

PS Reducing Uncertainty in Fracture Modelling: Assessing User Bias in Interpretations from Satellite Imagery*

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Abstract

Outcrop analogues provide crucial insights into fracture networks that are difficult to attain from borehole data alone, especially in exploration areas where wells are sparse, and knowledge of the reservoir is minimal. However, the interpretation of geological data almost invariably involves human input, which introduces interpreter bias into the workflow. To reduce the uncertainty that is inherent in data derived from analogue outcrop studies, the degree to which different interpreters may affect the resultant outputs must be understood, and non-geological variations need to be constrained and mitigated. We apply this approach to quantify the variability in fracture network interpretations derived from satellite imagery, using a population of geologists of varying levels of expertise and experience.

In this study we asked all participants to pick fractures from the same satellite image, at the same scale, under the same conditions, and then compared their results. We selected examples of different fractured carbonate units with varying degrees of image quality. Our analysis of the results focuses on the variations in topology, orientation, intensity and length within the resultant fracture network picked by each participant. We illustrate the implications of the variability with respect to DFN modeling and suggest strategies to standardize fracture interpretations to reduce picker-bias, by post-processing the picks using a topological correction and linkage algorithm.

As expected, we see significant variability in the interpretative picks from different geologists. The effect of this variability on fracture modelling is addressed with respect to orientation, connectivity, and length-intensity scaling. The biggest variations were in how different people digitized closely spaced fractures (fracture arrays), and which fractures people chose to pick. End-member styles in the picking were either to pick many segmented co-aligned fractures, or to pick a single fracture spanning long distances. Different styles have a profound effect on inferred size-intensity scaling relations and can result in a three-fold range in picked fracture intensity within an area.

By applying a topological and linkage correction to the picked data the variance in the measured parameters decreased. However, significant variations in bulk fracture properties still existed in the post-processed interpretations. Variability can be further mitigated by improved training of inexperienced pickers by fracture experts, or by expert-led implementation of machine learning algorithms. Understanding the use-case for a

specific fracture study is important: the human aspect of uncertainty in fracture modelling can and should be minimized at all stages in the interpretation process.

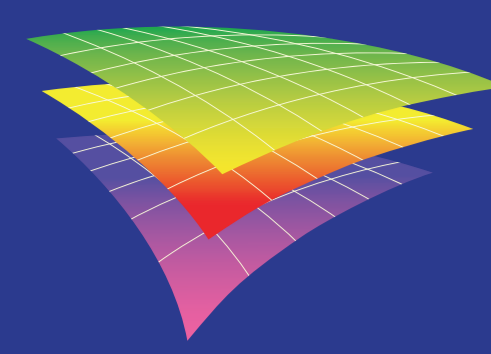
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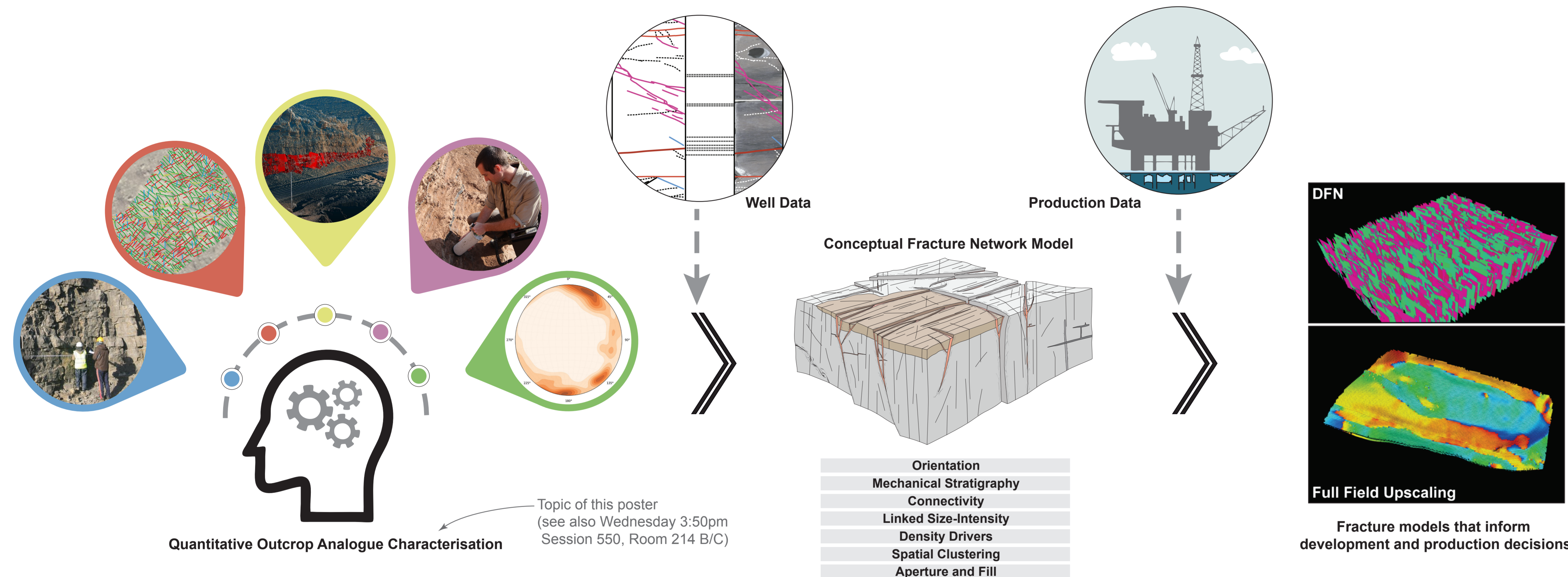
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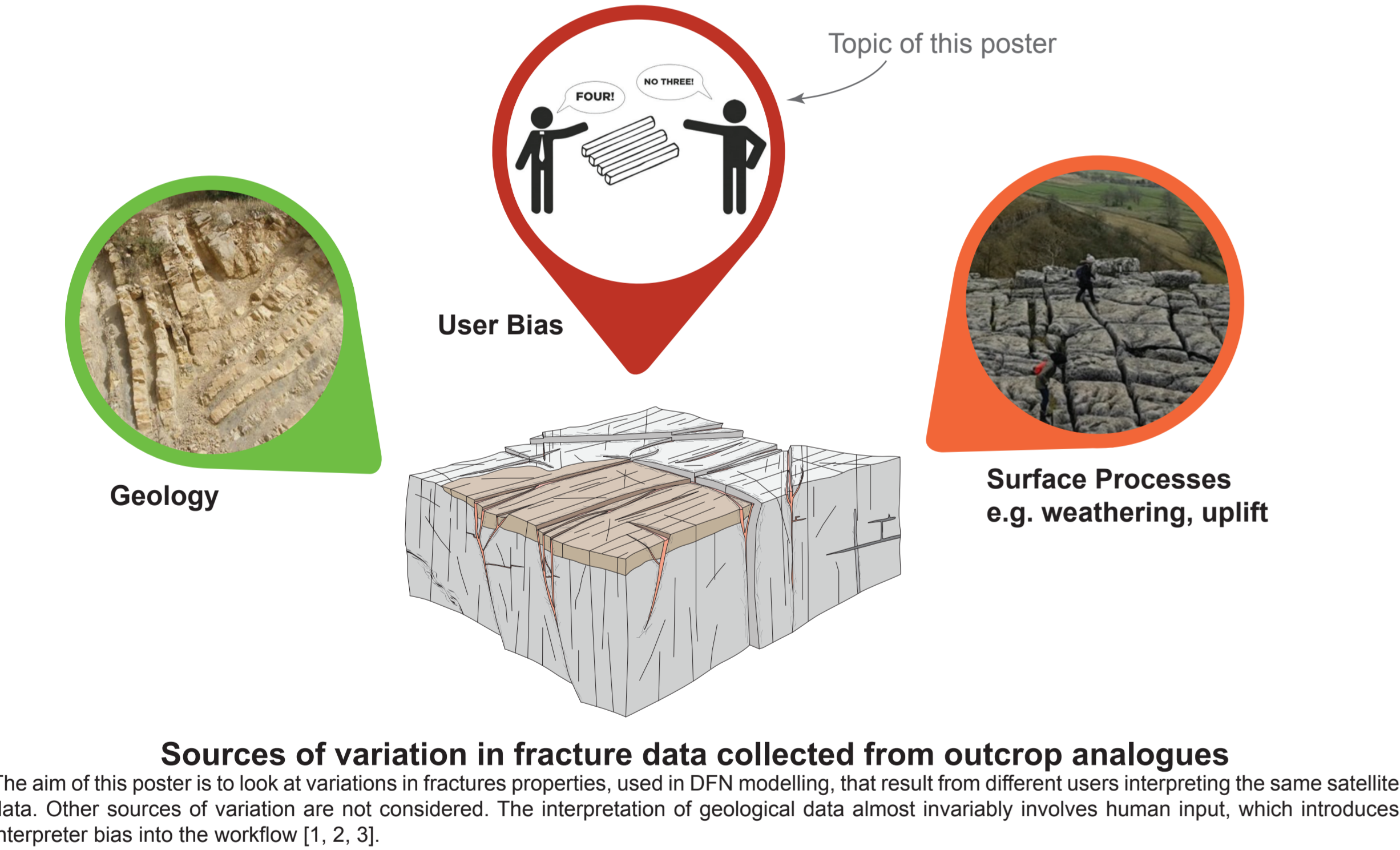
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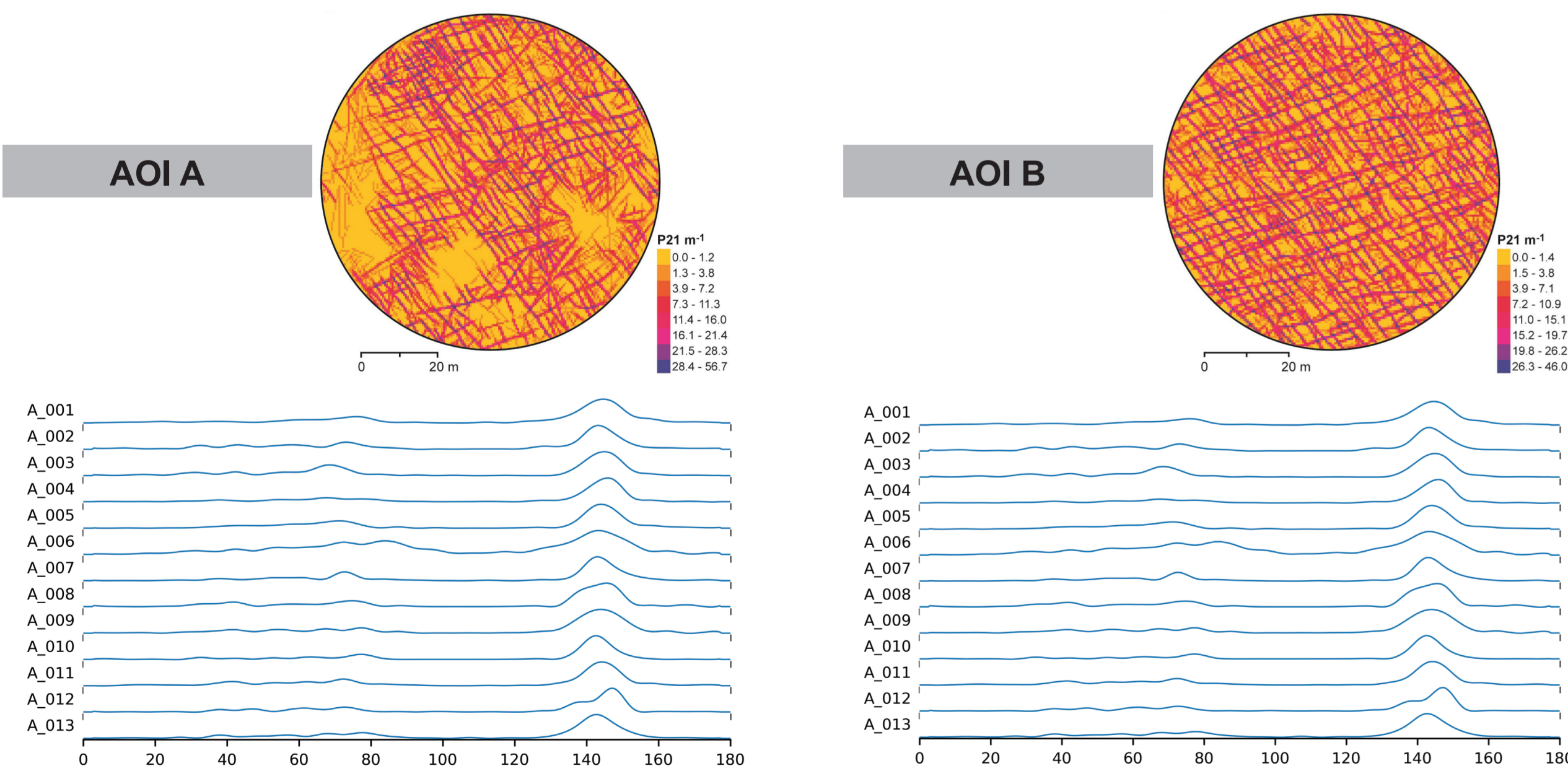
1. Introduction: The “Outcrop Analogue to Fracture Model” Workflow



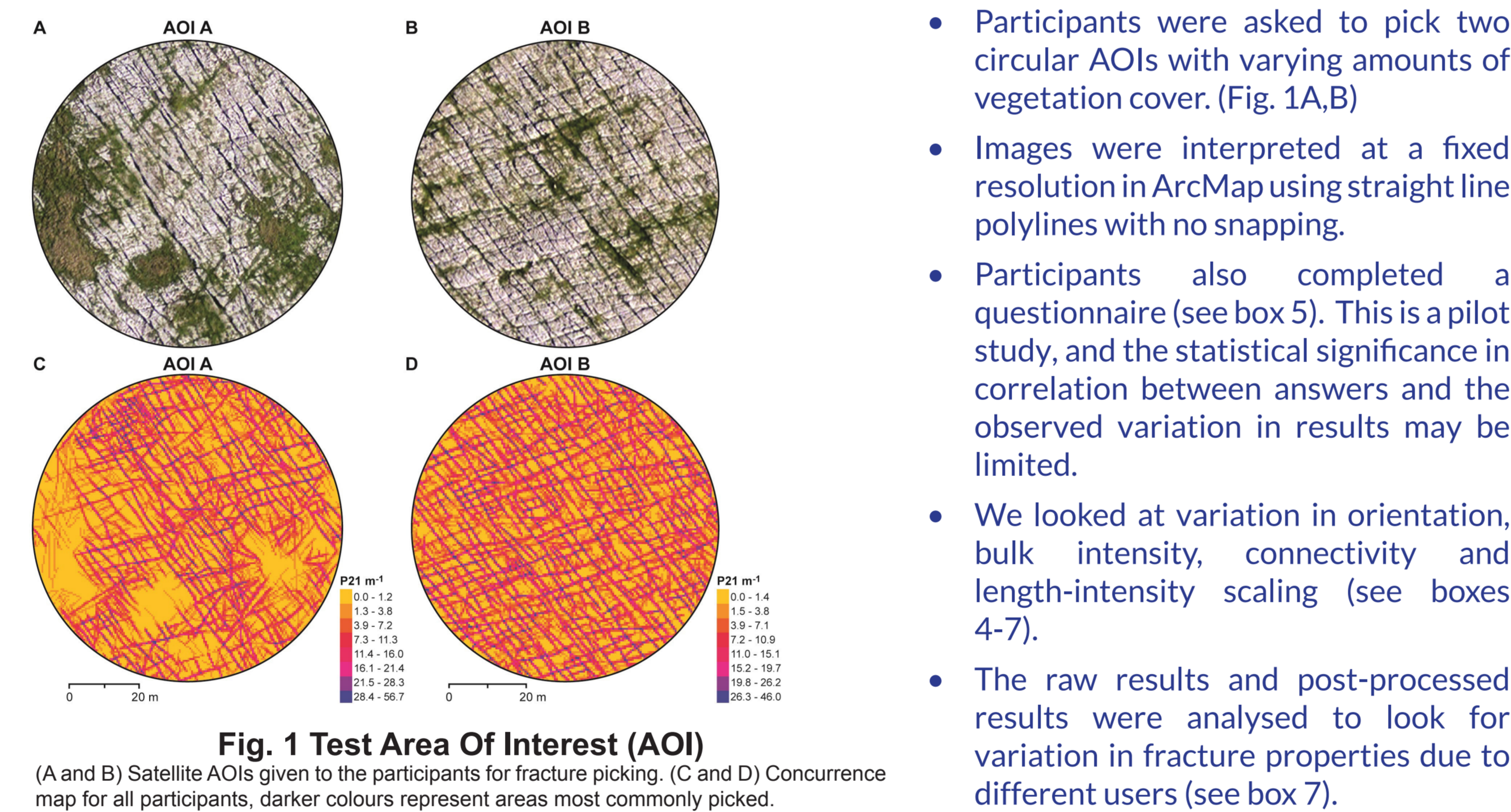
2. Introduction: Sources of Uncertainty/Variation



4. Results: Variations in Orientation & Intensity

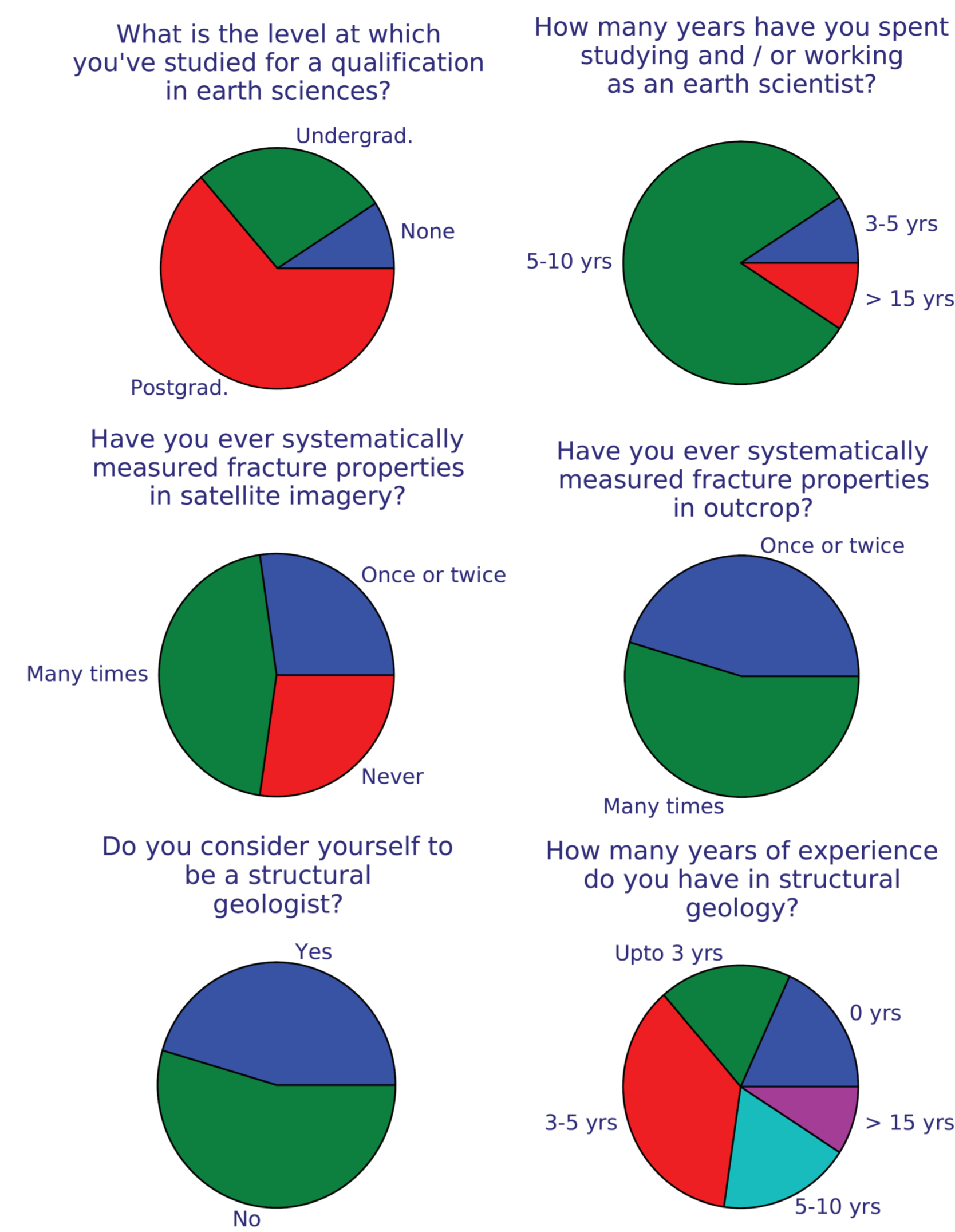


3. Methodology



- 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).

5. Results: Questionnaire

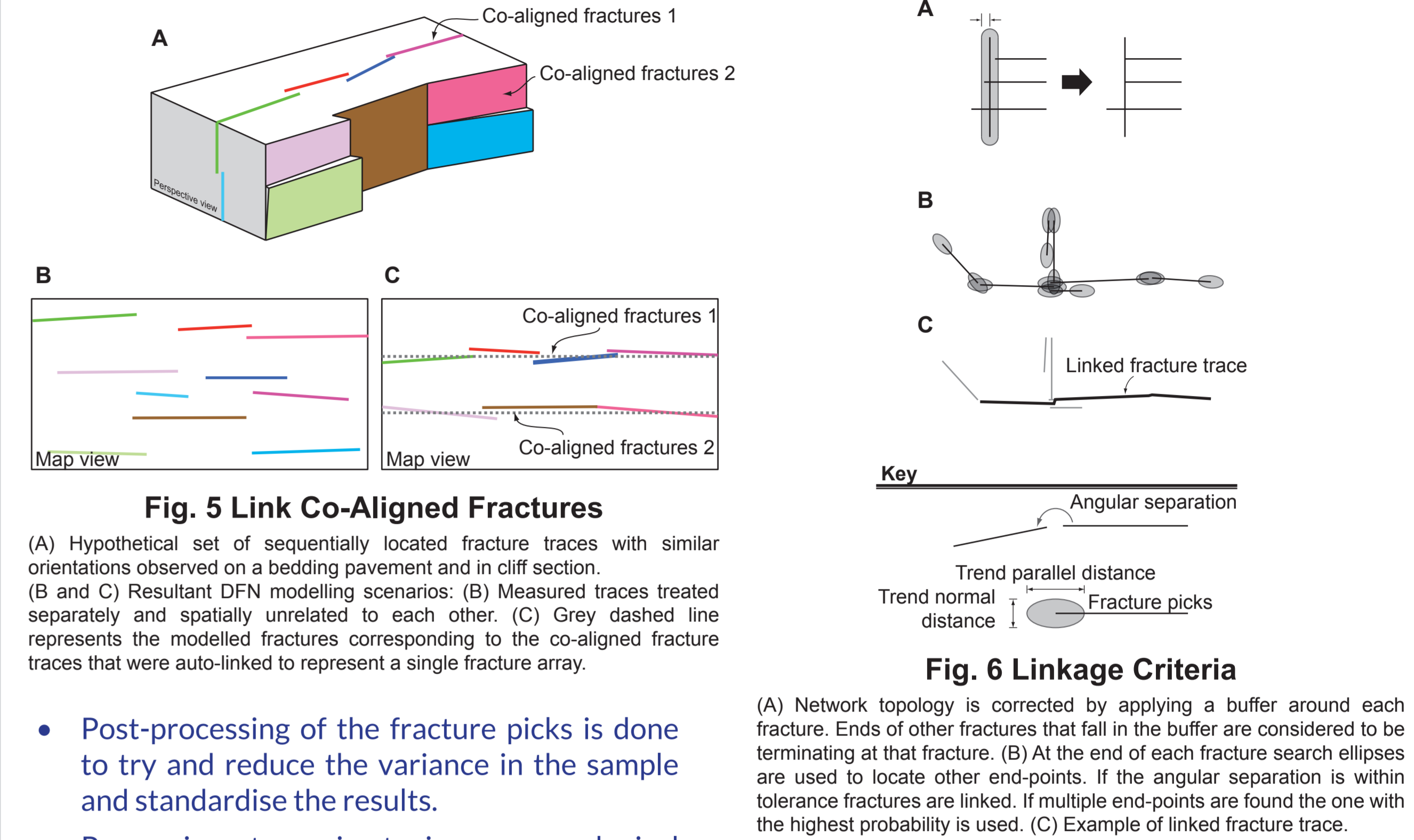


In spite of the low sample size results from Levene's test show that there is a significant difference ($p > 0.90$) in variance of bulk intensity between the following groups of people:

- 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.

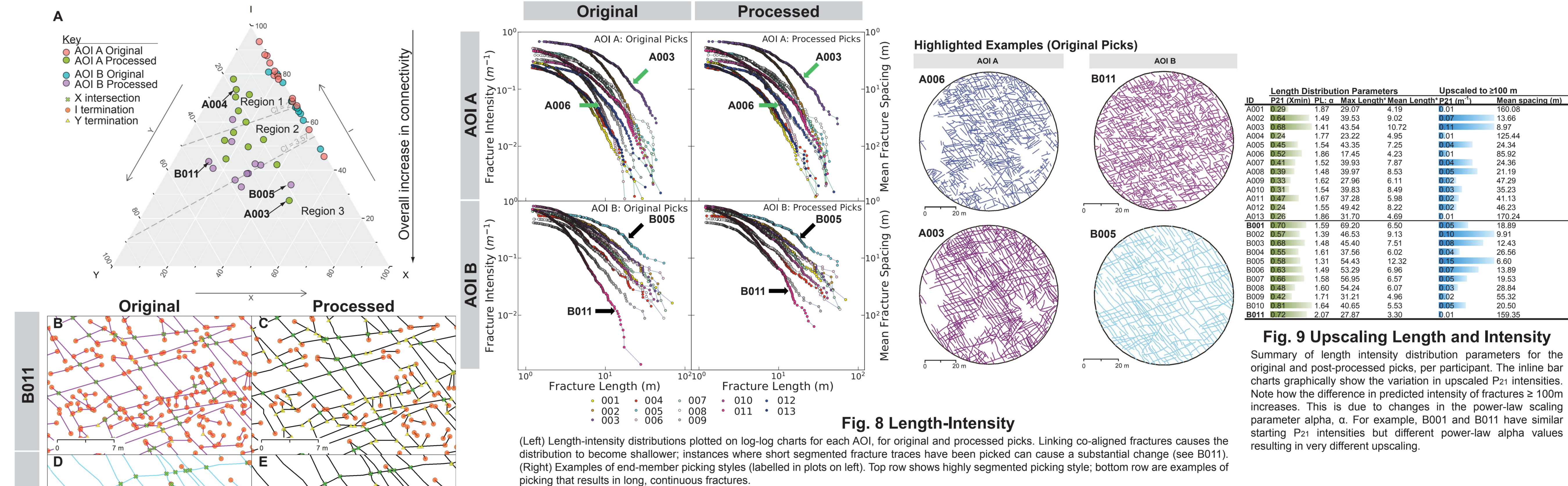
In summary, there is less variance within the experienced population; e.g. experienced people pick similar intensities of fractures, in contrast with inexperienced groups.

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



- Cleaning the topology mainly shifts the data along the I-Y axis but does not remove the large spread in the picked connectivity (Fig. 7). AOI A has the greatest range of values but both AOIs still span all three regions of the IYX plot. Region 1: no percolation; Region 2: orientation cluster systems become connected; Region 3: density clustered systems are connected [4].
- Applying the linkage post-processing reduces some of the outliers in the length-intensity data (Fig. 8) in cases where people chose to pick co-aligned fractures as segmented traces. However a significant spread of inferred intensities and fitted power-law distributions (α) still remain after post-processing. These differences are exaggerated when upscaled to modelling scale ranges (Fig. 9).
- Note how the scaling distribution dominates the resultant upscaled values more than the intensity at small scales (Fig. 9: see B001 and B011). Therefore the way in which people pick fracture length is highly important (not just how many fractures they pick in total).

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

- Bond, C.E., Gibbs, A.D., Shipton, Z.K. and Jones, S., 2007. What do you think this is? "Conceptual uncertainty" in geoscience interpretation. GSA Today, 17(11), p.4.
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