Solid Earth Discuss.,
https://doi.org/10.5194/se-2019-184-RC1, 2019

Solid Earth
Discussions
Open Access

Interactive comment on "A review and evaluation of the methodology for digitising 2D fracture networks and topographic lineaments in GIS" *by* Romesh Palamakumbura et al.

Anonymous Referee #1

Received and published: 10 December 2019

Documenting fracture patterns is a task of great intrinsic and practical interest. Fracture patterns figure prominently in a recent research directions white paper by the structure community to the U.S. National Science Foundation, a policy report of the U.S. Department of Energy, a 2018 Journal of Structural Geology theme issue, and a 2019 Reviews of Geophysics review paper. Although tracing fracture patterns from images is a practice that has been around a long time (see examples in the 1996 National Research Council volume Rock Fractures and Fluid Flow), the advent of inexpensive drones and rapid, 3D photogrammetry with standard cells phones, digital extraction of features, and similar developments has led to a resurgence in fracture pattern mapping.

Printer-friendly version

Discussion paper

This review and evaluation of methods for digitizing 2D fracture networks in GIS is timely and well within the scope of this journal. The paper is clearly written and well-illustrated. The step-by-step account of procedures will be useful to many practitioners.

I've made some suggestions for further clarifying the text. Some broader references could be added to the first part of the Introduction.

Overall, the impact and clarity of the paper can be improved. The paper is slanted toward near-surface engineering applications, and this should be stated. But because outcrop-based fracture trace maps are used as guides to fracture patterns in the deeper subsurface, the challenges of selecting and measuring fractures for this purpose should at least be alluded to, and some references provided to guide interested readers.

In the last part of the Discussion and in the Conclusions a more considered portrayal of 'fast' versus 'accurate' is needed. Fast is not necessarily more accurate.

6-8 This section of text at the start of the Abstract sounds like it should be in the Introduction instead. Consider revising.

11 font?

20-21 Some of the drawbacks should perhaps be discussed more explicitly in the text.
24-30 The distribution of citations to the literature in this section seems awkward. The first two sentences that introduce some of the key effects of fracture networks have no references, whereas the third line, pertaining mostly to engineering aspects of networks, has seven. Is there a reason for this weighting? The rest of the paper does not seem to be focused mostly on engineering applications. I suggest considering adding a call out to the 2019 Reviews of Geophysics paper on fracture pattern development and opportunities to advance interpretations of geological materials (v. 57/3). This paper has an extensive bibliography and can lead interested readers to earlier works. This would also be an opportunity to underline the (appropriately) limited scope of this MS: methods for digitizing 2d networks in GIS rather than a review of research on fracture

networks generally.

33 Transposed text? ‘in use’ or ‘used’?

53-54 Network connectivity characterization, including counting connections and plotting on triangle diagrams, goes back to papers in the 1990s. Some of those older papers point out something that recent fracture network topologists seem to be overlooking, namely that the appearance of connectivity can depend on scale (not just resolution).

54 There are several reasons to hesitate at this jump from 2D connectivity maps to fluid flow. The fractures might be connected in 3D. But even leaving this aside, the actual connectivity to flow for many networks depends on cement distributions in fractures, which may tend to more efficiently fill fracture tips and disconnect networks that have trace patterns that otherwise look interconnected. The Reviews of Geophysics paper noted above makes the case that this ‘chemical’ attribute of networks needs to have more attention paid to it. Cement deposits might not be an issue for analysis of joints for groundwater applications, but many fracture network descriptions are used as guides to fracture arrays in the deeper subsurface (as outcrop analogs), and in these networks cement deposits are prevalent. Since this is a methodology paper, these issues should be pointed out. And fractures in porous rock can have a considerable effect on fluid flow even if they are not interconnected, as shown by Philip et al. (2005, SPE Res. Eval. Eng.).

57 ‘very’ seems vague; omit?

59 It seems like the paragraph break should come here, with the preceding comment about 2D circular windows capping the description of network documentation methods. This last paragraph of the Introduction is the statement of claims of the paper and the roadmap to what material is covered. That will not be readily apparent from lines 57-58 to a reader scanning the document.

37-56 I suppose it is outside the scope of what you cover, but this way of characterizing networks seems to miss out on the insights that come from relative timing relations and identification of sets (e.g. Hancock, J. Struct. Geol., 1985). If parts of the network are of different age, it could be vital information in how the 'network' is interpreted. Probably some judgments along these lines are made without explicitly being stated (for example, vein arrays cut by joints; do you include all of them in the same network?). But since this is a methodology paper, at least pointing to these issues might be worthwhile.

62 'decent' is a bit slangy and vague; maybe replace with a general statement of acceptable digital camera type.

75 I appreciate that the focus of the MS is on a GIS method, but it seems to me that there is an essential step missing here in the work flow, namely, selecting appropriate outcrops based on the purpose to which the results will be used. Some of these issues are discussed in Ukar et al. 2019, and this paper contains references to related papers.

Ukar, E., Laubach, S.E., Hooker, J.N., 2019. Outcrops as guides to subsurface natural fractures: example from the Nikanassin Formation tight-gas sandstone, Grande Cache, Alberta Foothills, Canada. Marine & Petroleum Geology, 103, 255-275. doi.org/10.1016/j.marpetgeo.2019.01.039

184 How does this compare with other extraction methods? N.J. Hardebol, G. Bertotti, DigiFract: A software and data model implementation for flexible acquisition and processing of fracture data from outcrops; Comput. Geosci., 54 (2013), pp. 326-336

185 'detailed' is a vague term that can be omitted.

199 Or Marrett et al. 2018, J. Struct. Geol. There are other parameters besides connectivity that are important; for example, clustering.

For opening-mode fractures (joints and veins) in stratified rocks, it should be standard practice to at least describe and classify the fracture height pattern; in other words, provide more information beyond the 2D trace map. Worth mentioning.

202 Blast damage is not the only problem; but it depends on the use to which the mapped data will be put.

217-221 Pointing to some references for these points would be useful. 266-270 Cv has limited usefulness for characterizing clustering, and more robust methods are available (e.g. Marrett et al. 2018, J. Struct. Geol., also Wang et al. 2019, Pet. Geosci.). Why not point readers to these methods?

268 'Odling'

292 Put the acronym in the parenthesis?

301-310 But in application, doesn't some of the subjectivity arise because of the wide size range of fractures commonly present that can make quantification difficult, even using digital methods?

311-319 It seems like we ought to be moving past just reporting average fracture spacing values. There are lots of examples in the literature that show that fracture spatial arrangement is more complicated that in readily captures by an average spacing value.

320-322 Was the rock mass strength independently measured, or do you mean that the digital results match those derived from some other analysis method?

361 While I think this statement is true, this MS did not cover 'micro-scale' applications or cite any examples of micro-scale fracture studies. Maybe re-word this conclusion to more closely match what was actually covered. Also, for parallelism and a systematic size progression it should read 'micro-scale to the kilometer scale, including mineral cleavages to . . . outcrop scale . . . regional'

366-368 I'm not sure that I follow your argument here. A hand-drawn map is not necessarily less 'quantitative' than a digital map. They are equally ways of describing (and quantifying) the pattern. Digital capture might be faster, but whether or not it is 'accurate' depends. For example, it is a common observation of opening-mode fracture patterns that traces viewed from a distance that look like continuous features when examined more closely are seen to be segmented, en echelon traces that are discontinuous. A digital method that misses this attribute could rapidly yield highly misleading information. I think your commentary here needs to be more nuanced.

Likewise, 1D data is not less 'quantitative' than 2D data, and as Ortega et al. (2006) point out, 1D data (for example, aperture-distance) is less ambiguous to collect than some 2D attributes, as anyone who has seriously tried to measure fracture trace lengths can attest (see above). And it has the advantage of being readily comparable to typical 1D subsurface fracture observations.

Not all of the papers listed in the references are called out in the text. The Laubach et al. 2018 review paper is probably meant to be called out in lines 28-29 summarizing various elements of fracture networks and how they are described.

Reference mentioned in comments above:

Laubach, S.E., Lander, R.H., Criscenti, L.J., et al., 2019. The role of chemistry in fracture pattern development and opportunities to advance interpretations of geological materials. Reviews of Geophysics, 57 (3), 1065-1111. doi:10.1029/2019RG000671

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2019-184, 2019.