Solid Earth Discuss.,
https://doi.org/10.5194/se-2018-83-AC1, 2018

Solid Earth
Discussions

Interactive comment on "Seismic imaging of dyke swarms within the Sorgenfrei Tornquist Zone (Sweden) and implications for thermal energy storage" *by* Alireza Malehmir et al.

Alireza Malehmir et al.

alireza.malehmir@geo.uu.se

Received and published: 13 November 2018

(Public reviewer) I found this a very interesting read, partly because the combination of techniques and disciplines is novel to me. I have three comments, one slightly pedantic and two key observations that I think has been overlooked.

(Authors) We thank the public comments of C. Magee. We have addressed all the specific comments below and in our revised manuscript as detailed here.

(Public reviewer) On page 4, Line 27 you state: "Although a matter of a debate, Phillips et al. (2017) claim the first dyke swarm images observed in reflection seismic data in

the world." In Phillips et al (2017) [for transparency I should clarify I'm an author on this paper], it is stated: "While previous seismic-based studies have imaged or contain evidence of one or several dikes, which may or may not be part of a dike swarm (e.g., Zaleski et al., 1997; Malehmir and Bellefleur, 2010; Wall et al., 2010), we present the first seismic data set that images and constrains the geometry of a dike swarm."

(Authors) Thank you for the clarification.

(Authors) We have removed that sentence from the text in our revised manuscript.

(Public reviewer) To clarify our sentence construction here, we agree that other seismic-based studies have clearly identified individual dykes with a dyke swarm (e.g. Wall et al. 2010 image three or four dykes). The orientation of these dykes does provide information on the orientation of the dyke swarm, but it does not constrain other geometrical properties (e.g. width, changes in height) of the dyke swarm. As such, and after an extensive literature search, we think the data presented in Phillips et al. (2017) are the only data that images the entire width of a dyke swarm and does so for >100 km along-strike; thus providing a novel insight into the 3D geometry of a dyke swarm. However, please clarify why you consider this a matter of debate. If we have missed pieces of literature that seismically image the structure of dyke swarms (not just individual intrusions) then we would be very grateful if you could cite them to bring this work to light and make up for any oversight in Phillips et al. (2017).

(Authors) Thank you for the clarification. We read this as if this was the first time dyke-swarms were observed in seismic data and not the whole width of the system as mentioned here. We understood this wrong.

(Authors) We have removed the sentence as mentioned above.

(Public reviewer) A key observation when considering whether dykes intersect storage sites will be spacing between dykes. You clearly highlight that dip and thickness are important. From your images I think you could also say something about spacing.

Bunger et al. (2013) [Bunger, A.P., Menand, T., Cruden, A., Zhang, X. and Halls, H., 2013. Analytical predictions for a natural spacing within dyke swarms. Earth and Planetary Science Letters, 375, pp.270-27] show that dyke spacing should be systematic. The size of the storage site relative to the spacing between dykes could thus be a determining factor in its placement. From all your different data sources, it should be possible to put some quantitative constraints on dyke spacing.

(Authors) Thank you for notifying us on this article. As far as the height goes in the nearby quarry the dolerite dykes are continuing towards depth for over 100 m depth. As far as spacing goes, the dykes are mainly 200-300 m apart but occasionally smaller ones are present coming closer (see Figure 15). Given the history of the Tornquist zone, an estimate while possible it would only be too speculative. Most dykes are judged to have intruded into the earlier faults (extension system) while likely a few opened their ways up. We are a bit puzzled with the article as it refers to "height". If we take the spacing as the known parameters, the height would then be either 2.5 times less (i.e., slightly less than 100 m) or at its deepest point 0.3 times less (i.e., about 1000 m). Would this suggest that mechanically the dykes can extend at depth something around 100-1000 m? This however cannot tell anything about the dip.

(Authors) We therefore do not speculate further on this as the uncertainty is quite huge (10 times). No changes to the manuscript therefor required.

(Public reviewer) There seems to be no mention of what the resolution of the data is. You mention it is 'high-resolution' but there should be some consideration of what this means; in other words, what are you missing? E.g. are <5 m thick dykes imaged and, if not, what could their importance be? There should also be an explanation about tuned reflection packages.

(Authors) With the resolution we both meant fine source and receiver spacing as well as resolving power. Perhaps worth emphasizing that if our interpretation of the reflection from dolerite dykes is correct, the detection limit is somewhere around 10-15 m. This is

not the resolution and rather what the data have been able to image. The detection limit might be better than this but we do not know if there smaller dolerite dykes at where the seismic data have been acquired. On the basis of having useful frequency content between 40-180 Hz and taking 100 Hz as being dominant, we can estimate (using a 4000 ms-1 velocity) a detection limit on the order of a few meters and vertical resolution of 10 m. Judging from the data, it does not appear we have resolved the thickness and rather detected the dykes as one reflection (i.e., top and bottom are imaged as one).

(Authors) We have now added a short text to notify what we mean with high-resolution.

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2018-83, 2018.