Reviewer 2 (Sadegh Karimpouli)

Sadegh Karimpouli: *"Geological map lacks of enough data. I mean, all information in the text must be transferred into the geological map. Then, in a regional point of view, all data could be connected, judged and concluded. The most important points are:*

- ***i.*** *Putting rose diagrams of all sites on the geological map*
- ***ii.*** *Showing strike and dip of the target layers on each site and if possible on the other areas.*
- ***iii.*** *Showing orientation of the dominant and/or present day maximum stress (either from literature or the authors observation)."*

Author's reply: Thank you very much. You have listed a very good improvement point here, which we were very pleased to implement. Based on your comment, we have added the points mentioned above to the original Figure 1. The cross-sections have now been merged into a separate figure (Fig. 2).

Sadegh Karimpouli: *"I tried it as the attached figure. Based on maps in my figure, Hönnetal site is located on an anticline axis. The authors should be careful about combining fractures orientation data from this site with other sites. They should explain:*

- ***a.*** *How are those rose diagrams are connected to each other?*
- ***b.*** *How are they connected to the regional tectonic regime?*
- ***c.*** *Line 417: "The foundation of our model is an approx. 300 m thick carbonate layer, dipping northwards at a shallow dip angle of about 30 to 40◦". Fracture orientations on the anticline axis (HLO) show a different pattern compared to downward limbs (WHO, HKW). How do the authors combine them together?"*

Author's reply: We thank you for pointing out that our fracture results from the individual quarries are not sufficiently explained and discussed with regard to (a) common features, (b) the tectonic regime and (c) the formation of the regional Remscheid-Altena anticline. Your questions and similar comments by the other reviewer (John Hooker) have prompted us to revise the text to adequately address and answer the questions raised (line 469):

> „All studied outcrops are located in the large scaled fold formation Remscheid-Altena anticline. However, there is a disagreement between the three outcrop results which might be an effect of the formation of the regional Remscheid-Altena anticline, different stress states, or different time of origin (Table 3). Due to the anticline formation, the strike directions of the present fractures in this region exhibit a rotation from the northern limb (Wuppertal) towards the tip of the anticline (Hönnetal). Fractures striking NE−SW are highly related to folding mechanism and are parallel oriented to fold axes which have been studied within the Rhine-Ruhr area (Drozdzewski, 1985; *Brix et al*., 1988; DEKORP Research Group, 1990; Drozdzewski and Wrede, 1994). The dominant fracture strike directions NNW−SSE in Wuppertal agree with the structure of the regional Remscheid-Altena anticline (Fig. 1b) and the overall assumed mean principle stress direction according to the World Stress Map (Heidbach *et al.*, 2016) and additional available stress data (Rummel and Weber, 1993). In western Germany, or to be more precise in North Rhine-Westphalia, the World Stress Map contains a wide variability of mean principle stress directions (Heidbach *et al.*, 2016), that can be explained by shallow stress measurements, local anomalies which can be attributed to weak coal-seems, or regional NE−SW thrusts. The observed strong scattering of the fracture strike directions in the dolomitic carbonates exposed in Hagen Hohenlimburg is due to their formation by hydrothermal veins during the Hercynian Orogney (Gillhaus *et al.*, 2003). Furthermore, Gillhaus *et al.* (2003) explain that the existing NNW−SSE striking fractures are of post-Hercynian Orogeny origin. The cause of the slightly different fault strike directions in Hönnetal cannot be clearly specified according to the current state of scientific knowledge.

Most likely, the fracture formation can be explained by various local and temporal stress anomalies and different formation times."

Sadegh Karimpouli: *"Section 4.2.1: The authors explain "The main discontinuity orientations were documented as NNW-SSE, NW-SE, and NE-SW." and then conclude "we propose to focus on discontinuities that are approximately oriented N-S for future shallow geothermal applications.". Is N-S one of the main directions or what? Is this conclusion on the basis of maximum stress direction? How is the contribution of the other factors such as fracture filling, conductivity and so on?"*

Author's reply: After re-examining the text passages, we fully agree that in Section 4.2.1 not all results have been taken into account to adequately explain which fracture orientation is of interest. To specify the direction more precisely, we have concluded to rename N-S-striking fractures to NNW-SSE-striking ones, which corresponds to our results and is also comparable to the assumed mean principal stress direction (line 545):

> "When comparing the recorded discontinuity orientations with the orientation of the maximum horizontalstress (Heidbach *et al.*, 2016), we propose to focus on discontinuities that are oriented NNW-SSE for future geothermal applications, which are highly probable filled by calcite."

We would also like to thank you for pointing out that we need to look at the different filling material to substantiate our assumption. The new Figure 7 shows rose diagrams of all measured discontinuity sets as a function of their fracture filling, that is, whether the fractures are filled with (a) calcite or (b) debris. We have reformulated section 4.2.1 in order to link the individual results more clearly and to justify the discontinuity direction of interest (line 540):

> "In addition, we present fracture orientations versus filling materials, these are, calcite or debris. The orientation of the recorded veins allows us to conclude, that many of the discontinuities studied on the outcrop scale can be related to residual stress and stress release during unloading regimes (cf. Nickelsen and Hough, 1967; Roberts, 1974, Fig. 7)."

Furthermore, in line 549 we go into more detail about the fracture fillings and the resulting implications:

> "It can therefore be assumed that higher fracture permeability can be expected in the NNW−SSE direction, which could be of interest for the application of hydraulic stimulation techniques. In addition to the relative orientation of the fractures to the direction of the main principal stress, the filling is also decisive for whether the fractures are potentially open or closed in the subsurface (Laubach *et al.*, 2004). Thus, there might be open fractures that are not necessarily aligned in the direction of the principal stress and are still open. This is particularly true for fractures that are filled, for example, with cement (Laubach *et al*., 2004)"

Sadegh Karimpouli: "Use different parameter for thermal connectivity and discontinuity frequency (both of them are λ)."

Author's reply: Thank you very much for the hint. In the manuscript, the symbols for thermal conductivity, λ_{dry}, and discontinuity frequency, λ, have already differed, but for a clearer distinction, we will gladly accept your suggestion. Both in the text and in the tables the symbol κ_{dry} is now used for thermal conductivity.

Sadegh Karimpouli: "Figure 6: How do you translate connected pores more than total pores?"

Author's reply: Your observation is very correct. Physically, it is possible that the connected porosity exceeds the total one. Taking into account the measurement inaccuracies that may be present in the experimental determination of these volume properties, however, this is possible. The connected and the total porosity are determined with different methods and different errors. Therefore, we have already pointed out these errors in the text (line 340:)

"Taking into account the measurement uncertainties, the total and connected porosities overlapped (Fig. 8a).").