

RC2: 'Comment on egusphere-2024-2692', Anonymous Referee #2, 19 Dec 2024

This paper is well written, and the data could be of interest but it lacks physics and perspectives to fully understand its importance.

- First, the authors state that their new vertical stress gradients really improve the estimate of vertical stress but they never compare their model with a model using a linear trend. I guess their main results should be to show how wrong we are we use a simplistic equation.

- Then none of their equations are discussed in terms of physics, or their implication in term of geological processes. Using a power law implies a certain evolution type with depth. Authors don't justify neither the form of eq. 2.

- the principal explanation for outliers in bulk density is overpressure. But there are many others factors that can be important, as cementation, variation of stress paths, and they are barely discussed;

I've put more comments in the files attached.

for all this reasons I recommend majors revision

Author reply:

Dear reviewer#2,

Many thanks for your constructive feedback, which we take seriously. Our replies to your main comments can be found below.

Comment 1: - First, the authors state that their new vertical stress gradients really improve the estimate of vertical stress but they never compare their model with a model using a linear trend. I guess their main results should be to show how wrong we are we use a simplistic equation.

Thank you for this suggestion. We actually discuss this in section 4.3 but agree that this part is a bit hidden here. We therefore pick up this part again in section 4.4, where we discuss the established vertical stress gradient models.

Comment 2: - Then none of their equations are discussed in terms of physics, or their implication in term of geological processes. Using a power law implies a certain evolution type with depth. Authors don't justify neither the form of eq. 2.

Comment 3: - the principal explanation for outliers in bulk density is overpressure. But there are many others factors that can be important, as cementation, variation of stress paths, and they are barely discussed;

Section 4.4: We discuss the shape of the power law vertical stress gradient model, which reflects the effect of sediment compaction and thus increasing density with depth (or vertical effective stress).

We added a subsection in the Results and discussion section, where we discuss the geological controls on density, velocity and vertical stress including the impact of mechanical and chemical compaction, cementation, tectonic stress and diagenesis on density and velocity.

Regarding comment to equation 2: We are not sure what further explanations/justification need to be added here. We already explain that “for realistic ranges of density (1.5 3.0 g/cm³) and interval velocity (1500 6000 m/s), A and B will result in value combinations which follow a

logarithmic relationship” and that “low A and high B combinations refer to steep velocity-density relationships which are typical for softer, “compressible materials”. In contrast, high A and low B combinations reflect sediments where density is not changing as fast with velocity, which is typical for more competent or “incompressible materials””. *We believe that this is more than sufficient to explain the methodology of our study, which we consider much more a basin analysis / geological study than a geophysical study.*

Other major changes (also based on the other reviewers’ comments):

- *Several iterations to improve readability and to eliminate grammar and spelling errors*
- *We changed the naming of datasets A and B into datasets I and II.*
- *We agree that the abstract needs revision. We therefore completely rewrote the abstract and tried to implement all your suggestions. The equations have been removed from the abstract.*
- *Figure 1: We redrafted figure 1 to better reflect the regional geology. We also improved the figure quality of the inset and changed the caption of figure 1b, to highlight that the shown cross-section is a schematic cross-section and not based on real data (e.g. seismic reflection data).*
- *We restructured chapter 2 by dividing it into subsections (“Geological setting”, “Previous studies addressing velocity-density relationships and vertical stress”, and a newly added section which introduces the “Geothermal energy extraction in the NAFB”)*
- *Figure 2: we changed the color palette to black and white for better visuals. The lithostratigraphic descriptions have been changed such that they do not conflict with the main lithological units used in the density and vertical stress determination.*
- *Figure 3: we replaced the blue dots with a grey shaded area, which reflects minimum and maximum trends of possible A-B combinations. We also spotted a mistake in plotting Gardner’s mixed A-B combination, which we adjusted, and which now fits much better our A-B trend shown in figure 4a). We updated the respective parts in the discussion accordingly.*
- *Figure 5a: we added R^2 values for each density-depth trend in the figure caption*
- *Figure 5b & c: we annotated obvious outliers*
- *Figure 6: the background maps now follow the same style as the new figure 1*
- *Figure 7: We adjusted the grid line width and the title of the x-axes.*
- *Upper Jurassic: we added a small sub-section in the Results and discussion section where we discuss the implications of our results regarding geothermal exploration and production in the study area. We added a subsection to chapter 2 introducing geothermal energy production in the NAFB (see above).*

Point-by-point reply:

Please find our point-by-point answers to your additional comments directly in the annotated pdf of the manuscript “Reply_Manuscript_Comments_Reviewer#2.pdf”

Many thanks and kind regards,

Michael Drews, Peter Obermeier and Florian Duschl

