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Comment on egusphere-2022-255

Anonymous Referee #1

Referee comment on "Multiscale lineament analysis and permeability heterogeneity of fractured crystalline basement blocks" by Alberto Ceccato et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-255-RC1, 2022

Review of the manuscript "Multiscale lineament analysis and permeability heterogeneity of fractured crystalline basement blocks" by Alberto Ceccato and coauthors.

The paper presents a multiscale geometrical analysis of lineaments within a granodiorite pluton in the basement of the southwestern Norway, based on the interpretation of a DTM (Digital Terrain Model) at the 1:100000, 1: 25000 and 1:5000 scale, and an UAV-mapped zone at the 1:100 scale.

The paper is well written, and figures are adequately illustrating the results. The proposed methodology combines several methods used in previous studies, including box-counting on lineament maps, fracture orientations, fracture length cumulative distributions, fracture spacing distribution along virtual scanlines, fracture intensity and density at multiple scales. The analytical procedure is repeated also on fractures subdivided by set, allowing to define a hierarchical organization of the fracture network, with fractures controlling the network at the regional scale (type B fractures) and the other sets (type A fractures) having effects at smaller scales. These data are then discussed on the basis of detailed field and petrophysical data published by the same authors, and a conceptual model of the fracture permeability of the Rolvsnes granodiorite is proposed.

The paper is well suited to be published in this journal. I have some concerns about the analytical design and methodological approach, as discussed in the general comments below. Due to these issues, the paper needs some revisions before publication.

General comments

- In the study area, the outcrops are fragmented into many islands, which in turn are likely to have a fractal size distribution. The fragmentation of the outcrops probably influences the fractal dimension measured from box counting analysis, and the length distribution of the lineaments (i.e., the maximum length is controlled by the size of the islands). Have you tested whether and how the geometry of the outcrops influences the fractal geometry of the network? Specify the area considered for the box counting analysis and discuss the possible resulting biases.

- The shape of the islands is often concave (see for instance the map at the 1:5000 scale). 2D quantifications of fracture networks is generally done on convex polygons (scan areas), because otherwise the same line might be counted twice, and the effects of censoring are enhanced. Did the authors consider this effect on the length distribution?

- There is a large gap between 1:5000 and 1:100 scales, and the area close to the Goddo Fault zone mapped by UAV survey is L-shaped and very thin (50 *200 m). I would be careful in combining the lineament length cumulative distribution in the UAV map with those of the maps at a smaller scale. This results in a significant range of lineament lengths not being covered in Fig. 6. The R^2 for the linear regression are very low in Fig. 6 (from 0.552 to 0.679), and this makes the regressions meaningless, especially in Log-Log space. In Log-Log space, a R^2 of at least 0.9 is recommended to fit a power law distribution. Moreover, the shape of the surveyed area makes it difficult to intercept lineaments striking NS to NW, which might be one of the reasons for shortage of these orientations at the 1:100 scale in Fig. 5. The biasing effects of the scale gap and outcrop shape should be discussed with more detail in section 5.2.

- The lack of a unique fractal distribution fitting the multiscale fracture sets implies that the network is not self-similar. This finding is coherent with the fact that the granodiorite experienced multiple stages of brittle deformation, but it doesn’t seem the most common spatial arrangement found in similar settings. In my opinion, the discussion lacks a comparison with previous multiscale studies of fracture networks, which would allow to appreciate the pros of the suggested methodological approach and of the integration of statistical analysis with field geology.

Line by line comments

Lines 12-14: check this statement, which contradicts the following sentence (is there a scale-invariant spatial distribution or not?). See also general comment 1.

Line 14: the symbol is missing

Line 49 – Paragraph 1.2 doesn't seem necessary; the structure of the paper is quite conventional. Consider removing this paragraph, which basically anticipates the information given in a more detailed way in the Geological setting and Methods sections.

Lines 98 – 106: it would be useful to introduce in Fig. 1 a sketch shoving the orientation of the structures (faults and fractures) associated with each tectonic stage. Here, you could add some information about the dip angles: are fractures all subvertical, therefore justifying your analytical approach in map view? Are there oblique sets?

Lines 114 – 119: the relationships with the offshore reservoir could be mentioned in the introduction.

Line 120: delete "Materials and"

Lines 159 – 199: I'm a little confused about the procedure of fitting single-scale and multiscale cumulative distributions. For single scale data, you test three possible distributions and score the best one fitting truncated or non-truncated data. For multiscale analysis, you assume that all distributions are fitted by a power law, without truncation. I think that you should clarify your reasoning here. You might try to fit the multiscale power law distribution by using truncated data (see for instance Chabani et a., 2021).

Lines 229 – 230 and 237 – 238: 3 intersections per scan line are very few for these considerations – if your dataset does not fulfil the requirements for a statistically meaningful analysis, it's better not to perform that analysis.

Lines 242 – 251: this is merely a list of the number of picked lineaments – could you add some qualitative description about length, intersections, orientations? The lack exposure below the sea level can be introduced here.

Line 252: already commented, consider the effects of the fragmented exposures.

Line 275: remove reference to Dichiarante et al., 2020

Lines 271 and following lines: here, you could mention which of the datasets meet the minimum number of 200 fractures (now only in the supplementary material)

Lines 282 – 287: as commented above, the multiscale cumulative length distribution is not that robust, because there is a significant range of fracture lengths which is not covered by data (the tens of metres range), and both the large scale fracture lengths (1:100) and the small scale fracture lengths (1:100000) are not fit by a power law (if I understood well Table 3). To overcome this last point, you might consider only the part of the distributions having a power-law distribution for the multiscale fit. Lower and upper cut of the power-law distributions can be obtained statistically with the MLE method of Clauset et al (2009) (https://aaronclauset.github.io/powerlaws/).

Line 298: what does it mean a decreasing trend?

Line 300: ".;" > ","

Lines 321-322: see comment above about cumulative length distribution.

Line 327: and what about P21?

Lines 339 – 340: it is probably Fig. 6 and not 5

Line 347: check the sentence

Line 373 and following lines: as suggested in the general comments, the possible biases due to the outcrop shapes are not considered. I suggest evaluating them as well.

References

Clauset, C.R. Shalizi, and M.E.J. Newman, "Power-law distributions in empirical data" *SIAM Review* **51**(4), 661-703 (2009)