Solid Earth Discuss.,
https://doi.org/10.5194/se-2018-83-AC2, 2018

Solid Earth Discussions
Open Access
EGU

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

(Anonymous Referee #1) The paper presents results from three high-resolution 2D seismic lines acquired as a first stage characterization of the subsurface for a potential thermal energy storage site in Sweden. The focus of the paper is really on dolerite dykes which are important geological features in the study area. The topic is of interest and relevant to this special issue. In my opinion, the paper should be published after some weaknesses and loose ends are properly taken care of during revision (see main and detailed comments below).

(Anonymous Referee #1) Main comments: 1) The paper either was written quickly or

Printer-friendly version

Discussion paper

did not deserve all required attention prior to submission. The language is often imprecise and sometimes sentences are not grammatically correct. This is not systematic throughout the manuscript but prevalent enough to require proper and careful editing by a native English speaker.

(Authors) A native speaker will go through the revised version and we hope this shortcoming is fixed. We have taken additional steps to improve the readability of the text.

(Anonymous Referee #1) 2) The correspondence between log anomalies and reflections (R2 and R3) is particularly good on the un-migrated section (Figure 10b) but rather poor on the migrated section (Figure 10c, especially for R3). What makes you think that the anomalies on logs are really the signature of the dolerite dykes if logs and reflections are not at the same spatial location? Are there any other possible explanations for these log anomalies? The same observation applies to figure 11 (i.e. poor fit with log anomalies and reflection R2 on migrated section). How confident are you about the migration velocities and velocities used for T-Z conversion?

(Authors) We do not have a good control on the migration velocities nor can be 100% sure if the reflections are from the dykes. Based on the relative match and natural gamma/density logs, strength of the reflectivity and how regular they appear in the section we have tried to argue that they are originated from the dykes. Faults have been ruled out because in one of the cases the density increases too. Much of the discussion is to support this interpretation. One reason why the match is not perfect can be due to the 2D nature of the profiles. We can aim to push this to match as much as possible by changing the migration, lower velocities, however we avoided this to be clear. We are now discussing this in the revised manuscript.

(Anonymous Referee #1) 3) I suggest looking for references on physical rock properties of dolerite dykes to support the interpreted signature on logging data (especially low natural gamma) and seismic data. Specifically, the acoustic impedance of dolerite dykes and potential contrast with host rocks are not discussed in the paper. However,

Printer-friendly version

Discussion paper

acoustic impedance is the only property that can unequivocally confirm the reflective (i.e., P-wave) nature of dolerite dykes. The interpretation of steeply-dipping reflections as dolerite dykes currently lacks that irrefutable argument (even though strong conjectural arguments are provided to support this interpretation).

(Authors) Additional references are added now. âĂć Planke S, Cambray H (1998) Seismic properties of flood 727 basalts from hole 917A downhole data, Southeast 728 Greenland Volcanic Margin. Proc ODP Sci Results 729 152:453–462 730 âĂć Planke S, Rasmussen T, Rey S et al (2005) Seismic 733 characteristics and distribution of volcanic intrusions 734 and hydrothermal vent complexes in the Vøring and 735 Møre basins. In: Geological Society, London, petro736 leum geology conference series. Geological Society of 737 London, pp 833–844

(Anonymous Referee #1) 4) The paper includes a discussion on the implications of results for thermal energy storage without really providing the key characteristics of a good site for such storage. Some details about an optimal thermal storage site should be provided. For instance, what is the size of such a site (“caverns”)? Why is this area considered suitable for thermal storage (particular rock types, geomechanical properties, close proximity to city)? It is difficult for readers to assess the implications of results for something that is not properly defined.

(Authors) Additional details about a good site are added in the introduction. The main reason this specific site was chosen was the proximity to the quarry owned partly by the concept developer (Skanska) as a proxy also for geology and accessibility to the construction site (caverns), if tunneling should be done and of course being close to potential consumers (Lund and Malmö).

(Anonymous Referee #1) 5) Results from the Babel seismic lines are of certainly of interest but primarily from dykes are effective water barrier.

(Authors) We made a mistake with the orientation of the BABEL line section and now it might be that it is more interesting as the lower crustal reflectivity seem to orient the

same way as the interpreted dykes seen in the seismic sections. This is corrected now and text adjusted.

(Anonymous Referee #1) Page 2 line26: ". . .and if major bedrock undulations" with ". . .and determine if major bedrock undulations"

(Authors) Corrected.

(Anonymous Referee #1) Page 6 line 1: "where geological structures are favorable" please be more specific about the geological structures.

(Authors) We meant the dyke systems as they are the most dominant features in the area. A short text added.

(Anonymous Referee #1) Page 8 line 2: replace "where" with "were"

(Authors) Followed.

(Anonymous Referee #1) Page 8 line 9: What explains the better results with diversity stack over conventional stack on line 3?

(Authors) Likely because the noise level (wind and from car traffic) was higher when data acquired along this profile. This is added now.

(Anonymous Referee #1) Page 9 line 12: "Migration was not employed for the data along profile 5". Do you mean profile 4? (Authors) Yes. We have corrected this.

(Anonymous Referee #1) Figure 12 shows mostly dipping reflections, not steep but still dipping reflections. The migrated section should also be shown in the paper for a "proper" positioning of reflectors.

(Authors) The quality of the migrated section for this line is not so desirable and we wish to not show it in the manuscript. If the reviewer insists we can of course show it but it would just be distractive for the readers.

(Anonymous Referee #1) Page 10 line 8: replace "for where needed" with "where

needed”

(Authors) Followed.

(Anonymous Referee #1) Page 11 line 2: “A smooth 2D velocity model”. Please provide more information about this model (lower and upper velocities and their distribution (ie. constant gradient?)).

(Authors) Followed.

(Anonymous Referee #1) Page 11 line 14: “suggesting that the tomographic velocity models can be used to constrain the bedrock surface with a good level of confidence”. What velocity is the threshold to determine the bedrock surface? In addition, I suggest drawing the top of bedrock on Figure 9 (with dashed line or other).

(Authors) We were unclear on this. Given that there are smoothing constraint used for the inversion, bedrock is not resolved accurately. In our case, we used a rapid change of velocity (vertical gradient) from 3000 m/s to at least 4000 m/s as the bedrock. A dashed line is introduced to represent the interpreted bedrock level in Figure 9.

(Anonymous Referee #1) Page 11 line 23: “. . .depression-looking bedrock is clearly observed in the tomograms suggesting a possibility for major weakness zones (likely highly fractured and/or weathered) in the bedrock.” There are other supporting evidences for this elsewhere in the manuscript. I suggest including them here (for example, caption of figure 9 mentions cuttings from bedrock with alteration). What about velocities from tomography – can they help? Also, could you please be more specific about the alteration observed in cuttings?

(Authors) Followed.

(Anonymous Referee #1) Page 13 line 15: “using transverse type approach”. What do you mean specifically? (Authors) It meant to be just 2D profiles. Changed to “profiling”.

(Anonymous Referee #1) Page 13 line 17: “Several northeast-dipping, approximately

60-65 degree, reflections were imaged down to 400 m depth thanks to the close shot and receiver spacing strategy of the data acquisition." Not sure I understand what is meant by "thanks to close shot and receiver spacing". Aren't large offset required to image steeply dipping reflectors? (Authors) Both required. Spatial sampling and long offsets. Text modified.

(Anonymous Referee #1) Page 13 line 19: "but at occasions are discontinuous and have different appearances". Please be specific about the different appearances.

(Authors) Followed.

(Anonymous Referee #1) Page 13 line 25 "One particular reflection is associated with the topographic depression in the study area and matches well with the high-velocity zone observed under the depression." This is somewhat contrary to what was said before on bedrock depressions corresponding to faults and/or alteration which would normally have low velocity. Please clarify this statement or earlier statement about depression.

(Authors) It is correct. We meant R3 in this case, which is not as undulating as R4 or where HB5 was drilled.

(Anonymous Referee #1) Page 13 line 29: "suggest different geological structures than those observed along profiles 2 and 3". What would be the different structures and why can't they be observed on the two other profiles? Explanations that follow in the 4 lines after are rather vague.

(Authors) We think the central part of P4 is down faulted. The short reflectivity partly means imaging the dykes partly along this profile but also strong faulting that is partly reflected in the magnetic map (see below, the area between HB1 and HB2). We did not show this map before but show it here only.

(Anonymous Referee #1) Page 14 line 10: "..they are nearly equally observed in the country rock and likely can only act as a medium for other geological features.." Not

clear at all what you mean. . .

(Authors) We have rephrased the text. We meant volumetrically equal.

(Anonymous Referee #1) Page 14 line 11: “with some adjustments and better matching. . .”. What adjustments and better matching? Please clarify? See also main comment #2. (Authors) We have rephrased the text. See also above. This was addressed also earlier.

(Anonymous Referee #1) Page 14 line 18: “. . .connected to a reduced natural gamma zone (Fig. 11c), likely a dolerite dyke.” Why would dolerite dykes have low natural gamma? Any reference to support this?

(Authors) Typically dolerite (a basalt in composition) have very little radioactive elements like K40. We have already worked on this at other sites and provide a reference. See Malehmir and Bellefleur (2010. Ore Geology Reviews)

(Anonymous Referee #1) Page 19 line 8: is “appealing” the right word?

(Authors) Changed to “interesting”.

(Anonymous Referee #1) Page 19 line 8: “a pattern for the groundwater flow towards SE (Fig. 14b) and an orientation consistent with the directions of the dykes and major structures in the area (Fig. 1a). Reflections (R1-R4) greatly match this orientation”. I would argue that contour lines presented on figure 14b are more complex than described in the statement above which appears a bit oversimplified. Please provide a more precise description and location (i.e. between R3 and R4 near P2 and P3?). Also, why are lines of water table continuous across reflection R1, R2, R3, and R4 if these reflections are water barriers?

(Authors) You are correct. It might be that the down faulting system we referred to in the picture appended here makes the water flow more complicated in the region where R3 and R4 located. It is consistent to be on the same orientation as P2. We have revised the text accordingly. Thanks for noting this valuable information.

(Anonymous Referee #1) Page 21 line 21: ". . . transparent solidified, seismically homogeneous upper mantle" Could you please explain the meaning of solidified in terms of seismic characteristics of the crust?

(Authors) We just think the region there has no long fabric structure for to produce reflectivity. This is what is referred to. We keep the text as it is.

(Anonymous Referee #1) Page 21 line 23: "While there are a number of SW-dipping reflections in the lower-middle crust projecting towards the location of the Sorgenfrei Tornquist Zone, we can not be sure if these are dykes or frozen magma chambers where dykes intruded to the upper crust within the Tornquist zone." Agree. In fact, there are many possible explanations for those reflections. It might be worthwhile to add a few rather than just providing dyke-related possibilities (i.e., dykes and magma chamber that fed dykes).

(Authors) Actually, we made a wrong placement of the orientation on this section. The correct dip is NE, however we do not want to speculate further. We slightly modified the text.

(Anonymous Referee #1) Page 22 line 9: "Firstly, they are not sub-vertical everywhere within the Tornquist zone and they quickly turn steeply dipping in the subsurface as also observed at a few quarries in the area (e.g., Fig. 15. . .". Could you please clearly indicate what you are referring to in Figure 15 (may be use double arrows – one at the top of cliff and the other at the base to point to the feature you are referring to on Fig. 15)?

(Authors) Followed.

(Anonymous Referee #1) Figure 1. Please add coordinates to a) and b). (Authors) Followed.

(Anonymous Referee #1) Figure 2. It would be useful to add viewing direction for a) and b) or general orientation of the pictures. (Authors) The view directions were not

registered unfortunately. We can do it but it will not be very accurate.

(Anonymous Referee #1) Figure 13: The 3D perspective view is very difficult to visualize on this figure (especially for a). I suggest adding axis (x,y,z) that would improve the perspective view. (Authors) Followed.

(Anonymous Referee #1) Figure 14 please add a) and b).

(Authors) Followed.

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

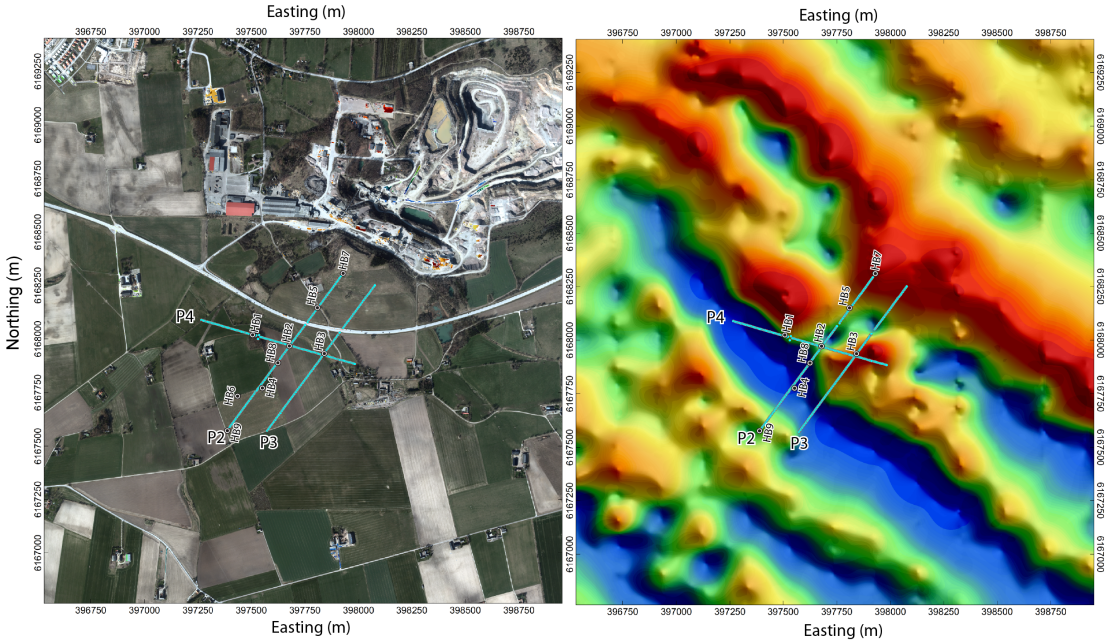

Fig. 1.

Printer-friendly version

Discussion paper