Integrated Workflow for Parametrization of Fracture Networks in Digital Outcrop Models: Focus on Topology and H/L ratio Calculation

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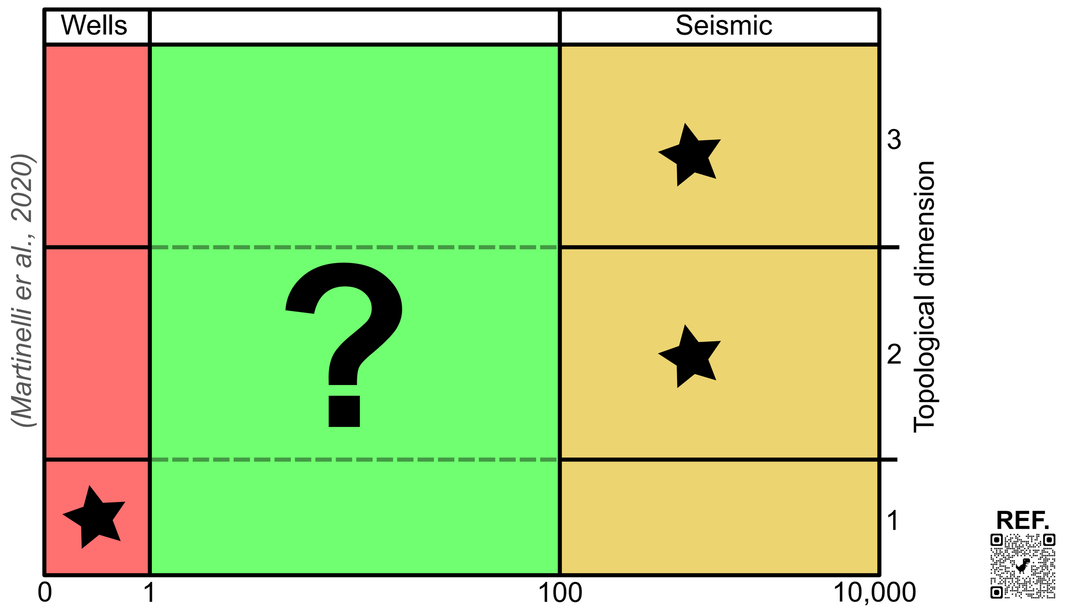
Context & Introduction

Fracture networks impact fundamentally the mechanical and hydraulic properties of rock masses, and their importance extends to multiple applications, including reservoirs of every kind of geofluids.

PROBLEM

Fracture at the mesoscale (1 - 100m) cannot be effectively characterized in the subsurface, due to resolution limitation of boreholes (upper limit) and geophysical techniques (lower limit), defining an information gap



SOLUTION

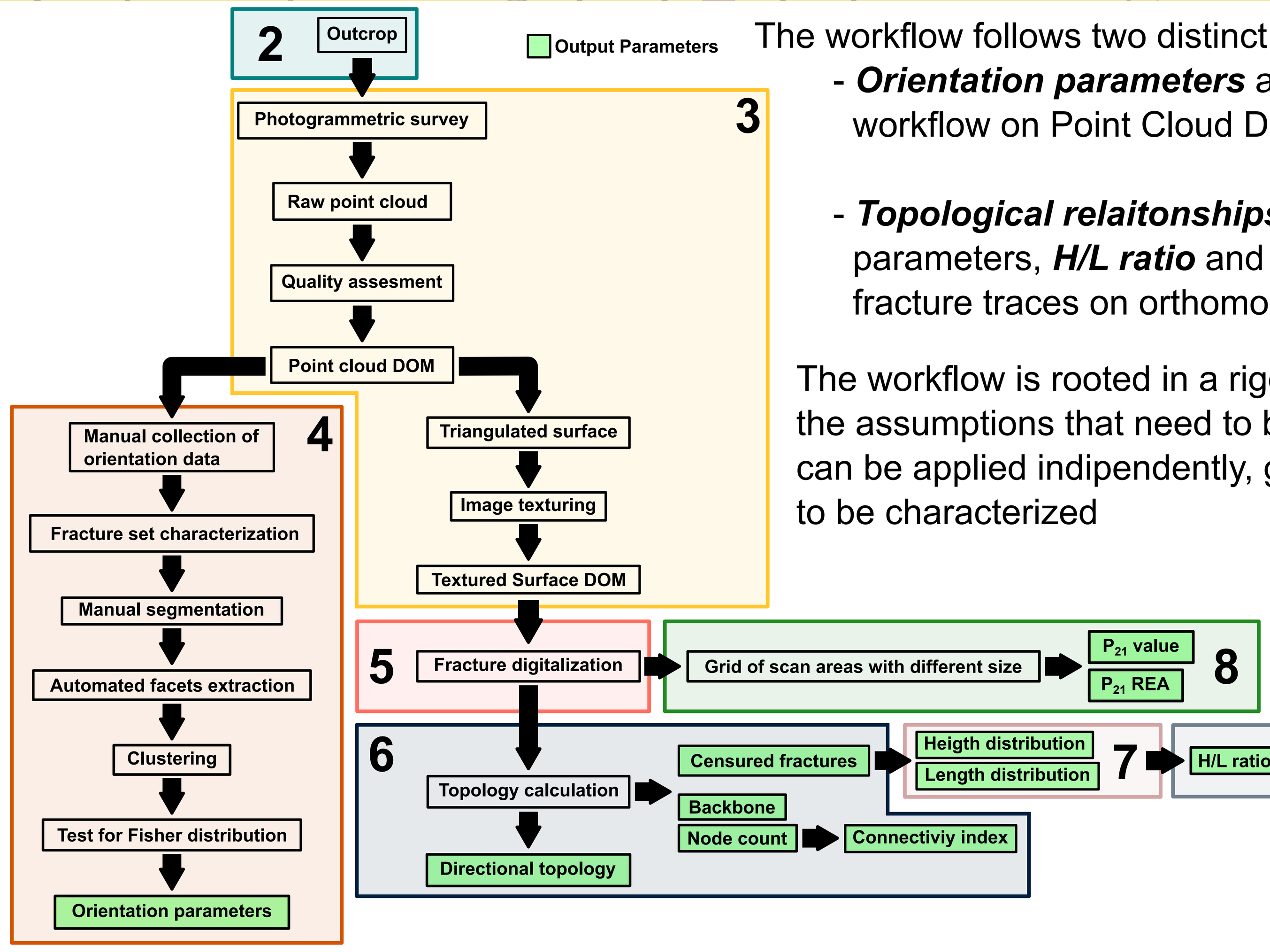
Fracture networks are quantitatively characterized by a set of parameters (static or dynamic) that at the mesoscale can be obtained from **outcrop analogues**. The outcrop analogue approach assumes that what we can characterize in outcrops can be representative of fracture network properties at depth, under the assumption that they undergone the same geologicalhistory as the reservoir host rock

Parameter	Fracture network	Fracture set
Number of sets	*	
Orientation statistics		*
Topology	*	
Spacing		*
Size (length)		*
Density/Intensity (P_{XX})	*	*
Aperture		*
Spatial distribution	*	*
Representative Elementary Volume	*	*

HOW?

This approach relies on robust datasets to calculate quantitative parameters used to generate modelling the structural and hydraulic properties of the reservoir. High-quality dataset can be obtained from the combination between **traditional filed survey** and **DOMs** (Digital Outcrop Models), **vertical** and **horizontal** outcrops and different types of input data.

Workflow



The workflow follows two distinct processing pipelines:

- ***Orientation parameters*** are obtained via a semi-automatic workflow on Point Cloud DOMs (PC-DOMs)
- ***Topological relaitonships***, ***length/height/spacing distribution*** parameters, ***H/L ratio*** and ***P_{21}*** are obtained from digitalized fracture traces on orthomosaics

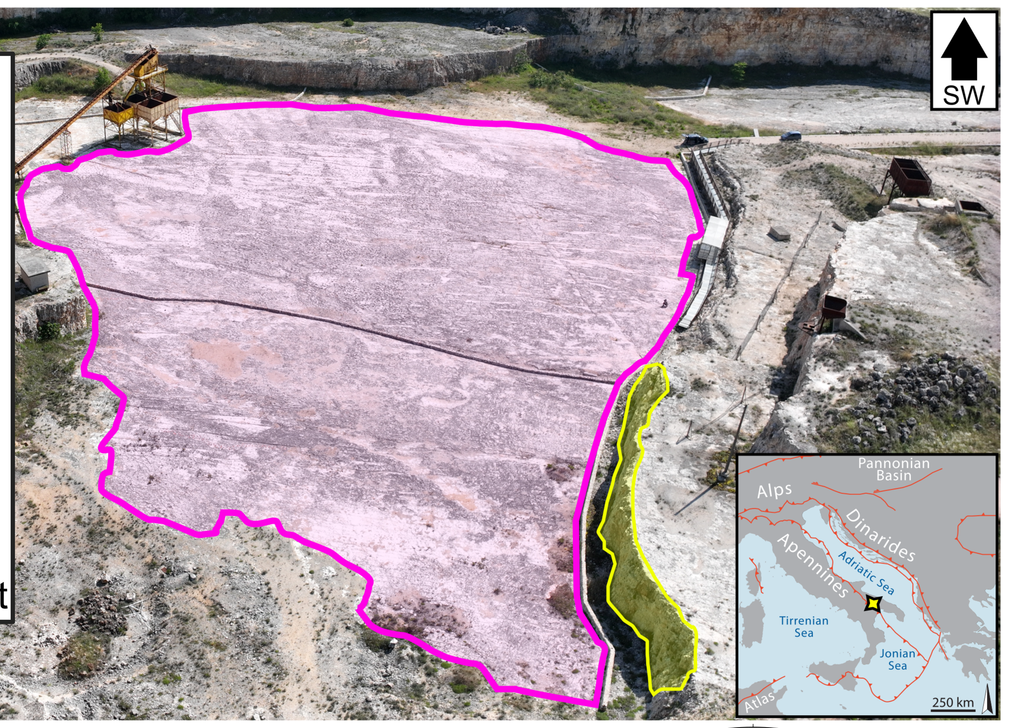
The workflow is rooted in a rigorous statistical background, minimizing the assumptions that need to be made at every step. Each of its parts can be applied independently, given the type of outcrop that need to be characterized

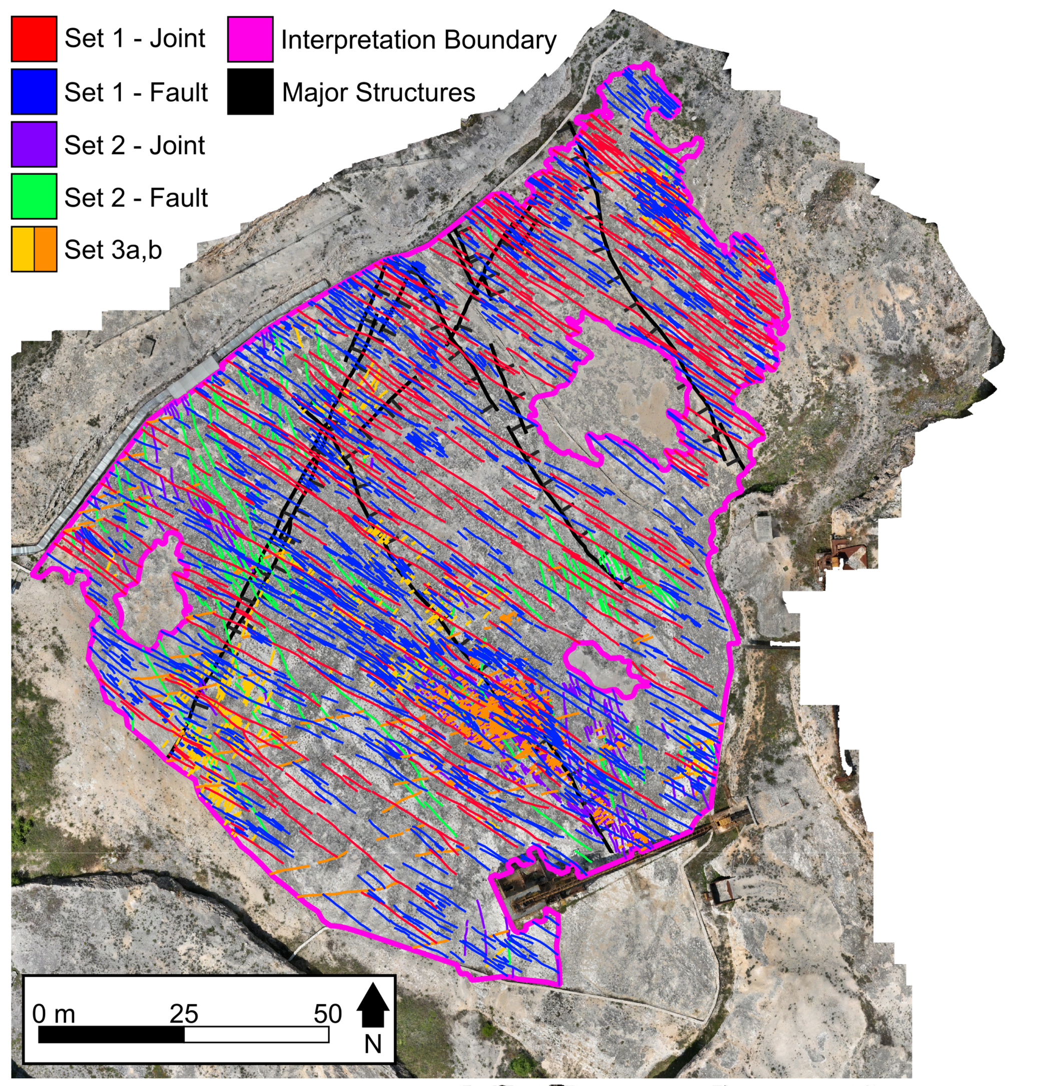
WORKFLOW PAPER

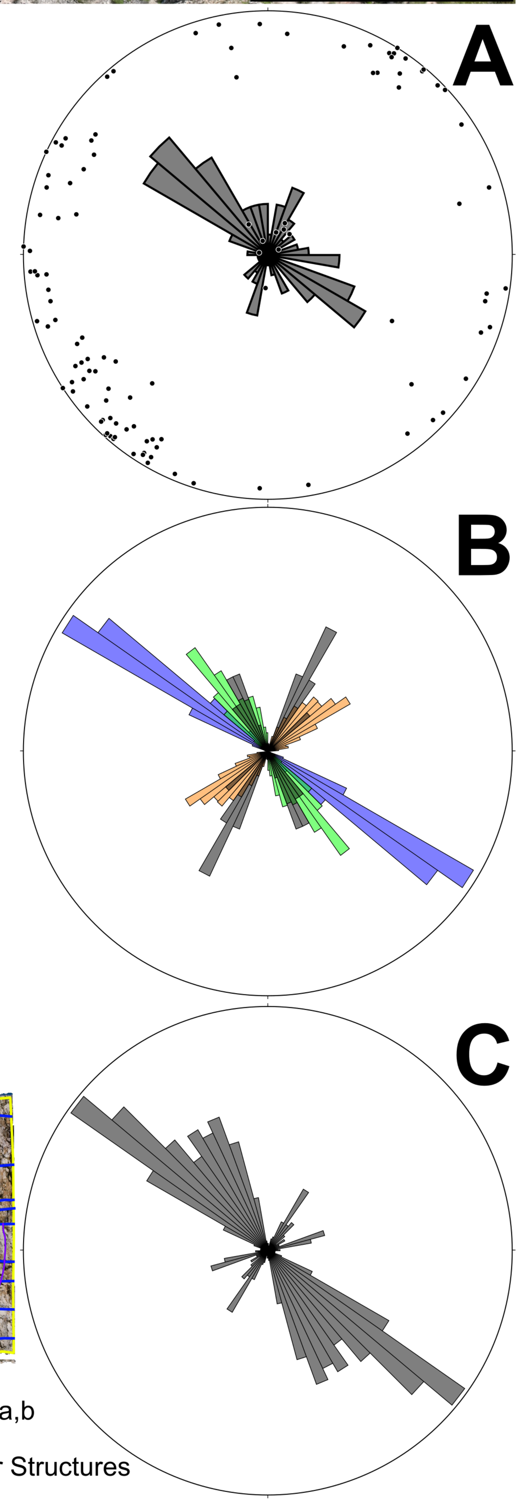
CODE REPOSITORY

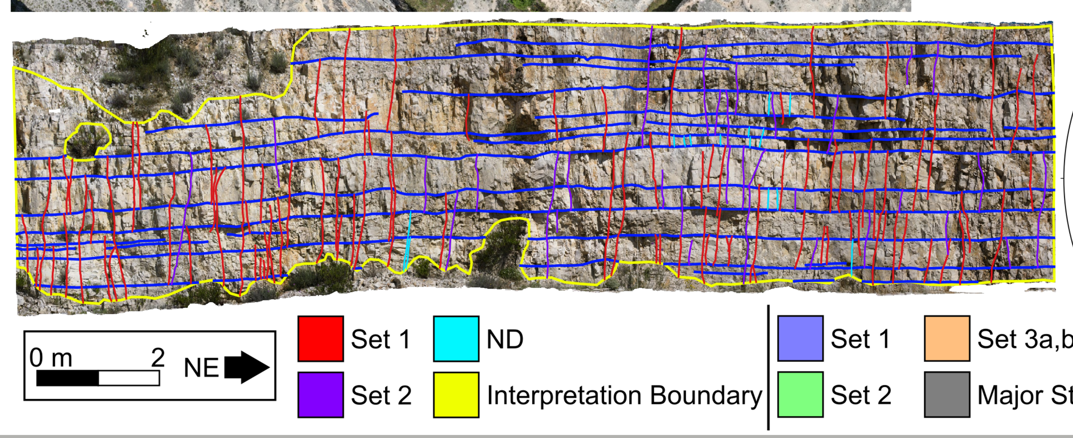
Case study

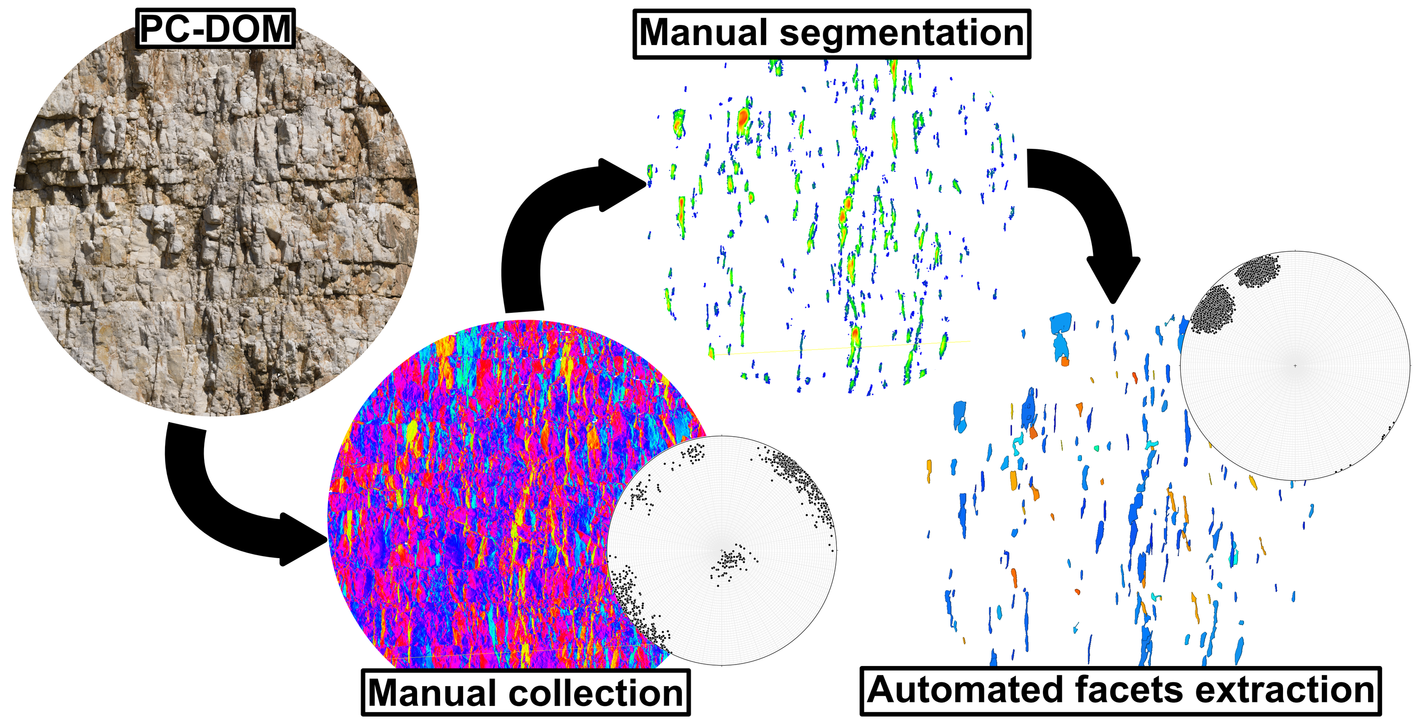
Quarry located in the Murge Plateau near **Altamura** (Puglia, Italy)
Suitable analogue for several reservoir in the area (*Zambrano et al., 2016*) REF.
(**A**) Rose diagram of the field data
(**B**) Rose diagram of the data collected on the TS-DOM
(**C**) Rose diagram of the fracture traces on the pavement



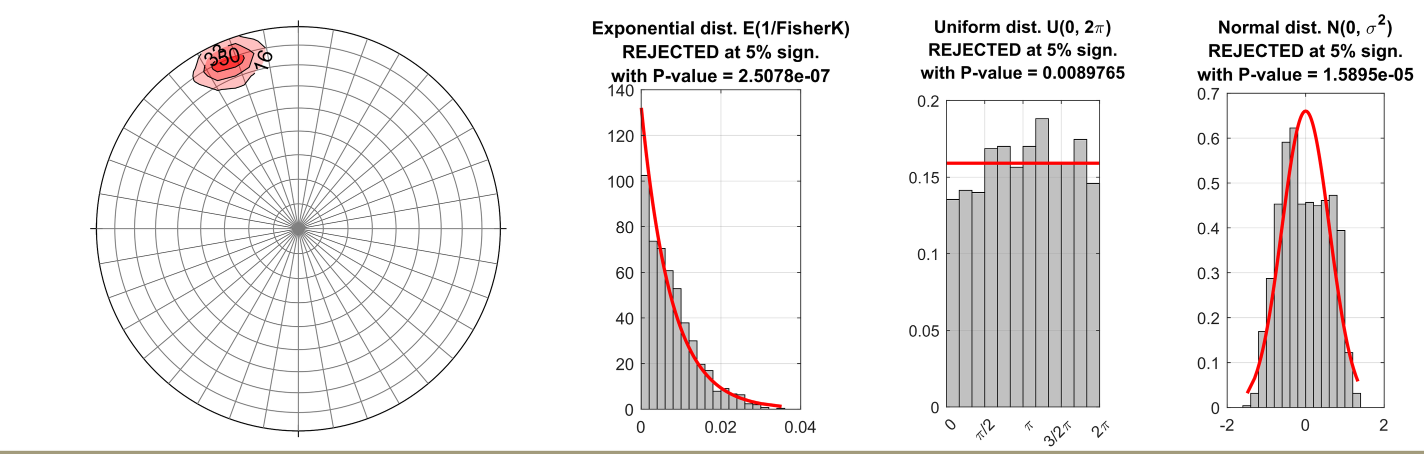


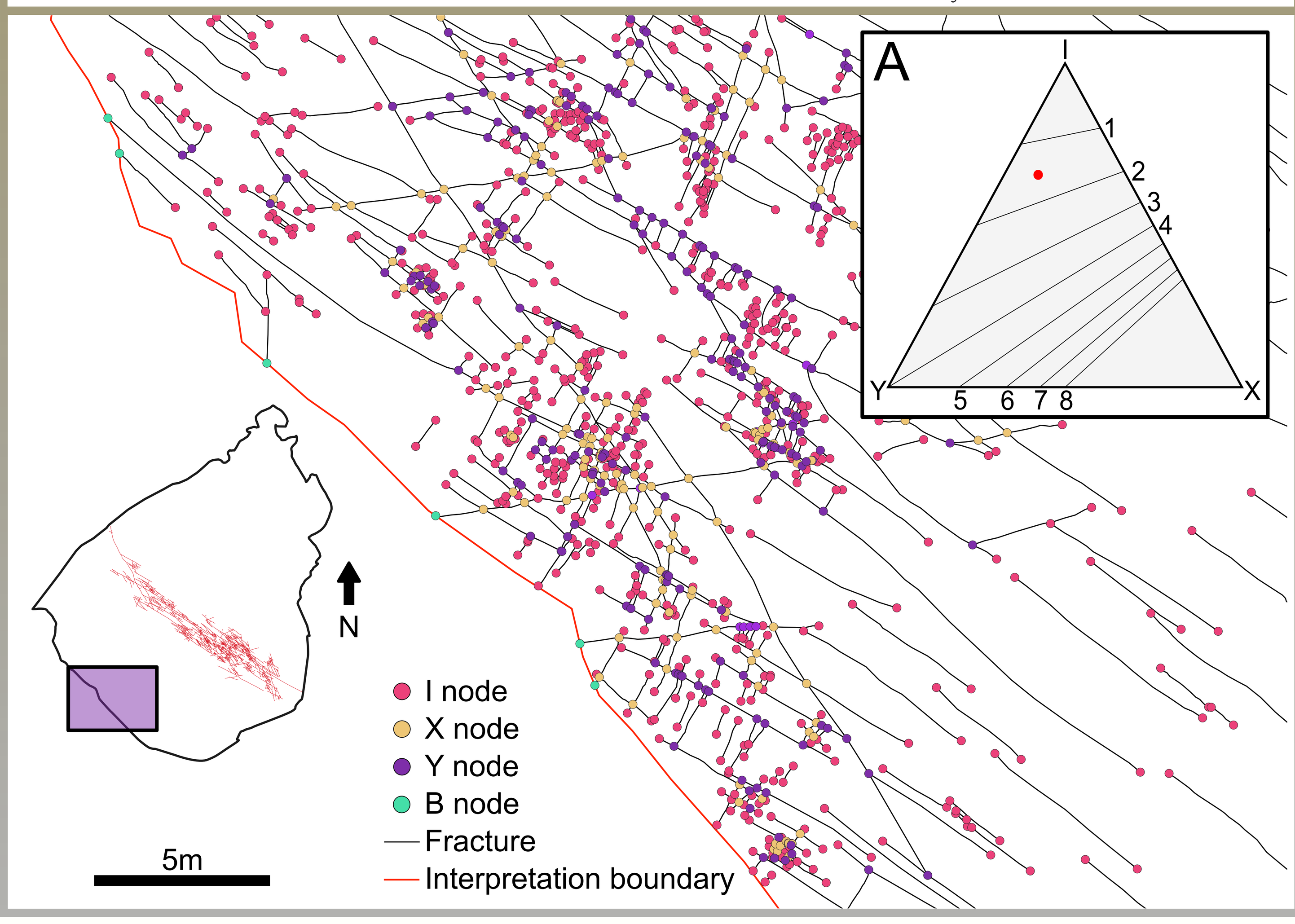


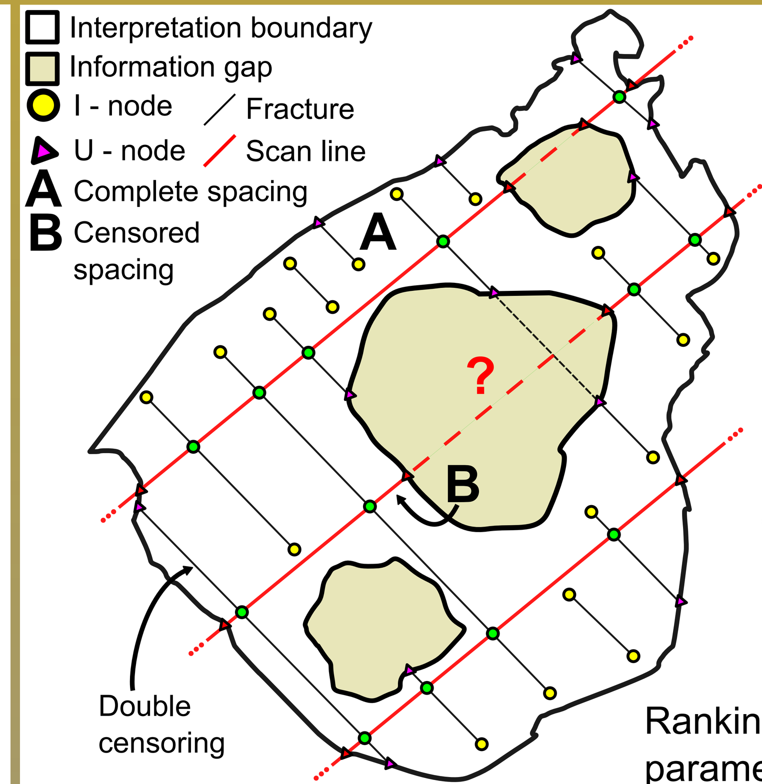


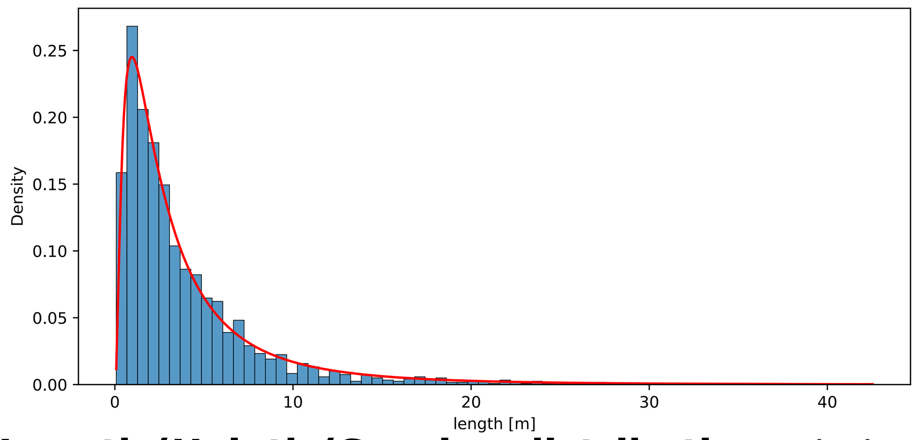


Test for Fisher distribution









CENSORING PAPER

PYTHON LIBRARY

Length/Heigth/Spacing distribution calculated by applying survival analysis techniques to correct the right censoring bias.

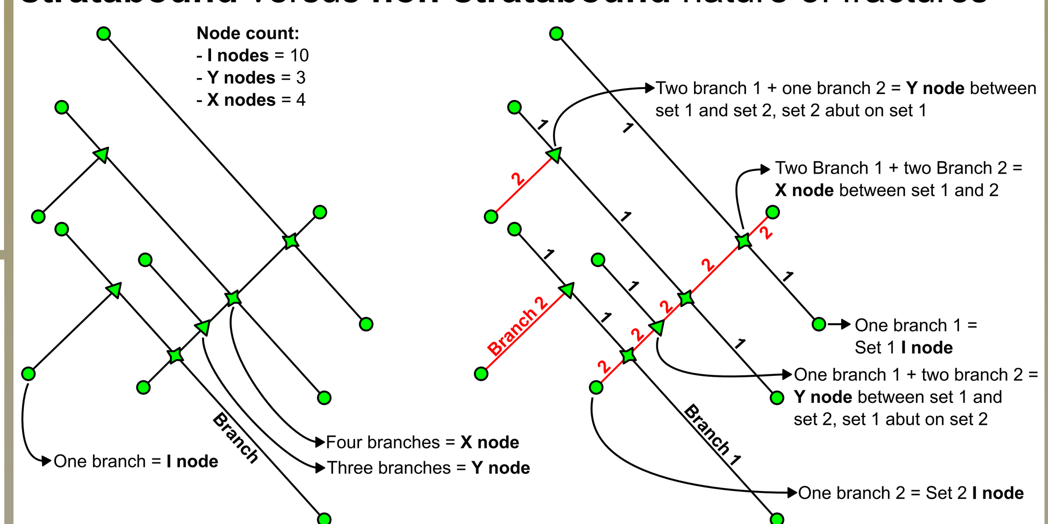
Total number of fractures	% censored
2014	8.6395

Akaike rank	KS rank	KG rank	AD rank	Mean rank
1	1	1	1	1.0

Ranking system based on statistic distances to select the most representative model parameters

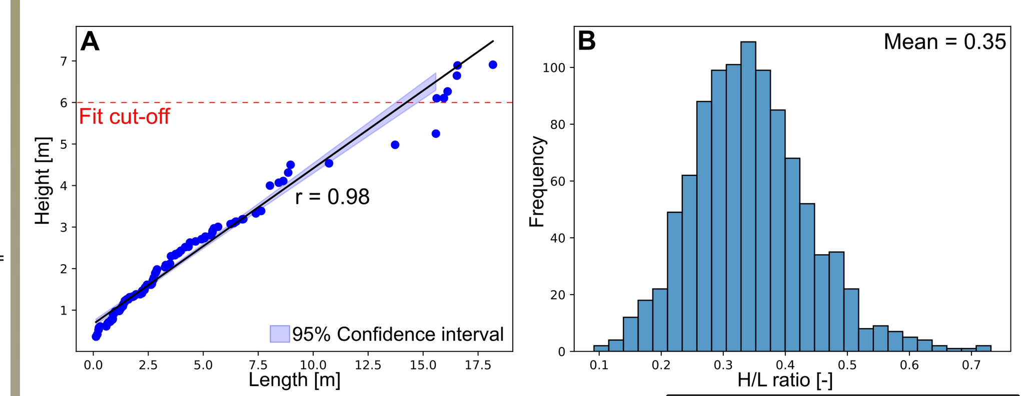
Directional topology: every node contains information about its origin

Quantitative parametrization of **relative chronology** and **stratabound** versus **non-stratabound** nature of fractures



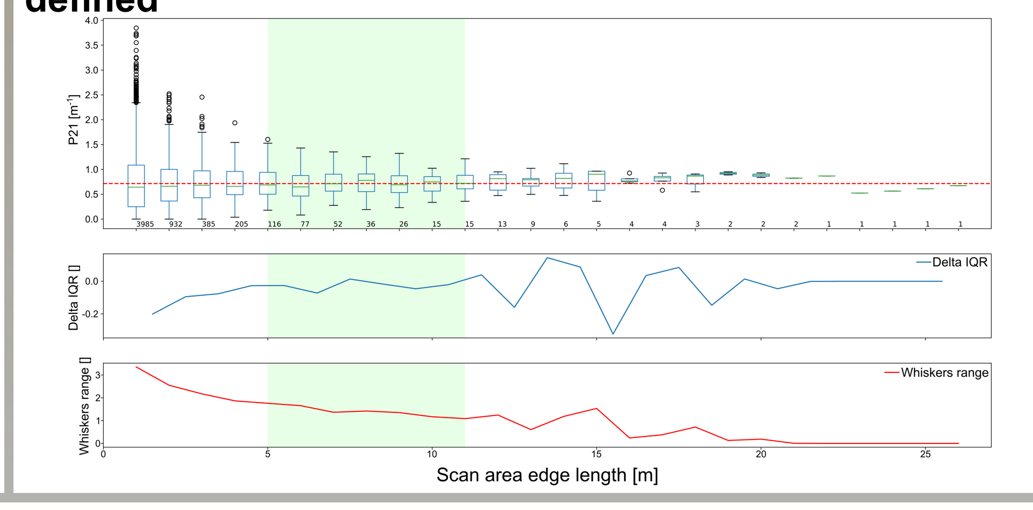
Hundred values of length and heigth are randomly sampled from the statistical distributions. **H/L ratio** is obtained from linear regression of height data. (A)

One thousand realizations are made to account for the variability of the random sampling. (B)



Intensity parameter (**P21**) calculated on exagonal windows of increasing size.

REA (Representative Elementary Area): Area above a parameter becomes statistically stationary, **qualitatively defined**



Conclusions

This Workflow maximizes fracture data collected from Digital outcrop models, integrating data coming from faces (extracted from point clouds) and traces (digitalized on orthomosaics).

Integration of horizontal and vertical outcrops allow a complete 3D characterization of fracture network properties.

Field survey remains a core part of the process, because it is impossible to measure important parameters such as aperture and tectonic phase of a fracture set from a DOM.