

Interactive comment on “Mapping the fracture network in the Lilstock pavement, Bristol Channel, UK: manual versus automatic” by Christopher Weismüller et al.

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General Comments: This paper presents a detailed analysis of the fracture network visible on the wave-cut pavement of the Bristol Channel Limestone sequence, in UK. The authors, focusing their study to one specific stratigraphic layer, called the ‘bench’, analyse the results obtained by using manual and automatic extraction of fracture traces from drone photomontages. The results of the two methods are then compared and used to describe the network in terms of connectivity and deformation history that generated the present-day fracture network. Finally, they discuss quality of the outputs obtained via manual vs automatic, demonstrating that the manual method, while more

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time-consuming, provides a better quality of data. This work covers the very interesting topic of manual vs automatic methods for extracting faults and fracture data from outcrops and, while I am very supportive to see it published, I think that it still needs major revisions before publication. In places, I found it quite hard to read; particularly, I found the Results section confusing as it goes back and forth discussing data obtained via manual and automatic. Another main issue that needs to be addressed is that some of the claims made are not always well justified. I have addressed all these points in the “Detailed Comments” below.

Detailed Comments:

Lines 147-148: Can you please provide an example for this, e.g. image/figure

Lines 150 – 151: I don’t disagree, but I would not say that is “obvious”; for example someone else can claim that they choose to manually pick all fractures because this yields the best results, due to the topography of an outcrop or light exposure during image acquisition. How long is a “reasonable time”? How do you account for it? In this regards, can you please give an overall estimate on the time needed by the automatic process to extract all the fractures from one of the tiles (including all the steps for pre-processing an image and the number of trials needed before finding the right set of parameters to extract the fractures) and compare this on how long it takes manually? In my opinion this would be a very interesting information. In addition, for someone that has never done fracture tracing would learning and using the software make the job faster/easier or it would take longer than do it directly manually? Can you please comment?

Line 156: Can you please report which software have you used during the manual digitalisation of fractures? Was it one of the vector graphics editors (e.g., Adobe Illustrator, Corel Draw, Inkscape), or a geographic information system-based software?

Lines 170 – 173: You never mentioned before any “intensity” parameter; can you please clarify? In addition, when discussing the needs for applying an ‘intensity threshold’ do

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you mean that this process is needed in order to make the automatically detected maps look similar to the original photograph from which you extracted the fractures? If this is the case, this sentence needs to be clarified.

Line 175: For completeness, can you please briefly explain the 'polygon sampling' strategy?

Lines 179 – 180: The sentence "2D fracture networks ..." needs a citation. Can you please clarify the meaning of "spatial graph"? In addition, can you please clarify the terms 'node' and 'edge'? In the context of fracture networks, these can mean different things, depending on whether the fractures themselves are viewed as graph vertexes (and therefore they are the 'nodes'), or if they are considered as links (the 'edges') between fracture intersections and terminations.

Lines 187 – 188: On lines 156 – 157 you mentioned that when manually tracing the fracture these are "traced as polylines". From the use of the prefix 'poly-' I have understood that one fracture trace is already made of many segments. So, can you please explain the need to further subdivide the fracture traces?

Lines 191 – 192: Can you please clarify if the correction for node degree > 3 was your improvement on the software, or it is already an option within of the original NetworkGT?

Lines 192 – 194: Can you please clarify and give more details on the use of the "spatial join function"? How does it work?

Lines 214 – 215: What is Passchier et al., interpretation? The paper is not published yet, so unless you clarify it is not possible to know how these features have been interpreted. Even if the paper was published, it would be more helpful if you could briefly explain this interpretation here, otherwise the reader would be forced to read another paper to understand what you mean.

Line 218: You can avoid the brackets here because you are directly mentioning the

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authors.

Lines 223 – 224: Can you please explain why have you chosen to show exclusively fracture intensity maps? To my knowledge NetworkGT allows also for fracture density maps, why have you opted for not showing these?

Lines 228 – 229: This sentence is not clear. Do you mean that number of trace segments is higher than the actual count of fractures? Or do you mean that the automatic extraction of fractures overcount the total number of fractures compared to the manual interpretation?

Line 239: If not resolvable from the drone images, was the 'minimum length' measured directly on outcrop?

Lines 239 – 247: Are all these results relative to the manually traces fractures, the automatic, or both. Not clear. Moreover, can you please add few lines to describe more in details how all the statistical parameter that you show are useful to describe the fracture network? What having a positive kurtosis means? Similarly, can you please better explain what do you mean by symmetric and asymmetric branch distribution?

Line 246: Data of fracture trace length distribution are only shown for the automatic trace detection method, but not for the manually derived network. Is there a reason for this choice? Since you are discussing both methods, and relative results, I would advise to add a similar figure to Fig.7 where showing data from the manually traced network.

Lines 248 – 250: This sentence is not clear. Can you please review it? Are you referring to a limitation of the automatic extraction method?

Lines 250 – 253: For helping the reader to compare/contrast the results of automatic vs. manual method, I would suggest adding to Fig.5 and Fig.6 (which currently only show results for the automatic extraction) the fracture maps obtained by manually picking fractures. I acknowledge that these figures are shown later in the manuscript (figures

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13, 14 and 15), but having the fracture maps produced with the two methods one next to each other would be ideal.

Lines 223 – 261 (all section 4.1): The whole section is a bit confusing and needs to be reviewed. It is never clear if you are referring to the results obtained by the manual of the automatic method. For clearness, I would suggest to first describe the results obtained by one method, followed by those obtained by the other, but I do not want to impose any style to your paper. As long as you make it clear which method you are referring to, find a way that you like better.

Lines 275 – 277: I understand that you are referring to the plot of fracture length vs. strike, however as written here it is not very clear. Please review.

Line 287: Is the fault to the Southeast corner of the tile NE2, or to the southeast to the whole outcrop? Please clarify.

Lines 288 – 289: This sentence is rather confusing. Can you please review it? Particularly, can you please clarify the meaning of 'perceived appearance'?

Lines 290 – 291: There is a 'IN' missing between 'domains' and 'the SW'.

Line 314: Should be 'strike at angle'.

Line 390: I understand that you might don't want to engulf the paper with too many figures, however, because you discuss largely around Figure S1, in my opinion this should be incorporated in the main paper, rather than be relegated to supplementary.

Line 396: Would it be more appropriate saying 'automatically extracted fracture network' rather than 'generated'? Usually the term generated is associated to Discrete Fracture Network (DFN) models.

Lines 401 – 402: Point (i), as written, it can be interpreted that the fractures are in the 'code', while the algorithm extracts these features from an image. Please amend. Point (ii), can you please expand on this point?

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Lines 402 – 404: As written these sentences are very difficult to understand. Please review them.

Line 404 – 405: Can you please give more details about this procedure? It is not clear to me if you have completely discarded erosional features from the network created when manually tracing the fractures. In addition, the sentence needs to be reviewed: missing 'AS' between 'not' and 'fractures'.

Line 405 – 407: Can you please provide a full description of what do you mean by 'sensitivity'? This term has not been used before in the manuscript, therefore needs to be fully explained. In addition, I would avoid the use of vague adjectives like 'too high' or 'too low'. How much? Can you please quantify?

Line 409: As per my last comment before, can you please quantify 'Slightly smaller'.

Lines 411 – 413: Rather confusing sentence. Do you mean that the dissimilarities between automatic and manual extraction of fractures are comparable to differences between two manual interpretations? Can you provide any evidence for this? Otherwise can you cite appropriate works?

Lines 418 – 421: Please review these three sentences as they are rather unclear. It might be necessary to add a 'the' between 'requires' and 'expertise'. What do you mean by 'several generations are possible for a single fracture'? That a single fracture can be overprinted by a series of tectonic events?

Lines 422 – 423: Can you please clarify? Do you mean that pre-existing fractures can cause distortions in the orientation of later-formed fractures? How widespread such distortions need to be for not be considered just noise in the data (particularly if you have hundreds or thousands of fracture data)?

Line 426: Do you mean that fracture length is not a useful parameter to assign one fracture to a specific set?

Lines 428 – 430: Are you still referring to the fracture set denominated Gen. 1? Not

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clear.

Lines 430 – 431: This sentence is not very clear and needs to be reviewed. What do mean by 'fractures as different appearances'?

Lines 432 – 433: Can you please explain which one is this 'larger structure' that you are referring to? Not clear to me.

Lines 436 – 438: In the sentence before this you have argued that gen.1 and gen. 2 can be seen as belonging to one fracture set, however here you assume, without proving it, that these are instead two different fracture sets? Please either refer to a work that shows that gen1 and gen2 were indeed formed at different times, or please provide a full explanation for your assumption.

Lines 442 – 444: A citation is needed when you mention a mechanical cause for the lack of gen3 fracturing in the NE area.

Line 449: what do you mean by 'complete distance'? Whole area?

Lines 462 – 466: All these claims are not supplemented by sufficient evidences or by citing relevant works. How was the paleo-stress oriented at time when gen.4 was formed? Are there veins filling gen1 and gen2 fractures that provide cementation for the fractures? If this is the case, why are you mentioning it just now? Otherwise, do you mean that fluids circulating through gen1 and gen2 fractures caused further cementation in the host rocks near the fractures? If this is the case, you should provide evidences or cite relevant works.

Lines 467 – 468: This sentence needs to be reviewed as it is not clear.

Lines 476 – 477: Can you please further explain the meaning of 'decreasing skewness'? How does this statistical parameter relate to the geometry of the fracture network?

Lines 4879 – 481: I feel that it needs to be made clearer how the variations in the count

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of Y nodes and I nodes are related.

Line 483 – 484: How can you establish that a representative domain has been sampled? Can you show examples using your study case? It can be easy to argue that on outcrop the possibility of sampling a 'complete fracture network' are relatively scarce and relegated to few ideal outcrops.

Line 502: What do you mean by 'undirected fractures'? Can you please clarify?

Lines 504 –505: Can you please provide examples that can prove this claim? And, can you please produce a conceptual model that exemplifies the described process?

Line 511: Do you mean that all subareas show comparable branch lengths? As now written is a bit unclear.

Conclusions: While I like bullet points in the conclusion to show the main findings, I also feel that you should have few sentences that wrap up and recap your work. In addition, some of the points listed are a bit vague, specifically point 3 and point 5, as written, do not add any value to the work. So please either reformulate or delete them.

Figure 1. Last sentence is not clear. Do you mean areas the labels show the areas where you have acquired the data?

Figure 4. Please add that P21 indicates 'Fracture Intensity'.

Figures 5 and 6: This is just a personal taste, so you can ignore it, but I would find useful if you can show in these figures the location of the analysed tiles.

Figure 7. Since this plot refers to the automatic extraction method, can you please include in the caption that these are branch lengths and not trace (whole) fracture lengths? AS mentioned in the comments, I would suggest integrating this figure with the length distributions in the manually extrapolated network.

Figure 8. Similar to previous comment. Please indicate that these orientations refer to branches.

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