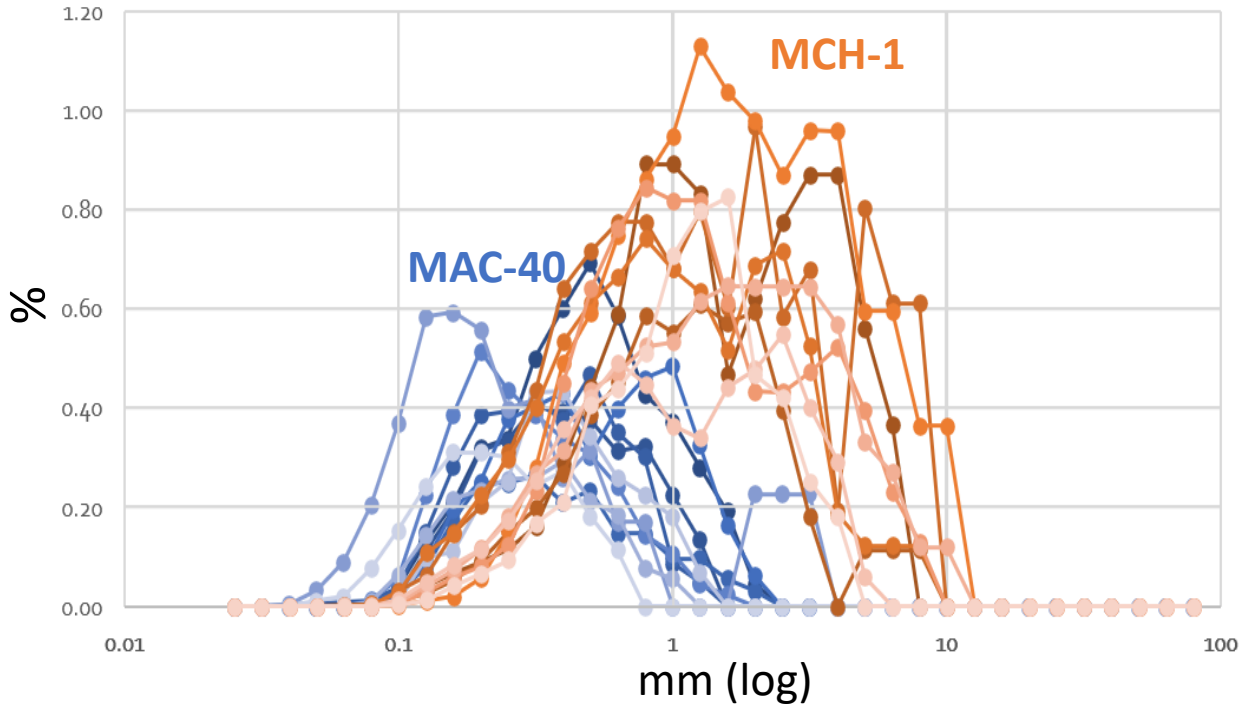
Que-Hellyer

- MAC-40 and MCH-1 are 1 km apart
- CSD totally different – no match
  - Independent coherent bodies



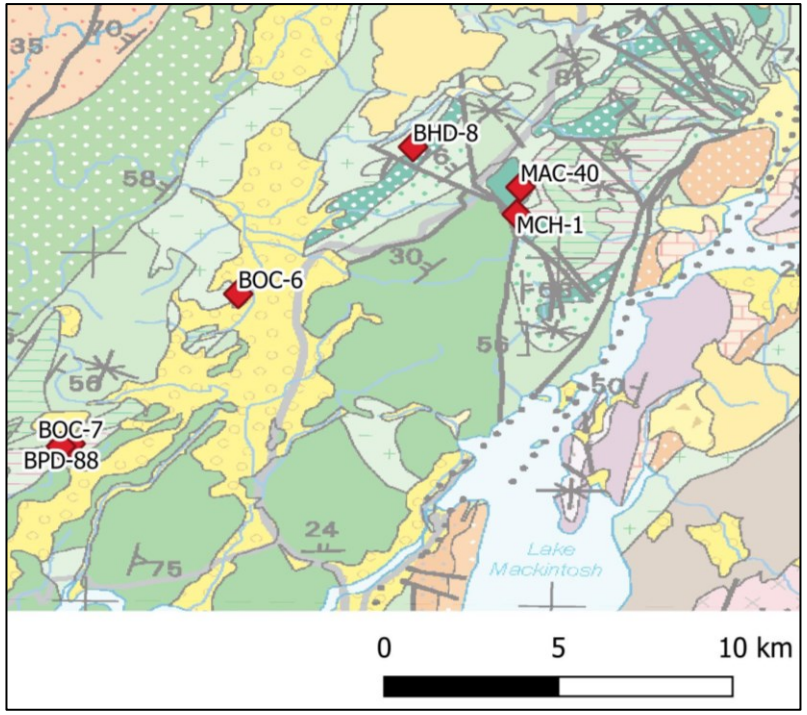




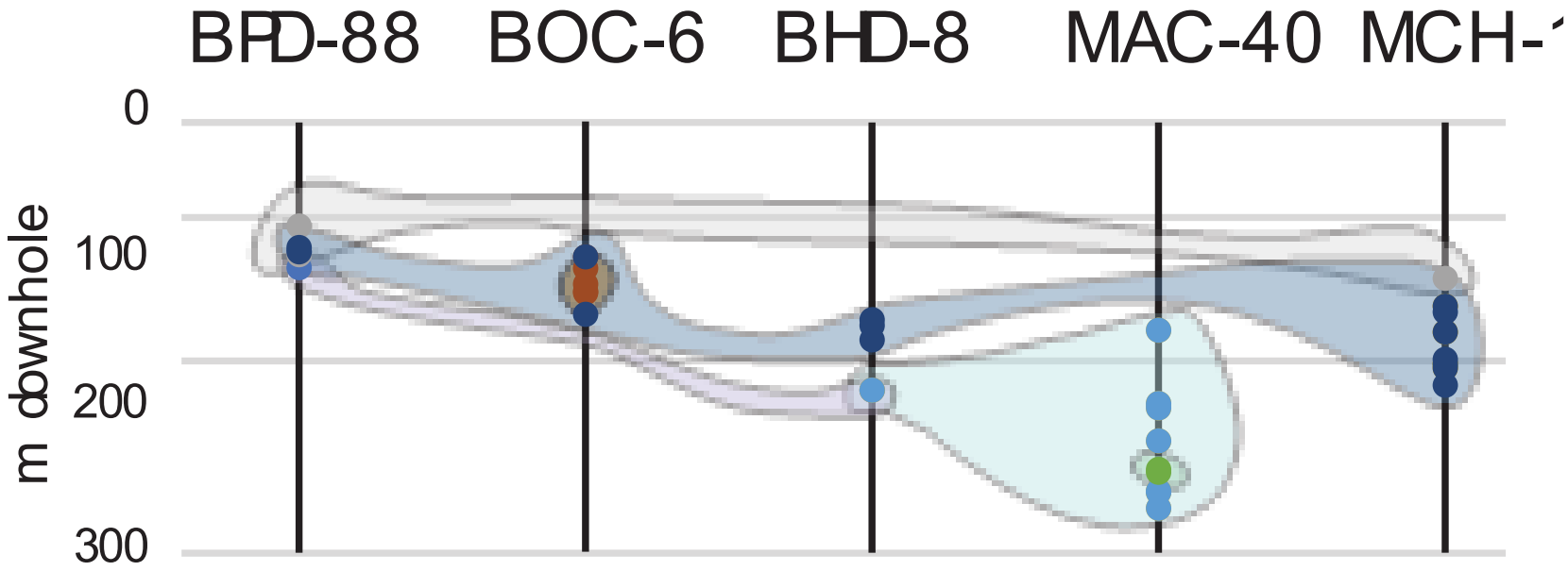


Que-Hellyer

- Good lateral continuity between holes
- Laterally very extensive volcanic bodies, but possible
- Some facies are clearly intrusive (dyke/sill)



This preliminary interpretation does not include downhole information and known faults yet

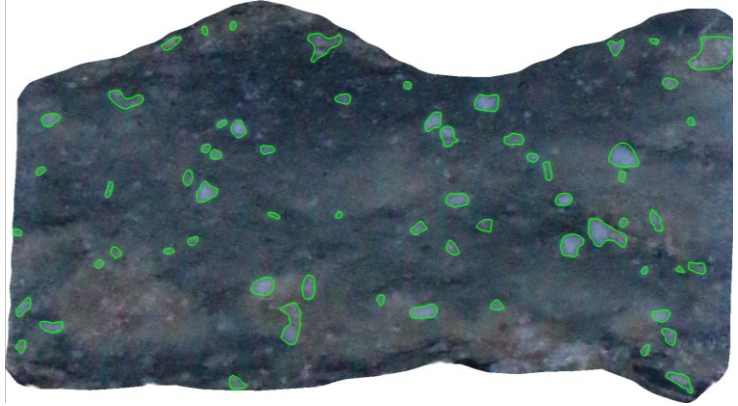


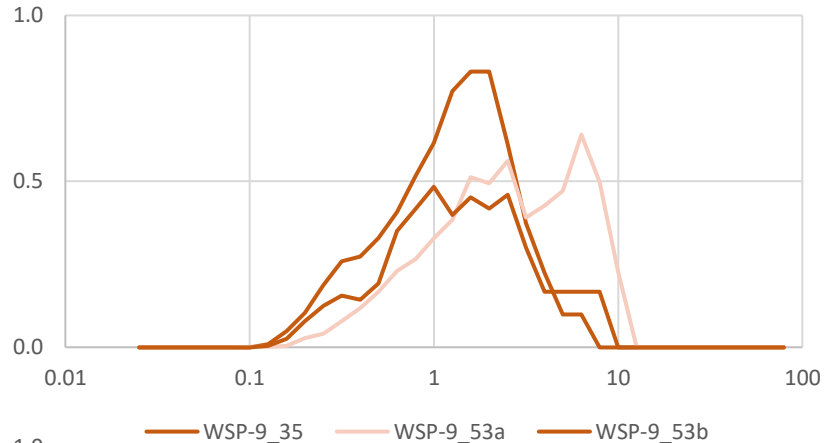
Rosebery-White Spur

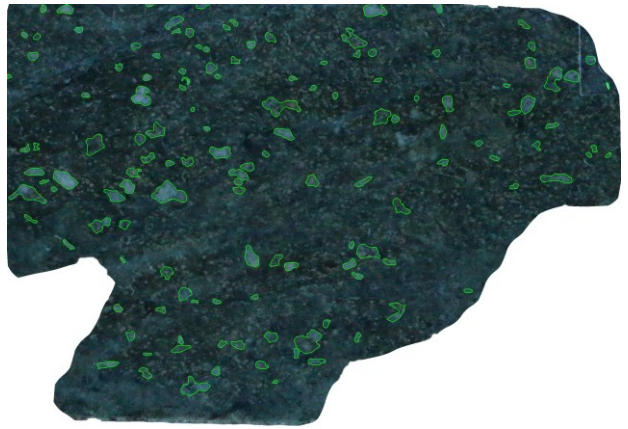
Same hole comparison: WSP-5

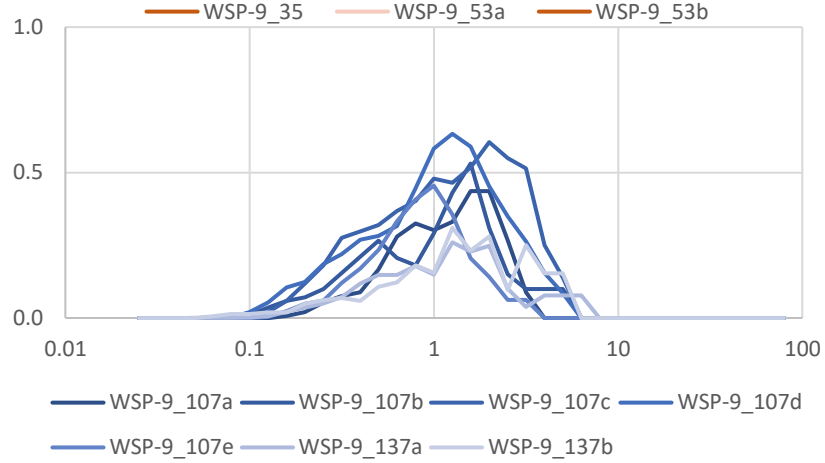
- Alteration effects not obvious: all rocks are altered
- 3 distinct CSD populations

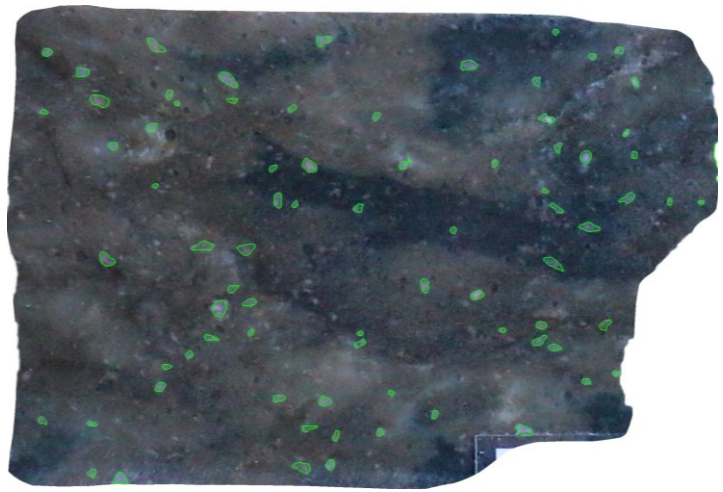
→3 distinct bodies

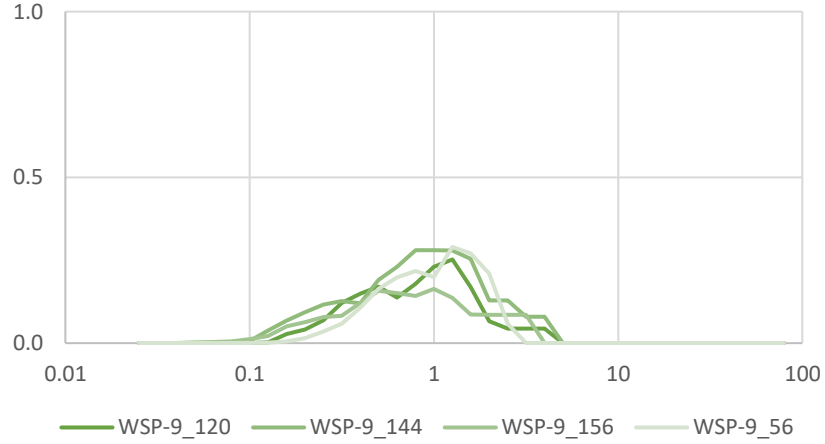












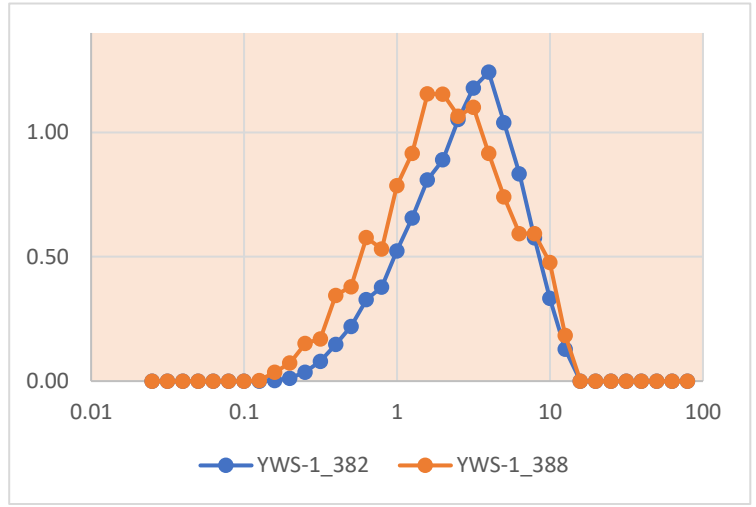
Rosebery-White Spur

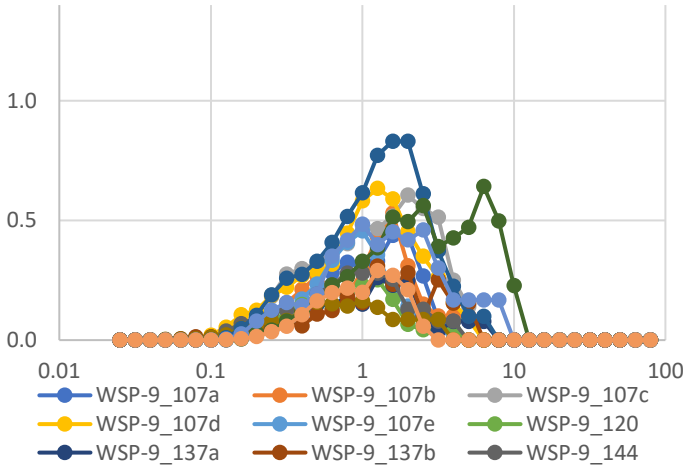
YWS-1 compared to WSP-9 (nearest Hole)

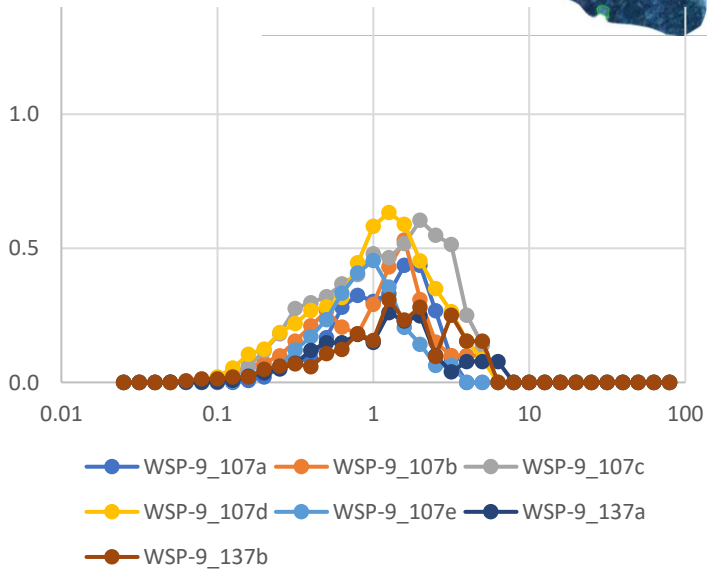
YWS-1 is unlike any other dacite in the area

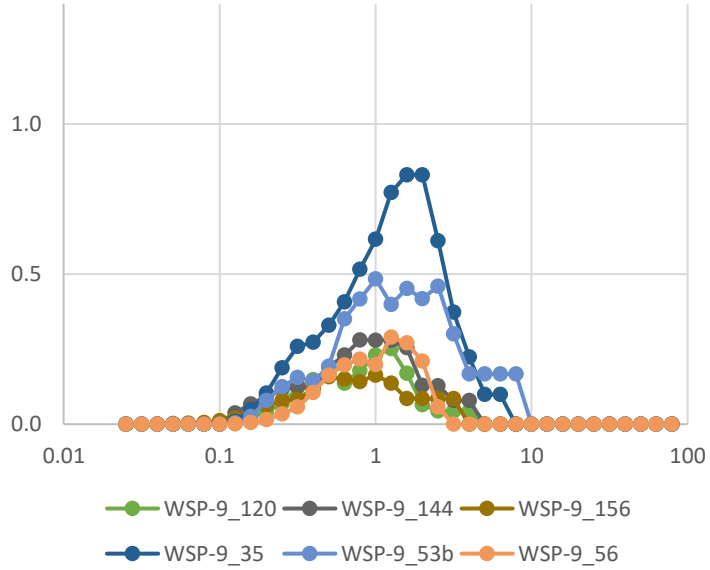
- Coarse grained
- Crystal-rich
- Unimodal distribution

→ Coherent body with no stratigraphic equivalent





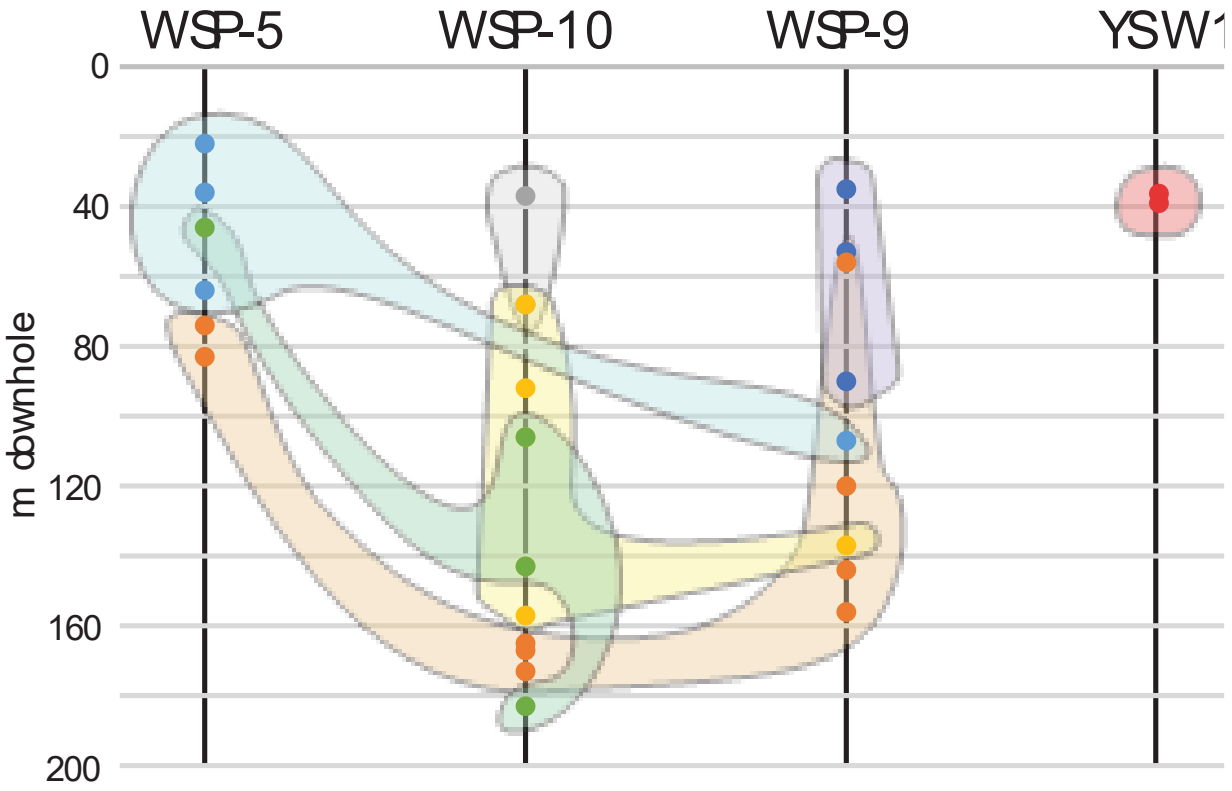


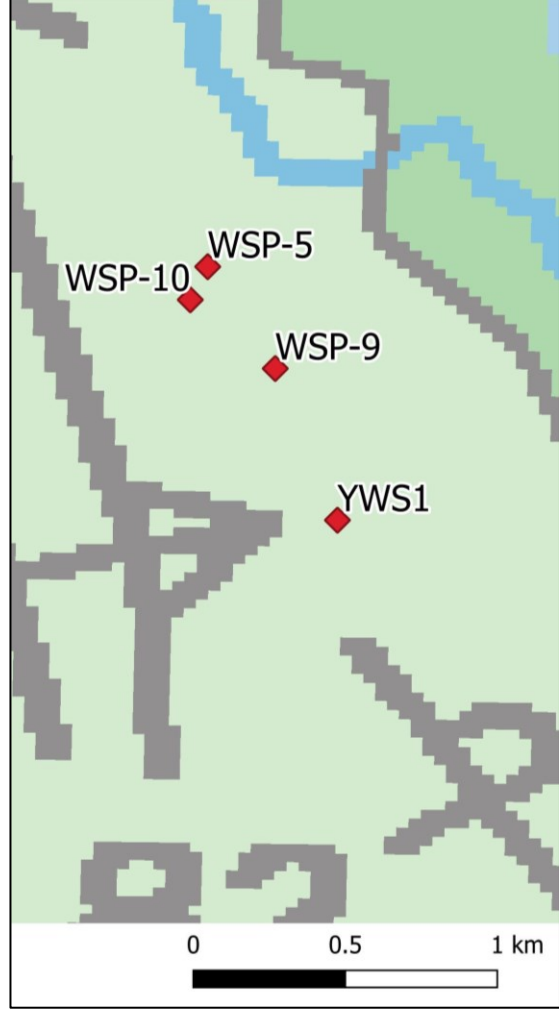


Rosebery-White Spur

Interpretation of all CSD facies

- Spread and isolated dacitic bodies
- Some dacites must be intrusive





This preliminary interpretation does not include downhole information and known faults yet

Independent verification by geochemistry

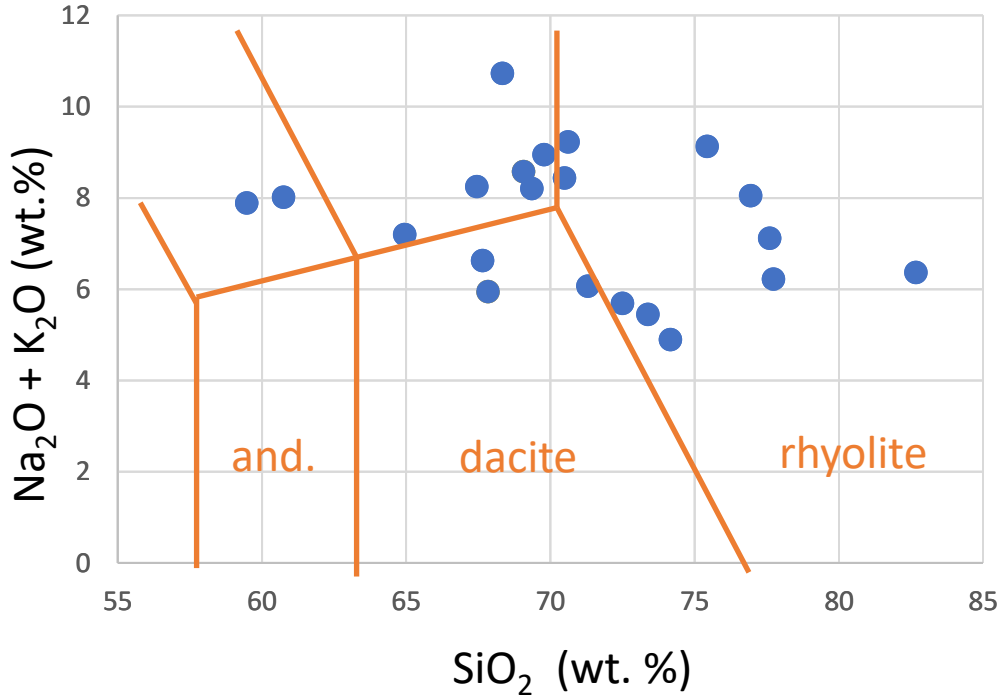
- 21 analyses (major + traces) in all 10 cores
- Sampling strategy
  - Least altered domains
  - Fully independent from CSD calculations

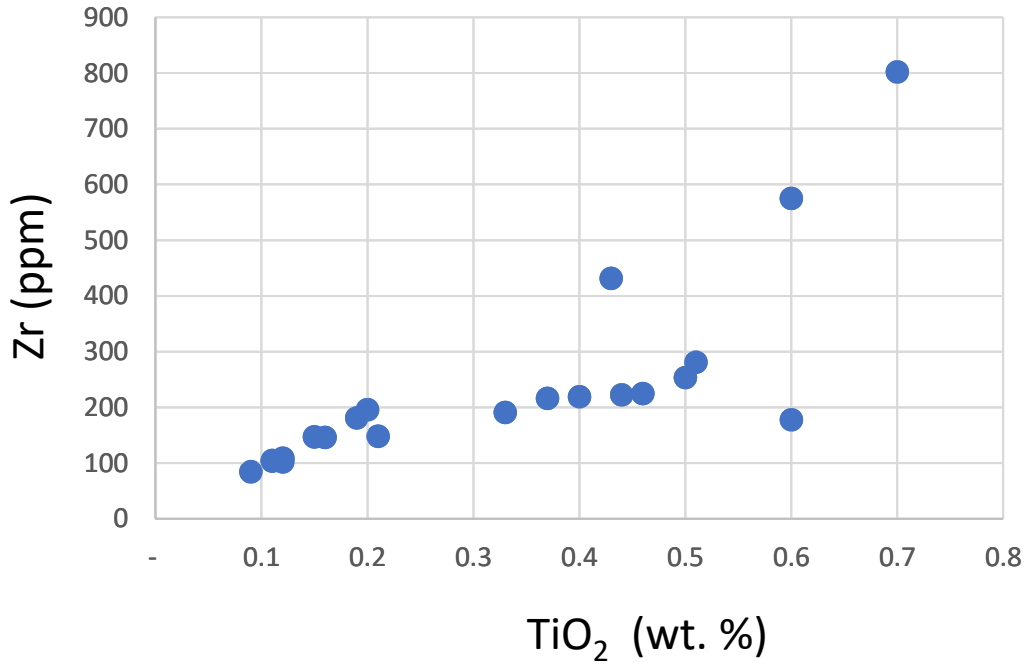
Composition

- Andesite-rhyolite
- Altered rocks

CSD groups

- In compositional clusters
- Validation of the CSD method





Summary

- Novel, automated volcanic facies analysis method
- The method uses ***the*** ubiquitous feature in most volcanic rocks: feldspars
  - Volcanic architecture reconstruction
  - Identification of key stratigraphic markers
  - Complementary to geochemistry
  - Easily exportable to other formations

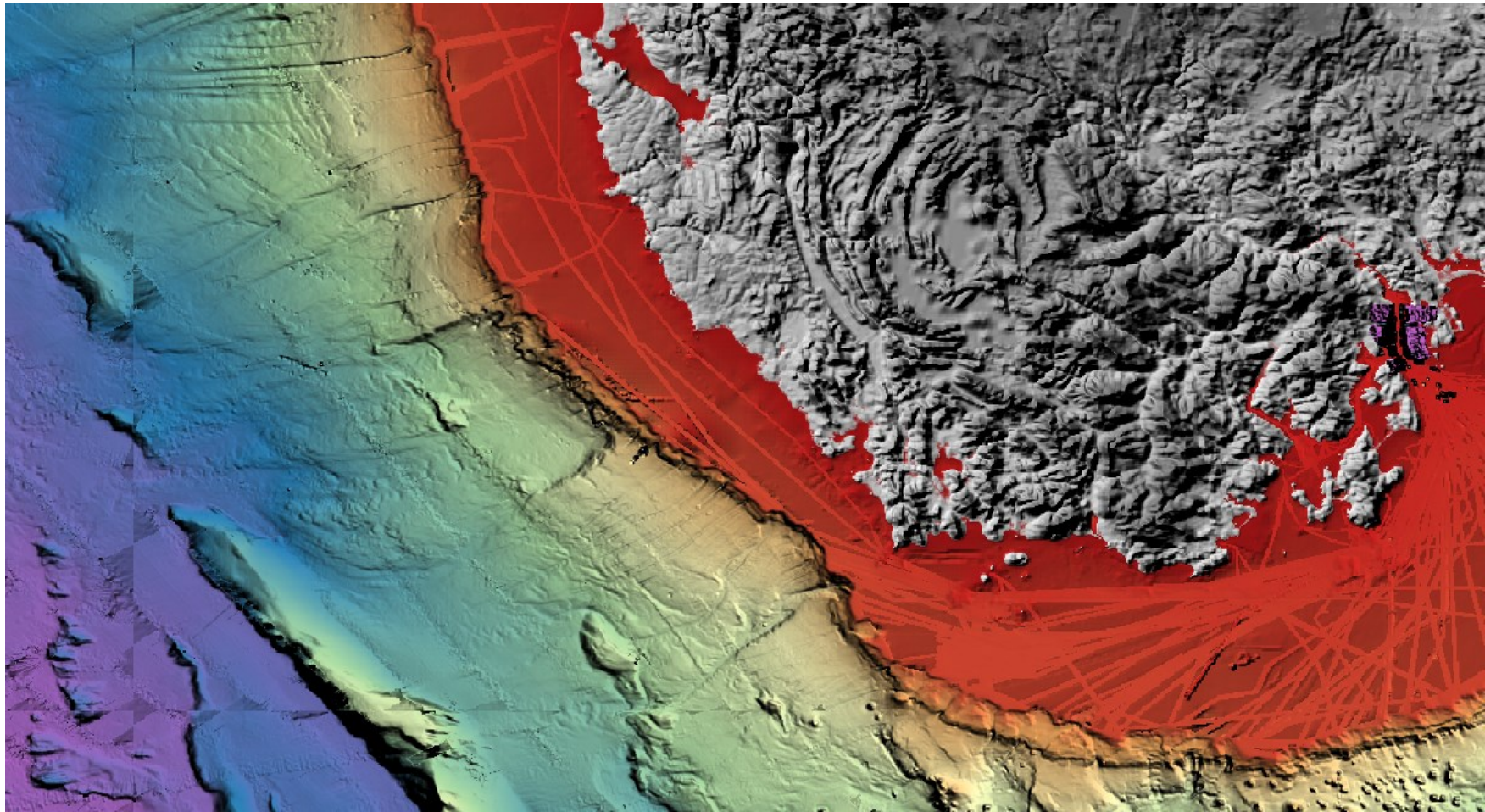
UTAS-led voyage to W-Tasmania

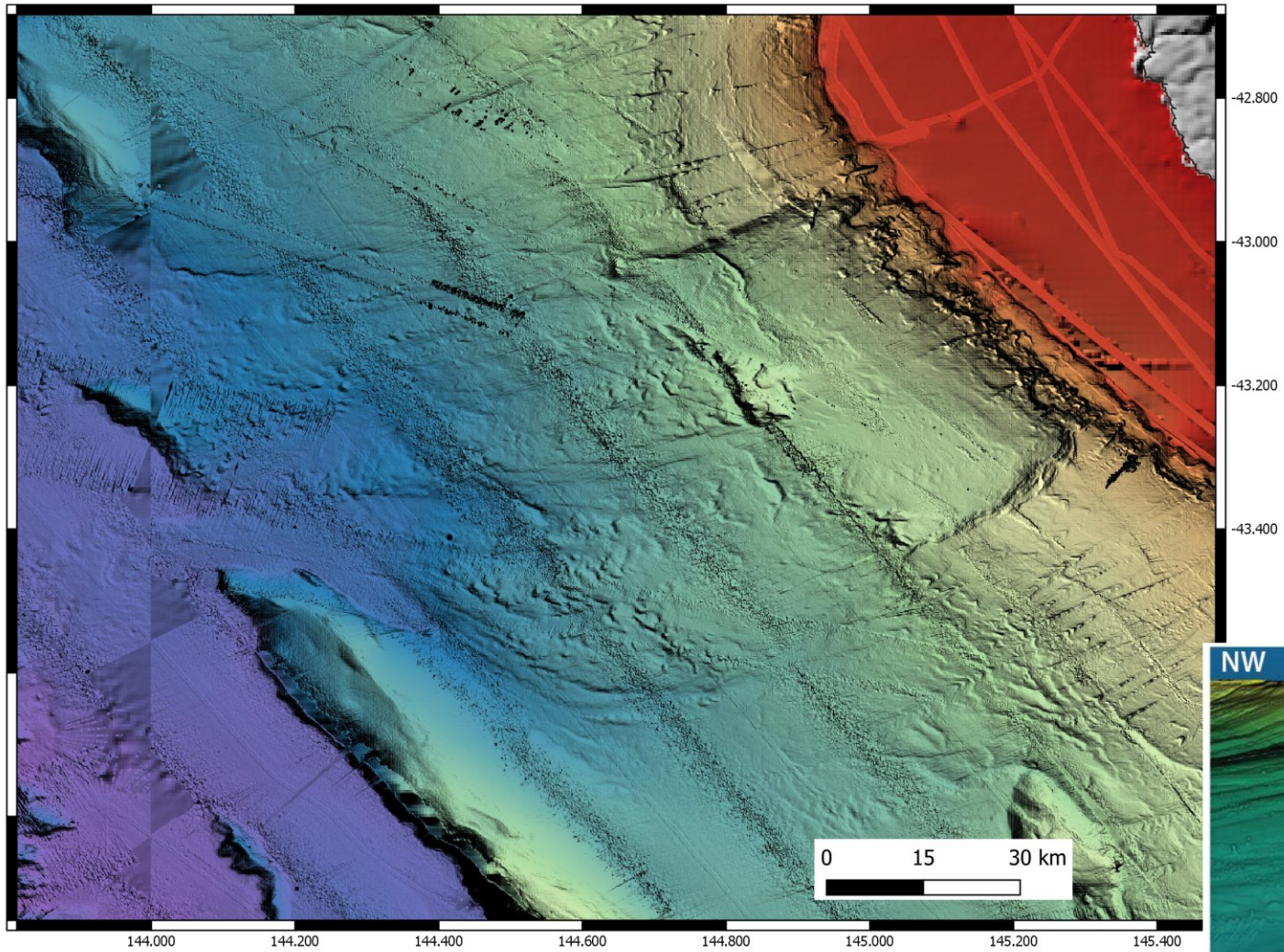
March-April 2023

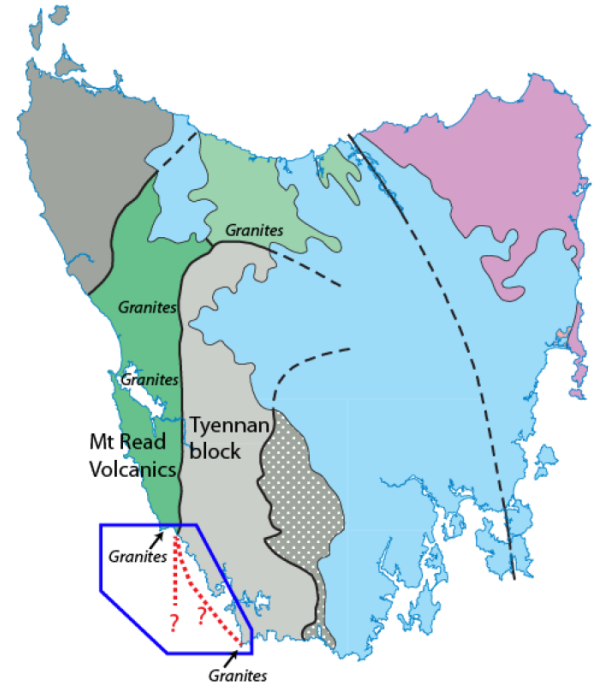
CSIRO

Marine National Facility

- Landslide processes
- Sedimentation processes
- Tsunami modelling
- Offshore geological map
- Habitat mapping
- …







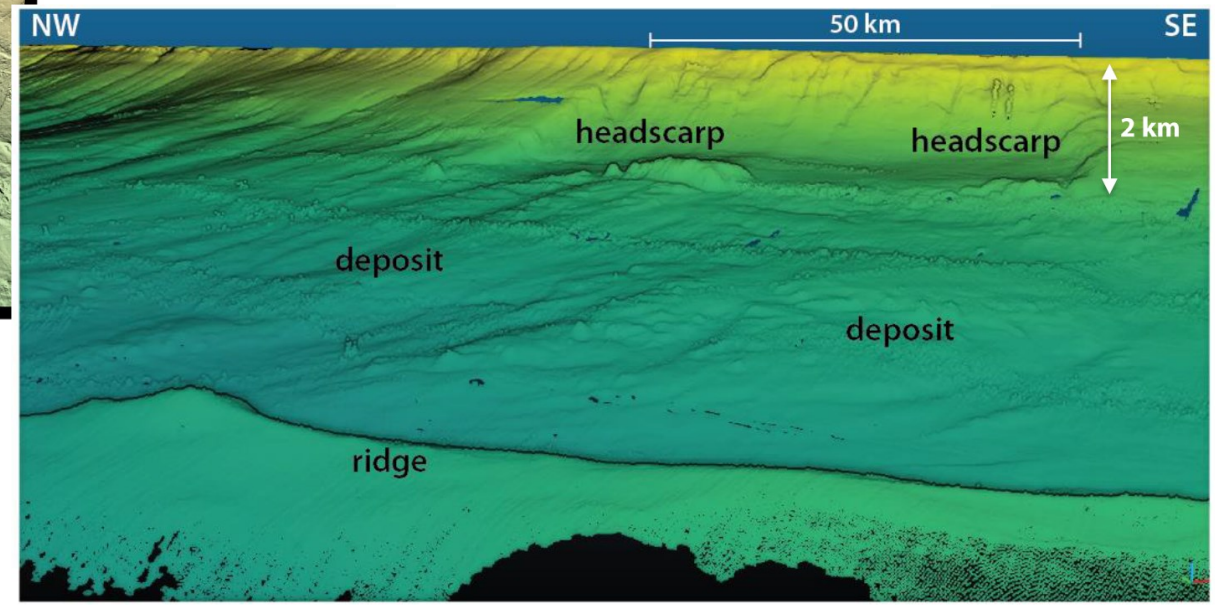
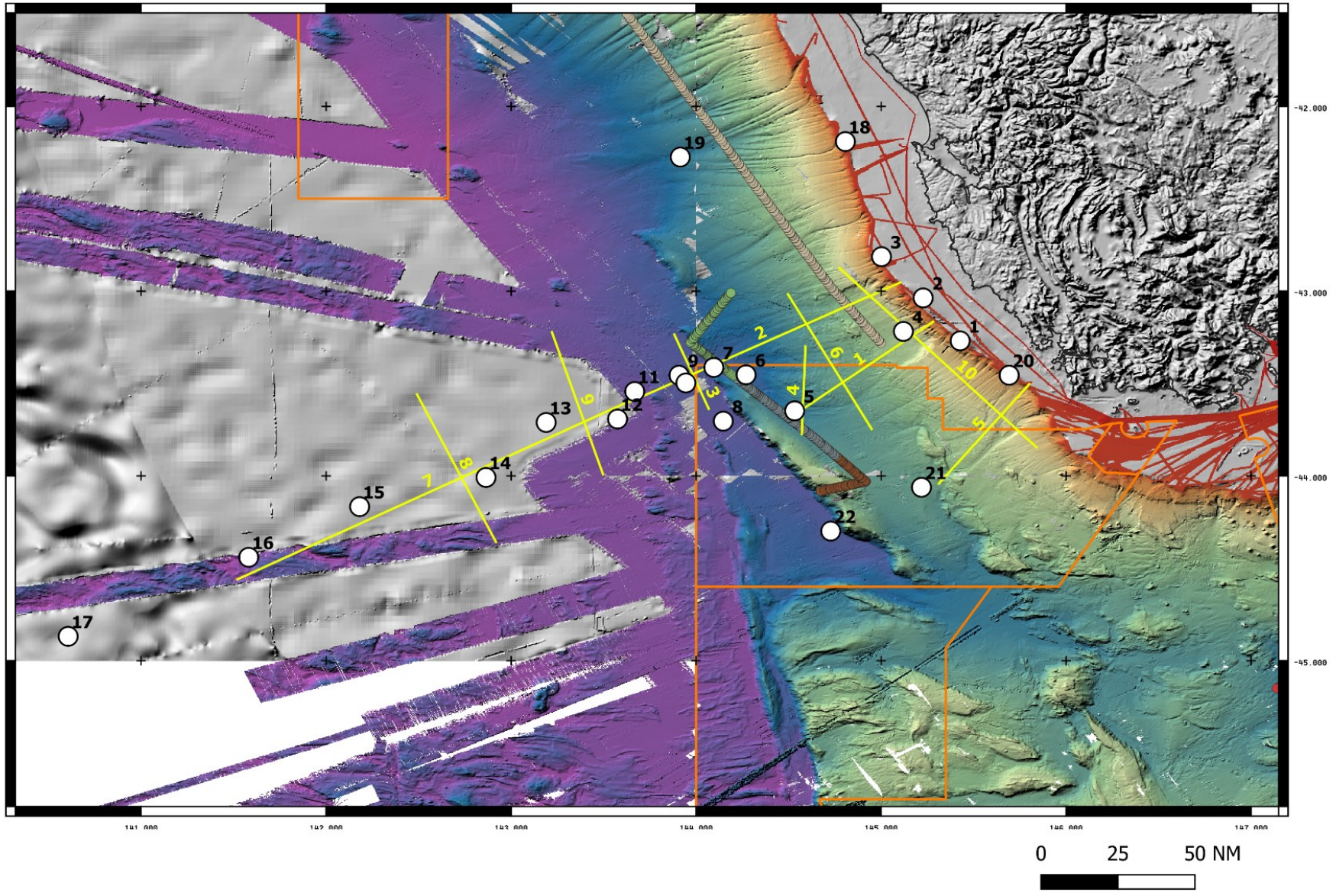


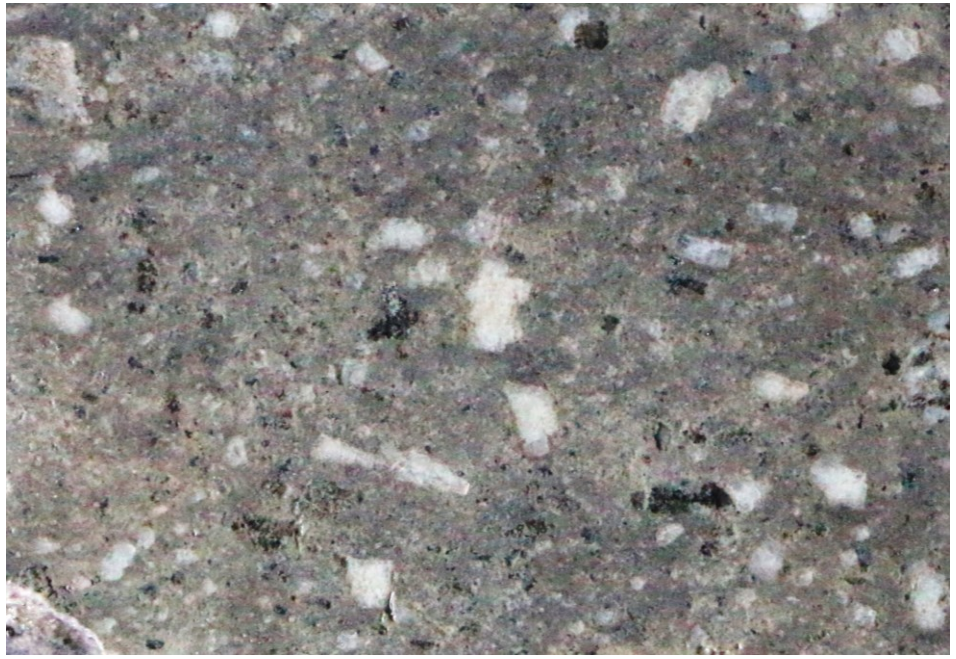
Fig. 3 3D view of the landslide headscarp and deposit. The section of collapsed shelf is ca. 50 km long. The ridge in the foreground may represent a much older landslide deposit.

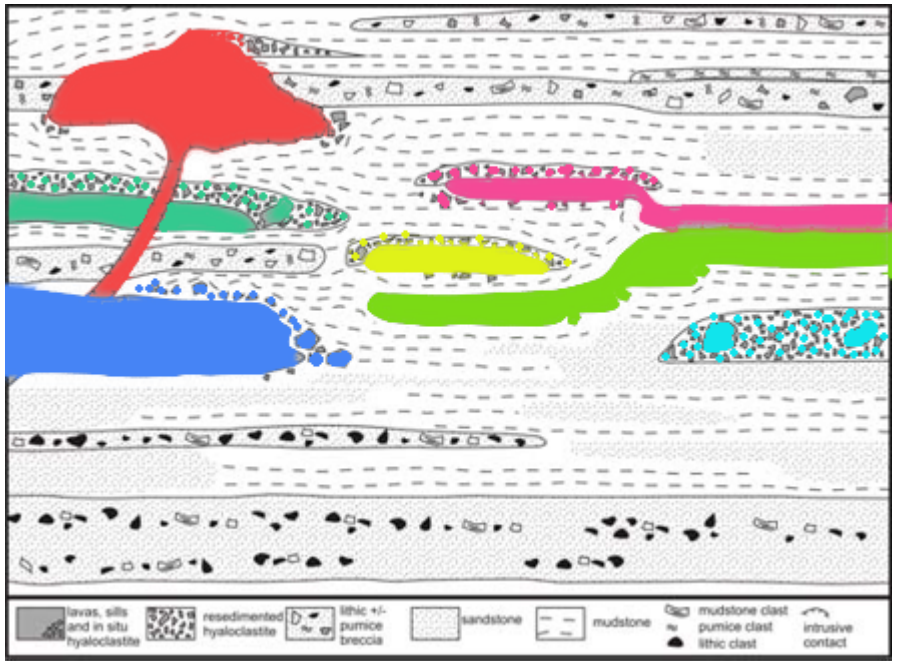
Piston coring
Seismic reflection
Dredging
Deep-towed camera
…



Phenocrysts are the most fundamental characteristic texture in volcanic rocks

- Primary qualitative characteristic to name volcanic rocks
- Most volcanic rock contain phenocrysts
- Phenocryst content varies between volcanic bodies (0-60% crystals)
- Phenocryst populations overall homogeneous in one volcanic body
- Feldspars (K-Feld, plagio) are overall ubiquitous in volcanic rocks





After Simpson, 2006

CSD Workflow: Machine-Learning & trained Geologist

Human
Automated

1. Outcrop/Core photo (DSLR, iPhone) with ad-hoc scale
2. Area pre-selection
3. Area selection
4. Scaling
5. Deep Learning
6. Quality check & ‘manual’ improvements
7. Extraction of statistical values
8. Export in CSV files
9. Import into an Excel macro
10. Comparative analysis of **size** & **shape** of crystals

Model Building and Updating

Labels

- **Datarock CVAT platform**
- 3 separate **deep learning trained** using **Mask RCNN***
  - Resolution Model
  - Cropping Model
  - Segmentation Model

Libraries

- **Detectron2 library in Python**
- **imea package in Python** for quantitative measurements of crystal shapes

* He, K., Gkioxari, G., Dollár, P., & Girshick, R. (2017). Mask r-cnn. In *Proceedings of the IEEE international conference on computer vision* (pp. 2961-2969).

Same rock shows very similar CSD