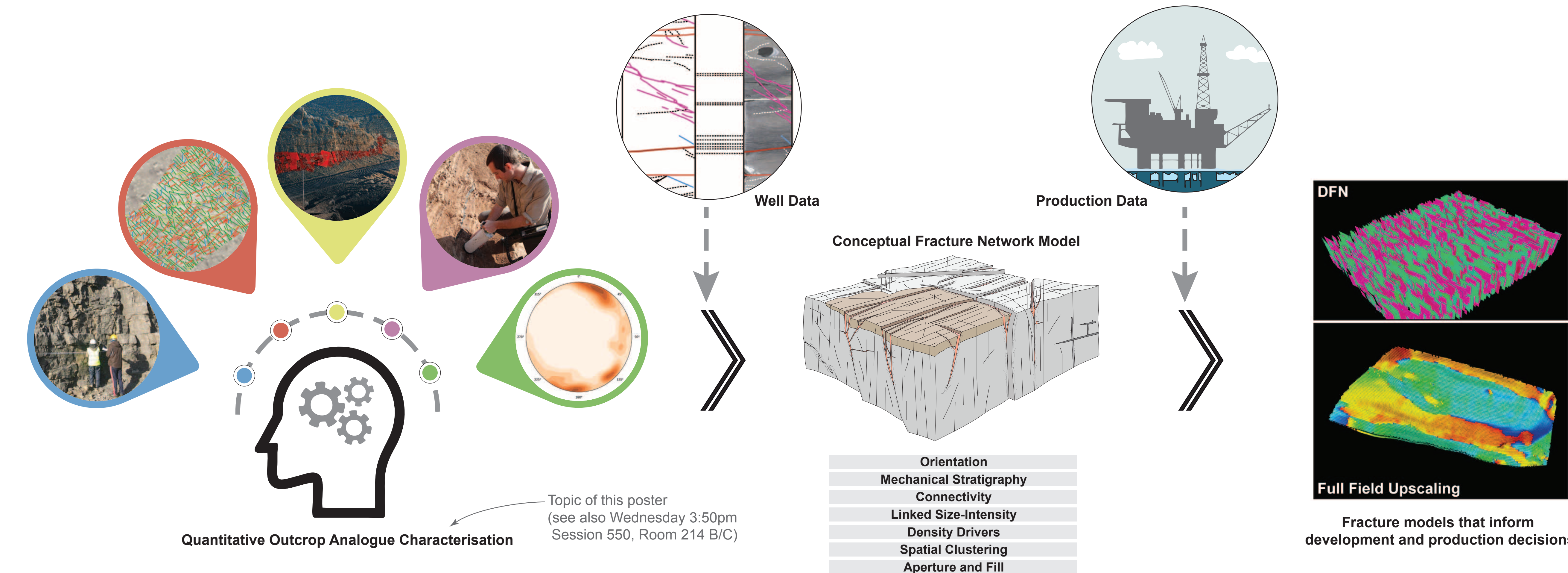
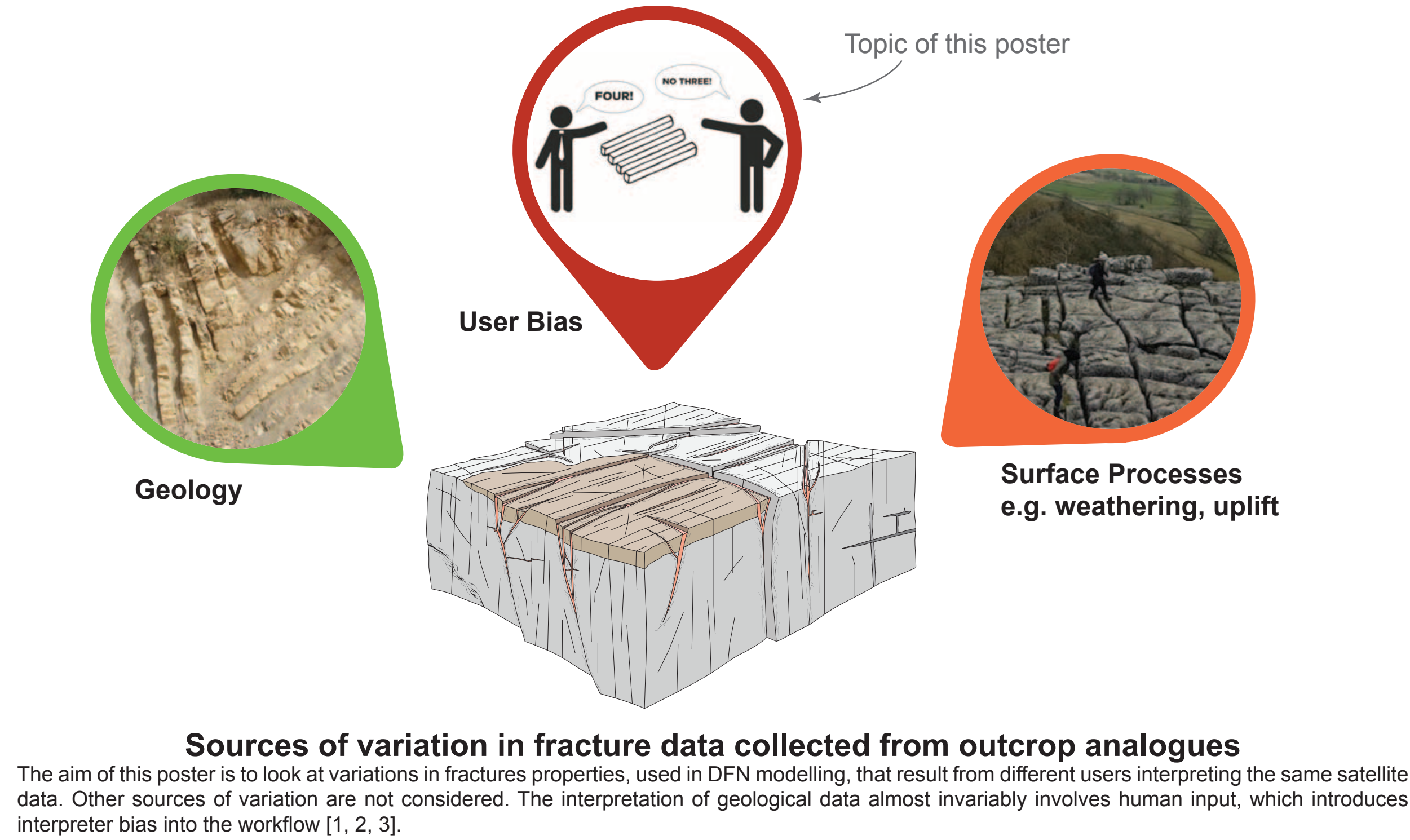


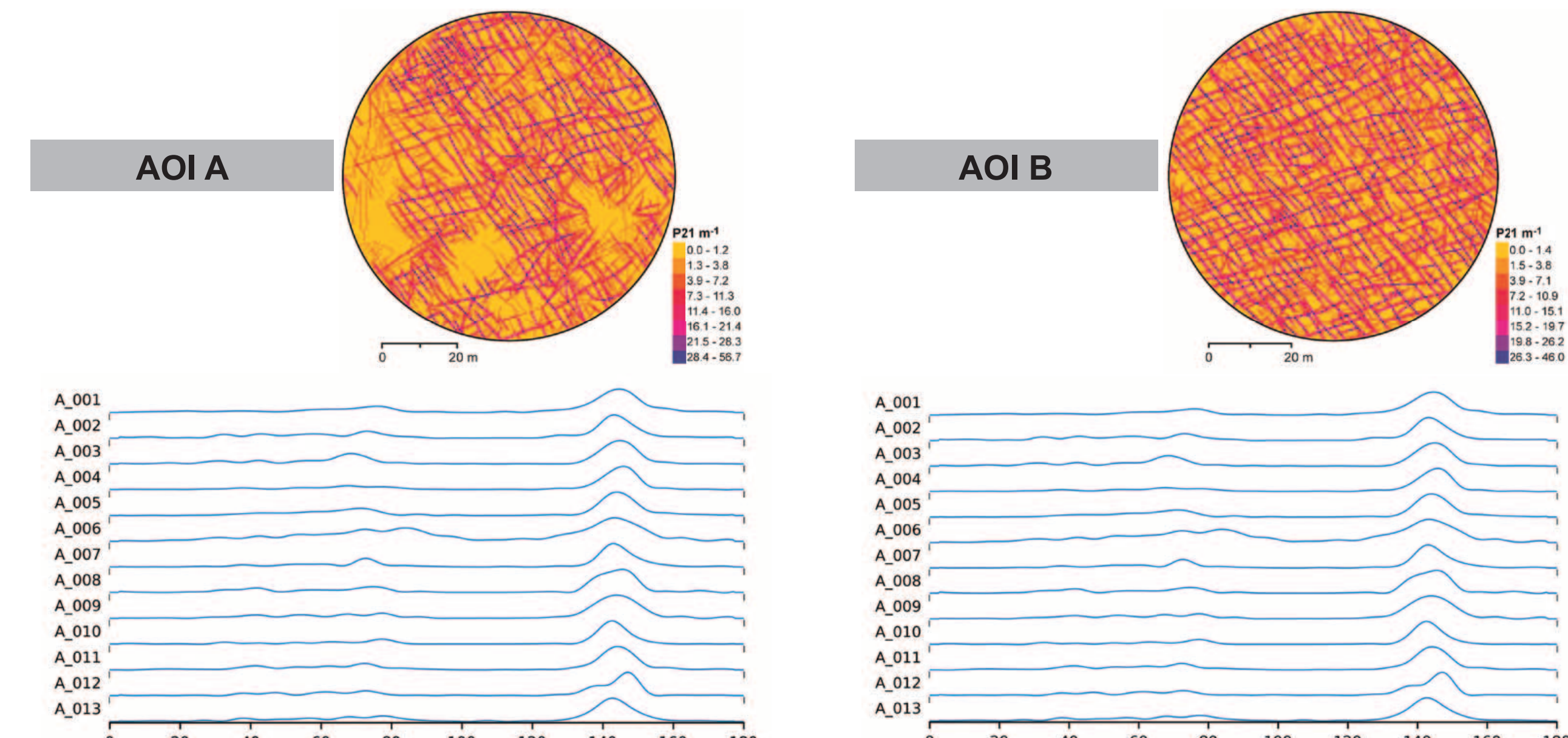
1. Introduction: The “Outcrop Analogue to Fracture Model” Workflow



2. Introduction: Sources of Uncertainty/Variation



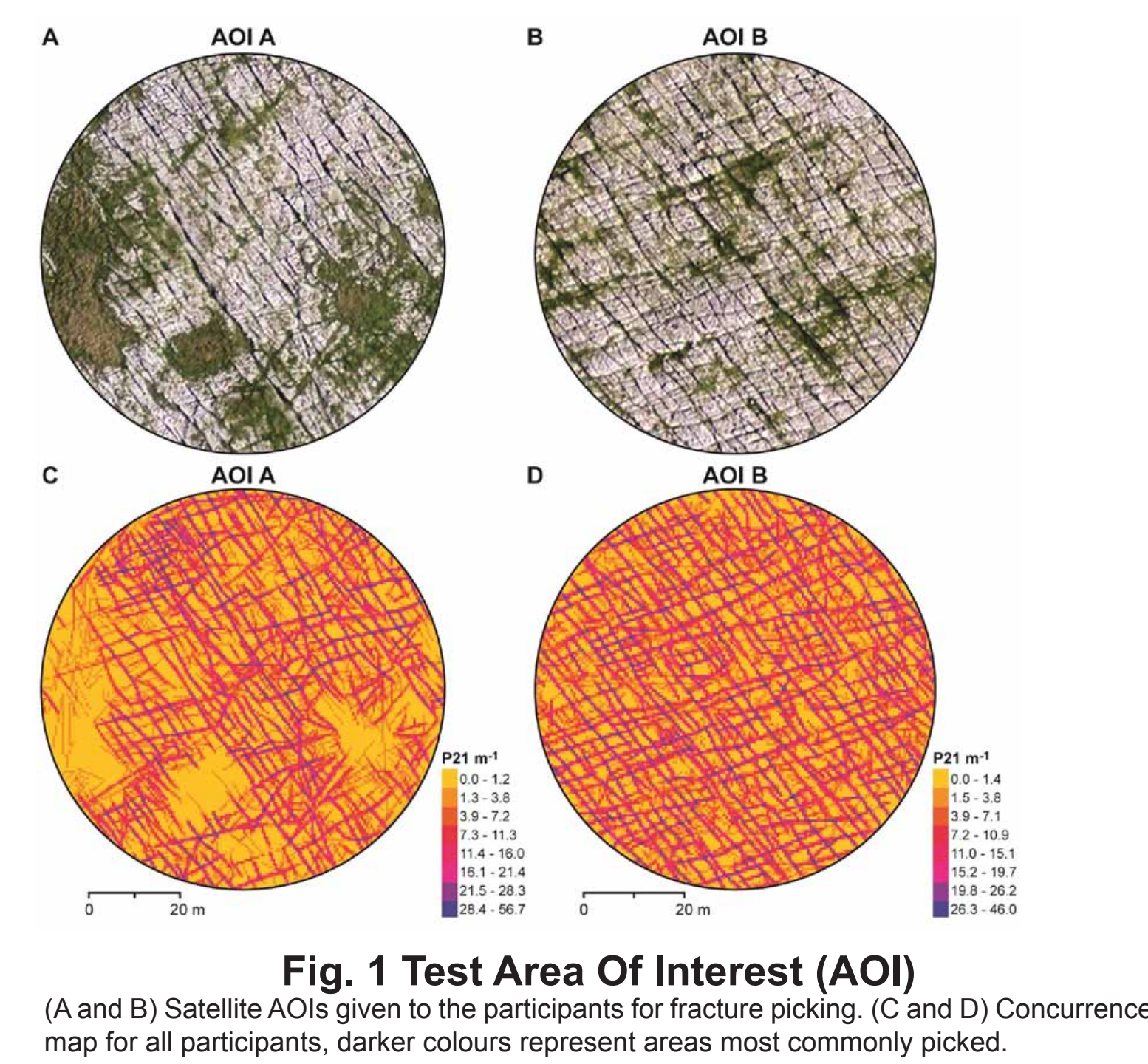
4. Results: Variations in Orientation & Intensity



- AOI A has a greater percentage of vegetation cover and there is also a greater variation in observed picks.

- Most people pick the same dominant orientation peaks, but when vegetation increases weaker sets are poorly identified.

3. Methodology



- Participants were asked to pick two circular AOIs with varying amounts of vegetation cover. (Fig. 1A,B)
- Images were interpreted at a fixed resolution in ArcMap using straight line polylines with no snapping.
- Participants also completed a questionnaire (see box 5). This is a pilot study, and the statistical significance in correlation between answers and the observed variation in results may be limited.
- We looked at variation in orientation, bulk intensity, connectivity and length-intensity scaling (see boxes 4-7).
- The raw results and post-processed results were analysed to look for variation in fracture properties due to different users (see box 7).

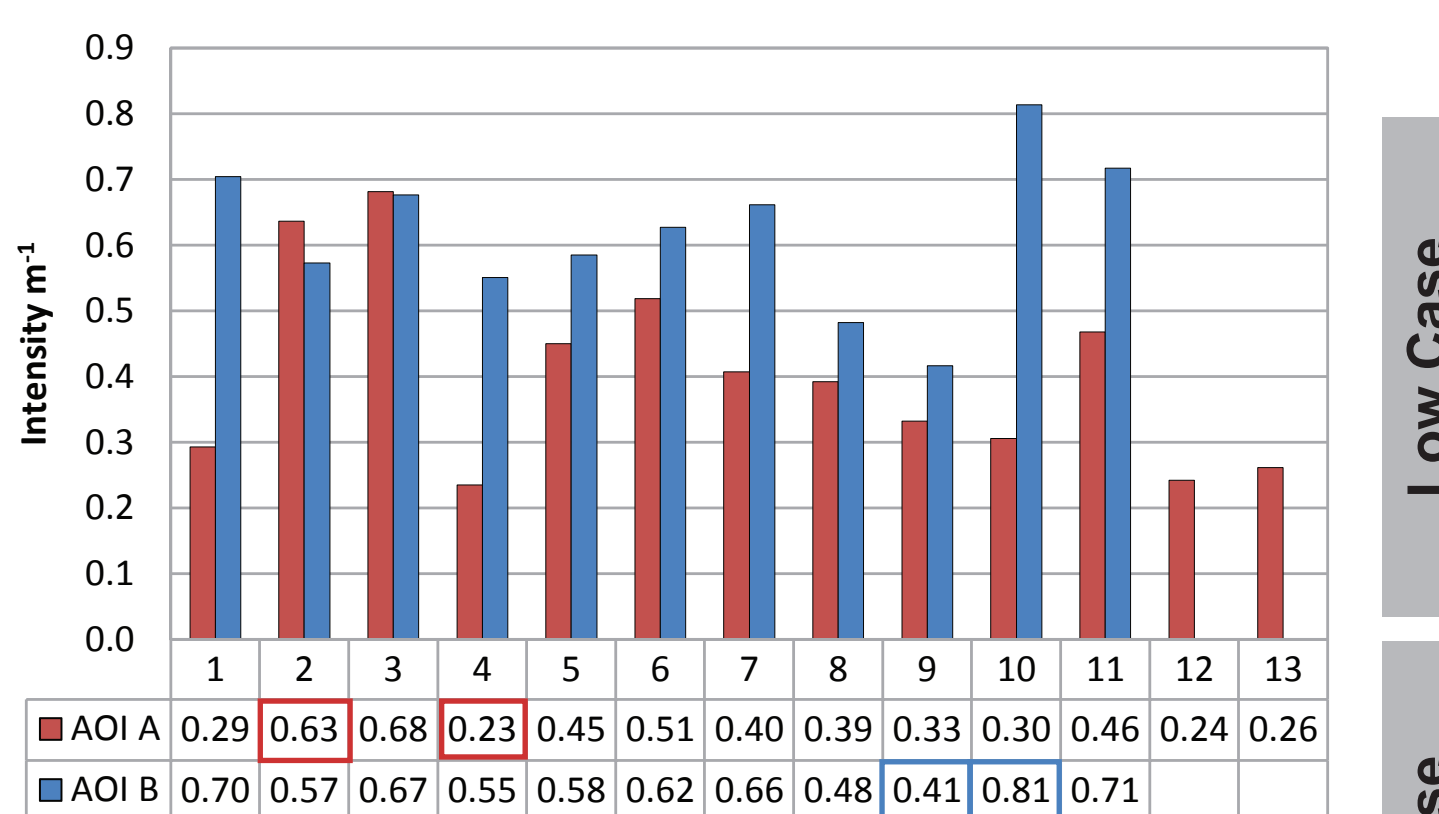
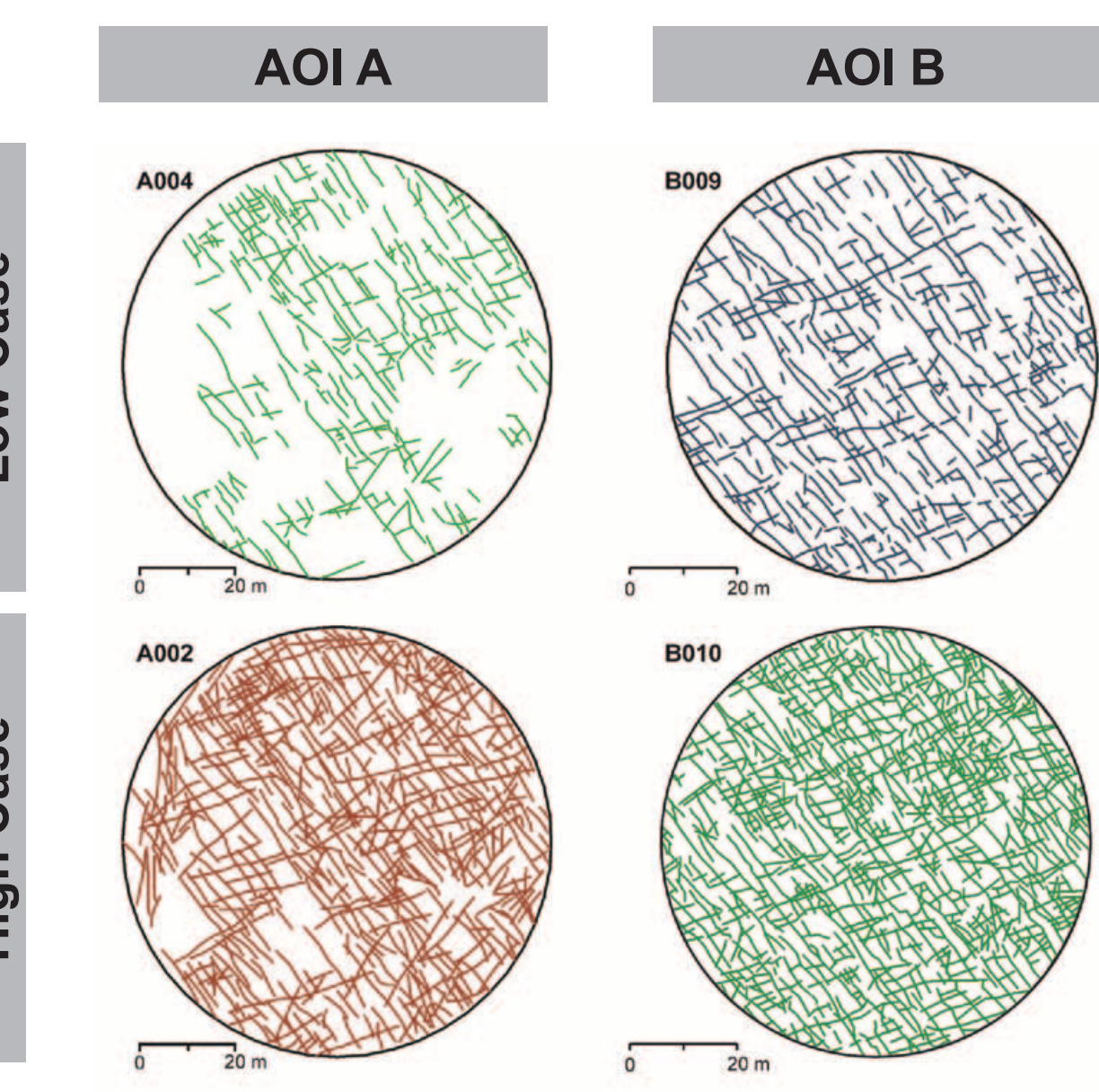


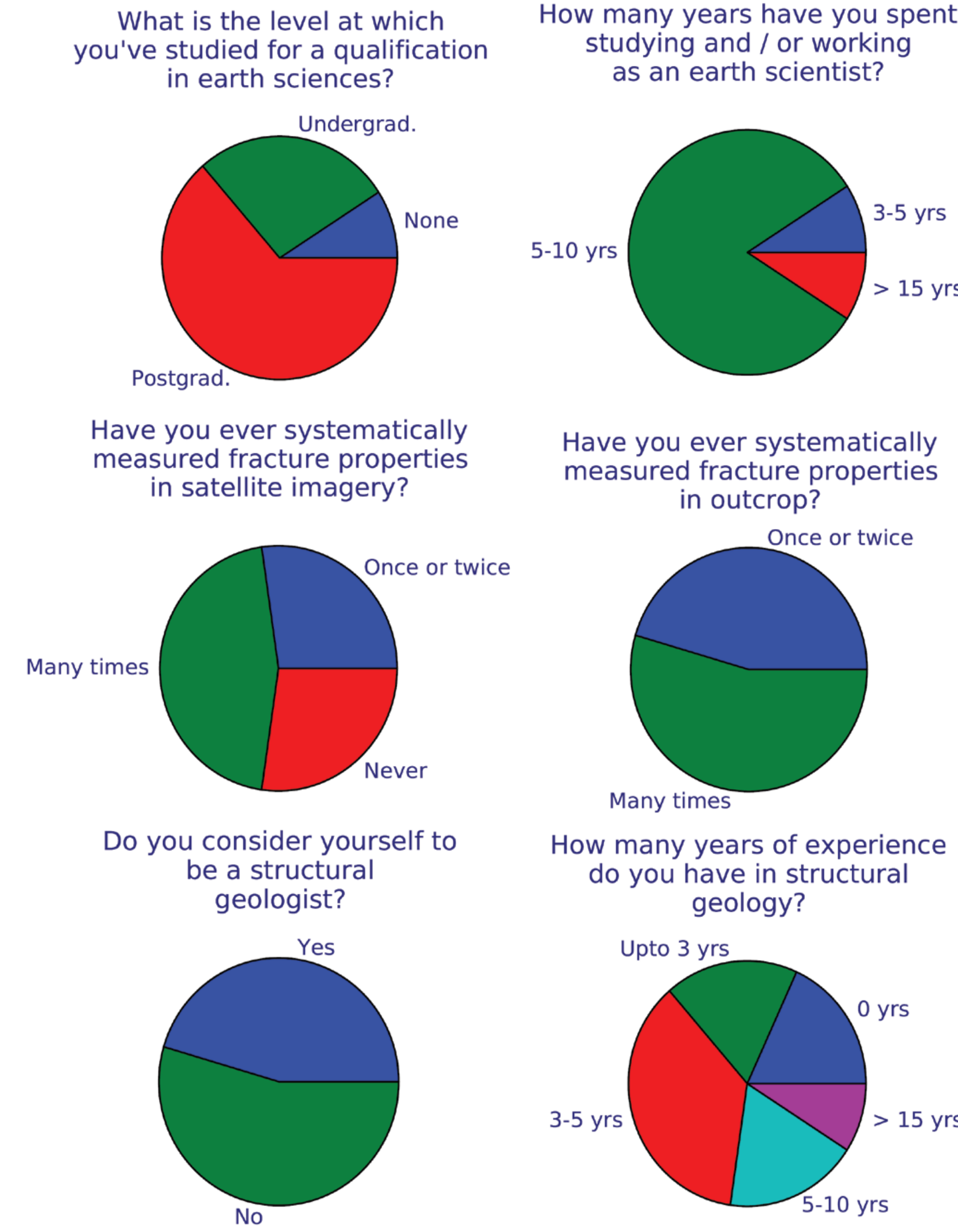
Fig. 4 Bulk Intensity Variations
(Top) Bulk intensity for each participant, per AOI.
(Right) Examples from each AOI showing the end member picking results (high and low cases), corresponding values are highlighted in the table above.

- AOI A: 2.9x difference between min and max bulk intensity (Fig. 4).
- AOI B: 2x difference between min and max bulk intensity (Fig. 4).



- With greater vegetation cover (ambiguity in signal to noise in AOI A) there is an increase in the variation of picked fracture traces.
- Orientation showed the least variation of all the fracture properties investigated.

5. Results: Questionnaire

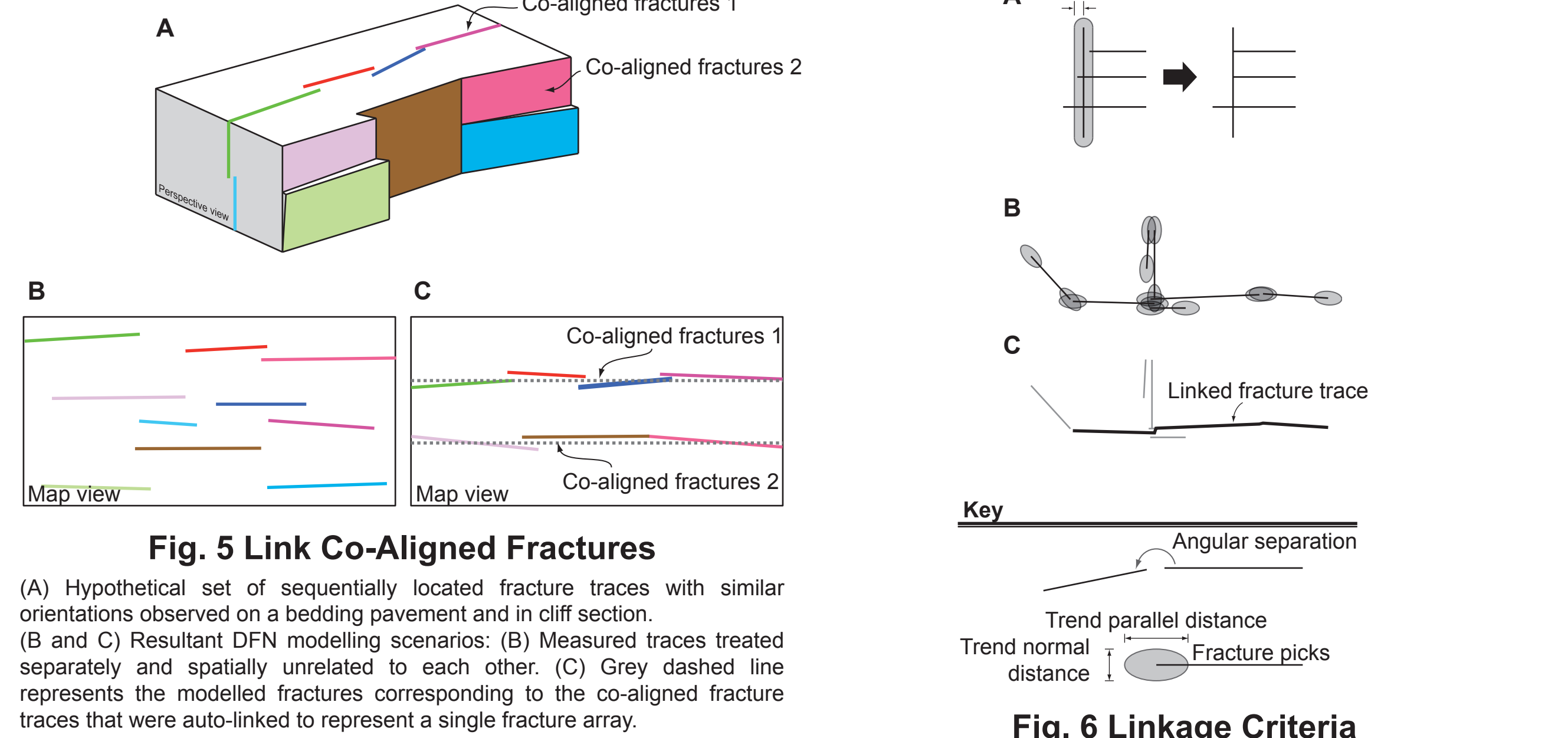


In spite of the low sample size results from Levene's test show that there is a significant difference ($p > 0.90$) in variance of bulk intensity between the following groups of people:

- People who consider themselves structural geologists and those who don't.
- People with > 3 years structural geology experience and those with less.
- People who have measured fractures in outcrop many times and those who have only done it once or twice.
- People who previously have measured fractures in satellite data and those who haven't.

In summary, there is less variance within the experienced population; e.g. experienced people pick similar intensities of fractures, in contrast with inexperienced groups.

6. Post-Processing



- Post-processing of the fracture picks is done to try and reduce the variance in the sample and standardise the results.
 - Processing steps aim to improve geological representation of the natural fracture network within the modelled DFN (Fig. 6).
- Topological uncertainty in the digitalisation of end-point connectivity is cleaned using a buffer size proportional to the resolution of the underlying satellite imagery (Fig. 6A).
 - The input parameters that define whether fractures are co-aligned are angular difference and proximity of end nodes to each other (Fig. 6B). An elliptical search is used to find nodes within a constant area (ellipse axes oriented parallel and normal to the fracture trace). When multiple valid end points are located, the linkage favours the creation of the longest most co-aligned fracture.

7. Comparison of Raw and Post-Processed Results

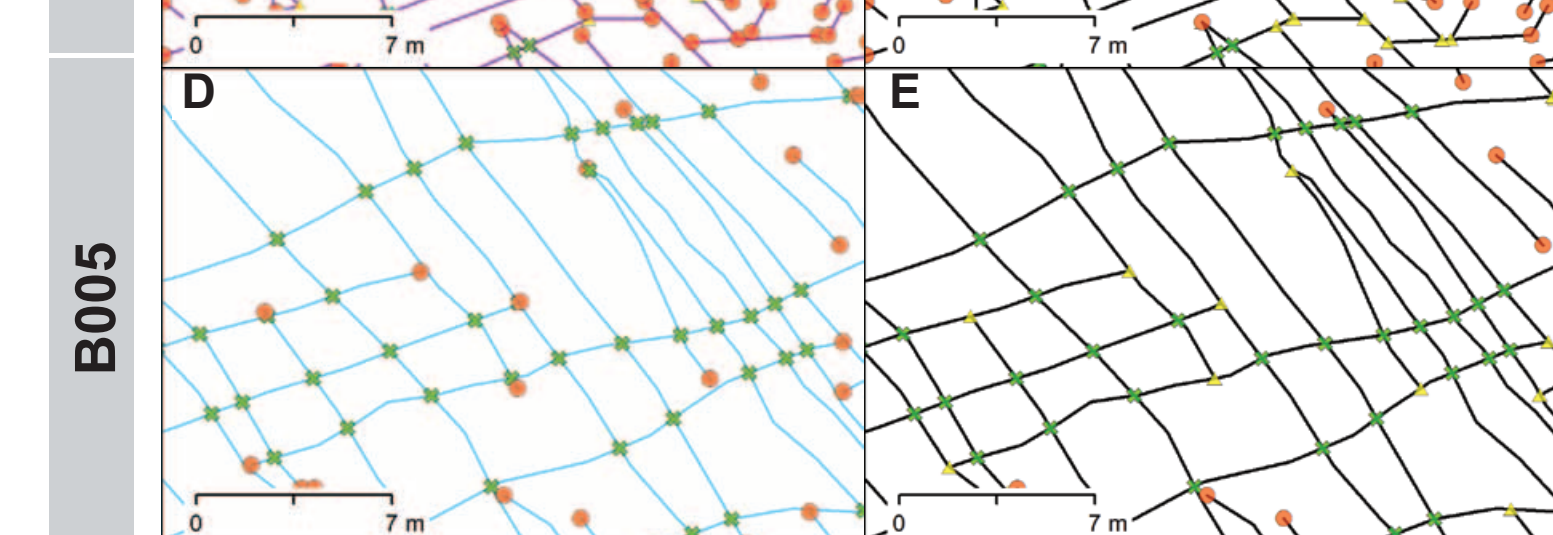
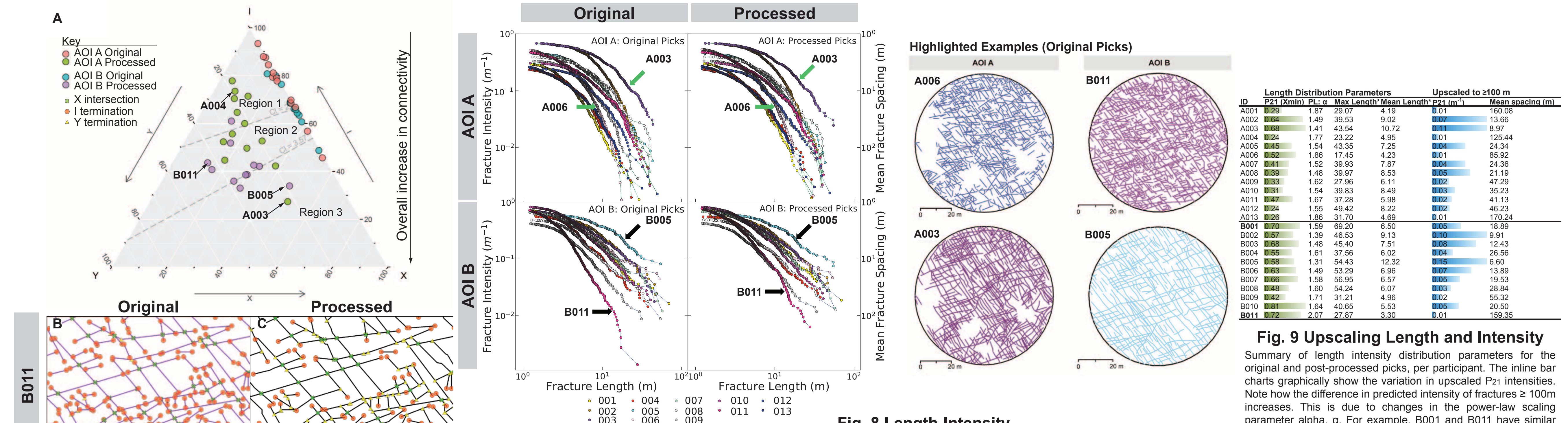


Fig. 8 Length-Intensity
(Left) Length-intensity distributions plotted on log-log charts for each AOI, for original and processed picks. Linking co-aligned fractures causes the distribution to become shallower, instances where short segmented fracture traces have been picked can cause a substantial change (see B011).
(Right) Examples of end-member picking styles (labelled in plots on left). Top row shows highly segmented picking style; bottom row are examples of picking that results in long, continuous fractures.

8. Conclusions

- Fracture networks are highly susceptible to user picking differences, which adds uncertainty to fracture modelling parameters, especially length, intensity, scaling and connectivity.
- Changes in outcrop/image quality within an AOI causes increase in variance within the measured fracture properties.
- Increasing the skill level of people interpreting fractures and applying post-processing corrections can help standardise results for DFN modelling.
- However, post-processing can only partially mitigate against the effects of under- or over-picking and consequent effect upon the derived length distributions within satellite datasets.

9. References

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- [3] Watson, F., Long, J., Wilkinson, M. and Javis, Z., 2013. April. Variability in interpretations when picking fractures from satellite images. In EGU General Assembly Conference Abstracts (Vol. 15).
- [4] Sanderson, D.J. and Nixon, C.W., 2015. The use of topology in fracture network characterization. Journal of Structural Geology, 72, 55-66.

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