Solid Earth Discussions

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Reply on RC1

Hamed Fazlikhani et al.

Author comment on "Variscan structures and their control on latest to post-Variscan basin architecture: insights from the westernmost Bohemian Massif and southeastern Germany" by Hamed Fazlikhani et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-95-AC1, 2021

Reply letter to referee comment by Anonymous (RC1) on the article se-2021-95

We would like to thank Anonymous referee RC1 for constructive and generally positive comments helping further improvement of our manuscript quality. Following are comments made by anonymous referee (RC1) in italic and authors reply.

Comment 1: *Carboniferous-Permian boundary: Seismically the tectonic-stratigraphic contact between the Rotliegend and the subjacent ST sediments and metamorphics cannot be easily constrained in most of the seismic sections. This makes the exact definition of Rotliegend basin architectures very difficult, as they may be given by intra-BSF 1 (BSF is basaement seismic facies) reflections. Rotliegend thickness is very variable (0-2800 m) if drillhole data are used. I am not sure if this can be improved by different processing parameters, but this is certainly one of the weak points in the geological story.*

Reply to comment 1: Thank you for your comment. Thickness of Rotliegend units is highly variable in the study area, as it is also mentioned by anonymous referee. Beyond the study area and in SE Germany Naab Basin stores maximum of ca. 2800 m of Carboniferous-Rotliegend sedimentary rocks (Müller 1994). In the vicinity of FRANKEN seismic survey thickest Rotliegend units is penetrated by well Mürsbach 1 with 109 m (Table 1). A summary of penetrated Rotliegend units and their thickness changes in the study area is given in section 2.2, lines 110-131 and in the Table 1. We agree with anonymous referee that the boundary between Rotliegend sedimentary rocks and underlying low-grade metasedimentary rocks is not particularly reflective. In the section 3.3 line 227-237 we describe seismic reflection facies related to the Rotliegend units and mention that upper parts of the Rotliegend units are semi-continuous and medium amplitude reflections. To the depth it is not easy to distinguish the boundary between Rotliegend and low-grade metasedimentary units only based on the seismic reflection data. Hence, interpreted Rotliegend unit thickness would represent the minimum thickness, and as anonymous referee mentioned some of upper parts of interpreted low-grade metasedimentary rocks could also represent lower parts of the Rotliegend. However, it appears that there is a limited density difference between Rotliegend units with ca. 2500kg/m3 and Carboniferous units with 2520-2560 kg/m3 (e.g. Hofmann 2003) creating very limited velocity contrast between highly compacted Rotliegend units and low-grade metasedimentary rocks. This is basically main reason why the boundary between Rotliegend and low-grade metasedimentary rocks is not reflective. For instance, we referee anonymous referee to Fazlikhani et al 2017 (https://doi.org/10.1002/2017TC004514, 2017) where high density and therefore velocity contrast between sedimentary rocks and basement units create a very high amplitude reflection.

Comment 2: *Basement Seismic Facies (BSF) concept: The BSF 1-3 scheme looks logical at first, as it depicts a similar superposition everywhere - also in the published DEKORP seismic sections that are extensively discussed and form an important cornerstone of the paper. BSF 2, a packet of high-amplitude and continuous reflections is interpreted as reflecting a system of Variscan shear zones. This has been seen identically in the DEKORP publications (op. cit.), but note that some of these interpretations were in part dramatically disproven by the drilling data of the KTB further to the SE of the studied area. So, are these reflections necessarily images of shear zones? They may be, or may be not, and without ground-truthing by drillholes this is a difficult conclusion. More neutrally, BSF 2 reflections as zones of high seismic impedance contrast, that may relate zo a marked lithological change, grading downward into BSF 3, a seismic facies characteristic for higher grade metamorphics and plutonics of the Cadomian basement of the Mitteldeutsche Kristallinschwelle.*

Reply to comment 2: Unit boundaries show high amplitude reflections if important velocity change occurs, for example the Permian-Triassic boundary in the study area (Fig. 3E). In such cases unit boundaries show thin (<ca. 20 ms) high amplitude reflections, instead bundle of high amplitude reflections (BSF2) interpreted as shear zones in this study are 100-700 ms thick and dipping reflections shallowing generally westward. Shear zone interpretation along the FRANKEN survey is correlated against DEKORP90-3B/MVE and DEKORP85-4N, transecting the Münchberg nappe units and underlying shear zones. Surrounding Münchberg nappe units shear zones transporting nappe units are imaged as thick (>1000 ms) high amplitude reflection below the Münchberg nappe units (see Fig. 5) that are described at the surface a zone containing several thrust fault, low-grade metasedimentary rocks schist and phyllites.

As it is mentioned in lines 279-285, interpreted shear zones are not a distinct lithological unit but rather highly deformed parts of various rock units and therefore includes the upper parts of the Saxothuringian parautochthonos (highly sheared parts of inner shelf facies) and lower parts of allochthons involved in Variscan tectonics. Similar intrabasement, high amplitude and dipping reflections are interpreted as orogenic and postorogenic shear zones in the Norwegian Caledonides (Phillips et al., 2016; Fazlikhani et al., 2017; Wrona et al., 2020), offshore Brazil (Strugale et al., 2021; Vasconcelos et al., 2019), offshore New Zealand (Collanega et al., 2019), and in the South China Sea (Ye et al., 2020) and many other places.

Across the Franconian Fault System (FFS) towards the west, continuation of these high amplitude reflections are observed along the DEKORP90-3B/MVE profile (Fig. 5). At the intersections of DEKORP90-3B/MVE profile with FRANKEN1802, 1803 and 1804 profiles similar high amplitude reflections are observed and interpreted as Variscan shear zones. In our methodology we start from the well-studied DEKORP90-3B/MVE and DEKORP85-4N profiles where pre-Permian basement units are exposed and their seismic reflection characteristics are directly correlated with surface geology. At the next step we used

DEKORP90-3B/MVE profile as a guided to interpreted pre-Permian units and structures along the FRANKEN survey. KTB borehole is tied to DEKORP85-4N and KTB-8502 2D sections and KTB 3D seismic cube (e.g. Hirschmann 1996 and references therein). Along mentioned seismic reflection data several high amplitude and dipping reflections are identified (SE1-4) and are interpreted as thrust zone. For instance, SE1 is interpreted as a ca. 450 m thick thrust zone (Altenparkstein Fault Zone) being part of the Franconian Fault System (de Wall et al., 1994). In addition to interpreted thrust zones, some sub-horizontal high amplitude reflections are also observed (B1-B2, G1-4) that are displaced by SE1-4 reflections. These sub-horizontal reflections are interpreted as Erbendorf high velocity body (e.g. Hirschmann 1996).

Based on the observations from the DEKORP profiles imaging Variscan basement units exposed east of Franconian Fault System, tectonostratigraphic superposition of Variscan nappe units and published studies from various locations, BSF2 reflections are interpreted as Variscan shear zone. Our interpretation is also in agreement with anonymous referee that BSF2 reflections are unit boundaries, as interpreted shear zones are (in the study area) boundary between higher grade metamorphic and plutonic of the Cadomian basement and low-grade metamorphosed inner and outer shelf facies.

Comment 3: The FRANKEN seismic survey itself: The ST basement here has much weaker BSF facies expression than in the DEKORP lines. I am not clear if this is driven by different choices of the seimic processing parameters, or it but could equally well reflect a NW-ward (e.g. FRANKEN 1801) and SW-ward (FRANKEN 1802, 1803) change in ST basement characteristics (e.g. loss of possible shear zone signature). Possible causes for this are discussed (lines 426 ff. of the ms), but it is the marked absence of other (e.g. drillhole) data and observations that makes any interpretation difficult.

Reply to comment 3: Agreed, without well control and only based on seismic reflections it is very difficult to comment on the rock types observed along the FRANKEN survey weaker appearance of ST basement along the FRANKEN seismic could be related to the acquisition and processing parameters. DEKORP profiles are aimed to images deeper (down to Moho) parts of the crust while FRANKEN seismic is targeting mainly the first 10 km of the crust. We agree with anonymous referee that additional well data would have been a great help in the interpretation of the deeper parts of the profiles. However, at present day, are available deep wells in the study area are integrated in our seismic interpretation practice and are presented in Table 1.

Comment 4: In summary, the paper appears to need some thorough revision before being acceptable for publication. There is also a multitude of typographic errors to be corrected (I have not started to do this and trust that copy editing can do the job), and the citations and reference list need a close look at (see e.g. the citations of SCHWAN, 1974, and SCWAN, 1974 for an obvious example) and improvement.

Reply to comment 4: Agreed, we have revised the manuscript according to the referee comments. Please see revised version of the manuscript.

Please also note the supplement to this comment:
https://se.copernicus.org/preprints/se-2021-95/se-2021-95-AC1-supplement.pdf