Comparison of digital outcrop and conventional data collection approaches for the characterisation of naturally fractured reservoir analogues

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Outstanding Student Poster Contest

Thomas Seers **David Hodgetts**

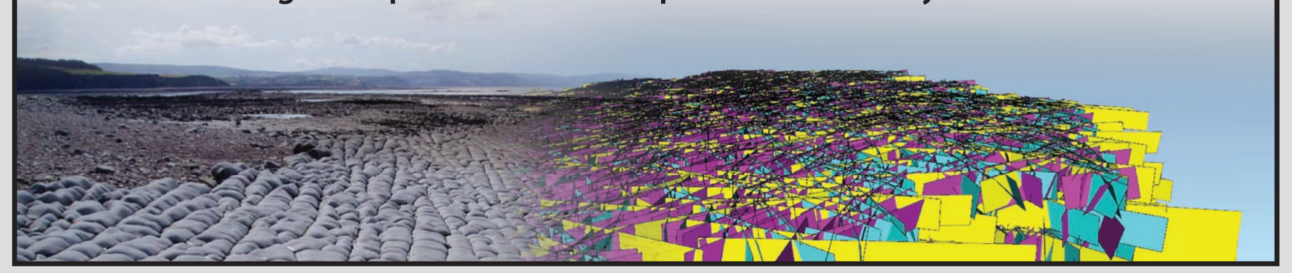
School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Williamson Building, Oxford Road, Manchester. M13 9PL.

(thomas.seers@postgrad.manchester.ac.uk)

1. Motivation and Aims

- Greater synergy is required between outcrop and field datasets in the pursuit of unconventional and structurally complex reservoir objectives
- This objective is hindered by conventional methods of fracture characterisation in outcrop which prove biased and inefficient (direct surveys) or incapable of resolving key network properties (lineament mapping)

In this study, we develop terrestrial lidar based digital discontinuity analysis techniques as alternatives to such methods. Validation and calibration is attained through comparison with an equivalent manually collected dataset



2. West Mine Case Study

We mapped exposures of the Triassic aged Helsby Sandstone Formation (HSF), a direct analogue of the producing Ormskirk Sandstone Formation of the East Irish Sea Basin, within the West Mine, Alderley Edge, Cheshire (**Fig 2**), using terrestrial lidar and calibrated digital imagery. The mine workings offer a high degree of 3D control over the fracture network, prove conducive to the extraction of fracture attributes, and provide a level of exposure of the HSF not afforded at the surface.

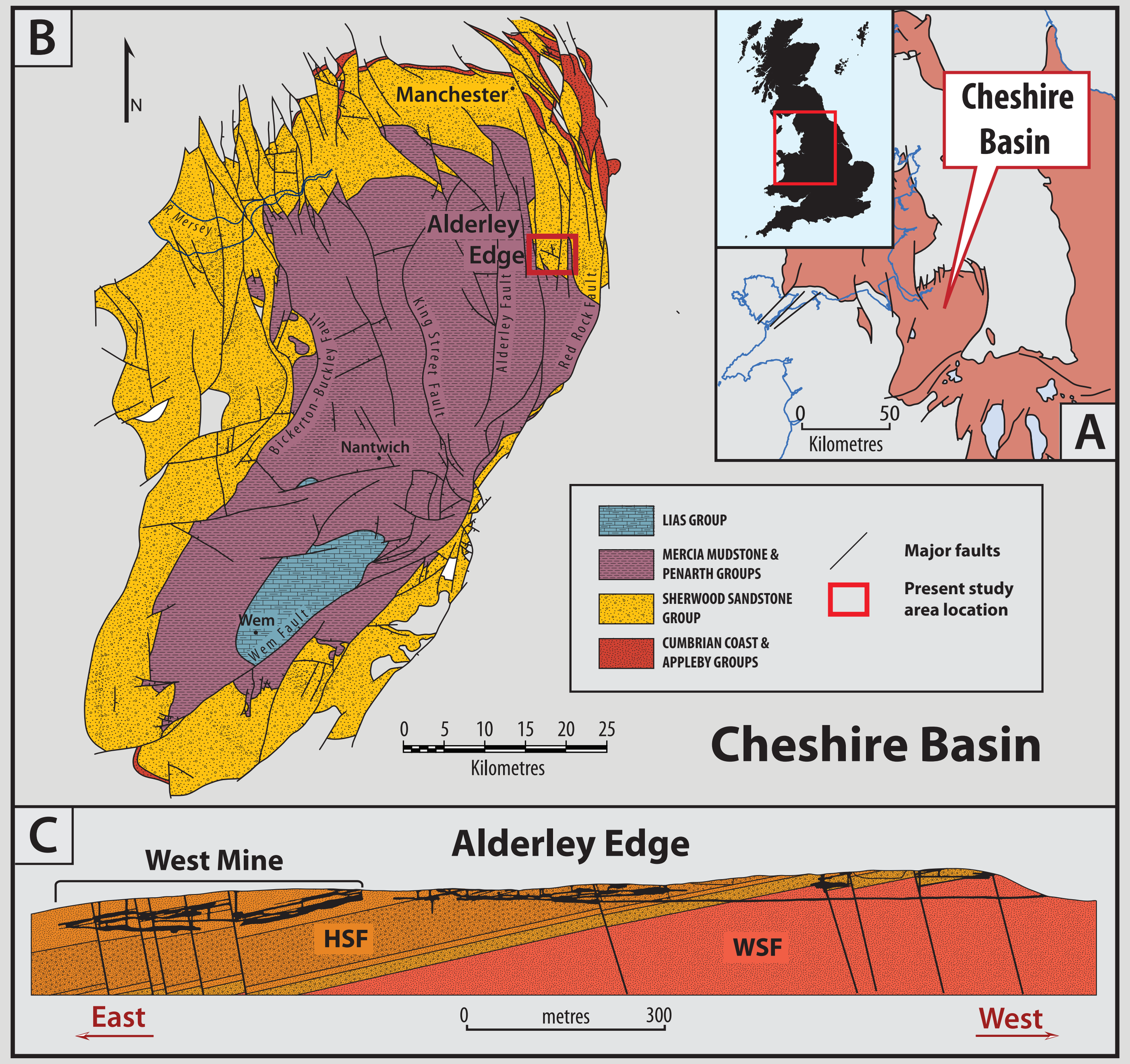


Fig 1. (A) Onshore-offshore Permo-Triassic outcrop of the NW UK with the Cheshire Basin indicated. (B) Bedrock geology of the Cheshire Basin indicating the location of Alderley Edge. (C) The Alderley Horst Block with the location of the West Mine indicated (*HSF/WSF: Helsby / Wilmslow Sandstone Formations*).

3. Digital Discontinuity Analysis

- RGB triangular irregular networks (TIN) generated using in-house software, with surface attributes calculated using moment of inertia analysis (Fernández 2005)
- Surfaces optimised via smoothing of high coplanarity regions (**Fig 2a-c**)
- Frequency distributions of TIN surface orientation used to identify sets (**Fig 2d,e**)
- Fracture facets extracted via targeted filtering of geometric attributes, with displays of coplanarity used to identify fracture traces (**Fig 2f,g**)
- Fracture orientations measured from outcrop models (**Fig 5b**) compared to those from a manual scanline dataset from the Alderley locality
- Fracture spacing and trace lengths collected using 'virtual scanlines' (Voyet *et al* 2006) and compared to results from congruent manual scanlines
- Virtual and manual fracture attributes used to construct discrete fracture networks (DFN), which are upscaled to equivalent porous medium (EPM) properties

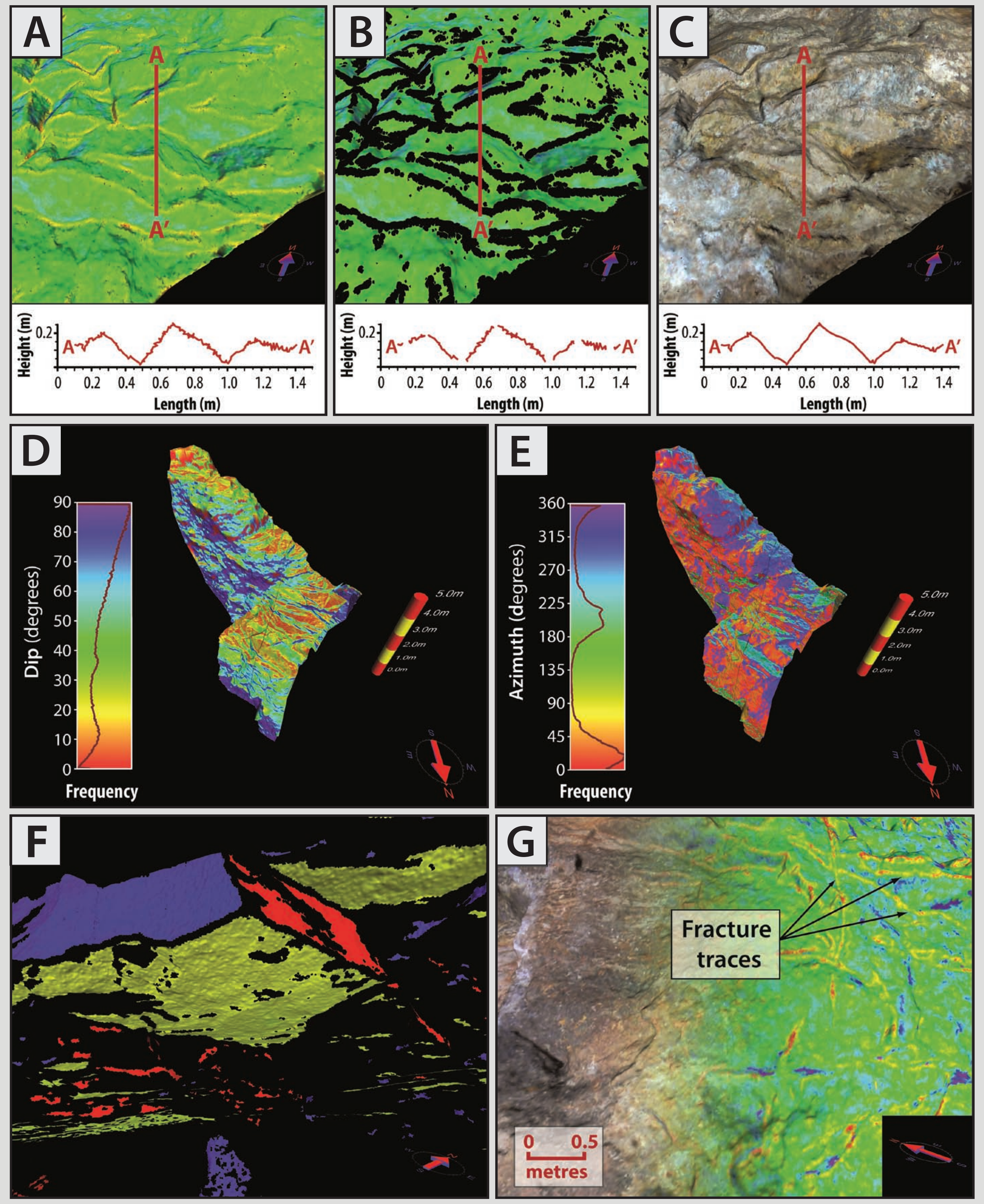


Fig 2. (A) The fidelity of TIN surfaces is limited by scanner ranging error (**B**). Regions of low coplanarity are filtered and smoothing operations conducted. (**C**) Surface is restored after smoothing operations. (**D**) Increases in frequency density for dip and (**E**) dip azimuth may indicate the presence of subparallel fracture sets. (**F**) Frequency distributions used to guide the filtering and extraction of fractures by sets. (**G**) Areas of low coplanarity indicate the presence of fracture traces.

4. Geometric Properties

Manual and virtual fracture orientation distributions show excellent agreement, with three orthogonally arranged sets identified (**Fig 3**). Moreover, geometrically corrected lidar fracture length and density (e.g. Terzaghi 1965; Odling 1997 / **Fig 4**) are broadly comparable to manually derived equivalents. However, systematic underestimation of fracture trace length and density are observed within the lidar dataset, attributable to the limited fidelity of TIN surfaces and intrinsic downsampling of projected imagery, resulting in resolution dependent censoring.

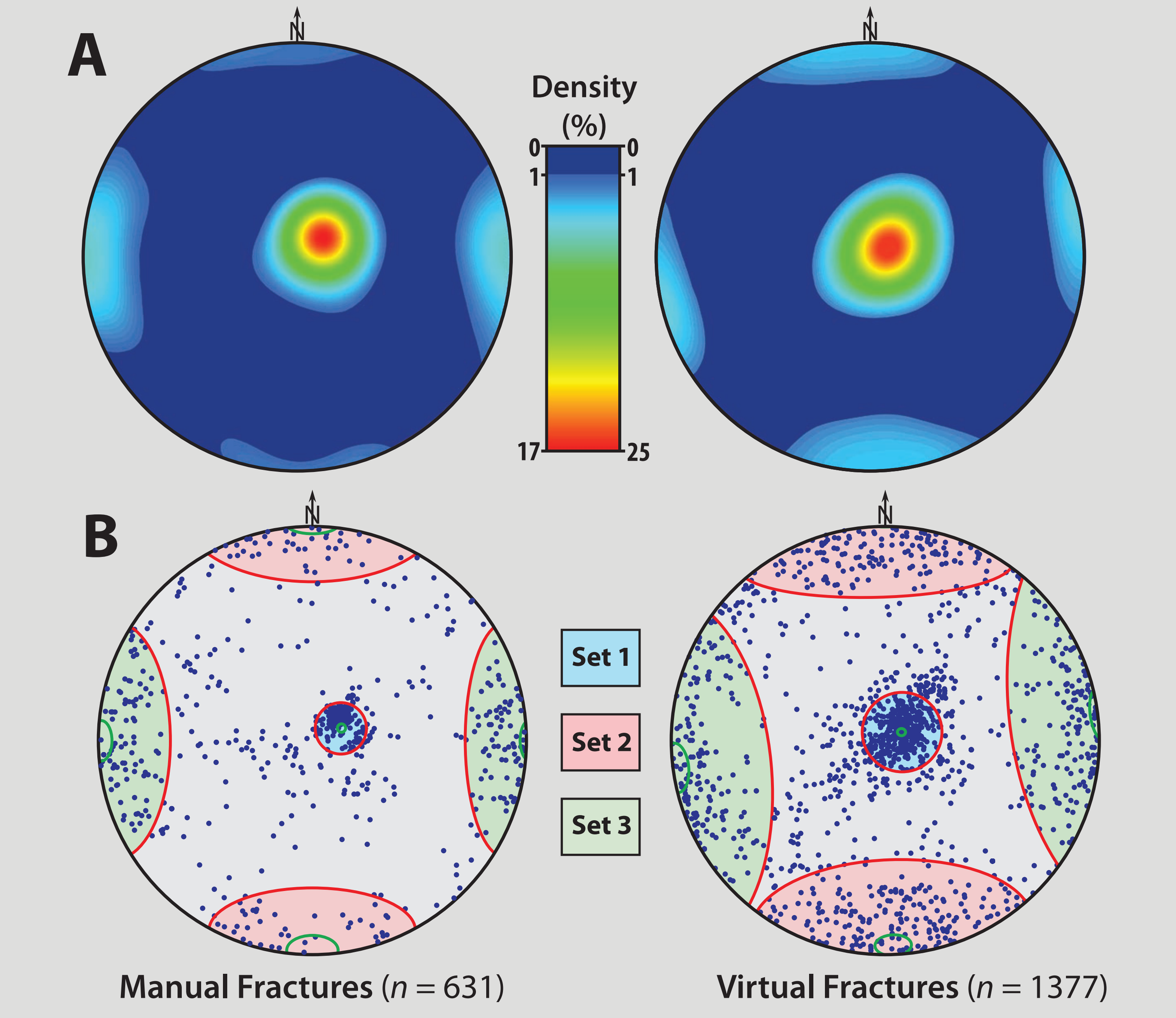


Fig 3. (A) Density plots showing manual scanline and lidar derived fracture orientation distributions. (**B**) NE-SW subhorizontal and north-south / east-west subvertical sets delineated using the clustering algorithm of Wallbrecher (1978).

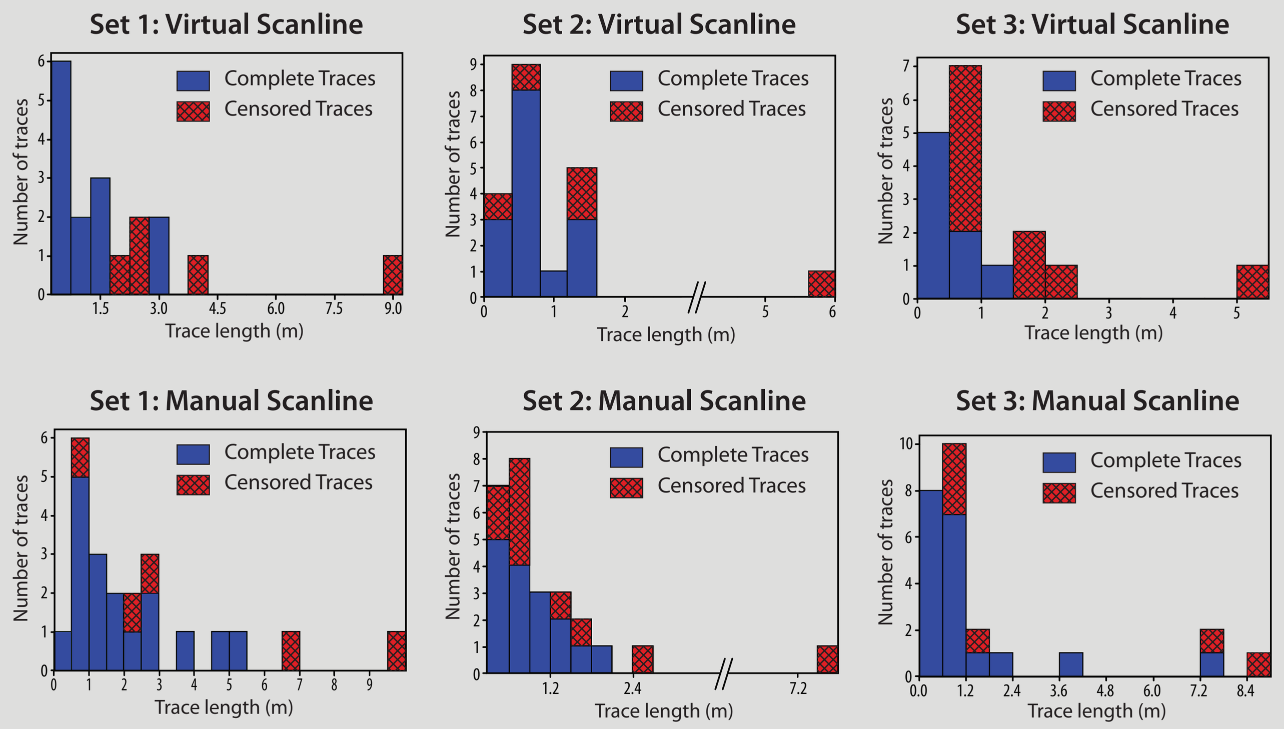


Fig 4. Trace length frequency distributions from manual and virtual scanlines.

5. Petrophysical Modelling

The impact of these censoring effects within the lidar dataset on the petrophysical characteristics of modelled networks is significant, resulting in a contracted and more laterally isotropic, vertically flattened permeability tensor in comparison to the manual equivalent (**Fig 5**).

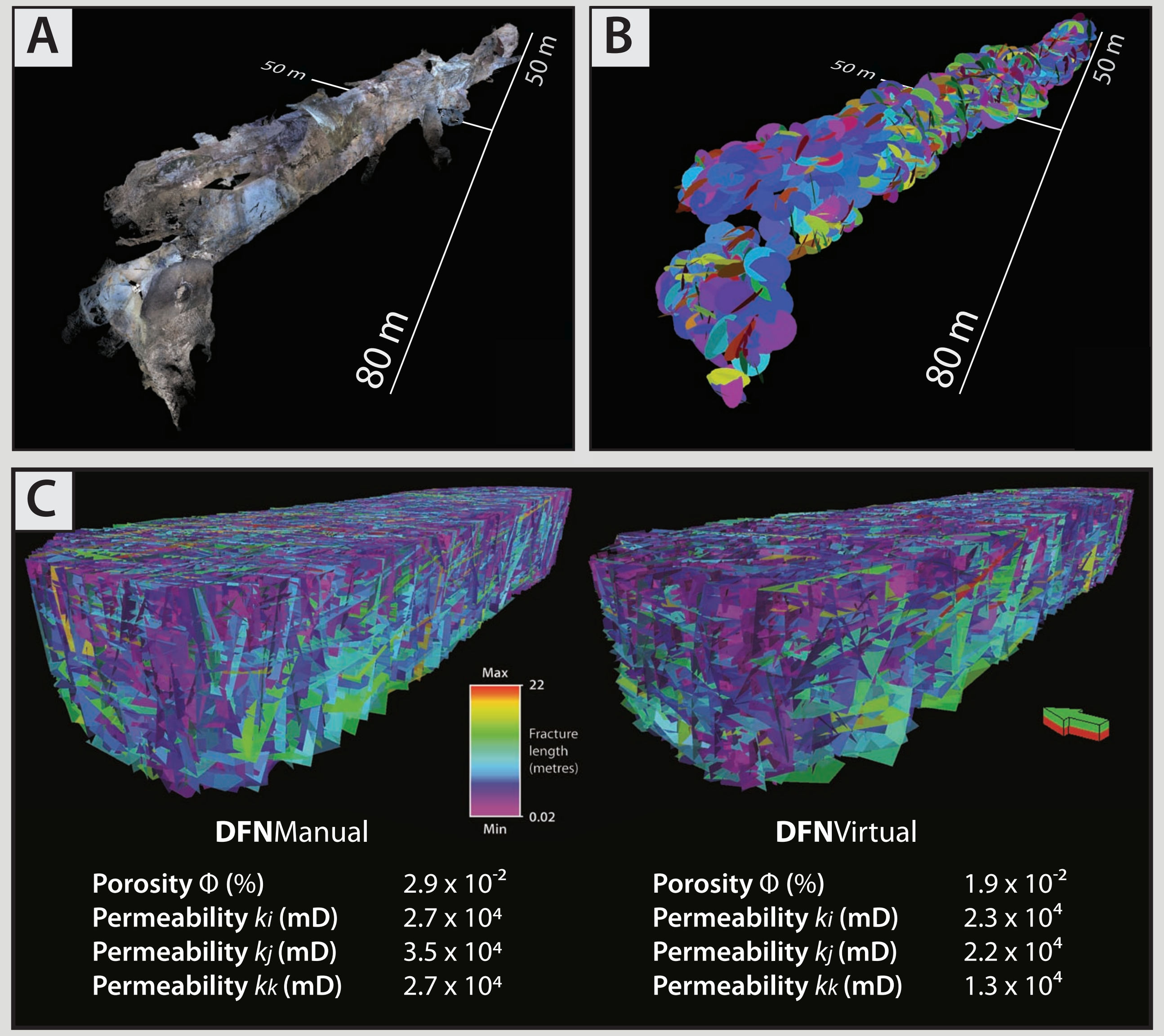


Fig 5. From outcrop model to DFN workflow summary: (**A,B**) Lidar outcrop models form the proprietory medium for the extraction of geometric fracture network properties. (**C**) Comparison of virtually and manually derived DFN models, with upscaled EPM properties indicated. Cumulative effects of spatial aliasing results in a 15-50% contraction in EPM properties in the lidar derived DFN.

6. Conclusion

- Lidar geometric fracture properties have a high degree of equivalence to manual measurements
- Data capture and analysis is an order of magnitude faster, and allows greater representation of the exposure than conventional methods
- However, resolution dependent censoring relating to sensor and data structure limitations results in a contraction in network storage capacity and permeability

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Acknowledgements

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