Earth Syst. Sci. Data Discuss., author comment AC3
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Reply to the review by Paola Montone

Michal Kruszewski et al.

Author comment on "In situ stress database of the greater Ruhr region (Germany) derived from hydrofracturing tests and borehole logs" by Michal Kruszewski et al., Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2022-196-AC3, 2022

Dear Paola Montone,

Thank you for your insightful comments regarding our manuscript. Please see our replies below.

With Best Regards,

Authors

Reviewer: Figure 1: to clarify the spatial location of data for a wider international audience, Germany has to be included in a wider map (e.g., Europe).

Authors: We agree with the comment and implement a map of Europe into Figure 1b.

Reviewer: Figure 1b: it could be helpful for the readers to have information on the kinematics of faults and about their age and relevance. I would suggest also adding a first order tectonic scheme.

Authors: Thank you for the comment. We add an indication of fault kinematics and their age to the text in the chapter "Geological Setting" of our manuscript. We have also described the relevance of these structures in the area in the text in the same chapter. How these structures influence the present-day stress state of the area remains unknown, however results from the analyzed Natrap-1 well could prove that these structures perturb the regional stress state. We also add a sentence about the first-order tectonic scheme of the region and add the NE-SW striking thrust faults, as well as major natural regions of Germany (i.e., Westphalian Lowlands, Rhenish Massif, and Lower Rhine Plain with their representative lithological units) to Figures 1, 7, 9, and 10.

Reviewer: Figure 1a: Morawietz et alii is reported as 2021, please check the year.

Authors: This reference is reported as Morawietz et al., 2020 across the manuscript.

Reviewer: Figure 1c refers to a section that is not shown in Figure 1 a) or b). Please, also add some information about the lithology of the geological formation.

Authors: We improve that by adding a seismic line location to the Figure 1b. We are not sure to what exactly the second part of this comment refers to. We indicate stratigraphic units in the cross section in Figure 1c and describe the lithology in chapter "Geological Setting" of our manuscript. We hope that this amount of information will help the reader to familiarize him/herself with the geology of the region. For more in-depth analysis of the regional geology, all relevant studies are referenced within the manuscript.

Reviewer: Line 75 to line 85: for a better comprehension this paragraph should benefit from an additional figure.

Authors: We tried to reduce the number of figures in the paper and believe that having a geological cross section in Figure 1c as well as fault maps in Figures 5,7, 9, and 10 is enough for the reader to comprehend this part of the text. Thus, we decided not add additional figure to the manuscript.

Reviewer: Line 108 and 109: I didn't find within figure 1b the places and names the authors reported along the text, as well as the toponyms described in the test location description. For those unfamiliar with the region, it is difficult to follow the text and almost useless to report so many names if they are not represented in the figure. Surely most readers do not know the studied region.

Authors: Thank you for this comment. We agree with the comment and add the names mentioned in the text to all figures (i.e., maps) of the manuscripts.

Reviewer: Line 206 and 207: This sentence has already been written on lines 191 and 192.

Authors: We amend the sentences to omit the repetition.

Reviewer: Line 231: Please provide more information about Muskat pressure plot.

Authors: We add reference to this sentence and briefly describe the methodology.

Reviewer: Caption Figure 6: not very clear the sentence "is shaded in light grey" (there is no shaded areas in the figure)

Authors: To improve readability, we change the shaded area to an ellipse outlined with red colour.

Reviewer: Line 320: please provide the location of Natrap 1 well

Authors: Natrap-1 well is presented in Figure 1c. We decide to include the names of cities where wells (discussed in the manuscript) were located; for the Natrap-1 well it will be the city of Hoetmar (and Natrap-1 well is therefore indicated as a green bubble in this figure). We update Figure 1b and 7 and include the mentioned location.

Reviewer: The authors use a standard density of 2.5 g/cm3 in their calculations. I am wondering if this value is not too low for this kind of rocks. Please give more explanations for this choice.

Authors: The bulk density value of 2.5 g/cm3 was based on the results from laboratory studies on the Ruhr Sandstone rock samples. We included in the manuscript references to two laboratory studies, which confirm these bulk density values (i.e., Brenne, 2016; Duda and Renner, 2012). Assuming, however, that coal seams (of much lower bulk density, i.e., approx. 1.5 g/cm3), as well as shales (of slightly higher bulk density i.e., approx. 2.7 g/cm3) are common in the Carboniferous layers of the greater Ruhr area, the mean bulk

density of the area will fall around the value of 2.5 g/cm3. As a result, we consider this value to be a good first-order approximation for the region. For more local studies, of course, more detail bulk density profiles (or local geological models) should be considered. To prove our assumption on bulk density, we attach a figure (see .pdf file in the "Supplement") with the bulk density values registered from geophysical borehole logging campaigns in 11 wells across the greater Ruhr region penetrating in the Carboniferous rock mass. In the Figure below, with red solid line we indicate the assumption made in our study (i.e., bulk density of 2.5 g/cm3) and with dashed lines we present standard deviation limits based on data from the 11 considered wells. Although, we cannot statistically prove the correctness of our assumption, based on the gathered data, bulk density of 2.5 g/cm3 is still a reasonable assumption for the region at depths considered.

Reviewer: I am wondering what is the dipping of the induced fractures. Are all verticals?

Authors: To see the dip angle of induced fractures please see column "frac_DIP" from the database: https://fordatis.fraunhofer.de/handle/fordatis/272. But to answer the question, not all induced fractures were vertical.

Reviewer: The average Shmax orientation is affected by a large error (+-43°): although the statement starting at line 382 is formally correct it must be emphasized the large standard deviation. It may be argued that with such a large uncertainty it is difficult to find something in strong disagreement. In essence, I'm asking the authors to reshape the statement considering the existing important uncertainty.

Authors: We agree with the comment and make changes to the text in the "conclusions" chapter in the manuscript accordingly.

Reviewer: Lines 385 and afterwards. I would suggest authors to reshape the conclusion about the "most critically stressed structures" in a smoother way due to the large uncertainties on the results of this study.

Authors: We agree with the comment and make changes to the text in "conclusions" as well as "discussion" chapters in the manuscript. We also include a comment where we emphasize that to fully understand the uncertainty on the slip and dilation tendencies of the major faults in the region, more probabilistic assessment (such as the ones presented in Walsh and Zoback, 2016 or Healy and Hicks, 2022) are needed and should be investigated in future studies.

Please also note the supplement to this comment:
https://essd.copernicus.org/preprints/essd-2022-196/essd-2022-196-AC3-supplement.pdf