Solid Earth Discussions

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Comment on se-2021-142

Anonymous Referee #1

Referee comment on "Reflection imaging of complex geology in a crystalline environment using virtual-source seismology: case study from the Kylylahti polymetallic mine, Finland" by Michal Chamarczuk et al., Solid Earth Discuss.,
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General comments

The authors of the preprint elaborate a novel approach of reflection imaging of complex geology in crystalline environment using virtual-source seismology by the example of the Kylylahti polymetallic mine in Finland. The relevant scientific questions within the scope of SE are properly addressed. The title of the paper well reflects the contents. The abstract provides a concise and complete summary of conducted research. The scientific methodology is clearly outlined and its precise description allows their reproduction by fellow scientists. All the abbreviations, symbols and units are defined and used both in the text and on figures. The language used is fully understandable and the terminology is correct. The substantial conclusions are reached and supported by the results. The paper is clear and well structured. The exhibited references (32 items) are appropriate to the research topic and include the most recent studies which are relevant and connected to the subject matter. The supplementary materials including the original raw and unprocessed ambient-noise recordings consisting of the whole recorded data volume, as well as all passive results presented in the paper, are available in open access through the Finnish Fairdata services and quoted by the authors in the paper.

The structure and the content of the paper is briefly described below.

The authors start with a description of pioneering and recently published works about ambient noise seismic interferometry (ANSI) used for reflection imaging in hardrock-environments. They designed a new seismic experiment to test the feasibility of ANSI to produce a reflection seismic 3D image of much more complex medium than former published studies and explain the reasons for attempting it. They note that it is an extension of their previous research. The authors present a full-scale 3D seismic virtual source survey (VSS) approach to extract the 3D reflection response from the Kylylahti passive seismic data. The authors highlight that their full 3D ANSI approach is the first which aims to extract reflection response in a hardrock-environment after the first state-of-the-art applications quoted in the paper. At the beginning, the authors present a geological background of the research area providing a detailed description of the Kylylahti polymetallic ore deposit. They also address expected reflectivity between so called Outokumpu assemblage rocks and Kylylahti mineralization. Then, the authors present in detail acquisition parameters, acquired data and expected sources of strong energies. Data processing is clearly and extensively elaborated and brightly divided into sections forming the full-scale 3D seismic VSS methodology for the purpose of near-mineral exploration. The authors' modifications of the state-of-the-art AN imaging workflow was clearly presented on the flowchart. The authors characterize, step by step, the proposed sequence of processing and discuss the methodology and the results. They compare 3D active-source and virtual-source processing results and provide a broad interpretation. The comparison is clearly displayed on figures 6 and 7. Images present active-shot gathers and virtual source gathers (VSGs) using 10 and 30 days of ambient noise (AN) co-located with selected receiver stations. The results confirm that there is a possibility to retrieve similar reflection responses of the medium with the passive seismic data even though some places are masked by artifacts. Then the authors provide a detailed comparison of post-stack migrated sections from active and passive surveys as well as the results from 10 and 30 days of AN. They continue by comparing the post-stack migrated sections obtained from the 3D virtual-source survey along selected crosslines. The authors indicate reflections related to geological contacts within the Kylylahti formation based on geological model. Next, they compare the interpreted base of the Kylylahti formation to the reflection signals from passive 3D cube from 10-day subset of AN data dominated by the body waves. Images on figure 10 demonstrate similarly processed active-source 3D data and passive 3D 10-day subset as well as the overlapping of two selected lines of the passive 3D cube. The authors indicate that the base of the Kylylahti formation, previously interpreted from the active-source data, is fairly clear represented by continuous reflections on some of the crosslines and inlines. Moreover, in the paper the authors discuss the main reasons for the differences in VSGs and co-located active-source data. Afterwards, they brightly discuss ANSI processing with regard to the stationary phase regions. The authors explain the favourable conditions for seismic interferometry which contributed to retrieve of reflection events in the VSGs and the almost full reflection response of the complex Kylylahti formation in the migrated sections. The authors provide a detailed interpretation of the passive reflection images and they verify the use of selective stacking approach. The authors note that the proposed one-directional illumination diagnosis technique would be a typical issue for the VSSs conducted above active underground mines where the most of the seismic activity is in the direct vicinity of the mine operations. Additionally, the authors describe the main differences in the passive imaging approaches (10-day and the 30-day) and the active-source imaging. At the end of the paper, the authors lead to conclusions and prove the usefulness of proposed full-scale 3D seismic virtual source survey for the purpose of near-mine mineral exploration, on the basis of the Finnish Kylylahti polymetallic mine. Their own designed approach pretends to guide the exploration drilling efforts at lower total acquisition costs. The authors claim that it can be also used for other geological issues, e.g. geothermal exploration in crystalline rock basement.

Specific comments

I have no specific questions and comments. In my opinion, everything is clearly presented without any scientific inaccuracies.

Technical comments

However, I suggest some technical corrections to improve the quality of the paper.

- 1 section is missed
- Lines 18, 412, 604: should be "10-day subset", "10-day stack" instead of 10-days (because words "subset" and "stack" are singular)
- Line 18: "an" should be added between "We use" and "illumination" (-> We use an illumination diagnosis technique)
- Lines 39, 229-230: Dales et al. 2020 is missed in the References
- Line 52: there is no need to start the word "eastern" with the capital letter
- Lines 67-69: repeated sentence
- Lines 211, 484, 486, 496: Snieder 2004 is missed in the References
- Lines 299-300: sentence hard to follow, should be rewritten
- Line 357, caption for the figure 6: missing "Hz" inside the brackets
- Lines 358, 360, caption for the figure 6: "s" should be added to VSG (-> VSGs)
- Line 383: "to" should be added between "It helps us" and "determine" (-> It helps us to determine)
- Line 389, caption for the figure 7: missing "Hz" inside the brackets
- Line 390, caption for the figure 7: "s" should be added to VSG (-> VSGs)
- Line 404: should be "Fig. 8f" instead of "Fig. 7f"
- Line 404: the numbers of figures are missing after "Figs."
- Line 457: "to" should be added between "due" and" their" (-> due to their)
- Line 473: "as" should be added between "as well" and "the confirmed" (-> as well as the confirmed)
- Line 576: "a" should be added between "would be" and "typical" (-> would be a typical)
- Line 577: "the" should be added between "where" and "most" (-> where the most)
- Line 647: "a" should be added between "This article is" and "part of" (-> This article is a part of)
- Line 678: this reference is not included in the paper
- Line 727: this reference is not included in the paper